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Journal of Medical Physics

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The Journal of Medical Physics (known as AMPI Medical Physics Bulletin till 1994) is a quarterly publication of Association of Medical Physicists of India (AMPI). Issues are published quarterly in January, April, July and October. The main objective of the Journal is to serve as a vehicle of communication to highlight all aspects of medical physics. The scope of this journal covers all aspects of the application of radiation physics to health science, mainly radiation therapy, radiodiagnosis, nuclear medicine, radiation dosimetry, radiation standards, quality assurance, calibration and radiation protection. Papers / manuscripts on radiobiology pertaining to cancer therapy also fall within the scope of the journal. Apart from the original research work, papers which are of practical importance to medical physicists e.g., those dealing with practices (performance and quality assurance tests, clinical investigations and follow-ups with novelty), radiation accidents and emergencies are also published in the journal. Brief manuscripts dealing with the validation of relatively newer concepts may be considered as technical notes or letter to editor. Reviews of publications (e.g., ICRP/ ICRU reports and books related to the scope of the journal) may also find a place in the journal. Manuscripts with no or oblique relevance to the scope may not find place.

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Invited Talks

I-1

DOSIMETRY OF SMALL STATIC FIELDS USED IN EXTERNAL BEAM RADIOTHERAPY: A REVIEW OF IAEA TRS 483

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In 2008, Alfonso *et al.* (Med. Phys. 35, 5179-86) published a stage setting paper outlining a well thought out dosimetry formalism for reporting corrected relative output factors for small and non-standard fields. However, many questions remained. Both experimental and Monte Carlo implementations of the proposed formalism helped guide the community in developing a code of practice (COP). The IAEA has now published a COP for small field dosimetry. Report 483 *"Dosimetry of small static fields used in external beam radiotherapy – An International code of practice for reference and relative dose determination"* follows a productive 10 years of research that addressed the many questions associated with the challenges related to small field dosimetry. A review of small field dosimetry physics, a detailed discussion of the formalism and practical aspects of clinical implementation will be covered.

I-2

THREE DIMENSIONAL DOSIMETRY BY POLYMER GEL AND SOLID PLASTIC DOSIMETERS

Yoichi Watanabe
University of Minnesota, Minneapolis, Minnesota, USA

Accurate dose measurement tools are needed to evaluate the radiation dose delivered to patients by using modern and sophisticated radiation therapy techniques. However, the adequate tools which enable us to directly measure the dose distributions in three dimensional (3D) space are not commonly available. One such 3D dose measurement device is the polymer-based dosimeter, which changes the material property in response to radiation. These are available in the gel form such as polymer gel dosimeter (PGD) and ferrous gel dosimeter (FGD) and in the solid form as solid plastic dosimeter (SPD). Those are made of a continuous uniform medium which polymerizes upon irradiation. Hence, the intrinsic spatial resolution of those dosimeters is very high, and it is only limited by the method by which one converts the dose information recorded by the medium to the absorbed dose. The current standard methods of the dose quantification are magnetic resonance imaging, optical computed tomography, and X-ray computed tomography. In particular, magnetic resonance imaging is well established as a method for obtaining clinically relevant dosimetric data by PGD and FGD. Despite the likely possibility of doing 3D dosimetry by PGD, FGD or SPD, the tools are still lacking more extensive clinical applications. In this presentation, I summarize the current status of PGD, FGD, and SPD and discuss the issue faced by these for broader acceptance in radiation oncology clinic and propose some directions for future development.

I-3

PATIENT DOSIMETRY IN DIAGNOSTIC RADIOLOGY

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Estimating patient dose is an important skill for a Medical Physicist to have since medical physicists are called upon to estimate patient dose in several modalities. These requests for calculating patient dose may originate from patients, providers, or Institutional Review Board within an organization which reviews doses for research studies. Dose estimates may be used for quality assurance and improvement processes, protocol optimization, benchmarking, or patient risk estimates.
In this session, CT, Fluoroscopy and fetal dosimetry as well discuss recently published diagnostic reference levels (DRLs) for adult CT exams in the USA will be discussed.

- CT - Dose metrics displayed on the CT scanner such as $CTDI_{VOL}$ and DLP can be useful tools however each has limitations that must be understood in order to provide an appropriate dose estimate for the circumstance at hand. Evaluation of individual patient risk estimates often requires a more rigorous evaluation.
- Fluoroscopy and Interventional Radiology – Review dose metrics and radiobiology relevant to the modality and work through adult and pediatric dose calculations using a case-based approach
- Fetal dosimetry - The goal here is to provide a review of scientific, regulatory, and educational material on the topic of fetal exposure (and risk calculation).
- Discuss recently published DRLs for the ten most common adult CT exams in the USA.

Learning Objectives:

1. Describe the limitations of displayed dose metrics for estimating patient dose
2. Review dose metrics and radiobiology relevant to the modality
3. Provide a review of fetal dose risk from ionizing radiation
4. Provide a review of dose calculation techniques
5. Discuss the recently published DRL for adult CT exams in the USA.

I-4

MODERN TECHNOLOGY: CLINICIAN'S FEEDBACK TO THE MEDICAL PHYSICIST

D. N. Sharma
Department of Radiation Oncology, All India Institute of Medical Sciences, New Delhi, India

Radiation oncology acts as a center stage in the treatment of cancer. About 70-80% of cancer patients require radiotherapy, either for cure or palliation, at some point of time during their illness. There has been lot of advances in radiation oncology in the recent years. The major highlights of the last two decades have been the advent of state of the art technologies like IMRT, IGRT, SBRT, proton therapy and image guided brachytherapy etc.

Technological advancement is the key factor behind the advances in radiation oncology. Computerization has played a pivotal role and the advances in imaging technology have helped radiation oncology a lot. Computed tomography is used routinely for radiotherapy planning. The radiation oncology has evolved from two dimensional to three dimensional planning. The auto contouring and auto segmentation tools in the new planning systems are highly useful. With current technology, we can precisely conform high doses to tumor target at the same time protecting the critical structures. This helps in dose escalation without increasing radiation related morbidity thus improving the therapeutic ratio.

However, the modern technology should be assessed whether it has made a significant clinical impact. The radiation oncologists must convey the therapeutic results achieved by the technological and refined dose delivery advances to all the personnel involved in radiation treatment (medical physicists, dosimetrists, radiation therapy technologists etc.). This will help in adopting, rejecting and amending a particular radiation technology. Any given new technological advancement may be measured with at least three yardsticks namely, local control, survival and quality of life.

There have been definite improvements in toxicity outcome with modern precision RT techniques. For head and neck cancer patients, xerostomia rates have significantly come down. The GI toxicity with pelvic IMRT has also been reported to be significantly lower. SBRT has improved the local control rates in early lung tumors and posing a challenge to the traditional treatment like surgery. The survival improvement data across all tumor sites is yet to come with the use of modern technology as pr the literature so far. The risk of secondary cancers induced by dose spillages to OAR in IMRT continue to be an issue although no such data exists as of now. The waiting times have definitely becoming longer due to extra time consumed by the sophisticated RT techniques. This could jeopardize the overall cure rate in a specified population. This aspect may be more relevant in the Indian context where majority of patients still come in advanced stages needing palliative RT. It is to be seen as to what extent the IMRT/IGRT will benefit the palliative group of patients.

These developments also mandate a fresh look at our physician training programs. Appropriate training in image acquisition and interpretation would be highly useful in this scenario to prevent systematic errors in treatment planning. Incorporation of a good quality assurance programme to monitor treatment delivery and execution is another challenge to be met head on. However prudent clinical judgment must be used in applying these new tools as indiscriminate and over enthusiastic usage may not auger too well in this era of evidence-based medicine.

I-5

QUALITY ASSURANCE OF SPECIALIZED RADIOTHERAPY EQUIPMENTS: PRELIMINARY REPORT OF ATOMIC ENERGY REGULATORY BOARD TASK GROUP

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Atomic Energy Regulatory Board (AERB) constituted a Task Group (TG) to develop quality assurance (QA)/Acceptance criteria for specialised radiotherapy equipments (TGQA-SRTE) such as Robotic Radiosurgery Device (tradename-Cyberknife), Helical Beam Delivery device (tradename – Tomotherapy), Gamma Radiosurgery Device (tradename – Gamma knife) and Intra Operative Radiation Therapy units. To accomplish this task, the TG thoroughly reviewed the relevant reports published by international agencies [International Atomic Energy Agency (IAEA), Vienna, Austria; International Electrotechnical Commission (IEC), Geneva, Switzerland], professional societies (e.g. American Association of Physicists in Medicine, USA), and scientific papers published by individual researchers. The technical brochure and acceptance test proforma provided by the manufacturer of these equipments were thoroughly studied and salient features were noted. Specific inputs of manufacturers/suppliers of the equipment were also obtained. It was decided by the committee that general layout followed in Acceptance test proforma developed for standard radiotherapy equipment will be followed and test parameters and their tolerance values were clubbed in the four-general category namely, electrical, mechanical, dosimetry and radiation safety.

The QA proforma of Cyber knife machine includes general technical information about the equipment and the treatment and monitoring accessories; details about the safety systems and interlocks; mechanical performance of couch, collimator and robotic manipulator; dosimetry tests related to beam profile, depth dose, penumbra, relative surface dose, beam quality and performance of the beam quantity monitoring system; radiation safety compliance of the accelerator and facility; and performance of imaging systems. Tolerances of some of the test parameters were also assigned by the TG.

The layout of the QA proforma of Helical beam delivery device (Tomotherapy unit) is also the same and it includes tests on both beam delivery as well as imaging systems. The dosimetry tests include the evaluations of both transverse and longitudinal beam profiles using the criteria for flattening filter free beam (i.e. unflat beam). Radiation safety tests includes the test of the accelerator and the collimator system. The test parameters are selected in such a way that it should be applicable to all the models of this treatment delivery device.

The QA proforma of Gamma Knife unit is somewhat simpler than the above mentioned two specialised radiotherapy

equipment. The important mechanical test is the verification of unit centre point radiometrically. Test on collision interlock and safety tools to avoid collision of patient with unit during treatment have also been included in the acceptance test proforma. For output measurement, the methodologies outlined in recently published IAEA technical report series 483 (TRS 483) has been adopted.

In case of intraoperative radiotherapy systems, the QA proforma is being modulated to include test parameters related to all the devices, both based on beam therapy and brachytherapy concepts, and is yet to be finalized by the task group.

In summary, the AERB task group has developed QA proforma for all the specialized radiotherapy equipments for which systematic regulatory protocols were not available. It is expected that the newly developed QA proforma by the AERB TG will be helpful for the user in conducting the performance test of these devices in a systematic manner.

I-7

RADIATION DOSIMETRY AND CLINICAL OUT COME

R. Jayaraman

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Dosimetry plays a vital role in the field of Radiation Oncology. Any radiation event is a probabilistic function. Hence an error can be expected and accepted. Any error in the dose delivery, dose prescription affects the clinical outcome for the patient. Dose delivery depends on the dose measurement and QA Program of the department. Based on the steep dose response curves for normal tissues and tumour, a less than 5% uncertainty in dose delivered to the patient is required.

In the Absolute dosimetry of the beam, as per IAEA, uncertainty involved in the determination of the different factors, is 0.9%. That's one of the reasons for accepting +/- 2% error in absolute dosimetry. This means total of 4% in the total dose can be expected. In the era of IMRT and VMAT, Leakage measurement through the jaws and MLC leaves, becomes important. Choice of dosimeter plays a vital role in the error. Still the studies are going in the field of small field dosimetry and choice of dosimeters, Dose verification systems need to be evaluated carefully based on the type of treatments carried out.

The errors could be random error or systematic error. Random errors cannot be avoided, but has to be accounted. Systematic errors may be evaluated and may be corrected in the future. The systematic error depends on the individual institutional setup, depends on various factors, including the setup of patient.

Dose prescription and reporting mechanism, as per ICRU reports have to be followed for evaluating the clinical outcome any protocol based patients. Even though 4% or 5% looks smaller, when it comes to the deterministic effects of the vital structure, it is critical. If the error is in the positive side, then the damage may be produced. The same error in the dose delivery to the tumour is critical, if it is in the negative side. Based on criticality of the tumour and the critical organ, a balance has to be arrived.

I-8

DOSIMETRY OF MAGNETIC RESONANCE IMAGING-LINEAR ACCELERATOR

V. Subramani

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Need for Magnetic Resonance Imaging-Linear Accelerator: The current image-guided radiotherapy systems are sub-optimal in the esophagus, pancreas, rectum, lymph node, kidney, etc. These locations in the body are not easily accessible for fiducials and cannot be visualized sufficiently on cone-beam computed topographies, making daily patient set-up prone to geometrical uncertainties. Additionally, interfraction and intrafraction uncertainties for those locations arise from motion with breathing and organ filling. To allow real-time imaging of all patient tumor locations at the actual treatment position, a fully integrated system combining of on-board magnetic resonance imaging with a linear accelerator (MRI-Linear Accelerator or MR-Linac) is needed.

Magnetic Resonance Imaging-Linear Accelerator Systems: The MRI-Linear accelerator is a hybrid ring-gantry technology combining both MR imaging system and linear accelerator in a single unit which is used for MRI-guided radiotherapy (MRIgRT). The MRI-guided radiotherapy provides real-time images of a patient during treatment and offers more detailed and higher contrast images for the identification of tumors and soft tissues than conventional IGRT techniques. This boosts tumour targeting accuracy, reducing side-effects and increasing survival rates. Hence, accurate radiation dose is crucial to the safe and effective treatment of patients but radiation transport is strongly affected by the magnetic fields used in MRI-Linac.

The superconducting magnets with range from 0.35T to 1.5T magnetic field strength MRI scanners with 45-50 cm FOV are used and share their common isocenter with linear accelerator. The gradient coils, body coils and surface coils are used during imaging with different MRI pulse sequence techniques. The MRI scanner is either of parallel or perpendicular configurations.

The 6MV or 7MV low energy linear accelerators with flattening filter free beam having dose rate of 500-600 MU/min at 90 cm SAD is used. The multileaf collimator (MLC) having field sizes of 27 x 24 cm^2 or 57 x 22 cm^2 is used for step and shoot IMRT. Treatment planning system with Monte Carlo based algorithms for the dose calculation becomes mandatory in the presence of magnetic fields. The MRIgRT systems such as ViewRay MRIdian Linac and Elekta Unity are commercially available, besides there are two prototypes research system's work is underway.

Radiation Dosimetry in the Presence of Magnetic Fields: Because the isocenter of the linac coincides with that of the MR scanner, dose will be deposited in a magnetic field environment. Secondary electrons released by the photon beam will therefore be deflected by the Lorentz force which causes the particle to curve in a direction perpendicular to the magnetic field. The particle's radius of curvature in a magnetic field is dependent on its kinetic energy and the strength of the magnetic field. This is known as electron return effect (ERE). For a homogeneous phantom, in regions where electron equilibrium is reached, the impact of this effect is negligible. However, for interfaces with a large difference in density,

like in an air-filled ionization chamber, this effect cannot be ignored. However, MRI lacks the electron density information and may suffer from geometric distortions, and therefore is not directly suited for dose calculation. Therefore The MRI-linac pose technical challenges such as (i) Radiofrequency (RF) interference between linac and MR and hence MR needs to be isolated which collects weak signal from patient as linac is a significant source of RF. (ii) magnetic field mutual interaction: MR magnet and linac because the electron trajectories perturbed by the presence of B0 Lorentz force (iii) Dose deposition effects in MR's magnetic field (iv) Skin dose effects in MR's magnetic field. The current commercial systems are having limitations such as only static IMRT delivery, co-planar treatment, carbon-fiber couch can't be used as they conduct electric current and plastic couch is used and its attenuations are accounted for in the treatment planning systems.

Clinical Commissiong of Magnetic Resonance Imaging-Linear Accelerator: The radiation dosimetry can be classified as (i) reference or absolute dosimetry (ii) relative dosimetry. The dosimetric and other ancillary equipments used in MRI-linac should be of non-ferromagnetic and MR-safe. The MRI compatible different detectors and phantoms need special considerations while performing dosimetry in the magnetic fields. The ionization chamber, multi-axis ionization chambers, IC-Profiler film, OSLD and plastics phantoms are used in the commissioning and routine quality assurance process. The dosimetry and the dose distributions are highly influenced by the magnetic field of the MR (+/-10%). Therefore the magnetic field correction factors and electrometer correction factor for change in meter reading due to magnetic field while absolute dose determination. For the absolute calibration, the real water as 1D phantom and solid water phantom is not suitable for MRI-linac.

The MRI-compatible 3D water scanning phantom is used for relative dosimetry. In the standard 3D scanning water phantom, any ferromagnetic components have to be replaced with non-ferromagnetic components (e.g. electric stepper motor need to be replaced with ultrasonic motor/transducers etc). The special MRI-compatible daily QA phantom, 4D dynamic motion phantom and additional phantoms filled with water or water gel are used for commissioning dosimetry, patient-specific treatment QA and routine machine QA dosimetry for both MRI system as well as linac system used in MRI-linac.

Conclusion: The MRI-Linac is advancements in IGRT system for MR guided Radiotherapy (MRgRT) which allows the simultaneous use of beams of ionizing radiation and magnetic resonance imaging (MRI) to image a patient during treatment. The MRI-Linac is the only system allows for 2D, 3D, 4D real-time image guided on-line adaptive and stereotactic body radiotherapy basis on the soft tissue and organ at risk with beam gating and motion tracking capabilities. Apart from providing better soft tissue visualization of anatomy, it also provides several functional imaging modalities for measuring biological function and physiology and also used in treatment response assessment as imaging biomarker towards personalized therapy.

I-9

RADIOBIOLOGY OF LUNG STEREOTACTIC BODY RADIATION THERAPY TREATMENTS

T. S. Kehwar

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Purpose: This study reviews radiobiological phenomenon response of lung stereotactic body radiation therapy (SBRT) treatment.

Introduction: Cancer is the second most common cause of death in the USA, exceeded only by heart disease,[1] and also a leading cause of death allover the World, among other cancers, which typically present in locally advanced or metastatic stage. Traditionally, conventional fractionated radiation therapy was the preferred choice of treatment for the patients who were unfit for surgery.

Recently, the SBRT treatment has increasingly been used for surgically inoperable stage I lung cancers. Local control rates for SBRT treatment dramatically improved compared to the conventional fractionation treatment.

Radiobiology of Conventional Radiation Therapy: The response of a tumor to the conventional fractionation schemes have been well explained by 5 R's of radiobiology. First 4 R's were initially described by Withers,[2] and subsequently 5th R was introduced by Steel *et al*.[3] based on the data that the responsiveness of the tumors to radiotherapy treatment correlated with intrinsic radio-sensitivity of the cells *in vitro*.[3]

The linear – quadratic (LQ) model, with appropriate modifications, is able to explain above said 5 R's of radiobiology and used as most popular method of fitting experimental results derived from *in vitro* and in vivo radiation survival experiments and to explain the responses of different dose fractionation schemes.[4]

The LQ model is a low dose approximation and at lower doses the effects of 5 R's of are exploited in the design of various fractionated treatment schedules. The biologically effective dose (BED) for such fractionation schemes may be given by

$$BED = nd\,(1+\frac{nd}{\alpha/\beta}) \quad (1)$$

Where n is the number of fractions, d dose per fraction, and a/b is the tissue specific parameter, that implies the dose at which the component of lethal damage is equal to that of sublethal damage.

Radiobiology of Stereotactic Body Radiation Therapy: The LQ model has been used to interpret treatment outcome within its validity range up to 6 Gy per fraction.[5] The dose – response curves of the LQ model keep on bending beyond its validity range and become inconsistent with *in vitro* survival curves, which are straight on semilogarithmic plot at high doses used in SRS and SBRT treatments. In the high dose range, this might be due to overloading of the repair enzymes.

To explain radiobiological phenomenon in the high dose region the LQ – L and the USC models were developed by Carlone *et al.*[6] and Park *et al*.,[7] respectively.

The linear – quadratic – linear model: The LQ model fits appropriately in the conventional fractionation range and smoothly transition to the linearity at a transition dose, D_t, which explained by the LQ – L model. The survival fraction (S) can be written in bipartite form after single dose of radiation as

$$S = e^{-\alpha(D+\frac{D2}{\alpha/\beta})} \text{ for } D \le D_t \quad (2)$$

and

$$S = e^{-\alpha(D_t + \frac{D_t^2}{\alpha/\beta}) - \gamma(D - D_t)} \text{ for } D \geq D_t \quad (3)$$

where a and a/b are the LQ parameters, as explained in previous section, and g is the coefficient of the damage in the final linear portion of the survival curve at high doses, which is the $\log_e$ cell kill per Gy dose in the linear portion of the survival curve at high doses, and at D_t and can be given by

$$\gamma = \alpha\,(1 + \frac{D + D_t}{\alpha/\beta}) \quad (4)$$

The universal – survival – curve model: The USC model is a hybrid model derived by combining the LQ mode and the MT model, where the LQ model smoothly transition to an asymptotic linear portion of the MT model at Dt (transition dose). The S of USC model for single dose fraction is given by

$$S = e^{-\alpha(D + \frac{D2}{\alpha/\beta})} \text{ for } \quad D \leq D_t \quad (5)$$

and

$$S = e^{-D/D_0 + ln(\bar{n})} \text{ for } D \geq D_t \quad (6)$$

Unified LQ-L Model: Unified LQ-L model[8] uses transition dose Dt derived by equating the dose responses of the LQ and the MT models at transition dose, $D_{t,}$ which can be given by

$$D_{t\text{-}mt} = \frac{2D_0 \ln(\bar{n})}{(1 - \alpha D_0)} \quad (7)$$

Results and Discussion: Sheu *et al*.[9] reported that the LQ model overestimates the magnitude of the cell kill at larger doses compared to conventional doses, which could affect the accuracy the dose-response results at larger doses. Guerrero and Li[10] modified the LQ model to address the issue of high dose per fraction regimens and to get best fit at large doses, which exhibit linear-quadratic-linear (LQ-L) behavior. Wang *et al.*[11] presented a generalized LQ model, which also shows a linear-quadratic-linear behavior. Park *et al.*[7] proposed a bipartite universal survival curve (USC) model, which is hybrid of the LQ and the historic multi-target (MT).

Astrahan[5] reported that LQ-L model predicts decreasing fractionation sensitivity for higher doses with increasing dose per fraction. Wennberg & Lax[12] have shows that at doses of about 15 Gy or higher, the USC model predicted much lower fractionation sensitivity, compared to the LQ model, for both tumor and normal tissues.

Kehwar *et al*.[8] had studied the best fit survival curves for non-small cell and small cell lung cancer cell lines fitted to the LQ, LQ-L and USC models, and found that the LQ-L model with D_t derived using the MT model provide appropriate fit and is the best to use to predict SRS and SBRT treatments. These radiation cell survival data were used to determine the values of a and b, using the best-fit regression method and an interactive inspection and chi–square best fit to the initial curvature points with $R^2 \geq 0.97$, respectively, for low dose survival data, and D_0 and by the best-fit regression method to the final slope survival data, using MT model. Table 1 enlists representative LQ and radiation cell survival parameters for SC and NSC lines.

Conclusions: The unified LQ-L model provides best fit to the radiation cell survival data with smooth and gradual transition of the LQ model to linear portion of the survival curve at transition dose D_t. The Fitting of the experimental dose response data in the range of high doses, used in SRS and SBRT, to the LQ, LQ-L, and USC models illustrates that the unified LQ-L(D_t) model provides the best explanation of the problem. On the other hand, the LQ model overestimates the severity of response at high doses due to continues to bending of the curve, other models do not transition smoothly to the linear portion of the curve. The transition dose D_t and final slope g, the $\log_e$ cell kill per unit dose in the final linear portion of the survival curve, can be calculated using D_0 and obtained by the best fit exponential regression of experimental or multi-fraction dose response data. Plots of this study show that the unified LQ-L(D_t) model offers a best description of the cell survival data for SC and NSC cell lines in the high dose region well beyond the shoulder, and is a best suitable model for clinical use.

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Table 1: Representative values of the parameters that can be used to predict lung stereotactic body radiation therapy treatments

Cell lines	α (Gy^{-1})	β (Gy^{-2})	α/β (Gy)	D_0 (Gy)	$\bar{n}$	D_t (Gy)
SC	0.47	0.07	6.71	1.05	3.89	5.63
NSC	0.30	0.05	6.00	1.19	5.95	6.60

SC: Small cell, NSC: Nonsmall cell

I-10

PET COMPUTED TOMOGRAPHY IN RADIOTHERAPY PLANNING

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Radiotherapy is one of the most effective modalities for treating malignancies especially the tumors of the head and neck apart from surgery. This is due to the advent and integration of most advanced techniques like intensity modulated radiotherapy (IMRT). These high precision techniques need accurate tumor location and its extent and further the volume of tumor to be irradiated. Radiotherapy planning during the last few years has been solely based on anatomical tumor volumes. This may sometimes under or over estimate the tumor as well as missing of occult primaries with metastatic cervical nodes. Molecular imaging with FDG could help overcoming some of these as well as can be complementary to the conventional imaging.

An essential step in RT planning is to define the tumor location and extent, further to define volume to be irradiated. Commonly used was anatomical tumor target volume with Computed Tomography (CT) which includes Gross tumor volume –GTV, clinical tumor volume –CTV and planning tumor volume –PTV. Incorporating PET with anatomical tumor volume gives metabolic tumor volume MTV. This is described as the volume of tumor tissue with FDG. This volume corresponds to GTV of CT. Studies had shown that this volume was found closest to the pathologic GTV from specimens after surgery. Information obtained from novel tracers like those of hypoxia, proliferation, apoptosis, and receptor expression can be integrated with that of FDG PET imaging, which provides greater insight into the biologic pathways involved in radiation responses. Few tracers of molecular imaging with 18F MISO and 18F FAZA could identify patients who could fall into the radio resistant subgroups. This would help to identify hypoxic cells and to augment higher doses, which are resistant to radiotherapy. This complex cross-sectional dose distributions and the delivery of differentiated dose a within the target, a technique that has been referred to as “dose painting” is possible with IMRT. Contouring the outline of the tumor or metastatic lymph nodes applying PET/CT, the so-called “dose painting”, is still one of the most challenging and controversial issues in radiation therapy planning.

PETCT in RT planning helps in the management of patients when the location of tumor is in the vicinity of complex anatomy and critical organs. MTV guided volume delineation determines the metabolically active component which is generally smaller than that of the morphological appearance there by reducing the gross tumor volume, an unique advantage in sparing the surrounding organs at risk. This would help in those organs with dose constraints. Non enlarged nodes harboring micro metastases which are metabolically active in PETCT are included in the treatment which often not included in anatomical tumor delineation by CT alone. PET/CT has also been found helpful in the management of occult primary head and neck tumors by determining a site of origin of the primary tumor in 60%. This translates into reduced dose distribution to uninvolved mucosal sites compared with the results of CT scan only–based plans. PETCT would also be very useful in differentiating tumor recurrence from postoperative and post RT changes. In addition Whole body PETCT adds complementary information which could modify TNM staging resulting in shift in treatment perspective from curative to palliative because of identification of distant metastases. Several studies have documented that the improved staging with FDG PET can be used to improve patient management and significantly impact RT planning and therefore improve outcome and minimize toxicity.

PETCT can also used in the interim period of an early RT. This would help to find out the response to the treatment. Based on the response a revision of the treatment plan can be done either by reduction or augmentation of the mean dose delivery. This might help in reduction of radiation to non target tissue.

However PET also bears some disadvantages like limited spatial resolution which is overcome by a large extent by the fusion of metabolic images with CT images (Hybrid PETCT) which is the present day equipment and false positive findings because of inflammation and physiological distribution of tracers. Smearing of targets might happen due to motion artifacts which can be eliminated considerably using respiratory gating and 4D PETCT imaging in the place of conventional PETCT images.

To conclude the data from functional imaging greatly improves RTP by enhancing the mean radiation dose to the target and minimizing unnecessary irradiation of normal tissues. The potential of PET to quantify metabolism and identify new imaging targets within tumor tissue such as cellular proliferation, hypoxia, tumor receptors, and gene expression, thereby helping in the biological optimization of dose delivery.

I-12

COMPREHENSIVE QUALITY ASSURANCE PROGRAM FOR VOLUMETRIC ARC THERAPY VOLUMETRIC ARC THERAPY OR RAPIDARC™ TREATMENTS

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Volumetric arc therapy (VMAT) or Rapidarc™ is an advanced form of the intensity modulated radiation therapy (IMRT) technique in which radiation dose is delivered in an arc of ≤360-degrees while simultaneously modulating the multileaf collimator (MLC) position, dose rate, and gantry speed. The delivered dose is precisely sculpted to provide sharp dose

falloff beyond the target, thereby providing dose sparing of normal tissues and critical organs while maintaining high target dose. The use of VMAT in radiotherapy is constantly expanding. In our clinic, the majority of treatments are carried out using the VMAT technique, ranging from very small to large convoluted targets. Rotational beam delivery with simultaneous modulation of MLCs, dose rate, and gantry speed, creates a highly patient-specific plan and poses a challenge for accurately verifying the dose the patient receives during treatment. 3D *in vivo* dosimetry would be ideal to determine patient dose but is not practical. In order to take full advantage of VMAT treatments a comprehensive quality assurance (QA) program from the treatment plan to the dose delivery at the Linac, along with patient setup verification, is required. We present a comprehensive QA program for VMAT delivery comprised of multiple elements: 1. Treatment planning and plan quality assurance, 2. Treatment delivery specific to patients, 3. Cone-beam computed tomography (CBCT) accuracy verification, and 4. Routine machine QA tailored to VMAT/IMRT.

1. Treatment planning and QA of treatment plans: Initial imaging, arc start and stop angles, collimator angle, optimal constraints, treatment and critical structure volumes and their overlaps and field sizes all play an important role in developing optimal plans. We describe the methodology and appropriate treatment plan QA performed to achieve this
2. Patient specific treatment delivery and its effects are always challenging. Ideally, BANG gel tied to patient anatomy could provide such verification, but is not practical. Currently there are a number of devices available in the market to measure patient specific QA however none of them are ideal to provide the actual dose delivered to the target and critical structure. We developed a unique method to utilize dynalog files (log files created after each delivery providing leaf, gantry, dose information) to recreate the dose distribution both in Eclipse and Monte Carlo. We also utilized the isocenter wobble from gantry, couch, and collimator motion along with daily variation in the output and fraction to fraction MLC variations in our reconstruction. The dose can be calculated in CBCT used for patient setup. Inclusion of all these factors provide us with an accurate estimate of the dose delivered to the patient and can be compared to the planned dose
3. We typically use CBCT 3D-3D matching to setup the patient. We have determined the accuracy of 3D-3D matching and have incorporated it in our planning target volume (PTV), specifically for small targets
4. We perform extensive MLC QA regularly to verify the performance of MLC. Some of these tests include MLC backlash test, picket fence test, complex MLC movements, MLC and gantry statistics, and so on

   We have also established some tests to verify the accuracy of Dynalog log file recordings. More work is underway to routinely introduce this in the clinic.

I-14

QUALITY OF QUALITY ASSURANCE PROGRAM IN RADIOTHERAPY PRACTICE

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Typically dose delivery to the patient is aimed to be within ±5%. ICRU report 24 considered ± 5% accuracy was required in the delivery of absorbed dose to the target volume, but in critical situations ±2% may be required. Dutrix reported that a difference of 7% dose delivery effected tumor regression and normal tissue reactions. The term accuracy in radiotherapy is often used loosely. Overall uncertainty is combination of type "A" uncertainties assessed by statistical means (Random errors) and type "B" assessed by other means (systematic). The objective of any QA program is to minimize the random error and eliminate systematic error as much as possible. The objective of the talk is to show with some examples as to how to achieve this.

Some of the examples discussed are 1: Absolute dose measurements where the depth of ionization chamber needs to be measured accurately. We have noticed a discrepancy between mechanical position and actual depth and also manual measurement of the depth. 2. Not levelling the water tank affects the absolute dose measurements specifically low energy electrons. 3. Solid water cavity temperature variation can add to the uncertainty in the measurements. 4. MLC backlash, improper MLC QA will affect precision treatments like IMRT and Vmat. 5. Beam modelling in treatment planning system results in systematic error 6. Isocentre wobble can affect functioning and small target treatments 7. Annual QA parameters comparison could create unsuspected errors. The errors associated with these measurements and methods to minimize them are discussed.

I-16

GAFCHROMIC EBT3 FILMS DOSIMETRY FOR CLINICAL BEAMS OUTPUT AUDITS

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Introduction: The Radiation Oncology Physics subcommittee of the Saudi Medical Physics Society is interested in launching a service to audit outputs of clinical photon beam with a postal dosimetry system. This service will be available for 14 radiotherapy clinics distributed across the Kingdom of Saudi Arabia. The goal of our work was to study the feasibility of using EBT3 GafChromic films for carrying out this task.

Methods: EBT3 file calibration - Two EBT3 film batches were calibrated using 5 megavoltage x-ray beams (two 6 MV, two 15 MV, and an 18 MV). For each film batch, 2 × 2.5 cm^2 film pieces were cut and irradiated to doses in the range between 0 to 350 cGy. The film pieces were scanned prior to and after irradiation using EPSON 10000 XL desktop flat-bed document scanner (Seiko Epson Corporation, Suwa, Nagano, Japan). All scans were carried out using transmission scanning, spatial resolution of 300 dots per inch (dpi) and 48-bit RGB (Red, Green, and Blue) mode. Irradiation of the films was carried out at depth of maximum dose z_{max}, 10 × 10 cm^2 field size, and 100 cm source-surface distance SSD. Dosimetric characterization of the films was based on the red channel colour value of the scanned images. To describe

the calibration curve of the EBT3 film batch the following relationship was used:

$$D = b \times OD + c \times (OD)^n \quad (1)$$

where D is the dose; b, c, n and are parameters determined from the fit; and OD is the net optical density of the film given by:

$$OD = \log_{10} \frac{I_{unexp}}{I_{exp}} \quad (2)$$

where I_{unexp} and I_{exp} are the red channel colour values of the unexposed and expose film scans, respectively.

Figure 1a shows a typical calibration curve for our GafChromic® EBT3 film obtained in a 6 MV x-ray beam and the parameters b, c, n and for the two film batches for the five calibration x-ray beam are shown in Figure 1b-d, respectively.

Postal phantom: The proposed postal phantom is a 4 × 4 × 20 cm³ lucite phantom as shown in Figure 2. The phantom consists of two parts to allow placement of a 2 × 2.5 cm² GafChromic® EBT3 film at 8.9 cm depth. Conversion factors - listed in Table 1 - that relate the dose at 8.9 cm depth in the lucite postal phantom to the dose at 10 cm depth in a large water phantom for 10 × 10 cm² field size and 100 cm source-surface distance were calculated using DOSXYZnrc/EGSnrcmp Monte Carlo code for a number of clinical x-ray beams.

Thus, the schematics of the relationship between the dose measured in the lucite phantom to the dose at in water is shown in Figure 3.

Results: The performance of our proposed lucite postal phantom was tested in 15 clinical megavoltage x-ray beams across 4 radiotherapy centres in Saudi Arabia who were participating in postal services provided by either the International Atomic Energy Agency or the Radiological Physics Centre. The measured to stated doses of the 15 clinical beams, listed in Table 2, are within ± 5%.

Conclusion: In this work we have designed and tested a postal dosimetry system based on GafChromic® EBT3 films embedded in a custom made lucite irradiation phantom. Our results shows that outputs of clinical x-ray beams can be monitored with our system. Because of their energy independence at high energies, GafChromic® EBT3 film is a practical dosimeter that may be used for auditing clinical beam outputs.

Table 1: Conversion factors that relate the dose at 8.9 cm depth in the luctie postal phantom to the dose at 10 cm depth in large water phantom for 10×10 cm² field size and 100 cm source-surface

Beam	f_{postal}
Co-60	0.905
6 MV	0.920
15 MV	0.941
18 MV	0.964

Data calculated using DOSXYZnrc/EGSnrcmp monte carlo code

Table 2: Measured output with our lucite phantom to stated output for 15 clinical x-ray beams

BEAM	Measured / Stated	Batch	BEAM	Measured / Stated	Batch
A	1.04 ± 0.03	1	H	1.05 ± 0.03	2
B	1.02 ± 0.02		I	1.02 ± 0.03	
C	1.02 ± 0.04		J	1.02 ± 0.02	
D	0.98 ± 0.06		K	1.03 ± 0.04	
E	1.00 ± 0.02		L	1.04 ± 0.03	
F	0.98 ± 0.03		M	1.04 ± 0.03	
G	0.98 ± 0.02		N	1.01 ± 0.03	
			O	1.02 ± 0.03	

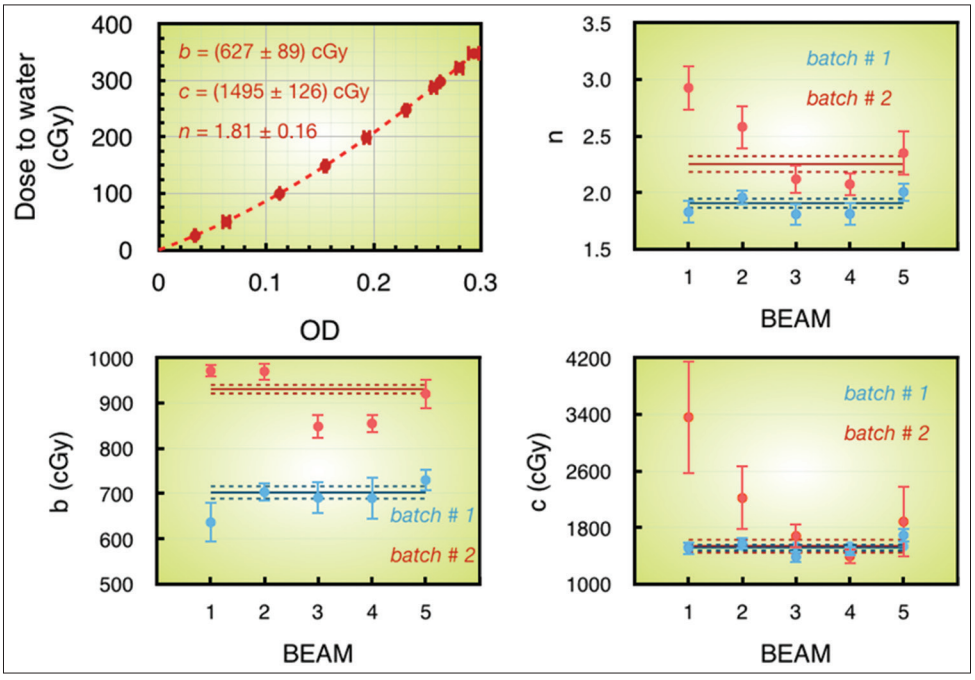

Figure 1: (a) Calibration curve for a GafChromic® EBT3 film in 6 MV beam (Red channel); the parameters, and of Eq. (1) as well as their statistical average (lines) for two film batches for five x-ray beams are shown in (b-d), respectively

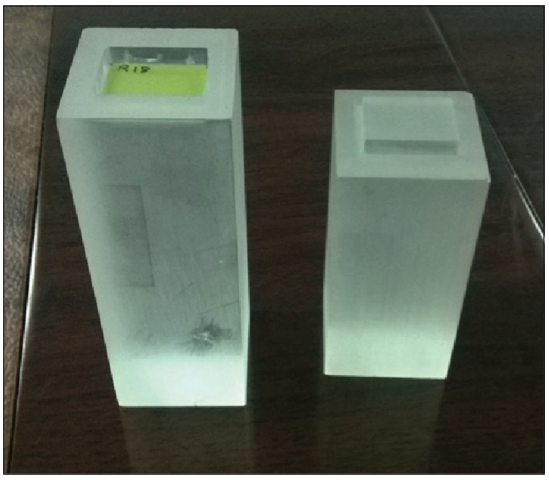

Figure 2: The postal phantom is a 4 × 4 × 20 cm3 lucite phantom consisting of two pieces to allow placement of our GafChromic® EBT3 film at 8.9 cm depth

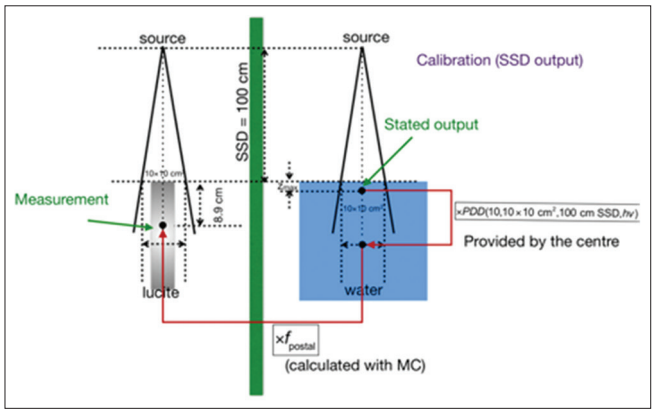

Figure 3: Schematic representation of parameters relating the dose at zmax in water to dose measured at 8.9 cm depth in the lucite postal phantom

I-18

METHODOLOGY OF DOSE REDUCTION IN INTERVENTIONAL RADIOLOGY

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All fluoroscopy equipment marketed in the United States must meet radiation control design specifications as mandated by the FDA. However, *no regulation on design can guarantee safe use.* Almost all fluoroscopic machines can expose patients to unacceptable and dangerous levels of radiation. In 1994, the FDA issued a public health advisory regarding "Avoidance of Serious X-ray Induced Skin Injuries to Patients During Fluoroscopically-Guided Procedures." Several key points in this communication are: (1) that all operators of a fluoroscopic system must be trained and understand system operation, including the implications for radiation exposure from each mode of operation, (2) facilities should ensure that physicians performing fluoroscopic procedures have education, and (3) assure appropriate credentials and training for physicians performing fluoroscopy.

As the operator of the equipment, you must know:

- How to properly operate the x-ray machine and how to properly use the features specific to that unit
- How to properly position the patient and the x-ray system for the procedure,
- How to control image quality (by properly selecting image quality and special dose rate controls, magnification, geometry, collimation, etc.),
- How to minimize radiation levels (by employing the same features as in the previous item),
- How personnel should be positioned for minimum radiation exposure, and
- How to properly utilize shielding devices and personnel monitoring devices.

Regardless of who controls the machine, the physician remains responsible for assuring that x-rays are properly/safely applied and appropriate radiation protection measures are followed. In the talk on fluoroscopy dose reduction, we will review the dose reduction options mentioned above.

I-19

ADDRESSING PUBLIC CONCERNS ABOUT THEIR EXPOSURE TO LOW DOSES OF ANTHROPOGENIC RADIATION

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The COG Strategic Research and Development (SRD) Low Dose Radiation (LDR) research program has now embarked on an independent and evidence-based research initiative in response to concerns and worries about the effects of exposure to anthropogenic radiation at low dose levels. A Canadian research team have taken up the challenge and will look to answer the following - What are the public concerns regarding exposures to low dose anthropogenic radiation; To what extent are the public concerns justified by evidence of adverse effects; Why are effects seen or not seen following LDR; How best are the results of studies communicated to the public; How effective have the communications been in reducing concerns? The LDR program is forecast to sustain at $1M per year over several years. A program overview will be presented with a detailed description of the individual research projects provided.

I-20

DIFFERENT MAGNETIC RESONANCE IMAGE CHARACTERISTICS FOR USING MAGNETIC RESONANCE IMAGING AS A READ-OUT TECHNIQUE FOR 3D GEL DOSIMETRY

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With rapid advances in radiotherapy treatment, 3D dose measurement techniques of great precision are required more than ever before. The fundamental chemical and

physical phenomena that occur in 3D gel dosimeters are used for detection and verification of dose distributions. Gel dosimeters are prepared with the help of radiation sensitive chemicals that, upon irradiation with ionising radiation, undergo a fundamental change in their properties as a function of the absorbed radiation dose. Fricke gel dosimeter and polymer gel dosimeters are the two emerging types of gel dosimeters. In order to evaluate the exposed gels different 'read-out' imaging modalities like magnetic resonance imaging (MRI), optical computer tomography, x-ray CT or ultrasound are used. The use of magnetic resonance imaging as a non-destructive measurement of a dosimeter gel was first proposed in 1984 by Gore *et al*. Different MR characteristics should be investigated before using MRI as a read-out technique for 3D gel dosimetry to avoid dose errors. Hence, in this talk, various MR image characteristics such as T1 and T2 contrasts, gradient imaging coils, spatial encoding methods i.e., slice thickness, frequency and phase encoding, properties of the K-space are discussed. Moreover, Spin Echo family sequences with their important parameters like TR, TE, Turbo factor, Inversion time, NEX, SNR, and Bandwidth are analyzed.

I-21

DOSIMETRY OF NUCLEAR MEDICAL IMAGING: CURRENT PRACTICES AND NEW MODALITIES

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Radiation dosimetry is a multi-disciplinary activity of theory, experiment and numerical evaluations, which involves physics, biology, statistics, instrumentation and computer modeling. Of primary interest are biological effects either for the harm they cause to living organisms or otherwise. As biological effects are consequences of chemical transformations, which in turn are due to ionization phenomena, the dosimetry relies on the number of ions created. In the context of medical imaging, the interest is mainly on photon interactions with matter. For practical assessment of dose deposits, great strides have been made in terms of the transducer development, speeds of data processing thanks to technological innovations of the latter half of the 20th century and they continue to evolve. The ever increasing computational power and the activities of high energy physics communities also contributed vastly to the dosimetric evaluations. In this regard, the Monte Carlo simulation codes based on the electron -gamma-showers are worth noting. In the last few decades, MCNP, EGS and the GEANT based GATE are now widely used with precisions and details unimaginable a few decades ago. Despite all these developments, the dosimetry is still missing an important ingredient. The dosimetry's ultimate aim is to assess the biological risk to the patient. However, physical instruments cannot access it.
My talk will highlight these developments and suggest a possible path to achieve accurate estimates of physico chemical phenomena for dose due to various species of radiations of use in medical imaging.

I-22

ELECTRONIC BRACHYTHERAPY

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Electronic brachytherapy is an advanced radiation treatment technique specifically designed to deliver high doses of radiation inside or very close to the tumor-bearing tissues. Unlike the traditional radionuclide-based brachytherapy, electronic brachytherapy uses a miniaturised x-ray tube that can produce radiation when energised. Most of the electronic brachytherapy systems operate at 50 kVp, therefore posing less radiation exposure to both patients and staff when compared to the standard Cobalt-60 or Iridium-192 based brachytherapy systems. Electronic brachytherapy systems have broader applications that include the treatment of skin, brain, breast, spinal metastasis, endometrium, and cervix. Most of the electronic brachytherapy systems require less shielding and can be operated in remote centres with minimal radiation shielding facilities. The dose fall-off characteristics of the Xoft Axxent electronic brachytherapy system mimic those of the low energy isotopes, yet the unit still maintains the high dose rate property of an Ir-192 source. Electronic brachytherapy systems have the potential to replace conventional radionuclide-based brachytherapy sources and systems.

I-23

A PLACE OF COBALT-60 UNITS IN REDUCING THE GLOBAL DISPARITY OF ACCESS TO QUALITY RADIATION THERAPY

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Cobalt-60 (Co-60) units are increasingly being replaced by linear accelerators (linacs) as the radiation therapy (RT) treatment unit of choice. The main reasons driving this change are the perceived disadvantages associated with Co-60 radiation such as lower photon energy, larger penumbra, lower radiation output, periodic source replacements, technological limitations and security issues. In contrast, linacs are considered to offer superior and state-of-the-art solutions including multiple photon and electron beams, intensity modulated RT (IMRT), image guided RT (IGRT) and motion management. Paradoxically, Co-60 technology has been responsible for many major RT milestones ahead of linacs, including, the first treatment of a patient with megavoltage RT (1951), the first stereotactic radiosurgery (Gammaknife, 1967), and the first magnetic resonance guided IGRT (Renaissance™, ViewRay 2014);[1,2] in part due to the uncomplicated aspects of Co-60 technology. More recently, specialized Co-60 units such as GammaPod for breast stereotactic body RT (SBRT) (Xcision Medical, USA) and the GB500 total body irradiation unit (Best Theratronics, Canada) have also become available.

Major Co-60 unit manufacturers now provide options for IMRT, IGRT and DICOM connectivity with their conventional units. For example, the Equinox unit (Best Theratronics, Canada) can be equipped with motorized wedge and multi-leaf collimator capable of three-dimensional conformal RT (3DCRT) and IMRT deliveries; the Bhabhatron 3i system (Panacea Medical Technologies, India) which allows for patient positioning with a hexapod couch with six degrees of freedom and low dose kilovoltage 'cone-beam' IGRT. Treatment planning studies have shown that Co-60 units can produce tomotherapy and IMRT treatment plans with quality similar to linacs.[3-7] These studies show that Co-60 radiation can provide clinically competitive plans compared to linacs, albeit with relatively less steep dose gradients outside the planning target volumes (PTV). Interestingly, a recent study involving lung patients treated with SBRT suggests that patients receiving higher doses outside the planning target volume (PTV) had less risk of developing distant metastases which highlights the potential pitfalls of treatment plans with steep dose gradients, a disadvantage usually linked with Co-60 radiation.

The global burden of cancer is continuously rising, more than half of cancer cases worldwide occurring in low and middle-income countries (LMICs) (GBD 2016); and >90% patients in low income countries (LICs) and >50% patients in LMICs lacking access to RT.[8,9] In high income/high resource settings, tremendous efforts are spent on fine-tuning steepness of the shoulder of the dose volume histogram (DVH) for the PTV, whereas the same DVH (PTV) for many patients in LICs/LMICs are either similar to DVHs for spared organs at risk, or don't exist at all (due to no access to RT). These issues have motivated many Co-60 and linac manufacturers to create clinically effective and economically viable solutions to perform quality RT in low resource and high volume settings. This has resulted in availability of "no-frills" Co-60 units including GammaBeam, (Best Theratronics); Bhabhatron II (Panacea Medical), and Halcyon™ linac system (Varian).

Linacs and Co-60 units offer different strengths in terms of infrastructure, maintenance, shielding requirements, staffing, costs, staff training, patient throughput, planning/dosimetry, and ease of clinical use.[10] Co-60 units and linacs thus offer complementary rather than competing technologies. Considering clinical needs, demography, geography, human and economic environments, Co-60 units and economic linacs can be strategically deployed to reduce the global disparity in access to quality RT.

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I-29

STATUS OF THE RADIOLOGICAL AND RADIONUCLIDE STANDARDS IN INDIA

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Radiation Standards Section, Radiation Safety Systems Division, BARC is the national custodian of radiation standards and also recognized as the Designated Institute (DI) for ionizing radiation metrology in India. It maintains a number of national standards for ionizing radiation and continuously updates them to achieve better accuracy. These standards include primary standards, secondary standards and working standards for radiological quantities, radioactivity, neutron, and chemical dosimetry. BARC has also been recognized as a Secondary Standard Dosimetry Laboratory (SSDL-BARC) by IAEA/WHO. Under this aegis, quality audits are being conducted since 1976 for assessing the dosimetric status of radiotherapy centres, nuclear medicine centres and radiation processing facilities in India.

Radiological standards for X-ray, gamma, neutrons and beta particles are maintained in BARC and their equivalence is established with international standards by participation in the international intercomparison programs organized by BIPM and APMP. Free Air Ionization Chamber is maintained as the primary standard for low and medium energy X-ray beam qualities (upto 300 kV). A graphite calorimeter is being developed as a primary standard for the measurement of absorbed dose to water for therapy level dosimetry. Diagnostic

beam qualities have been established for the calibration of instruments used in diagnostic radiology. Reference standard (cylindrical ionization chamber) calibrated at BIPM for absorbed dose to water and air kerma at ^{60}Co energy is used for the calibration of dosimeters of all the Radiotherapy Centres in India. A large volume cylindrical graphite ionization chamber is maintained as the reference standard for brachytherapy reference airkerma measurements. Traceable calibration to more than 300 brachytherapy facilities in the country is provided using this standard.

The SSDL-BARC activities also cover TLD postal dose quality audits for all the radiotherapy centres in the country under reference conditions. End-to-end IMRT Dosimetry audits are being conducted using film and TLDs inserted in a specially designed phantom. Beta dosimetry is carried out using an Extrapolation Chamber. A calibration facility has been developed at BARC for generating Series 1 and Series 2 reference fields as per international standards to calibrate beta measuring instruments.

Radioactivity standards have been established since 1970s in the laboratory. Over the years the $4\pi\beta$-γ coincidence method has evolved as the most powerful and widely used primary standard for radioactivity measurements. At present three $4\pi\beta$-γ coincidence primary standards with different detection mediums are operational in the laboratory. In addition, well type high pressure ionisation chamber and HPGe detector systems are maintained as secondary standard for radioactivity measurements. A gas flow multi-wire large area proportional counting system has also been developed and established for measurements of large area sources (10 x 15 cm^2). Traceability of radioactivity measurements at all the Nuclear Medicine Centres (~250) in the country is established by calibration of dose calibrators at BARC and also by conducting national audit of I-131 activity measurements. The talk will cover the present and future status of the radiological and radioactivity standards in the country.

I-30

IMPACT OF MEASUREMENT UNCERTAINTY IN MEDICAL PHYSICS

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Introduction: The measurements made within the Medical Physics discipline directly impact on the dose of ionising radiation that patients generally receive. Measurement uncertainty analysis is the process of defining the uncertainty of a measurement value. All measurements have an inherent uncertainty (the true value is never known). There are usually a range of factors that contribute to the uncertainty in the measured value. Each contribution may be large or small, and may contribute to the overall measurement uncertainty in different ways. Different measurements of the same quantity may yield different results, and it is impossible to tell which measurement is best without further information about the measurement. Measurement uncertainty analysis provides this additional information, allowing an uncertainty value to be assigned to each measurement. Measurement uncertainty was well entrenched internationally during mid 1900's and an accepted part of metrology. Historically many different measurement uncertainty techniques have been used to describe measurement uncertainty in various scientific disciplines including Medical Physics. This has led to problems whereby two scientific organizations wishing to compare measurement results have had difficulty because measurement uncertainties have not been calculated and expressed in the same manner. The development of innovative uses of measurement uncertainty analysis in the field of Medical Physics is the key focus of this work. The concept of measurement uncertainty is applied to generate innovative perspectives on issues that are important in the discipline of Medical Physics and the application of medical physics in a clinical setting. Specifically, the work addresses measurement uncertainty analysis to provide improved understandings of quality assurance test methods, effective dose calculation methods, and dosimetry indicators.

Purpose: The Guide to the Expression of Uncertainty in Measurement (GUM) is recognized by many peak international scientific organizations. However, there are shortcomings of GUM; for example, one of the biggest criticisms of the GUM is that it is a complex document to deal with, because it is underpinned with an extensive mathematical basis so that it has the capacity to deal with almost all measurement uncertainty problems. It has been identified that in certain circumstances, the assumption in the GUM that the probability density function of the measurand is a t-distribution (in accordance with the Central Limit Theorem) is not always the case. There has also been criticism that the evaluation of type A uncertainties should be conducted using Bayesian methods in certain circumstances The objective of this work is to employ measurement uncertainty analysis to differentiate effective dose calculation methods in a scientifically rigorous manner. Nevertheless, eight of the world's peak measurement bodies are joint publishers of the GUM and so it is presumed that the guiding principles of the GUM represent the best methodology for calculating and expressing measurement uncertainty. For this reason, the methods of the GUM were chosen to calculate and express measurement uncertainty values for Medical Physics problems. Before proceed further, it is useful to define measurement uncertainty.

Material and Methods:

Definition of Measurement Uncertainty

Measurement uncertainty is the specification of a range within which the 'true' (unknown) value is believed to lie with a specified level of confidence.

Link of measurement uncertainty to medical physics

Medical Physics is the application of physics to medicine. Medical Physicists are involved in radiation therapy, nuclear medicine, medical imaging and radiation protection. A large portion of medical physics measurements involve ionising radiation that is used for imaging and for therapy. It is therefore important that any radiation doses received by patients for imaging purposes are minimized and in the case of therapeutic uses, only the specified amount of radiation is delivered to a specified location within the body. Medical Physicists are therefore intimately involved in making important measurements that determine the

health outcomes of patients and so the correct calculation and reporting of measurement uncertainty is paramount. **Results and Discussion:** A case study of measurement uncertainty analysis of adult CT head scan dose estimates has been explored in this work. The effective dose (E) in mSv is calculated as product of the weighted CT dose index ($CTDI_w$), measured in phantom (mGy), scans length (L) in cm, and normalized effective dose ($E_{w,\ DLP}$) in mSv/mGy/cm. Dose length product (DLP_w) is further calculated by multiplying $CTDI_w$ and L.The uncertainty of effective dose estimates calculated using the DLP method is dependent on two factors: DLP_w and $E_{w,DLP}$. The value DLP_w displayed by a particular CT scanner may be either a manufacturer's nominal value, or a calibrated value based on measurements performed on that CT scanner. The value $E_{w,DLP}$ is an average of the sensitivity of the volume of tissue typically irradiated during a head CT scan. The analysis of the uncertainties was assessed in accordance with the GUM. The uncertainty components were considered as uncorrelated, so the combined standard uncertainty, U_{comb}, and effective degrees of freedom,

$$\nu_{eff},\quad U_{comb} = \sqrt{\sum_{i=1}^{N}(c_i u_i)^2},\ \nu_{\mathrm{eff}} = \frac{u_{\mathrm{comb}}^4}{\sum_{i=1}^{N}\left[\frac{(c_i u_i)^4}{\nu_i}\right]},$$

where the uncertainty parameters are standard uncertainty, u, degrees of freedom, μ and sensitivity coefficient, c. DLP values are based on CTDIw values, which in turn are based on two dose measurements within a 160 mm PMMA phantom. The combined uncertainty of two independent dose measurements, each with a standard uncertainty of 2.5% is 3.54%. The standard uncertainty due to using a single $E_{w,DLP}$ value for all CT scanners is equal to the percent standard deviation of the effective dose to $CTDI_w$ ratios for a range of scanners and was found to be 7.3%. **Conclusion:** Analysis of measurement uncertainty in medical physics has a greater impact to deliver an accurate dose to patients during radiotherapuatic treatment.

Oral

OP-1

A RADIOBIOLOGICAL AND DOSIMETRIC COMPARISON BETWEEN SIMULTANEOUS INTEGRATED AND SEQUENTIAL BOOST INTENSITY MODULATED ARC TREATMENT OF LOCALLY ADVANCED HEAD AND NECK CANCER: A PART OF RANDOMIZED PROSPECTIVE CLINICAL STUDY

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Introduction: Intensity Modulated Arc Therapy (IMAT/VMAT/Rapid Arc) is now considered as a better choice of intensity modulated radiotherapy treatment technique because of its advantages like higher patient throughput, expenses of lower monitor units and simplicity in treatment execution. The treatment delivery regimen may be in the form of Sequential Boost (SEQB) or Simultaneous Integrated Boost (SIB).In the SEQB regimen different plans are used for each phase of treatment, where as in SIB regimen a single plan is used throughout the course of treatment delivering differential doses to different target volumes.

Purpose: To compare the radiobiological and dosimetric parameters of the two regimens of IMAT i.e. SIB versus SEQB in locally advanced head and neck cancer patients.

Materials and Methods: A total of 24 previously untreated locally advanced head and neck cancer patients were included in this study. The patients were prospectively randomized into SIB and SEQB arm. The CT data set in treatment position were transferred to the ECLIPSETM Treatment Planning System (Version 11.0.47). All the target volumes i.e. Gross Target Volume (GTV), High Risk (HR), Intermediate Risk (IR), Low Risk (LR) Planning Target Volume (PTV) and Organ at Risk (OAR) were delineated. The treatment plan of each phase in SEQB regimen were independently optimized. All the patients were treated using 6MV linear accelerator (UNIQUETM Performance, Varian Medical System).

Results: In the SIB arm 11 patients and in the SEQB arm 13 patients were enrolled. The BED (10) value for HR PTV was same in both group, whereas for IR PTV and LR PTV the values were 59.0, 63.6 and 50.0, 56.0 for SIB and SEQB arm respectively. The V (95) values were 100% for all the target volumes in both arms of patents. The average D (100) value for GTV, HR PTV an IR PTV were higher in SEQB arm than in SIB arm (7066cGy vs. 6900cGy, 6720cGy vs. 6497cGy and 6308cGy vs. 5917cGy). The average D (100) value for LR PTV were 5037cGy, 4871cGy for SIB and SEQB arm respectively. The spinal cord maximum doses were within the tolerance in both group of patients. The left and right parotid gland sparing was comparable in both group of patients. Average integral dose was 12.8% higher in SIB group than SEQB group. The average total monitor unit per fraction was 25.6% higher in SEQB arm than in SIB arm.

Discussion: The SIB treatment regimen offers more organizational benefits over SEQB regimen in terms of practicality and lesser chances of treatment uncertainty. But SIB treatment when combined with chemotherapy may increase the toxicity profile as larger volume is irradiated throughout the treatment course. To balance the radiobiological volume effect, BED (10) values for IR PTV and LR PTV intentionally kept lower in SIB arm. In the SEQB, each phases were optimized independently, which cause the higher D (100) values for GTV, HR PTV and IR PTV in the plan sum dose volume histogram. D (100) value of LR PTV is lower in SEQB arm as prescription dose is much lesser than SIB arm (5000cGy vs. 5400cGy). As large volume is irradiated throughout treatment course in SIB arm, a clear increase in integral dose is observed. Promising reduction in MUs in SIB treatment may be considered as a good merit of this regimen.

Conclusion: SIB treatment regimen may be considered as more logical and efficient in the treatment of locally advanced head and neck caner with comparable radiobiological and dosimetric parameters. The clinical comparison may explore more pros and cons of SIB and SEQB.

OP-2

MEASUREMENT AND ANALYSIS OF SURFACE DOSE FOR FLATTENING FILTER FREE MEDICAL ACCELERATOR USING ADVANCED MARKUS CHAMBER

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Introduction: Surface dose plays a significant role in radiotherapy. Doses received by the basal skin layer can result in complications such as skin erythema, epilation, dry desquamation, wet desquamation, necrosis etc depending on the magnitude of doses received.[1] Hence, accurate measurement of dose at the surface is essential for proper treatment of patients. Surface dose is machine dependent and can be affected by many parameters such as field size, source-to-surface distance (SSD), beam energy, materials present in the beam line, type of dosimeter used for its measurement etc.[2]

Purpose: Recently, flattening filter-free (FFF) medical linear accelerator (linac) has been introduced in radiotherapy. With the filter removed, this low-energy component is allowed to pass through to the patient and will act to increase the surface dose. Energy spectrum and electron contamination are the two factors, which can change the surface dose in FFF. In this study, the relative surface dose has been studied for two different linac models in FF and FFF mode for 6 MV beam energy considering the fact that 6 MV is the beam of choice for various clinical cases.

Materials and Methods: Measurements are carried out for photon beams of one nominal energ 6 MV generated from Elekta Ltd make Versa HD model and Varian Medical System make TrueBeam Linac model in FF and FFF mode. The plane parallel plate ionization chamber, PTW Germany make Advanced Markus chamber Ionization chamber type 34045, having volume 0.02 cm3 with a thin flat window thickness of 0.03 mm (membrane material: PE (CH2)), a window area density of 2.76 mg/cm^2, a plate separation of 1 mm and a collecting electrode material acrylic (PMMA) graphite-coated having diameter of 5 mm was used. The surface dose for any field size is defined as the dose measured at 0.5 cm depth (from the surface) for that field size divided by the dose at dmax at a 10×10 cm^2 field size[3]. Surface doses are expressed relative to the dose at dose maximum for the respective energy and field size. The measurements were done for field sizes of 5x5 cm^2, 10x10 cm^2, 15x15 cm^2, 20x20 cm^2 and 25x25 cm^2 with build-up depths extending from the surface to 2 mm towards the dmax and at dmax. As the window thickness of the chamber is very less in comparison to other chambers the positional accuracy is considerable. The PP chamber was placed at 0mm, 1 mm and 2 mm depth to interpolate the ionization reading at 0.5 mm depth. The ionization value was also recorded for dmax of respective field sizes at 100 cm Source to Surface Distance (SSD).

Results and Discussion: The relative surface dose was observed to be greater for the FFF beam as compared to the flattened beam for the photon beam energy 6 MV in case of Varian True beam Linac. However, for Elekta Versa HD, the trend was similar up to 15x15 cm^2 field size and after which the relative surface dose increases as compared to 6FFF. TrueBeam gives higher surface dose than Versa HD for all the field sizes. Table 1 presents the measured relative surface doses from the two accelerators.

Table 1: Measured relative surface dose (%) for 6 MV x-rays of Versa HD and TrueBeam medical accelerators

Field Size (cm²)	*Relative Surface Dose (%) for*			
	Versa HD		*True Beam*	
	6 MV	*6 FFF*	*6 MV*	*6 FFF*
5×5	24.75	27.61	33.28	41.42
10×10	30.83	32.26	36.76	46.86
15×15	36.33	35.94	42.65	48.86
20×20	42.65	39.97	46.83	52.83
25×25	47.38	42.70	50.87	55.69

Conclusions: FFF beam change the dosimetric characteristics of photon beams by softening the energy spectra compared to beam hardened FF beams, thus changing surface doses. Our study compares the surface dose for two different Linac model from two different manufacturer. It is found that the variation in surface dose in Versa HD Linac is less in comparison to TrueBeam Linac.

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OP-3

A METHOD TO PREDICT ACHIEVABILITY OF CLINICAL OBJECTIVES IN IMRT

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Purpose: A data-driven method to predict the achievability of clinical objectives before performing the IMRT optimization is proposed.

Materials and Methods: In our approach, "Geometric Complexity (GC)" is computed to estimate the achievability of clinical objectives. Here, GC is the measure of the number of "unmodulated" beamlets or rays that intersect the Region-of-interest (ROI) and the target volume. The geometric complexity ratio (GCratio) between the GC of a region of interest (ROI) in a reference plan and the GC of the same ROI in a given plan is computed. The GCratio of a ROI indicates the relative geometric complexity of the ROI as compared to the same ROI in the reference plan. Hence, by using GCratio it is possible to predict the achievability of clinical objective associated with the ROI optimizer. Basically the likelihood for the optimizer to achieve the clinical objective defined for a given ROI is inversely proportional to GCratio. We have evaluated the proposed algorithm on six Head and Neck cases using Pinnacle3 (version 9.10.0) TPS.

Results and Discussion: Out of the total of 42 clinical objectives from six cases accounted in the study, 37 were in agreement with the prediction, which implies an agreement of about 88% between predicted and obtained results. The Pearson correlation test shows a positive correlation between predicted and obtained results (Correlation = 0.81, $r^2 = 0.66$, $P < 0.005$).

Conclusion: The study demonstrates the feasibility of the proposed method in head and neck cases for predicting the achievability of clinical objectives with reasonable accuracy.

OP-4

DOSIMETRIC VERIFICATION OF 3DCRT/VMAT USING INDIGENOUSLY DEVELOPED CU DOPED LITHIUM TETRABORATE (LI2B4O7:CU) THERMOLUMINISCENT CRYSTALS

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Introduction: Dose verification in the radiotherapy plays a very important role in overall success of different radiotherapy

techniques. Since it is necessary to do dose verification for advanced treatment techniques where verification of planned MUs is not possible with manual calculations, hence it is followed regularly at most of the radiotherapy centre. Different type of dosimetry system are used for this purpose, however, thermoluminescent dosimeters (TLDs) features many advantage such as small detector size, close tissue equivalence, high sensitivity etc. and hence, still preferred over other dosimetry system for dose verification in radiotherapy[1]. The LiF:Mg,Ti (TLD-100) is the most chosen dosimeter in radiotherapy. Technical Physics Division of Bhabha Atomic Research Centre has developed a high sensitive, tissue equivalent Li2B4O7:Cu TL crystal for dosimetric applications [2]. The aim of this work was to study the potential application of the indigenously developed Li2B4O7:Cu TL dosimeters in dosimetric verifications of different treatment techniques used in external beam radiotherapy.

Materials and Methods: Technical Physics Division of Bhabha Atomic Research Centre has developed TLDs that are available in form of chip of dimension 3 x 3 x 1 mm^3. TLDs used in the study were selected on the basis of repeatability test. Repeatability of the TLDs was checked out by irradiating freshly annealed TLD chips to a dose of 200 cGy using 6 MV X-ray. The process was repeated 4 times. The mean TL read out value, its standard deviation and coefficient of variation were calculated for each TLD. The TLD chips with coefficient of variation under 1.5% were selected for further study. The selected TLDs were subjected to further tests such as linearity with dose, energy dependence, dose rate dependence, dose fractionation dependence, angular dependence etc. The calibrations of TLDs were done by calculating elemental correction coefficient for each TLD. Finally TLDs were used for patient specific dosimetric QA for different planning techniques. The TLD-100 samples were, in parallel, also evaluated for above mentioned tests. Indigenously developed anthropomorphic IMRT dosimetry QA phantom representing the thorax region was used. The phantom has in-built planning target volume (PTV) as well as organ at risk (OAR) with feature to carry out point as well as 2-D dosimetric QA using TLD/Optical stimulated luminescence dosimeter (OSLD) and radiochromic films respectively. Volumetric CT scan of the phantom was acquired with slice thickness of 2.5 mm at 120 kVp using helical CT machine. Dose Verification QA plans for different techniques (3DCRT and VMAT) were made using Varian's Eclipse treatment planning system. The phantom containing TLDs *in-situ* at different positions inside the PTV as well as OAR regions were irradiated for the planned treatment procedure. The TLD measured dose at all positions in the PTV as well as OAR were compared to TPS calculated dose at corresponding locations and relative percentage deviations with respect to prescribed dose was determined.

Results: The percentage variations in 3DCRT were found to be within 3%, both in PTV and OARs. However, percentage variations in VMAT were found to be within 3% at most of the points except at one point in OAR, where it was found to be 5.76%. This higher variation may be attributed to the higher dose gradient in OAR.

Conclusions: The results of dose verification, carried out using Li2B4O7:Cu in 3DCRT/VMAT were found to be satisfactory. These initial enthusiastic results also prompt to carry out further detailed study on the potential application of these crystals as a substitute of TLD-100 in much wider spectrum of medical dosimetry.

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OP-5

IMPACT OF ARTIFACT EFFECT IN THE PLANNING OF VMAT AND HELICAL TOMOTHERAPY PLAN ANALYSES IN THE HEAD AND NECK CASES AND ITS COMPARISON

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Introduction: The metal implant in the planning Computerized Tomography (CT) image is unable to be avoidable. The presence of metal implant leads to artifact in the planning CT image due to its Extreme high absorption, Artifact effect leads to loss of anatomical information and inaccuracy in the dose calculation.

Purpose: The aim of the study is to analysis the impact of artifact effect in the planning of VMAT and Helical Tomotherapy (HT) planning in the Head & Neck (HN) cases and to compare both VMAT and HT plans.

Materials and Methods: There are six patients have under gone planning CT image with and without manual inserted metal (Unknown density) from 15 total patients, and remaining 7 patients image data were selected with unavoidable metal like dental implant and fibula graft. The First seven patient's planning have done with both machine True Beam (TB) Linac (Varian Medical system) equipped with Millennium 120 MLC and Tomo (H) (Tomotherapy-accuray) having 64 binary MLCs, Each patient's plans have done with three different categories are With Artifact (W-ART), Without Artifact (WO-ART) and HU corrected (WC-ART), The second Each 7 patients plans done with two categories W-ART and WC-ART. Eclipse planning system (V13.6) and Tomotherapy planning system were used for All planning for both TB and Tomo (H) respectively. We were measured dosimetry data for all plans for comparison between Eclipse plan and Helical Tomotherapy (HT) plan.

Results: We were found significant variation in Conformity Index (CI) and homogeneity index (HI) between W-ART and WO-ART in TB and HT, and less than 1.5% variation between W-ART and WC-ART in both machine. Insignificant variation was found in OAR doses between W-ART and WC-ART. Almost 3-4% more deviation was found in OAR doses between W-ART and WO-ART in both machines. HT plans having better 98% dose coverage than TB patients plans. Avg 2-3Gy dose deviation was found more in TB than HT plans.

Discussion and Conclusion: True beam plans are better CI and HI than HT plans in image having with artifact. HT plans having better dose coverage and HI than true beam in image without artifact. HT plans are better dose reduction in OAR Dose than TB planning for both images having with and without artifact. There is no significant variation was found between corrected HU plans and W-ART plans.

OP-6

EVALUATION OF VOLUMETRIC MODULATED ARC THERAPY FOR THE CARCINOMA OF LUNG

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Introduction: In patients with locally advanced non metastatic carcinoma of lung with large Planning Target Volume (PTV) eligible for radical radiotherapy, meeting dose constraints for organ at risks (OAR) with Three Dimensional Conformal Radiotherapy Therapy (3DCRT) is not possible and in these patients VMAT is necessary to achieve this.
Purpose: The main goal of the study is to analyse the dosimetric parameters of radiotherapy planning with reference to International Commission on Radiation Units and Measurements (ICRU 83) for carcinoma of lung treated using Volumetric Modulated Arc Therapy (VMAT) on Varian Eclipse Treatment Planning Systems (TPS) version 15.1.
Materials and Methods: Thirty patients of Lung Cancer with Median Volume of (PTV) 784.71 cc were planned using the technique VMAT, in the Eclipse version 15.1 Anisotropic Analytical Algorithm (AAA). These plans were evaluated using dosimetric parameters Conformity Index (CI), Homogeneity Index (HI) as recommended in (ICRU 83).
Results: The median CI and HI for the VMAT plans were 0.89, 0.11 respectively. The Median Mean lung doses (MLD) was 15.84 Gy. Lung Median V20Gy, V10Gy, V5Gy were 29.88%, 46.6%, 64.74%. Heart Median V30Gy was 25.54%. Heart Median Mean doses was 18.13 Gy. Spinal Canal PRV Median Max Doses were 43.84 Gy. Esophagus Median Max dose were 60.36 Gy. Esophagus Median V15Gy was 52.76%.
Discussion and Conclusion: Even though We could achieve the good values in dosimetric parameters like CI, HI for the PTV Coverage normal tissues constraints for the lesser PTV volumes in the Field-in-Field Plans, VMAT plans seems to be better when the PTV volumes were larger and if were very much close to the Spinal Cord and concavity nature. VMAT enables delivery of radical doses of radiotherapy even in patients with very large PTVs where dose constraints could not be met with 3DCRT.

OP-7

OPTICALLY STIMULATED LUMINESCENCE OF LICAALF6: TB PHOSPHOR

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Introduction: The measurement of the radiation dose using highly sensitive TL/OSL radiation dosimeters with great precision and accuracy is increasing worldwide. In medical dosimetry, it is important to precisely measure and monitor the dose delivered to the patients to ensure that prescribed dose is received by the target area and normal tissue is within tolerance. OSL has become a well known technique to measure the radiation dose absorbed by the material. LiCaAlF6 is one of the important materials used as OSL phosphor due to its interesting properties such as non toxicity, low hygroscopicity, high thermal durability, wide band gap etc. LiCaAlF6:Eu2+ and LiCaAlF6:Ce3+ have shown good TL and OSL properties. Therefore, it is important to improve the OSL dosimetric properties of this phosphor doping with other rare earth ion dopant. In this work, we have attempted to prepare the LiCaAlF6 phosphor doped with Tb and investigate its OSL properties.
Objectives: To prepare the LiCaAlF6 phosphor doped with Tb using melting method and investigates the optically stimulated luminescence (OSL) properties.
Materials and Methods: LiCaAlF6: Tb was prepared by using reagent grade salts of the constituent metals and rare earth salt Tb in the form of TbF3 (Terbium Fluoride) in the stoichiometric ratios in a graphite crucible and heated in the furnace available in SERL lab at GGSIPU at ~ 1073K in argon gas atmosphere. The samples were annealed at 673K for 1 h before use. The CW-OSL was recorded on Risø TL/OSL reader after stimulated with blue light with a dose of 20 mGy.
Results and Discussion: The XRD pattern matches well with the standard XRD pattern (pdf no. 00-043-1481) which shows the formation of pure LiCaAlF6 phase. Optically stimulated luminescence - The OSL signal of LiCaAlF6 and LiCaAlF6: Tb prepared as described above compared with the OSL signal from Al2O3: C. The OSL intensity of LiCaAlF6: Tb is 25 times higher than undoped LiCaAlF6. It is worth mentioning that OSL intensity of LiCaAlF6: Tb was also higher about 1.5 times as compared with commercially available Al2O3: C (BARC), under the same measurement conditions explained earlier.
Conclusion: LiCaAlF6 and LiCaAlF6: Tb phosphor were synthesised by melting method and their OSL properties were investigated. The OSL intensity of LiCaAlF6: Tb is 25 times higher than undoped LiCaAlF6. It is worth mentioning that OSL intensity of LiCaAlF6: Tb was also higher about 1.5 times as compared with commercially available Al2O3: C (BARC). These promising results led to further investigation of the material and applicability of this phosphor in medical dosimetry.

OP-8

OUT OF FIELD DOSE MEASUREMENTS FOR ELECTRON BEAMS AT DIFFERENT DEPTHS AND DISTANCES

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Introduction: The large improvements in radiotherapy (RT) procedure have led to high survival rates of the patients, so the possible late side effects of the dose delivered to the normal tissues will be a growing concern. More understanding of side effects of RT will require not only improved control of the high doses delivered to the target volumes, but also better knowledge of the unintended but unavoidable lower doses delivered out of the target. Due to scattering radiation, it affects the normal tissues and probable to induce the secondary cancer. In external beam therapy, out of field doses are one of the core contributors.
Purpose: To investigate the out of field dose for the electron beams used in external beam radiation therapy with different applicators size with different depths and distances.

Materials and Methods: For this experiment we are using Elekta synergy platform linear accelerator. It has three electron energies of 6 MeV, 12 MeV, and 15 MeV. These measurements were carried out with the parallel plate ionization chamber with standard imaging electrometer. The chamber was placed at isocenter in slab phantom with 2 cm backscatter. For all this experiment we delivered 100 MU. Readings are taken at various depths like 1 cm, 3 cm, 5 cm and 10 cm with different applicator sizes. The out of field dose measurements were taken by 5 cm to 50 cm distance from the field edge in cross plane and in-plane. All measurements are taken at 100 cm SSD.

Results: Out of field doses in high energy electron beams are evaluated for different depths (1 cm, 3 cm, 5 cm, and 10 cm) with different applicator sizes. The readings are taken at isocenter and various off- axis distance, 5 cm to 50 cm in cross plane (x) and in plane (y+, y-). The percentage of the dose evaluated by corresponding meter reading at isocenter. The peak value of out of field dose for 6 MeV, 12 MeV & 15 MeV tabulated for different applicator size at the following depths 1 cm, 3 cm, 5 cm and 10 cm and at 5 cm distance the peak value of out of field dose observed and tabulated.

Discussion and Conclusion: Graphs plotted between percentage dose with off axis distances. Percentage dose increases in cross plane (x-plane). For all three energies and all applicator sizes, out of field dose at cross plane (x) are slightly higher than in-plane (y-, y+). Out of field dose gradually decreases with off axis distance in all three planes. The out of field doses for various distance 5 cm up to 50 cm, and for different applicator from 6 x 6 cm^2, 10 x 10 cm^2, 14 x 14 cm^2 at various depth 1, 3, 5, 10 cm. Outfield dose is higher in X-Plane as compared to Y plane due to X jaw replacement MLC.

OP-9

FEASIBILITY OF DYNAMIC FLAT BEAM TECHNIQUE IN FLATTENING FILTER FREE BEAM ONLY LINAC – COMPARISON OF DYNAMIC FLAT BEAM CHARACTERISTICS WITH STANDARD 6MV FLAT BEAM

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Introduction: In recent years application of flattening filter free beam (FFF) has increased tremendously due to its advantages like increased beam intensity, reduced head scatter & out-of-field dose and shorter beam-on time. Due to these advantages, linac vendors are now coming up with FFF beam only (Halycon). The one disadvantage of having only FFF beams is that for conventional 3D radiotherapy of large targets, total body irradiation and other extended SSD treatments such as mantle fields and spinal fields for crano-spinal irradiation, using FFF beams may not be possible. This issue can be addressed by including an internal optimization option to generate a flat beam profile but currently such an option is not available. Therefore in this study from a FFF beam, we try to create a dynamic flattened beam (DFB) using MLC's and IMRT optimization algorithm. Further, we analyze the beam parameters like flatness, symmetry, penumbra, full width at half maximum (FWHM) and cross compare it with standard 6MV flattened beam (FB).

Materials and Methods: In Varian Clinac-2100CD, beam parameters (gun current, voltage, etc.,) remain same for flattened and un-flattened beam, by removing the flattening filter from beam path increases the dose rate from 600 to 1400 MU/min and produces a forward peaked dose profile. Absence of flattening filter also increases the low energy X-ray component which leads to decrease in PDD from 66.6% (FB) to 63.8% (FFF). To create DFB, a homogeneous phantom image set (50 cm x 50 cm x 50 cm) was created in Eclipse TPS (V11.3). Dose calculations were performed in the above phantom for standard 6MV FB for different field sizes (FS) 6 cm x 6 cm, 10 cm x 10 cm, 16 cm x 16 cm and 20 cm x 20 cm and the dose was normalized at different depths of 1.5, 5, 10, 15 & 20 cm. Similar dose profiles were recreated for a 6MV FFF beam using DVO optimization algorithm and millennium 120 MLC. Further these dose profiles were exported to OmniPro software for beam profile analysis. Comparisons of beam parameters like flatness, symmetry, penumbra & FWHM were performed between the FB and DFB plans. Also the global hotspot (GHS), monitor units (MU) and gamma agreement index (GAI) were compared between both FB and DFB plans. Statistical analyses were performed using the Student's *t*-test (un-paired). In linac, beam profile measurement was performed using EPID for both FB & DFB.

Results and Discussion: The mean GHS was 165.1% (±58.3) and 172.6% (±67.4) for FB and DFB (p-0.7129). The increase in GHS in DFB was primarily due to difference in PDD. The mean MU was 160.4 (±57.4) and 385.7 (±206.4) for FB and DFB respectively ($P < 0.0001$). Due to the presence of non-uniform beam profile of the FFF beam, compared to the FB, the DFB beam tends to use more MUs/Modulation to deliver the uniform dose profile. The average GAI between FB and DFB was 98.5 (±0.32) with criteria 3 mm DTA and 3% dose difference. Flatness calculated for different FS and depth, the mean values of cross-line and inline values were 2.05 (±1.07), 2.29 (±1.16), 1.97 (±1.03) and 2.23 (±1.13) for FB and DFB respectively. Flatness for cross-line and inline of FB & DFB matches closely with p value of 0.5042 & 0.2507 respectively. This clearly indicates that dynamically modulated MLC can produce flat beam as good as flattening filter created flat beam. Similarly for symmetry, the mean value of cross-line and inline values were 0.22 (±0.09), 0.51 (±0.06), 0.19 (±0.12) and 0.51 (±0.30) for FB and DFB respectively (P - <0.0001 & <0.0001). Although this is statistically significant, the symmetry values were well within tolerance limit of 2%. For penumbra, mean values of cross-line and inline were 0.53 (±0.21), 0.55 (±0.19), 0.53 (±0.22) and 0.56 (±0.19) for FB and DFB respectively (P - <0.7461 & <0.561). For FWHM, the mean values of cross-line and inline values were 14.36 (±6.28), 14.31 (±6.19), 14.38 (±6.17) and 14.29 (±6.17) for FB and DFB respectively (P - 0.9828 & 0.9649). The results clearly show there is no significant difference in penumbra and FWHM between FB & DFB. Measured flatness, symmetry, penumbra & FWHM using EPID for 20 cm x 20 cm FS in FB were 1.09, 0.86, 0.34 & 20.2 (cross-line) and 1.52, 1.19, 0.3 & 20.2 (inline) respectively whereas for DFB the values were 1.22, 1.15, 0.36 & 20.1 and 1.45, 1.84, 0.3 & 20.2.

Conclusion: The result from this study shows that new type of linear accelerators with FFF beam only can still produce flattened beam with its beam characteristics similar to standard 6MV flat beam.

OP-10

CLINICAL EVALUATION FOR SETUP ACCURACY OF OSMS DATA OVER CBCT MATCHED VALUES FOR BRAIN METASTASIS WITH STEREOTACTIC RADIOSURGERY

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Introduction and Purpose: To evaluate the accuracy of a video-based optical surface imaging system for motion monitoring during stereotactic treatment of brain metastasis. Precise patient positioning and thus of the PTV is a prerequisite for effective treatment with SRS for brain metastasis. The intra fraction motion should at least be within the CTV-PTV margin used. Conventional imaging modalities used to ensure exact positioning for treatment typically involve additional radiation exposure of the patient. Patient alignment and monitoring during treatment, without additional exposure, is provided by optical 3D surface scanning and registration systems. Typical SRS brain treatments with multiple couch angels limits the ability of CBCT verification during treatment. This paper aims to correlate the data obtained by the OSMS system with the internal shifts observed by the offline CBCT matches pre and post treatment.
Materials and Methods: Patients treated with stereotactic radiosurgery (SRS) and fractionated stereotactic radiotherapy (FSRT) were immobilized with a thermoplastic double shell open face mask and a SRS immobilisation system (Encompass™ Immobilisation System and Encompass™ SRS Fiberplast Qfix). During treatment a video-based three-dimensional optical surface monitoring system was used to monitor the motion of a region of interest. This motion monitoring was done in 6 dimensions. A tolerance of 0.2 cm for linear directions and 0.5 degrees for rotational directions was set. If the optical surface monitoring system detected an exceeding of the set tolerance, treatment stopped automatically. If necessary, the physician decided to take a new CBCT. A total of 13 patients were followed for SRS or FSRT treatment between January 2016 and May 2018 with a total of 19 fractions evaluated for intra fractional uncertainties. Both CBCT and snapshots obtained with the OSMS were acquired at the start and stop of every treatment to compare both methods. In addition the average motion and SD during treatment was monitored to investigate the validity of pre- and post-measurements for assessing intra fractional motion.
Results: A pre-treatment mean intra fractional shift for of 0.12 cm in vertical (STDEV of 0.08), 0.11 cm in longitudinal (STDEV of 0.11), 0.17 in lateral direction (STDEV of 0.14). Only in one patient, set tolerance was exceeded and a new CBCT was taken which showed a lateral shift of 0.47 cm. A post-treatment mean intra fractional shift for of 0.04 cm in vertical (STDEV of 0.05), 0.05 cm in longitudinal (STDEV of 0.05), 0.04 in lateral direction (STDEV of 0.05). None of the patient were exceeded set tolerance during treatment.
Conclusion: The CBCT data clearly shows that the intra fractional offset of all brain metastasis patients treated with SRS or FSRT was below the institution's predefined threshold. The OSMS data obtained during treatment still needs a more detailed evaluation. For further analysis the approach was changed and real time data during treatment is now continuously triggered, obtained, mathematically analysed and compared with the CBCT offline calculated offset.

OP-12

INTENSITY MODULATED TREATMENT PLANNING FOR TOTAL BODY IRRADIATION

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Introduction: TBI is traditionally treated using a conventional Linac using static AP/PA or parallel-opposed lateral beam arrangements at extended source-to-surface distance (SSD). Photon beam energies between 4 and 24MV can be used with tissue compensators to boost regions of varying patient thickness or shielding blocks to limits dose to organs at risk (lungs, kidney). Recently, there has been a shift toward more advanced TBI treatment technique with utilization of intensity modulation which achieves homogeneous dose distribution. The TBI treatment with IMRT doesn't require the bigger bunker as well special equipments.
Objective: The aim of this study was to investigate the feasibility of achieving acceptable TBI plan using Intensity modulated technique with the Eclipse treatment system.
Methodology: A retrospective analysis was performed on four patient's CT data. CT images were obtained in the Head-First-Supine (HFS) orientation from the top of the skull to feet with a 5 mm slice thickness. In the case of greater length (more than 140 cm) patient treatment, another CT in Feet-First-Supine orientation is required. The FFS is intended for the legs to be treated with conventional AP/PA fields. A full body vacuum bag was used for immobilization. The planning target volume (PTV) was defined as the entire body, contracted to 2 mm below the skin. The planning aims were to deliver uniform 12Gy to the PTV while limiting the mean lung dose to less than 8Gy, and mean dose to kidney below 9Gy. A jagged-junction IMRT technique using multiple isocenter was used to overcome problems associated with field junctions and beam edge matching as well improves planning and treatment setup efficiencies with homogenous target dose distribution.
Results: The mean conformity index achieved was 0.93 ± 0.02 and the mean homogeneity index was 1.10 ± 0.02. The mean dose to PTV was $11.82Gy \pm 0.2$ and max dose (D2) of PTV was $12.62Gy \pm 0.25$. The dose for the OAR's were found to be within the acceptable limit, the lung mean dose was $7.89Gy \pm 0.35$ and the Kidney mean dose was $8.78Gy \pm 0.48$.
Discussion and Conclusion: This study has demonstrated the feasibility of achieving clinically acceptable IMRT TBI plans with Eclipse treatment planning system. The advantages of this technique include improved patient comfort and positioning reproducibility during treatment, accurate 3D dose

information, and ability to selectively spare organs at risk. It is important to note that the irradiation of lower limbs was not included in this study. It is intended the legs be treated in the feet-first direction using AP/PA beams with conventional static fields. The Junction AP/PA beams for the legs are deemed acceptable owing to the absence of any organs at risk, and are the simplest approach to achieving the prescribed dose to the target.

OP-13

AN INDEPENDENT METHOD FOR MANUAL VERIFICATION OF MONITOR UNITS FOR MONOISOCENTRIC TREATMENT PLANS OF PATIENTS WITH CARCINOMA OF BREAST

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Introduction: Radiation therapy (RT) in breast cancer has evolved dramatically over the past century. The CT-based 3-dimensional conformal radiotherapy (3DCRT) planning of Breast and Supraclavicular Fossa (SCF) can be achieved by either Dual Isocentric technique (DIT), one each for Breast and SCF or using single Isocentre for both Breast & SCF i.e. Mono-Isocentric technique (MIT). The AAPM Task Group report 71, recommends that it is an essential part of quality QA to verify Monitor units (MU's) to be delivered using treatment plan calculated by treatment planning system (TPS) with independent MU verification to correct any potential errors prior to the start of the treatment. In case of DIT, MU verification is established. But in case of MIT, the MU verification for breast plans becomes challenging due to involvement of quarter fields, blocked Isocentre, contour irregularity and complex treatment geometry.
Purpose: To establish a method for manual verification of the TPS calculated MU for MIT plans.
Materials and Methods: Twenty patients with MIT treatment plans were retrospectively selected for this study. All patients undergone CT based Simulation in supine position with appropriate immobilization devices and planned for 3DCRT MIT plans with optimizing photon energy, beam angles, beam weights, field in field technique with fixed collimator jaws using multileaf collimators(MLC) to achieve clinically acceptable plans. The dose calculation was done with calculation grid size of 2.5 mm using AAA algorithm in Eclipse TPS (v 13.5) with heterogeneity correction. As isocentre was blocked, the plans were normalized on reference points with prescription dose of 40 Gy in 15 fractions. The various parameters required for MU calculation were derived from TPS. The equivalent Square field sizes & water equivalent depths (WED) were determined from field Beams Eye View (BEV) and WED tool respectively. The corresponding output and TMR values were taken from lookup tables. The Effective target to Surface Distance (SSD) in reference point plane was determined to calculate inverse Square factor (ISF). The normalization factor for each individual field was determined at reference point by dividing percentage normalization value of the field by percentage normalization value of the plan. The doses for individual treatment fields were determined by multiplying normalization factor with prescription dose. The Enhanced Dynamic Wedge (EDW) factors for quarter field with both positive and negative off-axis distance (OAD) convention were calculated using EDW formula and verified dosimetrically as well as using Segmented Treatment Tables (STT) generated by treatment unit. The output factors were measured at centre points of quarter fields for all four quadrants. The output factors were also verified by TPS as well as from diagonal profiles used for beam configuration. This output factor was incorporated in the MU calculation to account for output of quarter field. All Dosimetric measurements were performed using 0.65 cc cylindrical ionization chamber using slab phantom. Finally the MU's were calculated using formula: MU = Dose (cGy)/ Output (cGy/MU) * TMR * ISF * EDW (OAD) * Output factor.
Results: There is good agreement between TPS and manually calculated MU's, The Mean variation is found be 2 ± 1.9 MU.
Conclusion: A method for manual verification of the TPS calculated MU's for MIT plans has been devised and validated successfully. It is being routinely used for cross-checking the TPS MU's as an audit protocol in the department. As manual calculation do not consider all scatter factors & kernels like TPS, variation of ±5 MU is acceptable as a quality audit.

OP-14

COMPARISON OF ANISOTROPIC ANALYTICAL ALGORITHM AND ACUROS XB IN FLATTENING FILTER FREE BEAMS USING AN INHOMOGENOUS PHANTOM

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Introduction: Flattening Filter Free (FFF) beams are widely used in volumetric modulated arc (VMAT) based Stereotactic Body Radiation Therapy (SBRT) of lung tumors. Different types of dose calculation algorithms are clinically available and employed to compute the dose distribution for SBRT plans. Presence of tissue in-homogeneity poses challenges in dose calculation and the accuracy of such calculated dose with FFF beams needs evaluation.
Objective: To validate and compare the accuracy of Anisotropic Analytical Algorithm (AAA) and Acuros XB dose calculation algorithms in flattening filter free (FFF) beams using an inhomogeneous phantom.
Materials and Methods: An inhomogeneous thorax phantom (Computerized Imaging Reference Systems Inc, USA) having dimension of 17.5 cm long x 30 cm wide x 20 cm thick were used for the study. The phantom has two distinct spaces having different electron densities characterizing human lungs surrounded by soft tissues. Both the regions have provisions for measurements using film and ion chamber along with suitable inserts. The thorax phantom was CT scanned with a slice thickness of 1mm and imported in Eclipse TPS (Varian Medical Systems, USA). Two different types of dose calculation algorithms, AAA and Acuros XB are available in Eclipse TPS. AAA is a model based algorithm which uses a 3D pencil beam convolution-superposition model to calculate the dose whereas Acuros XB utilizes a linear boltzmann transport equation for dose computation.

Both the algorithms can be used for dose calculations with flattened and unflattened beams as well. For accuracy evaluation of algorithms at FFF beams in inhomogeneous media, treatment plans utilizing 6MV-FFF beams with varying degree of complexity which includes from simple open fields to complex modulated arc fields were planned in the thorax phantom. The doses were calculated in the phantom individually by both the algorithms using a calculation grid size of 2.5 mm for all the plans. Open field plans were created using jaws and MLCs separately for different field sizes (5, 10 and 15 cm^2) for both static (AP-PA, bilateral and obliques) and arc (full and partial) delivery. 5 VMAT based SBRT plans were also planned for delivery and dose comparison between algorithms. The plans were then delivered in Truebeam SVC linear accelerator (Varian Medical Systems, USA) equipped with 120 Millennium Multileaf Collimator (MLC) with the thorax phantom and an ion chamber (0.125cc) at suitable place for measurements. The measured point doses were compared against the algorithm computed dose in TPS for all the plans. Before comparison, measured doses were corrected for daily output variation in linac.

Results and Discussion: For open static fields, comparison made between the measured and TPS computed dose shows a maximum dose difference of +0.85% and -0.4% for AAA and Acuros XB respectively. An average point dose difference of 0.55 ± 0.4% in AAA and 0.3 ± 0.1% in Acuros XB is observed for open arc fields across the field size studied. In VMAT plans, for AAA and Acuros XB, the maximum point dose deviation between measured and calculated is +1.7% and +1.1% respectively. Plans calculated with Acuros XB algorithm has shown better agreement with measured doses than AAA.

Conclusion: The result of our study shows that both AAA and Acuros XB dose calculation algorithms are comparable and accurate enough in dose computation at inhomogeneous media with FFF beams.

OP-15

A STUDY TO DETERMINE THE LEAST SUSCEPTIBLE PLANNING TECHNIQUE TO PROTON DOSE COMPUTATION ERROR IN PSEUDO CT

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Purpose: This is to study and determine IMPT planning technique, which has least susceptibility to CT number approximation of Pseudo CT images based on dose computation accuracy.

Materials and Methods: Five male pelvis Pseudo CTs were studied which were generated by Philips Ingenia MRI system known as MRCAT (Magnetic Resonance for Calculating ATtenuation) images. Pinnacle3 Proton treatment planning tool was used to generate treatment plans with Proteus Spot scanning proton machine. Regular CT image plans were used as reference plans. Steps of Study: (1) Multi field Optimization (MFO), Single Field Uniform Dose Optimization (SFUD), Robust Optimization (RO) plans were created in CT images of 5 patients for ca. prostate cases. (2) Created plans were copied to MRCAT images using Dynamic planning tool of Pinnacle3 along with ROIs and POIs. (3) Dose is computed in the MRCAT pseudo CT images with the same dose grid resolution of reference CT plans. (4) Published MRCAT CT to Density table and correspondingly scaled CT to stopping power were used for dose computation. (5) MRCAT plans are compared against corresponding reference CT plans. (6) MRCAT and CT plans were analyzed with DVHs, iso-dose lines and 3D gamma analysis.

Results and Discussion: Comparison of MFO plans shows significant difference in dose suggesting this planning technique is susceptible dose computation error in Pseudo CT images. In MFO plans dose modulation is high such that even a slight change in the geometric CT error would result in high dose error. SFUD plan evaluations suggests a reduction in dose difference (around 4% more points pass the 3D gamma) and seems relatively better planning technique for MRCAT plans. Robust optimization, which is supposed to make the plans less vulnerable to patient set up error and range error, seems a good choice as it smudges rapid dose fall and compensate for range error of proton beams. Around 8% more points pass gamma criteria for robustly optimized plans. Plans created by combination of robust optimization and SFUD also gives a robust plan with 8% hike in gamma passing points, stating it is less susceptible to dose error caused by stratified CT number approximation.

Conclusion: The dose error is mainly due to difference in the radiological distance (WET-Water Equivalent Thickness) of the data sets and error in spatial distribution of CT numbers. With the right CT to density table and CT to Stopping power table, error in radiological depth of the pseudo CT can be minimized. But the CT number geometric/spatial error is difficult to tame due to the high heterogeneity resolution of patient image data. This study shows Robust optimization with 5% range error input helps to reduce the sensitivity of dose to CT density approximation. Due to the difference in CT density distribution between CT and Pseudo CT images results in range error of spot scanning proton beams resulting in dose errors. These range errors can be minimized using robust optimization with range error margin. A combination of RO and SFUD also results in similar results but there is not enough evidence to state SFUD adds to the advantage of robust optimization.

OP-16

PERSONALIZED PLANNING WITH PINNACLE3 AUTO PLAN

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Purpose: The purpose of this study is to investigate how the plan efficiency (quality) can be improved when Pinnacle Auto Plan is integrated with Plan IQ software.

Materials and Methods: Pinnacle3 Auto-Plan module is one of the established tools that can create clinically acceptable treatment plans without much intervention by the planner. On

the other hand, Plan IQ is an effective tool designed to predict the achievability of clinical goals before even performing the optimization. In general, Plan IQ makes case-specific predictions whether a given clinical objective can be achieved or not. Because of this possibility given by Plan IQ, the user can define stringent goals for OARs and check their feasibility very quickly before even performing optimization. Hence, by using the Plan IQ suggested goals instead of using standard goals, it is possible to produce plans that are superior in terms of OAR sparing. These two tools (Auto Plan and Plan IQ) have already been integrated in Pinnacle in order to enable a seamless workflow experience to the users. In this study, our aim is to investigate how this integration helps improve the plan quality. We used Pinnacle3 version 16.2 to create clinical plans using Auto Plan tool coupled with Plan IQ for Prostate, Lung, and H&N cases. Basically we created two set of plans for each anatomy wherein one plan is created using standard clinical protocols such as RTOG and the other plan is created using Plan IQ suggested clinical goals.

Results and Discussion: We compared the dosimetric results for these two set of plans (RTOG driven Auto Plan à AP_RTOG and Plan IQ driven Auto Plan à AP_PlanIQ) for all three anatomies. We observed a significant reduction of OAR mean and max dose in AP_PlanIQ as compared to AP_RTOG without any compromise in target coverage. On the average, there is a reduction of OAR dose (Mean and Max) of about 39%, 6% and 21% for prostate, H&N and lung respectively in AP_PlanIQ plans as compared to AP_RTOG plans.

Conclusion: This study demonstrates that the Auto Plan tool can be efficiently used when integrated with Plan IQ. Also in many situations this integration helps reduce manual back tracking steps performed by the user when the user-fed goals are too stringent and potentially unachievable.

OP-17

A STUDY ON SELECTING OPTIMAL FLATTENING FILTER FREE BEAM QUALITY FOR INTRACRANIAL STEREOTACTIC RADIOTHERAPY

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Introduction: Use of FFF based Volumetric Modulated Arc Therapy (VMAT) for Hypo fractionated SRT (HSRT) is a well-established therapeutic modality for intracranial metastasis and benign lesions in the modern era. 6 MV-FFF and 10 MV-FFF beams available in Varian True beam STx linac offers high dose rate and increased dose per pulse which makes them an excellent choice for stereo tactic treatments. As HSRT employs large dose per fraction, energy selection criteria should incorporate the impact of high and low dose gradients, integral dose and the effect of the increased Monitor Units (MU).

Purpose: This study aims to critically analyze the selection of optimal beam quality for FFF-VMAT based intracranial SRT plans.

Materials and Methods: Fifteen intracranial SRT patients of different diagnose were studied retrospectively. The mean target volume was 10.46 ± 6.73 cm3 (Range: 1.37–23.96 cm3) with dose prescription of 18 Gy to 30 Gy in 3 to 5 fractions (mean ± SD: 21.7 ± 4.01). FFF based VMAT plans were created for both 6 MV-FFF (1400MU/min) and 10 MV-FFF (2400MU/min). An attempt was made to minimize the influence of other variables by forcing both the plans with identical target coverage. All the plans were devised with 3 arcs (2 non coplanar partial arcs and one coplanar full arc with same collimator and couch angles). For both the beam quality, optimizer was driven with the clinically accepted plan constraints and dose objectives with the single hold and synchronized time in each multi resolution (MR) levels with a single intermediate calculation using Eclipse TPS (v13.6) and dose calculations were performed using Acuros XB algorithm with calculation grid size of 1.25 mm. Statistical significance was assessed for all dosimetric parameters {GIHigh, GILow, CI, MU, HI, and Beam On Time (BOT)} and OAR doses using Wilcoxon signed rank test.

Results: 10 MV-FFF plans were found to have lesser MU compared to 6 MV-FFF ($P < 0.002$) plans. This effect is more pronounced in deep seated tumours. 10 MV-FFF resulted in very short BOT ($P < 0.0003$). No statistical significance were found in OAR doses (Brain stem ($P < 0.054$), optic nerve ($P < 0.779$), optic chiasm ($P < 0.156$), lens ($P < 0.234$) and cochlea ($P < 0.28$)) between two energies. Mean Paddick CI was 1.262 ± 0.13 and 1.257 ± 0.12 for 6 MV-FFF and 10 MV-FFF respectively. HI was found to be 1.381 ± 0.08 and 1.392 ± 0.09 for 6 MV-FFF and 10 MV-FFF. Both the CI and HI were not statistically significant. We found GIHigh (V90%PI/V50%PI) was 2.9% higher ($P < 0.0006$) for 10 MV-FFF and GILow (V25%PI/V50% PI) was -5.69% lower ($P < 0.0006$) in 10 MV-FFF compared to 6 MV-FFF plans. Results showed that low dose volumes V2Gy and V5Gy were statistically not significant with P values <0.0648 and <0.1902 respectively. High dose volumes (V10Gy and V12Gy) showed a significant increase in 10 MV-FFF with P values <0.00064 and <0.0008.

Discussion: The high dose rate (2400MU/min) available with 10 MV-FFF allows the gantry to maintain maximum speed even for a large dose per fraction which in turn reduces the treatment time. Increased PDD attributed to the sparse gradient in high dose region. Reduction in number of MU's reduces the integral dose and the risk of secondary malignancy. Normal brain tissue doses were comparable between these two plans which make the 10 MV-FFF as preferable energy.

Conclusion: Adequate importance should be given for the high dose gradient region (GIHigh) when 10 MV-FFF energy is selected for intracranial SRT especially when critical organs are nearby. Results showed that increased mean energy and high dose rate of 10 MV-FFF makes it an ideal choice for VMAT based intracranial SRT.

OP-18

EVALUATION OF OPTIMAL COMBINATION OF PLANNING PARAMETERS (FIELD WIDTH, PITCH, MODULATION FACTOR) IN HELICAL TOMOTHERAPY FOR BILATERAL BREAST CANCER

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Introduction: Breast cancer is the most common malignancy among the women in the world, synchronous bilateral breast cancer is uncommon with the incidence of 2.1%. Bilateral Breast planning is time consuming and challenging because of the huge volume and nearby critical structures. Helical Tomotherapy (HT) is capable to deliver well tolerated homogeneous dose to bilateral breast without field overlapping.
Purpose: Aim of this study is to evaluate the influence of HT treatment planning parameters on plan quality and treatment time for bilateral breast and to find the optimal combination of planning parameters.
Materials and Methods: We have evaluated 5 patients CT data sets with 90 plans. For each patient, 18 plans were created using the combination of planning parameters (Field width (FW) of 2.5 cm, 5 cm; Pitch of 0.215, 0.287, 0.43; Modulation Factor (MF) of 2, 2.5, 3). For every patient initial plan was created with FW 5cm, Pitch 0.287, MF 2.5 and the PTV was prescribed to 50Gy in 25 fractions. Using helping structure we have blocked the beam from posterior direction to reduce the low dose spillage. We have optimized the plan to achieve 50Gy to 95% of the PTV, without increasing 107% dose more than 2% volume. After achieving acceptable OAR results, this plan was copied with its optimization constrain and 17 more plans were created by changing only its plan parameters. Plans were evaluated by dose volume histogram (DVH) analysis. Plan quality of target was quantified using Homogeneity Index (HI), Conformity Index (CI), Dmin by D98%, Dmax by D2%, and coverage by D95%. Organ at risk (OAR) doses were evaluated by mean dose, V5Gy, V25Gy for heart and mean dose, V5Gy, V20Gy for both the lungs. Treatment time were also evaluated for all the 90 plans.
Results: PTV: When FW lowered from 5 cm to 2.5 cm the CI and HI of PTV improved from 0.997 to 0.999 and 0.07 to 0.04. HI decrease with (more homogeneous) decreasing the pitch or increasing modulation factor. The average D98% and D2% were 49.2Gy, 49.4Gy, 49.5Gy and 51.8Gy, 52.1Gy, 53.2Gy for pitch value 0.215, 0.287, 0.43 respectively. Increasing MF slightly improved all the PTV indices. OAR: Average value of heart and lung mean doses were 4.89Gy, 5.17Gy and 10.5Gy, 10.7Gy for field width 2.5 cm and 5 cm respectively. V5Gy of, heart was 21.4%, 23.1%, 24.8% and lung was 45.6Gy, 46.7Gy, 47.8Gy for pitch value 0.215, 0.287 and 0.43. Increasing MF improved all the OAR indices. Treatment Time: As expected FW of 2.5 cm (~10 min) had a higher treatment time than 5 cm (~6 min). Pitch value didn't affect the treatment time. Increasing MF increased treatment time by 2-3 mins.
Discussion and Conclusion: Comparison of dosimetric indices showed that FW 2.5 cm improved all the indices but increased treatment time 40–50% than 5 cm FW. Pitch value 0.43 didn't offer any dosimetric advantage. Among the compared plans pitch value 0.215 showed better results compared to 0.287 and 0.43 for OAR dose (mean, V5Gy, V25Gy for heart and mean, V5Gy, V20Gy for both the lungs). Increasing MF increased plan quality as well as treatment time. By applying small FW, tighter pitch and large MF values, it is possible to get a sophisticated treatment plan with a very long treatment time. However, this results in two adverse outcomes: patient discomfort (to lie down static during irradiation) and inherent organ movement due to breathing. Considering all these and on the basis of our analysis, plan with FW 5 cm, pitch 0.215 and MF 2.5 can be considered as a optimal combination of planning parameters for bilateral breast irradiation in HT technique.

OP-19

EVALUATION OF DEFORMABLE IMAGE REGISTRATION AND DOSE ACCUMULATION FOR PROSTATE STEREOTACTIC BODY RADIOTHERAPY PATIENTS

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Aim: To quantify the difference between planned and the delivered dose using deformable image registration (DIR) and deformable dose accumulation (DDA) for patients treated with Stereotactic Body Radiotherapy (SBRT) for prostate cancer.
Materials and Methods: Five prostate cancer patients previously treated with SBRT (35Gy in 5 fractions) were retrospectively analysed for this study. All patients were treated with Rapid Arc (RA) using 10MV FFF beams (Varian Eclipse TPS v13.5.37, True Beam v 2.1, Varian Medical Systems, Palo Alto). Daily cone beam CT (CBCT) was carried out as per the institutional protocol, which includes a bladder filling and a bowel protocol which reproduces the anatomy on the treatment day as compared to the planning day. CBCT was acquired for a full FOV that includes PTV, CTV, bladder rectum, and part of the bowel. Delivered dose was calculated by accumulating the doses using DIR and DDA in Velocity DIR software (v 3.2.1). Planning CT images (pCT), RT structures, RT plan and RT dose were imported from the planning system to the DIR system. Daily CBCTs were also imported and deformably registered to the pCT in DIR software using CBCT corrected DIR algorithm and generated a Synthetic CT (sCT). RT plan was recalculated on sCTs. The dose calculated on sCTs were deformed back and accumulated onto pCT to estimate the total delivered dose. The planned and delivered doses were compared using various dose volume parameters for PTV, CTV and OARs (bladder and rectum). Target coverage was estimated by comparing the differences between the planned and accumulated doses of PTV and CTV in terms of V95% (%), Dmean (Gy) and Dmax (Gy). For OARs, Dmax (Gy), Dmean (Gy),volume receiving various doses such as 30Gy, 20Gy, 10Gy and 5Gy were evaluated. Registration accuracy were also evaluated using Dice Similarity Co-efficient (DSC) and Hausdorff distances (Hf avg).
Results: Mean (±sd) volume of PTV, CTV of pCT was 54 (±9) cc and 26 (±7)cc respectively. Mean (±sd) volume of bladder and rectum of pCT vs CBCT averaged over 5 fractions were 365 (±93) vs 344 (±79)cc and 44 (±6) vs 45 (±6)cc respectively. Mean (±sd) of DSC of bladder and rectum were 0.89 (±0.7) and 0.9 (±0.07), while Hf avg bladder and rectum were 2.8 (1.3) mm and 1.1 (0.9) mm respectively. Mean (±sd) difference in V95% between the planned and the delivered dose for PTV was 3.4 (±5)%. However, maximum variation in V95% between the delivered and the planned dose was found to be correlating with the variation in bladder volume on that particular treatment day.

For example, the variation in patient 1, 2, 3, 4, 5 along with their bladder volume variation is as follows: 9.9% (138 cc), -8.5% (114 cc), -17% (109 cc), -3% (14 cc) and 7.9% (36cc). Three out of four patients who had dose variation of more than 5% had bladder volume variation of >100cc. However the variation in other dose volume parameters was found to be negligible as well as for CTV. Mean (sd) difference between the planned vs delivered dose for bladder was -0.07 (1.5)%. However, patient wise analysis showed a maximum variation of 19% on the day when the bladder volume variation was 138cc (patient-1). We had also observed that the difference between the planned vs delivered dose for other patients was also correlating with the bladder volume variation. Mean (sd) difference between the planned vs delivered dose for rectum was 0.8 (±2)%. However patient wise analysis showed a maximum variation of 3.7%. In rectum the maximum volume variation was 12cc, and no correlation of dose variation with rectal volume variation was observed.

Conclusions: Deformable dose accumulation of SBRT prostate patients was feasible. The difference between the planned and the delivered dose to target structures and OARs were quantified.

OP-20

EVALUATION OF KNOWLEDGE BASED RAPID PLAN MODEL FOR PATIENTS OF CARCINOMA CERVIX

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Introduction: Cancer is one of the most complex diseases and one of the most effective treatments, Radiation therapy, is also a complicated process. Informatics is becoming a critical tool for clinician, Medical Physicists, scientists for improvement to the treatment and better understanding of the diseases. Computation techniques such as Knowledge based planning/Artificial Intelligence have been increasingly used in radiation therapy. Artificially intelligent computer systems are hungry for data. As a result, they must be continuously fed with the right kind of data so they continuously learn and update their algorithms. As AI is incorporated into cancer treatment planning systems, the impact of automation on existing workforce skill sets must be evaluated.

Purpose: This study is to evaluate the feasibility of using a knowledge based Rapid plan model to generate new intensity modulated radiation therapy plan for carcinoma cervix patients.

Methods: The 102 consecutive patients treated in our centre for Carcinoma Cervix were taken for this study. The above said patients are treated using the Intensity modulated radiation therapy (step and shoot method) planned in Eclipse treatment planning system (version 13.7). Those patients DVH data were extracted to generate Knowledge based Rapid plan model. The retrospective study were performed in Rapid plan model for twenty patients. Original IMRT plan mean OAR (Organ at Risk) doses compared with mean doses achieved when Rapid plan is used to make the new plan. Difference between the achieved and predicted DVH curves was analyzed. Finally the rapid plan prediction are used to evaluate achieved OAR sparing of Automatic Interactively optimized plan (AIO) and Manually interactively Optimized Plans.

Results: The Plan analysis performed based on dose distribution and Dose Volume Histogram for Planning target volume (PTV), the organ at risk (OARs) for bladder, rectum, small bowel, right and left femoral heads as well as other physical indices like Mean dose (Dmean), Maximum dose (Dmax), 95% dose (D95), %5 dose (D5), total number of segments, monitor units, Dose homogeneity Index and Conformity Index for the PTV were also evaluated.

Discussion: For all twenty patients with help of Rapid plan model we achieved a clinically acceptable plans and the same was compared with original plans. Dose homogeneity index in both plan is 1.03 ± 0.01 and significance difference $P = 0.02$. Conformity index of PTV is 1.08 ± 0.01 for both plans and significance difference of CI $P = 0.002$. Similarly OAR doses for bladder, rectum, bowel, Right femoral head and Left femoral head were evaluated there is no much variation in both plans for all twenty patients the significance difference for all critical organs ($P < 0.0001$).

Conclusion: We conclude that knowledge based Rapid plan is truly automated planning system. It generate clinically acceptable treatment plans of high quality in less time duration. This automated approach can improve the efficiency of the treatment planning process by ensuring that quality plans are developed for treatment.

OP-21

EVALUATION OF THE INTENSITY MODULATED RADIOTHERAPY TREATMENT PLANS COMPUTED USING PHYSICAL AND BIOLOGICAL OPTIMIZATION ALGORITHM

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Introduction: The main goal of radiation therapy is to deliver adequate high dose to the tumor so that all tumor cells are killed while avoiding the radiation induced damage to the surrounding normal tissue. Radiobiological models are used in the radiobiological treatment planning to estimate the tumor control probability (TCP) and the normal tissue complication probability (NTCP). TCP-PoissonLQ model is used to estimate the TCP and two models namely NTCP-PoissonLQ and NTCP-LKB model are used for the computation of NTCP. The TCP-PoissonLQ model and the NTCP-PoissonLQ model are based on the cell survival model and the Poisson statistics. The NTCP-LKB model is based on the probate function.

Purpose: (1) Evaluation of the Intensity Modulated Radiotherapy Plans using physical and biological evaluation tool. (2) Generation of IMRT plans using biological optimization algorithm in terms of probability for Complication Free Tumor Control, Tumor Control Probability and Normal Tissue Complication Probability. (3) Comparison of IMRT plans computed using physical optimization algorithm and the same using biological optimization algorithm.

Materials and Methods: In this study we have used the Eclipse Treatment Planning System Version 13.7 (Varian Medical Systems, Inc., USA). It uses Anisotropic

Analytical calculation algorithm (AAA) with a calculation grid of 2.5 mm for dose calculation. It has both physical and biological optimization algorithms for the generation of treatment plans and uses Dose Volume (DV) as well as Biological evaluation tools to evaluate the plans. Biological based evaluation tools are developed by the Ray Search Laboratories (Suveavagen25 111 34 Stockholm, Sweden). 20 numbers of patients with Head and Neck cancers treated with Intensity Modulated Radiotherapy technique were selected. Treatment plans of these cases were already performed by the AAA algorithm using a calculation grid of 2.5 mm. In each plan, the physical parameters such as maximum, minimum and mean dose for both Planning Target Volume (PTV) and Organ At Risk (OAR) were obtained from the Dose –Volume Histogram (DVH) generated. At first, these plans were evaluated by using Biological Evaluation tool. Secondly these same patients were re-planned using Biological based Optimization algorithm which calculates the biological parameters such as TCP and NTCP. Results were obtained in terms of probability for complication free tumor control, Tumor Control Probability and Normal Tissue Complication Probability. The '*t*-test' was carried out to find out whether the values of P+, TCP and NTCP have significantly changed for both physical optimization and the biological optimization.

Results: From the '*t*-test' values it was found that the '*P*' values obtained from the comparison for P+, TCP and NTCP were 0.001, 0.034, 0.04 respectively. Since these values are less than 0.05 we conclude that there is a significant change in the result of biological optimization when compared to that obtained from physical optimization. The average value of P+ for the Physical Optimization was 14.58 and for Biological Optimization was 32.34. Hence complication free tumor control has increased when Biological Optimization is used. The average value of TCP for the Physical Optimization was 38.18 and that for the Biological Optimization was 62.47.This shows the probability for tumor control has increased when Biological Optimization is used. The average value of NTCP for the Physical Optimization was 54.75 and the same for Biological Optimization was 46.10. Hence the probability of normal tissue complication is relatively less when Biological optimization is used.

Discussion and Conclusion: It is evident from this study that there is a significant increase in the probability of complication frees tumor control as well as Tumor Control Probability anticipated when we use the biological optimization. There is also significant decrease found in the probability of normal tissue complication while we used biological optimization. Hence it is concluded that the biological optimization is necessary to enhance the complication free tumor control while reducing the normal tissue complication.

OP-22

COMPREHENSIVE QUALITY ASSURANCE OF INTENSITY MODULATED RADIOTHERAPY AND VOLUMETRIC MODULATED ARC THERAPY TREATMENT USING ARCCHECK DIODE ARRAY, PORTAL DOSIMETRY AND LINAC TRAJECTORY LOG FILE ANALYSIS

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Introduction: In modern Radiotherapy, IMRT (Intensity Modulated Radiotherapy) and VMAT (Volumetric Modulated Arc Therapy) treatment delivery techniques are routinely practised. These are most complex due to various intricate delivery mechanism, sequencing algorithms and calculation algorithms. Thus verification of IMRT and VMAT treatment delivery plays a paramount role in clinical practice to evaluate the quality of radiotherapy treatment plan. For this a comprehensive quality assurance programme for patient treatment verification is important to assess the accuracy in machine delivery as per the desired accuracy.

Purpose: To compare and evaluate three different dosimetry system; ArcCHECKTM Diode Array, aSi-1200 EPID Portal Dosimetry and Trajectory log file Analysis for comprehensive quality assurance of IMRT and VMAT treatment delivery.

Materials and Methods: This study consist of assessment of Patient specific treatment plan quality assurance using ArcCHECKTM Diode array, VarianTM (amorphous silicon based) aSi-1200 EPID based Portal Dosimetry and Treatment Trajectory log file analysis of thirty patient who underwent IMRT and VMAT treatment on Varian TrueBeamTM Linear Accelerator. All Treatment plan were calculated using AAA Algorithm in EclipseTM (v13.7) Treatment planning system. Trajectory log files are generated in TrueBeamTM delivery and record system after delivery of the treatment plan, which records normalized MU delivered, Angle of gantry and Actual and expected position of each leaf of MLC in either Bank of MLC at every 20 millisecond. These trajectory log files generated in TrueBeamTM after performing Quality assurance of Treatment plan using ArcCHECKTM and aSi-1200 EPID portal dosimetry. These Trajectory log files were analysed using Assurance QA software. Gamma Analysis metric of DTA (Distance to Agreement) 3 mm & 3% with threshold dose of 10% is used for Gamma Analysis of TPS and Measured fluence comparison. Comparative evaluation of ArcCHECKTM Dosimetry, Portal Dosimetry and Trajectory log file analysis for thirty QA plans were done.

Results: The average Gamma pass rate (%) ($\gamma \leq 1$) of QA plans for ArcCHECKTM, a-Si 1200 EPID portal Dosimetry and Trajectory Log file analysis are 99.05 ± 1.04 , 98.38 ± 1.63 and 99.93 ± 0.08 respectively. The average dose (%) difference ($\gamma > 1$) in TPS and delivered plan is 0.95 ± 1.04, 1.62 ± 1.63 and 0.07 ± 0.08 respectively in ArcCHECKTM, Portal Dosimetry and Trajectory log file analysis. Mean Average Gamma (γ) for ArcCHECKTM, Portal dosimetry and Trajectory log file analysis is 0.37 ± 0.09, 0.38 ± 0.05 and 0.08 ± 0.08 respectively. Mean Maximum dose variation (γmax) in calculated plan and delivered plan for ArcCHECKTM, portal dosimetry and Trajectory log file analysis is 1.37 ± 0.44, 1.81 ± 0.84 and 0.46 ± 0.43 respectively.

Discussion: The average gamma pass rate ($\gamma \leq 1$) in ArcCHECKTM, portal dosimetry and Trajectory log file analysis is highly comparable to each other and constitute a comprehensive Quality assurance tool. Average dose difference ($\gamma > 1$) is more in ArcCHECKTM and portal dosimetry compare to Trajectory log file Gamma analysis. This is due to more complex parameter that influence the accuracy and stability of ArcCHECKTM diode detector and a-Si detectors in EPID.

Conclusion: Comparable results of Gamma Analysis for ArcCHECKTM, Portal Dosimetry and Trajectory Log File shows comprehensive and robust Quality of TrueBeamTM Delivery System. Portal Dosimetry can be used as a quick and efficient quality check system. Trajectory log file Analysis saves time for QA setup and is very good tool for quick and reliable dosimetry verification for Patient specific Plan quality assurance.

OP-23

WIRELESS ROBOTIC PHANTOM FOR QUALITY ASSURANCE OF 4D GATED RADIATION THERAPY

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Background: High precision Radiotherapy Technique such as Intensity Modulated Radiotherapy (IMRT), Volumetric Arc Therapy (VMAT) and Three-Dimensional Conformal Radiotherapy (3DCRT) requires accurate targeting of Tumour. However, due to cardiac and respiratory motions, achieving precise targeting is ambiguous in cases of intra-thoracic tumours, due to varying magnitude of displacement with respect to respiratory pattern and size of tumour of the patient. These displacement results in an increased treated volume and distribution of the dose delivered does not match with the intended dose distribution.
Purpose: To evaluate the accuracy of radiation dose delivery during gated radiation therapy with the Varian Realtime Position Management (RPM) System using an in house developed wireless respiratory phantom.
Materials and Methods: The Respiratory phantom was constructed and evaluated by Nihal Daniel and Paul Ravindran in 2009. However, in the present study we have improvised the control and simulation of respiratory phantom by introducing wireless communication through an Android mobile Application from the console room. The phantom is battery powered which eliminates the use of very long data transferring cables and power cables. The wireless communication is configured through two HC-12 Bluetooth modules connected as a serial transponder since the radiofrequency signals cannot pernitrate the wall thickness of Linac. Two Arduino Nano microcontrollers connected with the transponders which acts as the control unit for the respiratory phantom on the couch and for the Android application communication from the console. The unit in placed in the Console is configured with an additional HM-10 Bluetooth module for pairing up with the Android device. The movement of the Respiratory phantom is simulated through powerful stepper motor arranged in the setup. The control unit can move the phantom in x and y-axis and with varying frequency in accordance with the recorded RPM pattern. The respiratory pattern from RPM is taken and fed into the control unit of the phantom to simulate the recorded respiratory movement of the patient.
Results: The validation of simulation is done by making the phantom to mimic the recorded respiratory pattern of a patient in which the movement of the phantom is again monitored using RPM and verified against the actual plot. The DIBH was also simulated with the phantom for the automatic gating system to turn the treatment beam on and off.
Discussion: Thus, the wireless robotic respiratory phantom is very useful for doing a patient specific quality assurance in Gated treatment delivery. Since no cables are involved and the phantom is battery powered it's easy to setup. The use of Android application for controlling the phantom eliminates simulation errors caused due to voltage fluctuation in conventional electronics control unit.
Conclusion: The Respiratory phantom has been found to be useful in performing patient specific QA and accessing the effectiveness of the RPM gating system. The Varian RPM gating is found be effective in delivering gated Radiotherapy.

OP-24

NOVEL TOOL FOR MODELLING MECHANICAL OFFSETS WITH RADIATION ISOCENTRE AND EVALUATE THE EFFECT OF CLINICAL SRS/SRT TREATMENT

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Aim: To analyse the impact of mechanical offsets of gantry, couch and collimator with radiation isocentre using an in-house fabricated tool on SRS/SRT treatment plan quality parameters including target coverage, selectivity index (SI), conformity index (CI), gradient index (GI), dose to GTV, PTV and OARs.
Materials and Methods: Tool: An in house fabricated tool was used to locate the radiation isocentre with the precision of micro mm with 3 independent micro meter in X, Y, Z direction. The tool consists of a metal ball bearing of radius 5 mm placed at the geometric centre of a hollow fibre box (22 x 22x 22cm). The whole box ball bearing assembly is mounted on a fixation system along with the micrometres to enable translational movements and a rotation screw mechanism applied rotations to cancel out yaw, pitch and roll errors. The box tool was positioned on the couch followed by zeroing of any rotational errors using a spirit level.
Pre Verification: Four radio opaque markers per face of the box that are permanently fixed with a known geometry were portal imaged with gantry 0 and 90 for a field size of 10x10 cm^2 to check the alignment of the ball bearing centre with box without any tilt.
Radiation Isocentre: The MV radiation isocentre of an unflattened 6MV beam of an Elekta Agility linac was identified by acquiring images at 4 cardinal and 4 oblique gantry angles for a field size of 3x3 cm^2 using iviewGT portal imaging device. The images were analysed using Pipspro software. Any deviation in the position of the geometrical centre of the ball bearing to that of the radiation isocentre was corrected by applying shifts calculated by pipspro using the micrometers attached to the tool. The test was repeated until the geometrical centre of the ball bearing matched the mean of the radiation isocentre.
Laser Setup: The box had slits of 2 mm cut out in 'plus' shape at the centre of the left, right and anterior faces which enabled

readjustment of the lateral, sagittal and overhead lasers to match the mean of the radiation isocentre of the linac.

Mechanical Isocentre: A calibrated mechanical front pointer was fixed on the gantry such that the pointer tip matches the laser centre. An extended leaning pointer assembly was attached in place of the ball bearing. The pointer can be also moved with the same XYZ micrometer assembly. Radiation isocentre coordinates from the XYZ scale were noted for every 45 deg gantry angle, by matching the learning pointer tip to the front pointer by moving the independent XYZ scale. The difference in the scale value with respect to radiation isocentre coordinate is the actual mechanical shift from the radiation isocentre. The same method was followed for various couch and collimator angles. From these offset values the mechanical offset of the machine was plotted with respect to gantry, couch and collimator. Two models were created, an actual error model which is pre adjusted the radiation isocentre and corrected model which is adjusted the radiation isocentre to fit into the mechanical offset.

Clinical Analysis: Plans were created on an anthropomorphic head phantom on Pinnacle TPS v.16.0 as per our local SRS clinical protocol based on 2 clinical plans. These original plans were recalculated with the same beam parameters (beam shape, MUs) but with a new offset isocentre which was derived from the 2 models. The corrected plans and original plans were compared and plan parameters were analysed for both the models.

Results and Discussion: A Novel tool was successfully used for:

1. Effectively locating the radiation isocentre with micro meter accuracy.
2. In-Room laser alignment to the radiation centre.
3. Modelling mechanical Offset was modelled by plotting the offset of radiation centre with respect to gantry, couch and collimator.

Collimator and gantry-lateral offsets were found to be very small (max 0.2mm) and were not considered in clinical correction. On the clinical plan comparison, GTV dose has no variation on both the models and PTV coverage was noted with a maximum of 1 % volume deviation and better with corrected model where the radiation isocentre corrected to mechanical centre and OAR doses found a minimal variation but within our clinical tolerance.

This tool can be used for routine linac QA, acceptance and quicker laser setup.

OP-25

AUTOMATED TREATMENT PLAN QUALITY ASSURANCE USING ECLIPSE SCRIPTING APPLICATION PROGRAMMING INTERFACE

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Introduction: The main objective of this work is to estimate the effectiveness of Plan Quality Analyser (PQA) Script which was developed to estimate plan quality, reduce human error, increase the efficiency of electronic workflow, standardize and automate the plan review in the treatment planning system (TPS). PQA Script is used as an interface to compare the data from TPS and the ARIA Database. The fundamental aim behind PQA Script was to reduce the amount of time spent in reviewing the plan parameters for each plan and enhance the time for validating the dosimetric plan quality.

Purpose: In order to improve safety, radiation oncology departments have deployed checklists to standardize processes. It has been seen that the review check of the treatment plan has the greatest effectiveness for catching errors. Manuel checking of plan parameters can lead the physicist to focus on the mundane details instead of overall plan quality, and increase the chances of missing serious errors. The use of automation will bring more effect to safety and quality. Since the plan evaluation involves checking similar plan parameters for each patient, this process can be automated.

Materials and Methods: External beam treatment planning is performed with Eclipse (Version 13.7), the PQA Script was developed using C# in Visual Studio 2013. Eclipse Scripting Application Programming Interface (ESAPI) is the programming interface in Eclipse. PQA Script can perform Quality Assurance (QA) check for all types of treatment plans such as Volumetric modulated arc radiotherapy (VMAT), Intensity modulated radiotherapy (IMRT), Three-dimensional conformal radiotherapy (3D CRT). The PQA Script verifies the plan for 1. User origin position, 2. Inclusion of correct couch structure, 3. Complimentary collimator angle for VMAT plan, 4. Jaw tracking inclusion, 5. Field size, 6. Isocentre position of beam and a few other parameters that are necessary to be checked. PQA Script is made machine specific for better performance. The PQA script includes a Dose Volume Histogram (DVH) Analyser. Physicists can choose the desired Protocol before performing DVH analysis. One vital reason for the development of the PQA Script is to eradicate human error. PQA Script checks for Patient name, appropriate Image, Prescribed Dose, Prescribed Fraction and makes an alert to the physicist in case of any error.

Results: In this work, the script is run from the Eclipse Treatment Planning System tool bar which automates the complete Quality Assurance check and generates a file that is to be documented. The file is successfully generated for the plan where the script has not encounter any error. The Script is used clinically as an electronic checklist before finalizing the plan. The PQA script along with DVH evaluation for a plan is tested and practised clinically.

Discussion and Conclusion: The PQA script eliminates human error in the treatment plan that could have significant effect on patient treatment and also helps to analyse the DVH quickly**.** PQA Script being, an electronic process of checking treatment plans has made the cumbersome efforts of physicist simple and less time consuming.

OP-26

DOSIMETRIC COMPARISON OF GRAPHICAL AND INVERSE PLANNING SIMULATED ANNEALING BASED DOSE OPTIMIZATIONS PLANS WITH VARYING VALUES OF DWELL TIME DEVIATION CONSTRAINTS FOR INTERSTITIAL BRACHYTHERAPY OF CANCER CERVIX

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Introduction: Inverse planning in brachytherapy is a new concept in which very few institutes are venturing. Initial applications of inverse planning simulated annealing (IPSA) for treatment of prostate cases have yielded encouraging results. But further involvement of IPSA in gynaecological sites is not being done. Graphical optimization in interstitial application of cancer cervix is common practise for achieving therapeutic goals. The purpose of this retrospective study is to explore new possibilities of application of IPSA in interstitial brachytherapy of cancer cervix. Large deviation in dwell time while using IPSA optimization can be controlled by applying dwell time deviation constraints (DTDC). In some interstitial brachytherapy plans of cancer cervix based on the graphical optimization do not give sufficient target coverage while retaining the dose to organs at risk within recommended limits. In this study we examined whether such plans could be improved using IPSA with varying values of DTDC parameter. This is one of the very first studies in which DTDC applied IPSA plans are compared with graphically optimized interstitial brachytherapy of cancer cervix.

Purpose: The aim of this retrospective study is to implement IPSA optimized plans for interstitial brachytherapy of cancer cervix with varying values of DTDC parameter and compare the results with graphically optimized plans.

Materials and Methods: For this retrospective study we have generated IPSA optimized interstitial brachytherapy plans for 20 patients by using Oncentra Brachytherapy treatment planning system (version 4.3). The DTDC value of IPSA plan was increased from 0.0 to 1.0 in step of 0.2. The variation in dose volume histogram parameters D90, V100, V150 and V200, for CTV were studied and compared with graphically optimized plans. For dose analysis of bladder and rectum, their D2cc parameter was investigated. The conformity index (CI) and homogeneity index (HI), were also computed.

Results: Good target coverage for prescription dose was achieved with graphically optimized plans as compared with IPSA optimized plans. Homogeneity was good with the IPSA-based technique as compared with the graphically optimized plans. The homogeneity index was increasing with increasing value of DTDC. Graphically optimized plans resulted in a higher CI (with a mean value of 0.83) compared with the IPSA based optimization of DTDC value 0 (with a mean value of 0.71). But increasing DTDC value of IPSA plans resulted in higher CI compared with lower DTDC valued IPSA plans. V150 and V200 values were lower for DTDC based IPSA plans compared with graphically optimized plans. D2cc values for rectum and bladder were lower for graphically optimized plans compared with IPSA based plans.

Discussion: Adequate target coverage was achieved by graphically optimised plans compared with IPSA plans of varying values of DTDC. A higher value of DTDC in IPSA plan removes the larger of the dwell time in isolated dwell positions and also reduces overall treatment time, but this is at the cost of decreasing D90% and V100% value which indicate lower CTV coverage. Lower values of V150 and V200 for DTDC based IPSA plans indicate lower high dose volumes compared with graphically optimized plans. Greater sparing of bladder and rectum were observed in graphically optimised plans compared to IPSA plans with any value of DTDC.

Conclusion: This study shows that, graphical optimization may achieve good target coverage for interstitial brachytherapy of cancer cervix but DTDC based IPSA plans restrict the occurrences of high dose volumes.

OP-27

PERFORMANCE EVALUATION OF AXXENT ELECTRONIC BRACHYTHERAPY SYSTEM MODEL 110

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Introduction: Traditional brachytherapy refers to the placement of radioactive sources on or inside the tumor. Electronic brachytherapy (EB) is new form of radiotherapy which utilizes miniature X-ray source instead of radioactive source to deliver desired doses to tumor. The advantages of EB include low dose to surrounding organs, simple emergency handling procedures, lesser shielding requirements, no leakage radiation in off state and no radioactive waste. Purpose of this paper is to discuss performance evaluation of Axxent EB system model 110 with respect to conformance with manufacturer's specifications and existing QA protocol of brachytherapy, as applicable. This unit is intended to deliver intracavitary, surface radiation and Intra Operative Radiation Therapy(IORT) and not suitable for interstitial application due to larger source dimension.

Materials and Methods: The Axxent EB system model 110 is manufactured by M/s. XOFT (a Subsidiary of iCAD), USA. Device contains a miniature X-ray source, a controller, cooling tube set and applicators. The Controller supplies high voltage, filament current, and circulates cooling water to the X-ray Source. The dimension of X-ray tube is 1.5mm (dia) X 3.0 mm (length). The operating voltage and current are 50kV and 300μA respectively. X-ray source moves in stepped manner with minimum step size 1.0mm and maximum treatment length 7.5cm. The radiation output of the source is determined using the AAPM Task Group 43 formalism, using well chamber and electrometer attached to the unit. The equipment is designed to check several self-tests including constancy of air kerma rate prior to each treatment. As no national/international protocol is available, the existing QA protocol of brachytherapy, as applicable, was taken as base document along with manufacturer's specifications for testing purposes. Testing of the engineered safety features of the equipment and dosimetric tests were carried out. Some of tests includes interlocks such as emergency stop, pullback arm lock, check of cooling water level, coupling of the X-ray source with treatment unit, coupling of the X-ray source with pullback arm nest, coupling of the applicator with controller arm. Other tests are source position accuracy and reproducibility, timer linearity and error, and tests for treatment planning system. Tests results related to emergency and failure such as failure of controlling timer, positional accuracy and movement of sources were provided by manufacturer. In this model control console is located on the brachytherapy unit and operated from inside the treatment room. Radiation level at operator location behind the lead protective barrier was measured with and without flexi shield by simulating treatment conditions and dose was estimated based on the workload provided by the hospital.

Results: All electrical, mechanical, dosimetric and radiation safety parameters are within the specified tolerance limits.

In-built safety switches, displays and interlocks were provided and functional. Measured radiation level behind the protective barrier was 0.9 mR/hr and 0.3 mR/hr without and with flexi shield respectively. Based on the work load provided by the institute as 30 patient/wk and average 30 min/patient assuming all intracavitary cases having maximum treatment time, the radiation level are found within the permissible dose limit of radiation worker.

Discussion and Conclusion: Performance of the Axxent EB system model 110 was found satisfactory. As the equipment is operated from inside the treatment room, operational safety plays a major role in radiation protection. Hence, a standard operating procedure (SOP) should be made and implemented by the user institute. The staff who are not familiar with radiation safety such as anesthetist, surgeon may be involved during procedure, hence it is the responsibility of the licensee to establish SOP such that non-essential staff do not remain in the treatment room when the beam is switched ON. Access control, warning signages should be used for this purpose. Staff should use the protective accessories such as flexi shields, lead protective barrier, lead aprons and follow the SOP. *Authors are thankful to the Medical Physicists of Hyderabad Institute of Oncology, Hyderabad and M/s. Rosalina Instruments, Mumbai for their support in this study.

OP-28

DOSIMETRIC COMPARISON BETWEEN TG-43 AND TG-186 IN LIP AND BUCCAL MUCOSA BRACHYTHERAPY IMPLANTS

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Introduction and Purpose: TG-43 dose calculation formalism for photon emitting radionuclide sources used in brachytherapy, is based on the parameterization and superposition of single source dose distributions, obtained in liquid water under fixed geometry. Although, it is easy, fast and practically applied in clinics, it inherently lacks considerations for tissue and applicator heterogeneities, differences between absorbed dose in water and tissues, inter-seed attenuation, finite patient dimensions and dose contributions from electrons, can lead to under or overestimation of dose calculation. Model-based dose calculation algorithms (MBDCAs) have recently been emerged as a potential formalism for dose calculation in brachytherapy which involves tissue-inhomogenities and lack of scatter. It offers the possibility of departing from water-only geometries by modelling radiation transport in non-water media (tissues, applicators, air-tissue interfaces), resulting in a much more accurate dose distribution delivered to the patient. The present work provides the comparison between the dose calculation between TG-43 and TG-186 formalism for lip cancer and buccal mucosa brachytherapy Implant.

Materials and Methods: Five lip cancer and three buccal mucosa Brachytherapy implant patients previously treated in our hospital using TG-43 formalism (Oncentra Brachytherapy TPS v 4.5.3) were taken for this retrospective analysis. The mean(sd) of catheters in lip and buccal mucosa implants were 7 (2), and the number of implant planes were 2. CT images were transferred to TPS, followed by catheter reconstruction. The source activation was based on the clinical examination/or using the implanted markers. Dose prescription was done on basal points followed by geometric optimization on volume. Plan evaluation was carried out jointly by the treating physician and the physicist. Plans were made using TG 186 algorithm (Oncentra Brachytherapy TPS v4.5.3), keeping all the other parameters constant. A total of 16 plans were made. For this dosimetric analysis, a single brachytherapy fraction was considered. Dose prescription was 4Gy per fraction. The isodose volume covering 240%, 200%, 150%, 120%, 100% and 85% and 50% of prescription isodose were evaluated for TG 43 and TG 186 plans. The difference between these volumes in absolute difference was evaluated. In addition, Dose Homogeneity Index (DHI) was calculated and the difference between these plans were compared.

Results: The mean(±sd) of absolute differences of various isodose volumes was found to be 0.6(±0.2) cc and 1.0(±0.5) cc for lip and buccal mucosa implant respectively. Interms of percentage variation, the mean(±sd) difference was found to be 49(±21) and 30(±23)% for lip and buccal mucosa implant respectively. It was observed that TG 43 overestimates the dose more in higher isodose volumes as compare to lower isodose volumes. TG 186 plans were more homogeneous as compared to TG 43. The mean(sd) DHI of TG 43 vs TG 186 was 0.66(0.06) vs 0.76(0.08) and 0.73(0.02) vs 0.76(0.01) for lip and buccal mucosa respectively.

Conclusion: The difference between TG 43 and TG 186 algorithm was dosimetrically evaluated for brachytherapy implants such as lip and buccal mucosa. The difference between these two algorithms for the evaluated implants was found to be subtle. The clinical significance of these differences is not yet known.

OP-29

RECTAL AND BLADDER DOSE MEASUREMENTS IN THE INTRACAVITARY APPLICATIONS OF CERVICAL CANCER TREATMENT WITH HDR AFTERLOADING SYSTEM: COMPARISON OF TPS DATA WITH MOSFET DETECTOR

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Introduction: Brachytherapy of cervix carcinoma often results in high doses to surrounding structures, such as rectum and bladder. Therefore, these organs should be closely monitored.

Purpose: The purpose of this study is to evaluate the role of in vivo dosimetry with mobile MOSFET detector in HDR brachytherapy and to compare the actual doses delivered

to organs at risk (as measured using in vivo dosimetry) with those calculated during treatment planning.

Materials and Methods: A total of 50 patients were treated with Microselectron HDR. Out of 50 patients, 26 patients were treated with the prescription dose of 7 Gy and the other 24 patients with prescription dose of 9 Gy. The Oncentra TPS version-4.5.2 was used for the brachytherapy planning and the evaluation of dose to the bladder & rectum. Further for in vivo dosimetry, portable MOSFET dosimetric system with two MOSFETs (TN – 502RD-H, SN: 33545 & 33546) and an electrometer (Team Best, Canada) were used for the measurements of bladder and rectum dose. A Siemens Somatom Emotion 16 slice CT simulator was used for CT images. For calibration of MOSFETs detectors, an acrylic cylindrical phantom with a center at hole and four holes in perimeter at 00, 900, 1800, and 2700 was scanned for 5 mm slices with MOSFET dosimeters and the data was exported to TPS. The brachytherapy plans were generated in which Ir-192 source was placed at a single dwell position in the center hole and prescribed dose as 50 cGy, 100 cGy, 200 cGy, 300cGy, 500cGy, 700cGy and 900 cGy at MOSFETs predetermined positions respectively. The calibration graph has been obtained to the dose up to 500 cGy, and the dose-response curve was found to be linear. MOSFET dosimeters in standard bias were kept in perimeter holes and recorded the dose online.

Results: The percentage deviation between the TPS-calculated maximum dose and the dose measured by MOSFET was found to be less than 5% in 31 patients, 5–10% in 8 patients, and 10–15% in 7 patients for rectum while dose deviation was greater than 15% in 4 patients where as in the bladder this percentage deviation was found to be less than 5% in 28 patients, 5–10% in 14 patients, and 10–15% in 4 patients. The dose deviation was greater than 15% in 4 patients for bladder.

Discussion: Our results showed that out of the total number of 50 insertions, the maximum rectum dose in 11 insertions (72.5% of treatments sessions) and the maximum bladder dose in 15 insertions (45% of treatments sessions) were higher than the 80% of prescribed dose to the point of dose prescription. This may be related to either the experience of radiation oncologist or to Oncentra treatment planning system. A more detailed study in this field is required to illuminate the cause.

Conclusions: The main reason for the differences between the measured and calculated doses was patient movement. To reduce the risk of large errors in the dose delivered, in vivo dosimetry should be performed in addition to treatment planning system computations.

OP-30

MATHEMATICAL APPROACH IN DETERMINING USE FACTOR FOR EQUIPMENT WITH ROTATIONAL DOSE DELIVERY TECHNIQUE

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Introduction: The optimizing parameters required for shielding thickness calculations of a radiotherapy bunker need to be appropriately estimated to arrive optimized protective barrier thicknesses. Use factor as one of the optimizing parameters is highly dependent on the treatment delivery technique of radiotherapy equipment. Therefore, it needs to be derived and calculated for the equipment by considering dose delivery technique available in the equipment. Hence values of use factors for Cyberknife, Tomotherapy, Halcyon etc. are different than that of Medical Accelerator having same photon energy. In this paper, use factor is mathematically derived for equipment in which source is continuously rotating around axis of rotation such as Helical Tomotherapy and Halcyon. Therefore, this formula is useful to calculate use factor to be used in arriving primary protective barrier thickness of bunker housing radiotherapy equipments using continuous source rotation around axis of rotation for dose delivery.

Purpose: Aim of this paper is to establish mathematical expression for calculating use factor of radiotherapy equipment wherein source continuously rotates around the patient for dose delivery.

Materials and Methods: For the equipment in which source rotates in a circular path around isocentre in vertical plane, an arbitrary point of interest taken on primary barrier located at a distance 'd' from isocentre is continuously exposed by the projected radiation field length till source moves from one position to another such that complete radiation field length is swept away through this point of interest. Further, it is also found that point of interest on the primary barrier located nearer to source still keeps on receiving primary radiation whereas at farther distance from source irradiation is already over for the same geometrical set up. Hence, angle of rotation at isocentre corresponding to the source movement from initial to final position (α) is found to be varying with distance of the location of primary barrier from the source (d). The beam opening angle at source for corresponding field length is mentioned as θ. The relationship derived in terms of α, θ, d and distance of source from isocentre (R) can be derived and expressed as follows: As source is continuously rotating around patient, based on definition of use factor (U), it can be expressed as follows:

Results and Discussion: The mathematical expression as derived for the use factor (U) as given in equation (1) shows that value of use factor varies as per the location of placement of primary barrier from isocentre and equipment design specifications such as field length and source to isocentre distance. Further, it is also observed that value of use factor increases when primary barrier is placed nearer to source whereas decreases when primary barrier placed farther away from the source for the same geometrical setup.

Conclusion: Using above mathematical expression, the use factor can be calculated for given θ, R and d. This study is helpful for those users who wish to design bunker for the machines that use rotating source geometry (e. g. Tomotherapy, Halcyon) and desirous to replace their existing teletherapy equipment with such equipment. Results obtained using above expression are found to be in good agreement with the studies of other authors Robinson et al. and Chuan Wu et al. for tomotherapy.

OP-31

RADIATION SHIELDING CONSIDERATION FOR HALCYON VAULT DESIGN

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Introduction: Halcyon is a new model of medical linear accelerator introduced by M/s. Varian Medical Systems, USA recently. Halcyon uses single 6 MV unflat beam (flattening filter free) with maximum definable field size of 28cm × 28cm at isocentre (SAD=100 cm). In order to reduce shielding requirements, manufacturer has introduced beam stopper having transmission of 0.1%. Radiation dose to the patient can be delivered either using volumetric modulated arc therapy (Rapid Arc) or static gantry through intensity modulated radiation therapy (IMRT) technique. The optimizing parameters required for shielding thickness calculations of a radiotherapy bunker need to be appropriately estimated to arrive optimized protective barrier thicknesses. The optimizing parameters are highly dependent on the dose delivery technique of radiotherapy equipment and hence needs to be estimated/ calculated considering these aspects. Hence values of optimizing parameters and shielding requirement for the given design goal for Cyberknife, Tomotherapy, Halcyon etc. are required to be different compared to that of standard Medical Accelerator even for the same photon energy. Recently, one of the institutions approached Atomic Energy Regulatory Board (AERB) for obtaining layout approval for installing Halcyon from radiological safety view point. In this paper, authors have attempted to determine the appropriate values of optimizing parameters for calculation of radiation shielding thicknesses of walls/ceiling of the room for installing Halcyon.

Purpose: To find out adequate radiation shielding thicknesses of walls and ceiling of the Halcyon room so that radiation doses to the radiation workers and members of the general public shall not exceed their dose limits.

Materials and Methods: The minimum inner dimensions of room to house Halcyon unit, as recommended by the manufacturer, are around 5.9 m (length), 4.7 m (width) and 2.8 m (height). The minimum distance required between wall behind the gantry and isocentre of machine is 1.5 m. To estimate appropriate thickness of the protective barriers, the optimizing parameters such as workload, use factor and occupancy factor are established.

Workload:

i) For IMRT, Primary workload (Wpri) = 200cGy/pt x70 pt/ dayx5 days/wk/PDD =1.11x105 cGy/wk at 1 m; and Head Leakage Workload (WL)=IMRT factor x Wpri = 4.44x105 cGy/min at 1m.

ii) For VMAT, Workload (WPri)=200cGy/pt x70 pt/dayx5 days/ wk/PDD = 1.11×105 cGy/wk at 1 m.

Use Factor: Since the x-ray target is continuously rotating around the patient for treatment, Use factor (U) is determined to be 0.044 for VMAT. As product of workload and use factor for IMRT is found to be significantly higher than for VMAT, so the former is used for the calculations for conservatively safer. Using basic definitions and formulae provided in IAEA/NCRP reports, the radiation shielding calculations are carried out for primary and secondary barriers of all the walls and ceiling.

Results and Discussion: Calculated thicknesses of primary barrier of wall and ceiling are and found to be 135 cm and 150 cm of concrete (density 2.35 g/cc) respectively. Similarly, the thicknesses are calculated for the secondary wall (behind gantry), maze wall and secondary barrier in the ceiling and are found to be 140 cm, 80 cm and 140 cm of concrete(density 2.35 g/cc) respectively.

Conclusion: Based on the thicknesses calculated for all the walls and ceiling of Halcyon vault, a typical standard room layout drawing is proposed. From calculated thicknesses, it is inferred that any existing 6 MV accelerator or even telecobalt room can be used for installing Halcyon with minor modifications.

OP-32

A PRECLINICAL ANIMAL (RAT) MODEL OF RADIATION-INDUCED SKIN INJURIES TO STUDY VARIOUS WOUND THERAPY APPROACHES

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Introduction: Current events throughout the world underscore the growing threat of different forms of terrorism, including radiological or nuclear attack. In the event of an attack, exposure of human tissue to radiation may result in both acute and chronic toxicities which can result in a range of symptoms and decreased quality of life. Skin is the primary organ of the victim which is directly exposed to the radiation through radioactive contamination, incorporation and energised particles of ionising radiation. Also, in radiotherapy skin can be a dose-limiting tissue for certain cancers, such as breast, head and neck. Cutaneous radiation damage to the skin is a major concern in radiation therapy of these cancers. Therefore, treatments or therapies are needed to protect and treat a wide range of acute and chronic radiation induced injuries to the human skin. Future therapies may revitalise the affected tissue and stop the further deterioration of the skin.

Purpose: The objective of the study is to provide a functional preclinical animal model of cutaneous radiation injury which can be used to evaluate various pharmaceutical formulations in protection, decontamination, decorporation and healing of radiation-induced skin injuries. A protocol was designed to apply cobalt-60 radiation to the skin of rats while sparing the body and internal organs.

Materials and Methods: A circular cone of 20 mm diameter opening was designed locally to be used as a tertiary collimator for Bhabhatron-II teletherapy unit. Output factor, off axis ratio and beam profiles were measured using ionisation chamber and Gaffchromic film as per the small field dosimetry protocol. In order to find appropriate dose for wound creation, each rat, with skin pulled away from the body was irradiated for 25.2 Gy, 34.6 Gy, 45 Gy, 55 Gy and 65 Gy in a single fraction. Following multi dose trial, five additional wounds were created using 45 Gy dose. The photographs of each wound were taken daily and followed till 65 days post irradiation. The images were analysed for percentage ulceration created at given point of time using Matlab image processing program.

Results and Discussion: The radiation induced wounds were formed in more than 60% of irradiated skin area within 12 days at all doses except at 25.2 Gy dose (52% wound at 16 days).By day five, all irradiated areas showed acute skin reactions like erythema, mild dryness, and hair loss. On the day ten, intense skin reactions started appearing and by the day 14, wet desquamation started appearing with higher

doses (55 Gy and 65 Gy). The peak ulceration was ranged from 65.3% to 79% between 12 to 16 days postirradiation. The peak ulcerated area increased from 65.3% at 34.6 Gy to 75% at 45 Gy and then remained nearly 79% at 55 Gy and 65 Gy. The mean wound size calculated from day 10 to day 65, increased with the dose and showed a strong correlation (R=0.882) with the dose. In five additional rats irradiated with 45 Gy, the peak wound size ranged from 54.2% to 74.8% with a mean of 63.6% (SD = 3.1%) at 16th day postirradiation. The average wound size reduced to 23.1% (SD = 5.6%) at 65th day showed significant healing.

Conclusion: The preclinical animal model has been developed which is being used by various biological and pharmaceutical scientists to study biochemical mechanism of radiation induced wound healing and development of interventions for rapid healing of these wounds. This model may also be useful in the development of novel therapies to reduce skin reactions in radiother.

OP-33

DESIGNING AND STUDY ON RADIOLOGICAL PROPERTIES OF IN HOUSE DEVELOP LUNG PHANTOM

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Introduction: Phantoms are the devices which have been used in medical physics since the beginning. Soon after the discovery of X-rays physicist develop phantoms for diagnostic as well as for dosimetric purpose. Earlier it was thought that in order to quantify the dose delivered to a tissue of interest; the measurement should be made on the tissue itself. When the harmful effects of radiation were realized, the need for tissue substitute became clear, and thus the concept of phantom was born. As human body consists of water thus the dose measurement is done on the homogeneous phantom which is water equivalent. Whereas advance diagnostic techniques clearly suggest that the human body is complex heterogeneous medium comprises of varied densities. To study the radiological properties of photon inside heterogeneous medium thus necessitate developing a heterogeneous phantom for dosimetric purposes. However, the inconsistency of tissue equivalent materials still presents a large obstacle. The selection of the appropriate materials is critical to the design and function of any type of phantom. Though the anthromorphic phantoms are commercially available but they are not cost effective and as accurate as human tissues. Present study focuses on designing of in house cost effective lung phantom (slab-wooden dust-slab) SWS and to study its radiological properties for 15 MV photon.
Purpose: To study the designing of in house developed lung phantom and radiological properties of 15 mega voltage (MV) photon energy inside it.
Materials and Methods: The density of SP34 slab, wooden dust of pine, and thoracic region of 20 patients were calculated using computed tomography (CT) images. The depths of isodose curves of 100%, 95%, 90%, 85%, 80%, 75%, 65%, 60%, 55% and 50% were measured in CT images of both the mediums on TPS for 10×10 field size for 15 MV photon beam. Patient-specific quality assurance (QA) was implemented using homogeneous SP34 slab phantom and heterogeneous SWS phantom for 15 patients.
Results: The mean density of wooden dust, slabs, soft tissue, chest wall and lung was found to be 0.271, 0.994, 0.980, 0.947 and 0.287 gm/cc respectively. The isodose depth (of 100%, 95%, 90%, 85%, 80%, 75%, 70%, 65%, 60%, and 55%) for patient (2.83, 4.95, 7.03, 9.38, 11.04, 13.08, 15.14, 18.46, 20.29 and 20.89 cm) and for SWS (2.84, 5.02, 6.90, 9.07, 10.95, 12.60, 14.19, 17.75, 19.83 and 22.06 cm) are found to be approximately same. Furthermore, the mean percentage variation and standard deviation between the planned and measured doses in patient-specific QA was found to be 1.04, 0.64 and 1.41 and 0.80 respectively for SP34 and SWS phantom.
Discussion and Conclusion: Our aim was to design a heterogeneous phantom which can mimic the actual patient. The radiological properties of developed in house phantom are found to be equivalent to that of the actual thoracic region of human. Patient-specific QA was performed for 15 IMRT cancer patients. The variation between the measured dose and the planned dose calculated by TPS is found to be more in SWS phantom than the SP34 Phantom. Dose calculations were done by anisotropic analytical algorithm (AAA) which does not give accurate results when density variations are there. Thus we got more variation in SWS heterogeneous phantom as compared to homogenous SP34 phantom.

OP-34

AUTOMATION OF DELAY DECAY TANK FOR THE MANAGEMENT OF RADIOACTIVE WASTE

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Introduction: Department of Nuclear Medicine of INHS Asvini provides diagnostic and therapeutic facilities to its clientele using radioisotopes at this tertiary care hospital of Indian Navy. This department has been authorized by AERB for providing high dose radionuclide therapy to the patients. A nuclear medicine department which uses I-131 as a radioactive source for treatment of thyroid cancer, needs the patients to be admitted in wards for some days and their waste product is drained into separate waste management facility which is called delay tank. A significant amount of radioactive waste is generated from the patient. This radioactive waste is stored in delay decay tank for a minimum period of about 10 half-lives.
Purpose: In this paper we are describing the work taken up for renovating and upgrading the delay decay tanks from manual to automatic mode so that there will be no need of manual intervention in operating valves of the tanks while releasing the human waste containing decayed activity.
Materials and Methods: Liquid wastes generated from I-131 administrations are collected in the delay tank. In our Nuclear Medicine department there are two isolation rooms for administering high dose of radio iodine ablation therapy and sewage lines of these rooms are connected to the twin

concrete tanks located in the area at ground level behind the department. Both the tanks are of a size of 4m × 2m × 1.5 m (external dimensions) each and can accommodate approximately 10,000l of effluents. Earlier the tank's valves were operated manually at the time of releasing the decayed activity. The tank lids were also needed to be lifted up for checking the levels within the tanks. The automation of storage and release system of tank has resolved these efforts. The automation of radioactive sewage tank system has been carried out to monitor the volume and levels of effluent sewage in the tank and releasing the same to main drain once safe level of radiations has reached. The electronic system comprises of:

1. Programmable logic circuit (PLC) – to control motorized valves and to monitor fluid levels in both the tank. PLC are programmed to control motorized valves in automatic and manual mode.
2. Control panels (02 in no.) – one control panel was installed near the delay tank with level display and push button control system for motorized valves. Second control panel installed with 12 inch LED touch screen panel in the department.
3. Motorized valves-corrosion free, maintenance free valves of suitable size with manual and automatic controls.
4. Pump system.
5. Computer Software –to control automation of tanks.

Results and Discussion: The automation of radioactive sewage delay tanks at INHS Asvini is one of its kind, fully automatic and digitalized delay tanks in all armed forces hospitals. Automation has been executed and included renovation of existing delay tanks and installation of six motorized valves, ultrasonic sensors for monitoring effluent level, electronic relays, programmable logic circuit, touch screen control panel, push buttons for manual control and LAN port for desktop control.

Conclusion: Generation of radioactive waste shall be kept to the minimum. The automation of delay decay tank has reduced the dependency on the workers engaged in manual opening of lid and valves of the tank. The push button control panel has reduced the radiation exposure to the operators. The remote controlled valves helps in preventing any accidental overflow of the tanks by constantly monitoring the effluent's levels.

OP-35

PROTON RADIOGRAPHY STUDIES USING GEANT4 SIMULATIONS

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Introduction: Proton therapy is the recent trend in cancer treatment. The depth-dose profile of proton exhibits a flat plateau followed by a sharp peak known as Bragg peak where the maximum dose is deposited. The proton range should be known accurately to deposit the maximum dose at the tumor site. Any uncertainty in proton range causes partial covering of the tumor or zero dose to the tumor which severely damages the surrounding healthier tissues. Presently proton ranges are calculated from X ray Computed Tomography (XCT) images in which X-ray Hounsfield Units (HU) are converted into water equivalent path length (WEPL) using a calibration curve. Any error in the calibration will translate into an error in the proton range. This can be reduced if protons are used for imaging instead of x-rays-a method commonly known as proton radiography recent technique called as Energy Resolved Dose Functions (ERDF) seems to be promising for clinical applications due to its simplicity. The relation between ERDF and WEPL are well established experimentally. In this study, the proton radiography setup is simulated and studied its efficacy in imaging a solid sphere.

Purpose: To study the image quality and WEPL accuracy of proton radiography using GEANT4 simulation.

Materials and Methods: The simulation environment was developed using Geant4 libraries. Proton beams varying from 50 MeV to 250 MeV are shot using a particle gun and a water wedge of dimensions 5 cm x 5 cm x 30 cm (HxWxD) is placed in that path of proton beams and the dose deposited at the exit of the wedge is measured using a simple detector geometry from which the dose function is estimated (ERDF). A solid (water) sphere of radius 10 cm is now kept in the path of the beam and the energy is scanned as before. By comparing the pixel wise ERDFs with the wedge ERDFs, we retrieve the WEPL image of the sphere.

Results: ERDF has a unique dose pattern as a function of energy for a particular WEPL. WEPL can be calculated by using the depth at 80% of the proximal fall off of the ERDF in water. ERDF for WEPL range of 0 cm to 30 cm are generated from wedge simulation data. By matching the ERDFs pattern from the sphere with the wedge, WEPL for sphere is estimated and compared with the calculated WEPL. The results show a good match between the WEPL from the simulation with the WEPL from the calculations.

Discussions and Conclusions: Simulation of single detector proton radiography yields convincing results in evaluating WEPL accuracy. Beam energy used in simulation need to be varied in smaller steps for further improvement of the accuracy of WEPL. Scattering effects are not included in the present study. Beam parameters like mean energy and energy spread need to be optimised for extending this method for clinical applications.

OP-36

INDIGENOUSLY DEVELOPED COST EFFECTIVE HETEROGENEOUS PEDIATRIC PHANTOM

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Introduction: There is a spectacular technological development and advances in radiodiagnosis and radiotherapy while imaging or treating the cancer patients. The patient absorbed dose measurement is very essential to monitor dose level, but few verification methodologies are possible to know the radiation. A phantom study is a compatible and easy way to verify the dose level. Phantoms can be classified into

two major categories such as computational phantoms and physical phantoms. Tissue equivalent material of polymethyl methacrylate (PMMA) is used to fabricate physical pediatric phantoms in order to evaluate the doses received by patients.
Purpose: To fabricate a heterogeneous pediatric phantom and measure organ dose in 1 year, 5 years and 10-year-old pediatric phantoms.
Materials and Methods: Different age group pediatric patient anatomical information has occurred from Computed Tomography (CT) scan. After the simplification of the CT images each slice and its corresponding data, including thickness and size were drawn using the AutoCAD software. Then the output of the AutoCAD images was transferred to a CNC machine. The 10 mm thickness of PMMA sheets with a density of 1.17 g/cm3 was cut into many pieces of slabs, the dimension was 26×20 cm^2 for 10-year baby, 24×18 cm^2 for 5-year baby and 20×14 cm^2 for 1-year baby. In each slab drilled two 10 mm diameter hole was made which this hole is fixed in CNC machine to avoid motion. We made provision of OSLD nanoDots cavity in critical organ region at the phantom. The phantom irradiations were performed in digital radiography RADSPEED 80 equipment (Shimadzu Medical India Pvt., Ltd.,). Sets of nanoDot were positioned in the 5-year-old phantom at different locations like Head, Neck, Lung, and Abdomen. The operating parameters were selected 60kVp to 120kVp with an interval of 20 kVp at 50mAs, 100mAs and, 150mAs. The field size was fully opened and the phantom placed at 70cm away from the focal spot.
Results: The measured and calculated average absorbed dose is 0.35mGy for 60kVp and 50mAs, 0.40mGy for 80mGy and 50mAs, 0.48mGy for 100kVp and 50mAs, 0.56mGy for 120Vp and 50mAs, 0.56mGy for 60kVp and 100mAs, 0.61mGy for 80kVp and 100mAs, 0.72mGy for 100kVp and 100mAs, 0.92mGy for 120kVp and 100mAs, 0.72mGy for 60kVp and 150mAs, 0.82mGy for 80kVp and 150mAs, 0.95mGy for 100kVp and 150mAs, 1.13mGy for 120kVp and 150mAs respectively.
Discussion: The characteristics of the developed heterogeneous pediatric phantom were ensured and optimized to measure the radiation exposure level in diagnostic radiology. From this study, it is inferred that the radiation dose in pediatric phantom was varying with respect to tube voltage and tube current. The observation of organ absorbed dose in those phantoms was slightly varied due to a different location at the phantom. The dose received by the lung and a head region is more when compared to other parts of the body. Based on these, the present would be used to measure organ dose in the pediatric patient.
Conclusion: A unique methodology has been developed to construct heterogeneous pediatric phantoms for dosimetry studies. The total cost of these phantoms (3 Nos.) is less than Rs. 3 Lakh. The cost-effective phantom is well suitable for use in radio diagnostic procedures, to measure the actual dose delivered to critical organs while performing imaging.

OP-37

MACHINE LEARNING-ENHANCING PRODUCTIVITY IN NETWORKED ONCOLOGY CENTRES

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Purpose/Objective(s): The field of Radiation oncology has grown leaps and bounds in the past 3 decades. The technology has revolutionized the treatment outcomes. In the recent past number of cancer care centers in India has grown steadily. This lead in to the networking of these centers to enhance the productivity, quality of care in these networked treatment centers. The knowledge of machine learning, deep learning and artificial intelligence have played a significant role in this regard. Machine Learning is study of algorithms that improve their performance at some task with experience. We have used RapidPlan (Varian Medical Systems, Palo Alto, CA) for planning. RapidPlan is a machine-learning tool that studies best practices from past successful treatment plans and creates knowledge-based treatment models that are applied to improve the treatment plans for future patients. These RapidPlan models help to quickly generate and validate new high-quality treatment plans based on shared expertise among centres. We have taken 3 important sites for this purpose, i. e., Head & Neck, Pelvis and Craniospinal irradiation (CSI). The Head and neck and Pelvis under validation. The CSI clinical plans were generated and compared with Rapidplan done in one our unit on various treatment parameters. CSI remains technically demanding, with potential for treatment filed overlap or gaps to yield unacceptable dosimetric target heterogeneity and time consuming for planning. RapidPlan model for CSI were created using dosimetric inputs from Helical Tomotherapy (HT) planning to guide optimization and to generate plans with Volumetric Modulated Arc Therapy (VMAT) technique in a different planning system and then to test the performance of this model against user plans.
Materials and Methods: Thirty six CSI patients treated with HT were chosen to create Rapidplan model. All image set had organ at risks (OAR) such as Heart, bilateral Kidneys, Lungs, Eyes, Rectum, Bladder contoured and deliverable plans were created using Tomotherapy Volo planning system. The Radiotherapy dose dicom file were then transferred to Varian Eclipse planning system (Version 13.7) to train KBTP models. For the purpose of training KBTP model, we considered five OARs say Heart, bilateral Kidneys, Lungs to extract dosimetric data. The model quality was evaluated checking the model goodness of fit statistics for each structure, with the coefficient of determination R 2 (between 0 and 1: the larger, the better) and the average Pearson's chi square $\chi 2$. The published model was then used to guide VMAT Optimization and to generate deliverable plans on an independent set of 20 adult patients using three isocentre. Resultant model plans were then compared and analyzed against user plans using VMAT and HT. The planning target volume (PTV) coverage were compared using the Uniformity Index (UI). Four dose-volume points such as V5, V10, V20 and mean doses were used to compare the OARs doses.
Results: Out of 36 patient dosimetric data extracted, 27 dataset were used to train Rapidplan model excluding potential poor outliers from data set. R-square values of trained model as goodness of fit for OARs were Heart 0.623,Left Kidney 0.761, Right Kidney 0.887, Left Lung 0.965 and Right Lung 0.903. UI for PTV were 1.03 ± 0.02 and 1.06 ± 0.01 for KBTP model plan and user VMAT plan respectively. Mean dose to Heart, Right and left Lungs, Right and left kidneys were 400 cGy $\pm$ 59, 462.1cGy $\pm$ 53, 406.8 cGy $\pm$ 40, 431.7cGy $\pm$ 30, 406.6 cGy $\pm$ 31 for KBTP plans and 383.2 cGy $\pm$ 29, 423.8 cGy

± 17, 393.1 cGy ± 44, 557.6 cGy ± 20, 557.2 cGy ± 19 for user plans respectively. There is no significant improvement in OAR dose volume values between plans. The targets heterogeneity and global maximum dose were found to be high in VMAT user's plan by 2-3 % and closely fit to HT user's plans when compared with model plans.

Conclusion: RapidPlan CSI models are suitable for generating clinically acceptable VMAT plans and planning time is greatly reduced. An adequate choice of the objectives in the model is necessary for the trade-offs strategies. A possible clinical benefit as reduced toxicity remains to be tested.

OP-38

DOSIMETRIC VALIDATION OF ACUROS XB PHOTON DOSE CALCULATION ALGORITHM ON AN INDIGENOUSLY FABRICATED LOW DENSITY HETEROGENEITY PHANTOM

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Introduction: Precise confirmation of accuracy in dose calculation is an important aspect of quality assurance procedure in radiotherapy. Slab phantom of uniform density (water equivalent i. e 1g/cc) used for patient specific QA in most of radiotherapy department of developing countries. This is due to high cost of commercially available heterogeneous phantoms and limited access to advance technologies. Owing to known effect of tissues heterogeneity on dose distribution pattern and dose calculation, there is a need to fabricate a cost effective low density heterogeneous phantom. This can truly represent the accurate dose calculation in low density heterogeneous medium.

Purpose: The aim of the study is to fabricate a cost effective low density heterogeneous phantom using the combination of PMMA and racemosa wood. This study also validates the Acuros XB algorithm in low density heterogeneous medium of this fabricated phantom.

Materials and Methods: This study measured the Hounsfield units (HU), relative electron density, mass density for racemosa wood and PMMA. Point dose measurement were done at 6.5, 11 and 17.5 cm depths in heterogeneous PMMA-Racemosa-PMMA (PRP) and homogenous PMMA mediums and compared against AAA and AXB calculations. This experiments was performed using a 6 MV photon beam and dose calculations were performed on eclipse TPS. The dose was reported in dose-to-medium and dose-to-water mode for AXB and AAA algorithms respectively. The grid resolution of 2.5 x 2.5 x 2.5 mm3 was used for dose calculations.

Results and Discussion: The measured HU, relative electron density, mass density were-726.5, 0.273g/cc, 0.212g/cc and 201.8, 1.201g/cc, 1.175g/cc for racemosa and PMMA respectively.

For AAA algorithm, the mean dose variations from IC measurement were 0.73%,-0.99% and-1.39% at depth of 6.5 cm, 11 cm and 17.5cm respectively, in homogeneous medium of PMMA. Similarly, mean dose variations from IC measurement were-1.67%,-1.45% and-1.50% at depth of 6.5 cm, 11 cm and 17.5cm respectively, in low density heterogeneous medium of PRP phantom.

For AXB algorithm, the mean dose variations from IC measurement were-1.01%,-2.41% and-1.85 % at depth of 6.5 cm, 11 cm and 17.5cm respectively, in homogeneous medium of PMMA. Similarly, mean dose variations from IC measurement were 1.50%, 1.66% and 1.81 % at depth of 6.5 cm, 11 cm and 17.5cm respectively, in low density heterogeneous medium of PRP phantom.

The percentage dose variation between AAA and AXB were also calculated and compared in homogenous medium of PMMA and low density heterogeneous medium of PRP phantom. The variation of-2.58%,-1.44% and-0.47 % were found at depth of 6.5 cm, 11 cm and 17.5cm respectively, in homogeneous medium of PMMA. The variation of-3.13%,-3.06% and-3.26 % were at depth of 6.5 cm, 11 cm and 17.5cm respectively, in heterogeneous medium of PRP phantom. This dose difference in AAA and AXB algorithm exist due to the difference in dose calculation methods employed in both algorithms. The AXB calculations are sensitive to medium composition and characterization as they calculate radiation transport in the medium. In contrast, the AAA calculations model the medium was water of different densities.

Conclusion: Based on the physical and radiological properties studied for racemosa, it can be concluded that racemosa can simulate lung region of a human body. It can be use to fabricate a cost effective low density heterogeneous phantom in combination with PMMA and other suitable materials. The experimental validation of AXB calculations also concludes that AXB provides comparable results to AAA, in low density heterogeneous medium.

OP-39

IMAGE BASED DOSIMETRY QA TOOLS FOR ADVANCED RADIOTHERAPY

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Introduction: Patient-specific pre-treatment dose verification for safe and effective implementation of advanced radiotherapy techniques such as IMRT/VMAT is strongly recommended for all the patients. A number of commercial systems are available for pre-treatment dose verification in IMRT/VMAT; however these systems are costly, having limited features and dedicated to a particular dosimetry system. In view of this, an indigenous, versatile image based dosimetry QA system was developed. This paper describes features of indigenously developed image based dosimetry QA system for advanced radiotherapy techniques.

Materials and Method: Image based dosimetry QA tools for advanced radiotherapy has been developed using Visual Studio C++ programming language. It has 6 core menu items and there after a number of sub-menu for different activities/ task. Applications of this tool open with four windows namely 1, 2, 3 and 4. Window 1 and 2 are used to import the images

for analysis while Window 3 and 4 are used to display their analysis/ computed results. The system have feature for 2D and 3D analysis of data set. It can be used for relative as well as absolute dose analysis. As is the case with other QA systems, the study in this tool start with calibration. Pre-digitized calibration image (in tiff format) can be loaded or scanner can be called to digitize the calibration image. The calibration function (where A, B and C are constants) was used to generate the calibration curve. These constants were determined by solving equations with data of different calibration doses. In the sub-menu called BUILD, digitized image is converted into dose-map, isocentre and ROI are fixed, and the dose-map is converted into DICOM RT having tag of the patient details as communicated by the TPS. This QA system also has a dedicated database where all the data including the TPS calculated dose data as well as measured dose data are stored. Using the sub-menu called LOAD, these data can be loaded into windows 1 and 2. This system is equipped with a number of analysis toolbar such as gamma, DTA, dose difference, isodose comparison, profile comparison, histogram analysis, normalization option, data manipulation with simple arithmetic operation, data movement. Report of the analysis is displayed by the system. Physics QA for analysis of field width, flatness, symmetry, penumbra for flattening filter as well as flattening filter free beam also have been added. The analysis of these parameters are done using international/AERB protocols. To demonstrate its performance, pre-treatment dose verification for an IMRT case of H&N cancer was carried out. QA plan was generated using Eclipse Treatment planning system. The TrueBeam medical linear accelerator having 6 MV flattened filter beam was used for this study. The Gafchromic film strips were irradiated in the range of doses 60, 140, 300 and 340 cGy for the purpose of calibration.

Results and Discussion: The calibration curve was generated. The dose-map using the generated calibration curve was computed. Computed dose-map was aligned, isocentre and ROI was fixed. The computed dose-map was compared with TPS generated dose map. Analysis of results using gamma reveal that 99.19% point passed the set criteria of 3% and 3 mm. Analysis of results also reveal that the isodose lines and dose profiles of both data sets are well correlated with each other. Further, result of dose difference relative to the local and global dose (dose at isocentre) indicates that differences are mostly around 1% and -1% respectively. It should be noted that dose difference are found to be significantly higher than typical accepted dose difference of 3% but the frequencies are negligible.

Conclusion: The system's performance has been thoroughly evaluated and found satisfactory in comparison to the similar commercial system.

OP-40

HYBRID TECHNIQUE FOR BREAST CANCER: A DOSIMETRIC COMPARISON OF HYBRID VMAT AND HYBRID IMRT PLANS

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Introduction: Hybrid planning technique is an innovative method which combines conventional 3DCRT and VMAT/ IMRT plans with different dose proportions in a single fraction. In published studies, the average proposed dose ratios for 3DCRT and VMAT/IMRT are 75% and 25% respectively. Published Studies preferred IMRT for whole breast irradiation than VMAT. Further, there is no study on the feasibility of flattening filter free (FFF) photon beam in 3DCRT based hybrid techniques.

Objective: In the present study, hybrid IMRT and hybrid VMAT plans for whole breast irradiation were compared and the feasibility of FFF beam in hybrid plan was studied.

Materials and Methods: CT scan data of 10 early stage left-sided breast cancer patients were used for this study. The whole breast PTV was prescribed to 50Gy (2Gy/fraction) using 6X and 6X-FFF photon beams of Truebeam STx accelerator. The 3DCRT plan was prescribed with 75% dose per fraction and used 2 tangential fields with 2 cm air margin to accommodate breathing movement and setup variability of breast PTV. The VMAT and IMRT plans were prescribed with remaining 25% dose and created by keeping the 3DCRT plan as a base dose plan during optimization. All plans were normalized to target mean and statistically compared using various PTV dosimetric variables and organs at risk (OAR) doses.

Results and Discussions: Both H-VMAT & H-IMRT plans showed comparable PTV coverage, conformity, uniformity and gradient indices. Many clinical studies have warned about the potential risk for lung and heart even at low doses. The ipsilateral lung mean, V5Gy were significantly less in H-IMRT ($p < 0.01$) whereas V20Gy, V40Gy were comparable. The heart mean, V5Gy, V40Gy were significantly less in H-IMRT ($p < 0.01$) whereas V25Gy was comparable. The contralateral lung, contralateral breast and normal tissue mean doses were significantly less in H-IMRT ($p < 0.04$). The MU and treatment time were significantly less in H-VMAT ($p < 0.0001$). The hybrid plans with FFF beam showed statistically similar results compared to those plans with flat beam.

Conclusions: The H-IMRT plan achieved significantly better sparing of OAR doses compared to H-VMAT. Less low dose bath to the heart, lung and contralateral breast should be the goal since the breast patients are long term survivors. The use of FFF photon beam is feasible in hybrid plans with 3DCRT as one of component for whole breast irradiation.

OP-41

APPLICATION OF IAEA-AAPM TRS 483 FOR SMALL FIELD DOSIMETRY WITH TOMOTHERAPY: AN INITIAL EXPERIENCE

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Introduction: Recently IAEA-AAPM has published TRS 483 on small field dosimetry. It guides in detail about the testing the code of practice for small field dosimetry. Nowadays, advanced treatments are delivered with either static intensity

modulated radiotherapy (IMRT) fields or rotational IMRT fields by utilizing small beamlets. The appropriate use of the detector with minimal uncertainties is the need of the time. This study deals with relative dosimetry of the small fields that can be generated using the MLCs of Tomotherapy Machine by using various detectors.

Purpose: To determine the output factors (O. F) and TPR (20, 10) for a range of field sizes in water and virtual water with three different detectors on Tomotherapy Hi-Arts machine.

Materials and Methods: Tomotherapy Hi-Art System (Accuray, USA) having 6MV FFF energy was used for the dosimetry. Three different detectors (PTW Pin Point, IBA CC01, IBA EFD 3G Diode) with Tomotherapy Electrometer (8-channel) System were used. Tomotherapy water tank was used for TSD setup measurements in water whereas Scanditronix Wellhofer Gmbh I'mRT verification Tool Phantom with some customization was used for TSD and TAD setups in virtual water phantom. The Pinpoint and CC01 chamber axis was placed perpendicular to the beam axis, whereas the axis of EFD diode was placed parallel to beam axis. The detector positioning was crucial but was verified with the MVCT imaging for every measurements. Range of field size used varied from 5cm X 40cm to 1cm X 0.625cm.

Recommendations from TRS 483 were followed for O. F measurements. All O. F were normalized for the reference field size 5cm X 10cm. All measurements were carried out at 10 cm depth, and the O. F measured with three detectors were compared. In addition, the uncertainty budget was also estimated and reported.

Results: EFD diode showed the highest uncorrected O. F for the smallest field in both water TSD setup and virtual water TAD setup. Largest variation among detectors for uncorrected O. F were 10.73%, 5.38% and 14.69% for water TSD setup, virtual water TSD & TAD setup respectively. The corrected O. F of EFD and CC01 were comparable up to 3 decimal points in water. The corrected O. F of EFD were higher in comparison to CC01 with a difference of 1.7% and 11.71% for Virtual water TSD and TAD setup respectively. Both uncorrected and corrected O. F for detectors are in good agreement within 3% except field sizes smaller than 2.5cm. Maximum variation of TPR (20, 10) for reference and smallest field size among detectors was 0.34% and 1.5% respectively. The maximum total uncertainty (Type A: meter reading; Type B: time, couch position, Electrometer, Correction factors) of 3 detectors were found at smallest field sizes which are 1.25%, 3.55% and 3.64% for EFD, CC01 and Pinpoint respectively in water SSD technique.

Discussion: The output correction factor for PTW Pin Point was available upto equivalent field size 2.5 cm, so corrected O. F was not calculated for F. S <2.5cm. Due to the constraint of bore size, Tomo water tank cannot be used for TAD and TPR (20, 10) measurement in water.

Conclusion: The relative O. F for three detectors on Tomotherapy machine for 6MV energy were investigated for small fields. At the smallest field size, EFD showed the highest corrected O. F among the three detectors concluding its best suitability at small fields. The corrected O. F for the various detectors in water were found to be in close agreement (<3%) for all field sizes whereas, in virtual water the corrected O. F showed some variation for smaller field sizes (<2.5cm). The TPR (20, 10) values obtained for various detectors showed a similar trend, which increases with increase in equivalent field size.

OP-42

DOSIMETRY CHALLENGES ON VARIAN HALCYON LINAC–SIMPLIIFED WITH AUTOSETUP OF PTW BEAM SCAN

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Introduction: Varian Halcyon Linear Accelerator is the latest and advanced, fast treatment machine with 100% Image Guided treatment for all patients. The linear accelerator is designed like a Ring and is delivered pre-commissioned on the Varian Eclipse Planning System. Beam data measurements are required to ensure and verify the quality of the pre-commissioning data but these measurements are challenging for a physicist because there is no field light, no ODI and no laser on the Isocentre plane. The newly launched RFA, PTW BEAMSCAN, water tank was used for the first time in India to commission South East Asia's First Halcyon unit at Sterling Hospitals, Rajkot. The RFA has to be put on the couch top for measurements, so the couch tilt, tank level, water level, isocentre position is very difficult to align correctly. The BeamScan RFA was used using the Autosetup for the Acceptance Testing and Commissioning of the Halcyon Linear Accelerator.

Materials and Methods: The bore of the Halcyon Linac is 1 metre diameter and hence the ideal Beam Scan tank dimension to fit perfectly in to Halcyon bore is 70 cm width x 70 cm height, minimum. The weight of the water filled tank creates a Couch of sag of 3 mm to 5mm depending on the water level. PTW BeamScan has Auto setup feature and hence no need to do any manual adjustment and if couch sags due to more weight, auto setup mode will adjust as per the water level. The water tank is placed on the couch, aligned with the bore laser and the device homing is done using the wireless device. Water is filled upto the laser level for SSD 100cm and water surface is levelled is asserted using MV imager at gantry 90°. To setup the tank for SSD 90cm, additional 10 cm water is filled above laser level and the imaging is done at gantry 84.3°. The MV imager was also used to check the position of the reference detector using a brass build-up cap. The detector position, tank levelling and beam centering including detector at water surface is done with tank auto-levelling process. Once all setup was completed, PDD, In-plane and Cross-plane profiles for the filed size from 2X2cm to 28X28cm in the depths 13mm, 50mm, 100mm, 20mm were measured. The same setup was used for the absolute dose measurement using 0.6cc chamber for the output calibration and also for the TPR20/10 measurement.

Discussion: The Haclyon machine is a novel machine with pre-loaded beam data on the Eclipse Planning System. Hence, the validation of the beam data is very much necessary to gain confidence on the linear accelerator. At Sterling Cancer Hospitals, Rajkot the validation was done using PTW BeamScan RFA. The profiles were overlapped with the pre-loaded data in the Eclipse Planning System and found to be a perfect match. Automatic function of BeamScan constitutes as perfect solution for measurement. The big advantage of the BeamScan is reduced setup time with wireless auto setup with a maximum of 25min. Consistency of PDD at 10cm

depth, fs= 6X6, was CoV=0.24, and Consistency of Inplane at d=10cm, fs=6X6, difference is-0.16%,-0.20%,-0.14%,-0.24% and Crossplane difference 0.02%,-0.12%, 0.11%, 0.08%.
Conclusion: Automatic Setup of RFA is very much needful for Commissioning a machine like Halcyon Linear Accelerator. PTW BeamScan is a perfect solution for the same. The consistency, accuracy and precision of the Halcyon machine is assured with consistency of measurements done with the BeamScan RFA.

OP-43

INVESTIGATION OF THYROID RADIATION DOSES DURING MAMMOGRAPHY

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Purpose: The use of mammography as a diagnosis has increased in recent years, being currently, the most sensitive technique and mostly performed for early diagnosis of breast cancer. Consequently, there is an increase in the number of exposures to radiation on breast and adjacent organs, appearing the need to evaluate the dose absorbed by risk organs, like thyroid gland. This study was planned to quantify the scatter radiation dose to right and left lobe of thyroid gland during routine screening mammography examination.
Methods: The radiation dose to the skin overlying the thyroid was measured for 100 women undergoing routine mammographic screening within the age group of 35-60 years and BMI range of 20-30 screened on Hologic M-IVTM screen-film mammography system single handedly. Measurements were made using optically stimulated luminescent dosimeter (OSLD) detectors taped appropriately to the skin overlying on right and left lobe of thyroid gland. The radiographic parameter ranges used was KV (28-30), mAs (10-24).The standard technique of two craniocaudal views (CC) and two mediolateral oblique views (MLO) was used during screening examination.
Results: An average skin thyroid dose of 0.40 +/-0.26mGy per mammographic examination was measured with measurements ranging from 0.10 to 0.79 mGy.
Conclusions: The single examination doses were not found significant but higher frequency of screening examination will increase the risk of radiation doses.

Poster

PP-1

DOSIMETRIC INEFFICACY OF NONTISSUE EQUIVALENT THERMOLUMINESCENCE DOSIMETER FOR IN VIVO DOSIMETRY OF OUT OF RADIATION FIELD EXIT DOSE MEASUREMENTS IN EXTERNAL RADIOTHERAPY AND RECOMMENDATIONS FOR USE

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Purpose: The present study designed to evaluate entrance and exit doses for out of the radiation field in external beam radiotherapy (EBRT). The primary aim of this study was to investigate the efficiency of non tissue equivalent (NTE) thermoluminescence dosimeters (TLD) for in vivo dosimetry of out of the radiation field dose measurements.

Materials and Methods: All the measurements were performed in 10 head and neck patients (age range, 35–46 years; mean, 44 years) treated with two parallel opposed lateral fields on Bhabhatron-II TAW Telecolbalt unit (Panacea Medical Technologies, Bengaluru, India) using source to surface distance (SSD) technique. The TLDs used in this study were Nucleonix India Pvt. Ltd., CaSO4:Dy discs (13.3 mm diameter, 0.8 mm thick) and LiF: Mg, Ti chips (3.2 X 3.2 X 0.89 mm). The CaSO4:Dy discs were placed at the level of the eyes of the patient for a single right lateral treatment field only. This methodology provided the set up to assess out of field entrance and exit radiation dose to eye. TLD-100 chips were also placed exactly in the identical places in the next treatment fraction of same patient. The physical data measured were separation distance at the level of eye, distance between radiation field edge and ipsilateral right eye at SSD. The distances were calculated for radiation beam exit from isocenter at the exit surface of the patient.

Results and Discussion: The distance between radiation field edge and ipsilateral eye at SSD was measured in the range of 2.0–4.0 cm with mean 3.3 cm. The distances of separation at the level of eye, entrance and exit of edge of beam from isocenter were in the range of 11cm-15cm, 7.0cm-8.5cm, 8.0cm-9.5cm respectively. It was obvious to observe with theoretical calculations using radiation divergence property that the primary radiation beam was not passing through contralateral eye. The contralateral eye was away from the exit of edge of radiation beam in all the cases and distances were found in the range of 0.5cm-2.8cm. However, when the doses were analyzed for non tissue equivalent CaSO4:Dy discs and it was surprising to note that the exit dose to contralateral eye (Dexit) were measured 1.5 to 2.5 times higher than the entrance dose to ipsilateral eye (Dentrance).

To investigate this over-response, the doses were measured with tissue equivalent TLD-100 chips in the identical conditions. It was found that Dexit were measured 15% to 20% less than Dentrance. Thus, the possible cause for this over-response in NTE dosimeter is increase in the intensity of secondary electrons and low energy scattered photons reaching to dosimeter at the exit surface of the patient during out of field measurements. The results of this study suggested that non tissue equivalent CaSO4:Dy discs were not the dosimeter of choice for out of field exit dose measurements. One should be precautious to use non tissue equivalent CaSO4:Dy dosimeters for out of field exit dose measurements. Further study needs to be performed to deal this over-response using either appropriate correction factors or build up caps. However, studies of buildup caps should be conducted for out of field measurements. In addition, special attention should be paid to the selection of the appropriate materials for buildup caps, taking into account the impact of low energy radiation and attenuation of the beam.

Conclusion: The non tissue equivalent dosimeters were not the promising dosimeters for out of field exit dose measurements. The research outputs of this study may be helpful for the selection of the appropriate in vivo dosimeter suitable for clinical use for out of the radiation field dose measurement conditions in radiotherapy.

PP-2

A PROSPECTIVE STUDY ON INTER-FRACTION SHIFTING TO DETERMINE THE SET-UP MARGIN FOR THREE SITES

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Introduction: With the state of the art techniques now Radiotherapy is a proven means to cure and improve the quality life of cancer patients. Success of advanced radiotherapy highly depends upon the precession and accuracy. For accurate and precise delivery of the prescribed dose to the target volume, it is necessary to draw optimum CTV to PTV margin. To determine the margin, we have to consider factors like proper target delineation, use of proper immobilization device, proper patient positioning etc. Accurate patient positioning can be ensured with IGRT.

Purpose: Purpose of my study is to evaluate interfraction setup errors using daily CBCT with the patients undergoing IMRT and 3DCRT treatment for Brain, Head and Neck and Pelvis site cancer and to calculate CTV to PTV margin.

Materials and Methods: A prospective study was done selecting 30 patients, 10 from each site (Brain, Head and Neck and Pelvis). Initially all patients underwent CT simulation with slice thickness of 3mm in supine positions. Contouring was done as per ICRU report 50 and 62 guidelines in FocalPro. IMRT plans were generated for each patient in CMS Xio *(4.80.002 version, ELEKTA)* TPS and subsequently, the plans were transferred to MOSAIQ and XVI system respectively. On the very first day the shifting were made to the planned isocenter from the reference fiducial markers and CBCT were taken for each patient. Any error in the target (isocenter) was rectified based on the CBCT verification and the corrected

isocenter were marked which would be used for set up in the subsequent days. Following daily CBCT prior to treatment, positional errors were recorded in Medio-Lateral (M-L), Supero-Inferior (S-I) and Antero-Posterior (A-P) directions for each patient. The target positional errors were corrected by adjusting the patient position, through shifting the patient using the automatic motorized couch in all three translational dimensions. From the noted shift data, clinical target volume to planning target volume margin were calculated using Van Herk formula (margin=2.5Σp+ 0.7σp), where Σp is the systematic error and σp is the random error.

Result: A total of 217 CBCT scans for brain, 200 for head and neck and 211 scans were acquired for pelvis. Shifting errors for each site for the population of patients were analyzed. The interfraction shifts in brain was-0.21±0.58 mm (range-8.6 to 8.4),0.28±0.85 (range-6.7 to 8.6) and-0.063±0.64 (range-0.55 to 0.63); in head and neck, 0.037±1.7 mm (range-8.4 to 6.7), 0.0017±2.7 (range-7 to 7.3), 0.043±2.5 (range-9.7 to 9.4) and in pelvis region 0.03±3.13 mm (range-8.60 to 19.8), 0.35±11.02 (range-27.3 to 27),0.13±2.50 (range-0.7.6 to 6.1) in M-L, S-I and A-P direction respectively. From these data, calculated margins are 5.00mm, 3.86mm and 2.97mm (brain); 7.20mm, 6.40mm and 5.25mm (head and neck); and 7.29mm, 18.14mm and 4.25mm (pelvis) in M-L, S-I and A-P directions respectively.

Discussion: Proper CTV to PTV margin is essential for optimal dosimetry, minimizing marginal miss of tumour volume and sparing of OARs properly. In current practice in our institute, we are giving isotropic margin of 5mm in brain and head and neck and 10mm in pelvis region. It is imperative to that every institute which practices advanced techniques calculates its own margins based on the shifting errors.

Conclusion: The results of the study will be helpful to establish a standard CTV to PTV margin as an institutional protocol for treating brain, head and neck and pelvis region.

PP-3

PATIENTS DOSE ESTIMATION IN COMPUTED TOMOGRAPHY EXAMINATIONS USING SIZE SPECIFIC DOSE ESTIMATES

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Introduction: The x-ray computed tomography (CT) is an imaging modality to produce three dimensional thin cross sectional images of the patient body. In CT the radiation beams were not contiguous and unidirectional around the patient contour the maximum dose does not lie on the skin surface and is not an appropriate indices for risk analysis in CT. The CTDI is used for quantification and analysis CT doses. The *CTDIvol* indices does not estimate patient dose, as it does not take patient's size into consideration. The actual dose received by a patient during CT examination, not only depends on selected scanner parameters but also on the dimensions and composition of the body part being scanned.

Purpose: The aim of the present work is to reports data on radiation exposure to the patient in CT examinations using size specific dose estimates (SSDE).

Materials and Methods: The radiation exposure was estimated retrospectively in forty adult patients for head, chest, pelvis and abdominal CT procedures performed on a third generation 16 slice helical CT scanner. The CTDI values were measured in CTDI dosimetry phantoms of 10, 16 and 32 cm diameter. The water equivalent diameter (*Dw)* of this water cylinder is used to represent the absorption and scattering in the body and estimation of dose to the patients. The effective diameter for the scanned patient body part is measured as *effective diameter=(AP width×lateral widt*h) (1) The SSDE is obtained from size dependent conversion factor and *CTDIvol* as, *SSDE=fx ×CTDIvol, x* (2) where *fx* is the size dependent conversion factor.

Results and Discussion: The *CTDIc* values, evaluated at 120 kV using three CTDI phantoms, in *10* and 16 cm phantom are 4.4 and 3.2 times more than the value for 32 cm phantom. The *CTDIp* in 10 and 16 cm phantom is 2.2 and 1.6 times greater than the 32 cm CTDI phantom. For 32 cm phantom, the *CTDIc* is 50 % of *CTDIp* value, whereas, in small phantoms the radiation doses are nearly uniform in peripheral and central region. The measured *CTDIvol* value in 10 and 16 cm diameter phantoms is respectively 2.65 and 1.97 times more than the value measured in 32 cm phantom for same scan parameters. The reported mean SSDE value of 54 mGy and mean *CTDIvol* of 26.76 mGy in CT head, mean SSDE and *CTDIvol* is 45.2 mGy and 31.9 mGy respectively in pelvis CT examination. In CT chest mean SSDE and *CTDIvol* values of 22.8 mGy and 17.3 mGy are reported, whereas value of 21 and 14.6 mGy is observed as mean SSDE and*CTDIvol* respectively in abdomen CT. The reported SSDE values in this study shows significant underestimation in doses reported by CTDI parameter recorded on the CT console and should not be used to specify patient absorbed dose in CT procedure. The highest variation of 100 % is observed for head CT, as the displayed CTDI on this CT scanner were based on 32 cm phantom measurements.

Conclusions: The dosimetry on CT procedures in this study is an attempt to improve reporting of patient's doses based on *CTDIvol* indices. The application of SSDE methodology provides a better estimation of patient dose by including variation in size of individual patient into consideration and thus the relative radiation risk associated with CT examinations.

PP-5

DOSIMETRIC VERIFICATION OF STEREOTACTIC BODY RADIATION THERAPY FOR LUNG CANCER TREATMENT PLANS USING OCTAVIUS 4D PHANTOM

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Purpose: Radiation treatments have become increasingly more complex with the development of volumetric modulated arc therapy (VMAT) and the use of stereotactic body radiation therapy (SBRT). SBRT involves the delivery of substantially larger doses over fewer fractions than conventional therapy. Octavius 4D is a very effective device in radiotherapy treatment quality assurance (QA), due to its simple set-up and analysis package. This study aimed to analyze the dose distribution

using Octavius 4D phantom dosimetric tools in conducting pretreatment quality assurance for lung cancer stereotactic body radiation therapy (SBRT) plans.

Materials and Methods: Five patients with lung cancer treated via SBRT were randomly selected, and their treatment plans were generated using the Eclipse treatment planning system (Eclipse version 11.3). Plans were prescribed 48 Gy in 4 fractions on 80% of isodose to 95% of the PTV volume. For each patient, the same plan was applied to the Octavius 4D phantom (PTW OCTAVIUS 4D 1000 SRS) and portal dosimetry by the TPS, which calculated the dose distribution. It consists of an ion chamber array embedded in a cylindrical phantom. The phantom is connected to an inclinometer that is attached to the gantry so that the system is capable to rotate following the gantry orientation in such a way that the array is always perpendicular to the beam axis. Dose distribution and gantry angle are registered as a function of time. The Octavius 4D phantom and portal dosimetry were used to measure the actual dose distribution at the linear accelerator, and these measured doses were compared to with the calculated doses. Gamma analysis was employed in verifying the correspondence between the dose distributions.

Results and Discussion: The Octavius 4D phantom shows good agreements between calculated and measured dose. The mean gamma passing rates gamma criteria and the standard deviations were 98.2% ± 2.5% with 2%,2mm criteria and 98.8% ± 1.1% with 3%,3mm criteria by Octavius 4D phantom portal dosimetry respectively. Thus, the approach provides a fully automated, fast and easy QA procedure for plan-specific pre-treatment dosimetric verification.

Conclusion: The Octavius 4D system is a suitable device for patient-specific pretreatment QA to verify SBRT. It is however mandatory to calibrate for a field size and a dose rate close to the patient treatment plan.

PP-6

IMPACT OF MOTION PARAMETERS ON 4D IMAGING USING INDIGENOUSLY DEVELOPED FOUR DIMENSIONAL RADIOTHERAPY PHANTOM

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Objective: The purpose of this work is to study the impact of motion parameters (amplitude and frequency) and target size on 4D imaging using indigenously developed Four Dimensional Radiotherapy Phantom (FDRP).

Materials and Methods: The in-house fabricated 4D radiotherapy imaging and dosimetry phantom was used for the imaging study. The developed phantom has three different inserts which represents target sizes of 1 cm, 1.5 cm and 2 cm in diameter. The targets were driven in sinusoidal motion pattern in the longitudinal direction with different combinations of the amplitudes of 0.5 cm, 1 cm, 1.5 cm and frequencies 0.2 Hz and 0.25 Hz, one by one. For the performance validation of phantom, the set values of amplitudes and frequencies of motion were compared with the values measured by the tracking (Varian RPM) system. The GE 4DCT scanner was used to scan the phantom and the motion of the surrogate marker was tracked by the Varian RPM system. The phantom was imaged both in the static and dynamic state. The images of the target acquired in the motion were sorted into 0, 10, 20, 30, 40, 50, 60, 70, 80 and 90% phase by the phase binning software and Maximum Intensity Projection images (MIP) were also created. The images of the moving target in different phases were contoured and GTV final was obtained by summing the target volumes of the individual phases. Similarly, the GTV was also contoured on the MIP images i. e. GTV MIP. The GTV final and GTV MIP were compared with the GTV obtained by static images to assess the effect of the motion. The effects of varying the amplitudes, frequencies of the motion on the distortion of target volume were also evaluated.

Results: The values of amplitude and time period, measured by the tracking system matched well with the values set on the FDRP. The relative distortion in the final GTV ranges from 1 to 2.57, 0.84 to 2.58 and 0.61 to 1.85, for the target sizes of diameter 1.0 cm, 1.5 cm and 2.0 cm respectively. Similar pattern in the relative distortion of the GTV MIP were also observed. The distortion in the GTV increases with amplitude of the motion for given target size and frequency. For the target size of 1.0 cm, the frequency has negligible impact on volume distortion for all the studied amplitudes. For the target size of 1.5 cm, the variation in the GTV final and GTV MIP w. r. t. static volume were 21.05% and 26.31% for the amplitude 1.5 cm, while, no significant variations were observed at 0.5 and 1.0 cm amplitudes for 0.2 Hz and 0.25 Hz frequencies. For the target size of 2.0 cm, the variation in the GTV final and GTV MIP were 6.5% each for amplitudes 1.0 cm and 1.5 cm for all the exercised frequencies.

Conclusions: Impact of motion parameters in 4D imaging using indigenously developed FDRP has been carried out. Motion parameters have significant impact on target volume obtained using 4D imaging system in comparison to the static target.

PP-7

DOSE EVALUATION PRACTICE FOR IMRT TREATMENTS AT LIONS CANCER DETECTION CENTRE TRUST, SURAT

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Purpose: Intensity modulated radiation therapy (IMRT) allows the three-dimensional dose distribution with computer based optimization techniques using user-specified absorbed-dose and dose-volume constraints in specified target volume and normal tissues. Dose prescription, recording, reporting and delivery play an important role in radiation therapy outcome analysis. In IMRT treatment user defined acquired inhomogeneity within target and sharp dose gradient at

edge of target makes traditional dose prescription (Dmax, Dmin, Dmean) method less relevant and to overcome these issues International commission on radiation units and measurements (ICRU) provides guidelines for reporting doses in ICRU 83 Report. The study aimed to analyse the dose prescription according to ICRU-83 report for IMRT treatments at our institute.

Materials and Methods: Fifty patients of Ca-head & neck and pelvis treated by IMRT were randomly selected. Dosimetry data for these patients were collected and analysed. Eclipse (version.11.0.31, Varian Medical System, Palo Alto, CA) treatment planning system was used to generate IMRTplans (VMAT). The dose-volume histogram of each patients were evaluated for near minimum dose (D98%), D95%, median dose (D50%), and near maximum dose (D2%) of target volumes. Dmean, D2%, Dmax and VD for OAR were collected and analysed. The actual Dmin., Dmax. and Dmedian doses to the target volumes were normalized to the prescribed dose and analyzed for each disease sites. The homogeneity index (HI) = (D2%-D98%)/D50% and Conformity index (CI) were evaluated as per ICRU 83 report.

Results and Discussion: The median dose D50% were found 100.700 ± 0.29 and 101.318 ± 0.52, the HI were 0.098 ± 0.012 and 0.079 ± 0.007, the CI were 1.088 ± 0.027 and 1.052 ± 0.017 for Ca-head& neck and pelvis respectively. The D98% range was from 94.31% to 96.30%which was significantly greater than Dmin. The D2% doses were also found significantly lower than the Dmax doses. The 95% volume had received higher than D95% dose in all sites. The Maximum D2% of spinal cord and PRV Spinal cord has been recorded as 44.36 Gy and 46.50 Gy respectively for Ca-head&neck patients. The mean dose to the parotid was 15-40 Gy depending on overlapping inside PTV.

Conclusion: The Median dose D50% shows a good presentation of dose prescription for target volumes. The parameters introduced in ICRU 83 report (D2%, D98%) better reflect the target absorbed doses with IMRT planning techniques.

PP-8

DOSIMETRIC EVALUATION OF OUT OF FIELD MEASUREMENT

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Purpose: Dosimetric comparison between out of field dose measured in a radiation field analyzer (RFA) and implemented in Eclipse treatment planning system of version 10.0. Out of field dose measured under three different conditions such as jaw only, jaw+ MLC only and MLC only.

Materials and Methods: The data's were collected from Eclipse treatment planning system (version 10.0) and water phantom(RFA). RFA is set at source to surface distance(SSD) of 100 cm, and a semi flex ionization chamber(0.125 CC) is used. Measurements were taken for different distances (1,2,3,5,10, 15 cm) from the field edge for different field sizes (5x15,10x15,15x15) using energy 6 and 15MV. All measurements were performed in a Varian Clinac iX linear accelerator equipped with a millennium 160 leaf collimator and On Board Imager. The results were cross compared with Eclipse treatment planning system. Also same study extended using Versa HD machine where Montecarlo Algorithm is used. Measurements where carried out for the same distance and field sizes using 6MV and 10MV flattened and unflattened beams.

Results: Dose differences between calculations and measurements as a function of depth, field size and distances for three shielding conditions such as jaw only, jaw+ MLC and MLC only (for 6 and 15 MV) were evaluated in the study. Up to build up region the measured and calculated doses are in good agreement a slight overestimation of the calculated dose observed for 15 MV in this region; after the build-up region the dose difference increases with depth. By increasing the distances from the field edge, the out of field dose shows a gradual decrease after 3-4 cm distance away from the field edge for all the three shielding conditions and energy. MLC only condition show higher out of field does than other shielding condition. The study shows a dose differences of maximum 14±17 relative to the measurement points averaged from 0 to 16 cm depth.6MV and 15MV Flattened and unflattened were evaluated for out of field doses and found that for, 10x 15 and 15x15 field sizes FFF has higher dose as the depth increases compared to flattened beams. Up to 2-3 cm depth, the dose from flattened and unflattened beam found almost equal and an increase in dose observed for FFF beam with maximum difference observed for 10 FFF beams. But at 1cm distance from the field edge FFF dose is lower compared to the flattened beam. At distances more than 10 cm from the field edge both energies shows almost equal dose. But for smaller field sizes like 1x15 and 5x15 cm2 FFF dose is found less at shallow depth and becomes almost equal relative to the fattened beams.

Conclusion: The study conducted using ion chamber shows almost good agreement between measured and calculated values. Also gives valuable information on flattened and unflattened beam out of field doses.

PP-9

SCATTER DOSE MAPPING IN BEDSIDE X-RAY MACHINES

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Introduction: Mobile Radiography units are used for radiographic imaging of sick immobile patients in areas such as intensive care, critical care and in post-operative units. It is also used in operating and emergency rooms that lack standard, fixed radiographic equipment. X-rays are produced by the X-ray tube when a stream of electrons, accelerated to high velocities by a high-voltage, interact with the tube's target anode. A set of collimators confines the primary X-ray beam to the approximate size and shape that will cover only the area of diagnostic interest. Mobile CR units capture images using a photostimulable-phosphor plate. Mobile DR units are equipped with built-in or tethered flat panel detectors, which

use a scintillator material to convert X-rays to visible light.

- The patient is prepped and provided some form of radiation shielding
- The unit is positioned around the patient, who is asked to remain motionless while the image is being taken
- The operator takes the image by activating the X-ray beam using an exposure switch
- The operator repositions the patient or unit if needed for multiple images.

IMCU, ICU, emergency, trauma ward and critical care units are typically ill equipped to shield patients and medical staff from radiation exposure. Personnel and nearby patients can be protected by protective lead aprons and movable radiation shielding. Mobile units may give slightly higher scatter radiation. Aim of this work was to measured the amount of scatter radiation in and around the mobile X-Ray machine.

Objective: The purposes of this study were to apply near-real-time dose-measurement method with smart rad dosimetry to the assessment of real time scatter radiation level during bedside X-ray investigation at different location.

Materials and Methods: A smart rad solid-state dosimeter were used to obtain real-time scatter radiation dose levels. Using smart rad, measurements were conducted every selected bed side X-ray investigation for adult patients without affecting examination. 5 mobile bedside X-ray machines were involved in this study. The study was conducted for the period of 8 months and 100 real time dose measurements were done.

Results and Discussion: Based on this research work, we found that the bedside staffs, physician, attenders and radiographers were received considerable amount of scatter radiation from the patient. The personal received scatter dose range is 2 μSv – 31 μSv per examination. The amount of scatter radiation were differ from the patient age group, angulation, exposure parameters, type of the machine, and type of the study. In addition to this, IMCU, ICU, emergency, trauma ward and critical care units are normally not equipped to shield patients and medical staff from radiation exposure. Personnel and nearby patients can be somewhat protected by protective lead aprons and movable radiation shielding. Most of the units have safety features like AEC to regulate radiation exposure. This study will helps to improve radiation safety standards for personnel who are working in bedside X-Ray machines. Also it helps to increase radiation protection shielding in mobile X-ray examinations.

Conclusion: On whole, this research work gives the substantial overview of current mobile X-ray practice in the hospitals. From this study, it is recommended that it is very essential to protect personal and staffs in advance, also it is compulsory to adopt the ALARA and dose reduction principle strictly. This performance would positively be valuable to medical personals by preventing them from receiving unnecessary radiation dose. This practice would also promote safety awareness among the mobile X-ray users and operators.

PP-10

ORAL CANCER TREATMENT BY RADIOTHERAPY AT A TERTIARY CARE HOSPITAL IN RURAL AREA OF MAHARASHTRA STATE: A HOSPITAL-BASED STUDY

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Introduction: Oral cancer is traditionally defined as squamous cell carcinoma of the lip, oral cavity, and oropharynx. According to the World Health Organization (2005) cancer might kill 10.3 million people by the year of 2020, with an increase trend in developing and newly industrialized countries. Radiotherapy is an integral part of the multidisciplinary approach for treating cancer, in addition to surgery and chemotherapy. The current evidence indicates that 50% of all patients diagnosed with cancer need radiotherapy at some stage of their disease.

Purpose: To describe utilization of radiotherapy and treatment compliance in oral cancer cases in rural area.

Materials and Methods: A retrospective study was carried out on data collected from the radiotherapy treatment records of oral cancer patients treated at Rural Medical College Teaching Hospital, and Pravara HBCR, Loni Dist. Ahmednagar, Maharashtra state for the period from 1st December 2012 to 31st December 2012.

Results and Discussion: In all 279 cases of cancer with all sites of oral cancer, number of male patients was 61.29% (n=171) whereas females were38.71%.(n=108). Mean age of the patients was 56.31 years, ranging from 11-81 years, 31.90% (n=89) are more than 65 years of age. Curative treatment was given to 66.67% (n=186) and palliative to the remaining 33.33% (n=93).Patients older than 50 years were more likely to receive palliative radiotherapy (p=0.001). The most common cancers among the males and females are those of tongue 39.77% (n=111) and buccal mucosa 35.18% (n=98) respectively. Tobacco related cancer patients in males are 83% (n=142) and in females it was 62% (n=67). The majority of patients were between 50-70 years of age (n=163). Nineteen percent (n=53) did notcomplete the prescribed dose of radiation. Unplanned treatment interruptions were found in 36.20% (n=101) and this was not affected by age (p=0.1) or gender (p=0.1). The most frequent treatment interruption compromising optimal effectiveness of cancer treatment was observed for tongue and buccal mucosa 42.29% (n=118).

Conclusion: Tongue and buccal mucosa in both sexes were the most common cancers treated with a curative intent. Alveolus, the second most common in both genders, was treated with palliative intent in a large number of oral cancer cases. This indicates the need for early diagnosis for a possible curative treatment.

PP-11

DOSIMETRIC STUDY OF EFFECT OF CIRCULAR AND SQUARE CUTOUT ON PERCENTAGE DEPTH DOSE, OUTPUT FACTORS AND MEAN ENERGY FOR 6 MEV AND 8 MEV

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Introduction: In treatment of cancer using electron beams, depend on the shape of tumor, Cerrobend cutouts are used. The cutout changes the percentage depth dose (PDD), output factors (OPF) and mean energy.
Purpose: This study is related to investigate the effect of circular and square shape electron cutout on the PDD, OPF and mean energy.
Materials and Methods: In this study, the dosimetry was performed in Elekta Synergy Platform Linear Accelerator with electron energies 6 MeV and 8 MeV. All the measurements were done using reference electron applicator size 10x10 cm2 with 100 cm source to surface distance. The PDD curve and OPF for circular, square (with cutout area 7.06, 19.63, 28.26, 38.46, and 63.59 cm2) and 10x10 cm2 standard cutouts were measured. The circular cutout diameters were 3, 4, 6, 7, 9 cm and square had side lengths of 2.66, 4.43, 5.32, 6.2, 7.97 cm. Electron central axis PDD values have been measured with parallel plate ionization chamber. Data was initially collected as ionization readings; obtained graphs from percentage depth ionization (PDI) and were converted to PDD by MEPHYSTRO MC2 software (PTW, Germany). The PDD curves were drawn; the information was extracted as R100, R90, R80, R50, R20 and mean energy. The **OPF** for a given electron energy is the ratio of the dose for any specific field size to the dose for a 10×10 cm2 reference applicator, both measured at dmax.
Results: For 6 MeV, within circular cutout, R100, R90, R80, R50 and R20 changes from 14.48 mm to 11 mm, 19.59 mm to 17.05 mm, 21.64 mm to 19.53 mm, 26.12 mm to 24.91 mm, 30.51 mm to 29.90 mm respectively and for square cutout it changes from 14.03 mm to 11.51 mm, 19.45 mm to 17.44 mm, 22 mm to 19.91 mm, 26 mm to 25.17 mm, 30.47mm to 30 mm respectively.
For 8 MeV, within circular cutout R100, R90, R80, R50 and R20 changes from 17.99 mm to 12 mm, 24.96 mm to 20.08 mm, 27.64 mm to 23.32 mm, 33.32 mm to 30.62 mm, 38.82 mm to 37.89 mm respectively and for square cutout it changes from 17.53 mm to 12.50 mm, 24.77 mm to 20.76 mm, 27.50 mm to 23.97 mm, 33.15 mm to 33.10 mm, 38.82 mm to 37.43 mm respectively. Mean energy for 6 MeV and 8 MeV is lower for smaller field size. For both the energies, areas larger than 38.46 cm2, there is no significant difference between values of R100, R90, R80, R50 compare to reference field size 10×10 cm2. For 6 MeV, the OPF for the circular and square cutouts are reduced from 0.990 to 0.863 and from 0.985 to 0.860 respectively. For 8MeV, the OPF for the circular and square are reduced from 0.994 to 0.878 and from 0.984 to 0.869 respectively.
Discussion: The chart of changes for R100, R90, R80, R50, and R20 shows that while increasing the open area, the values of this parameter reaches at saturation after the certain area. Also the OPF are decreases with reducing the area of the cutout.
Conclusion: The PDD parameters, OPF and mean energy for circular and square cutouts varied from the reference field size; depend on the shape of the cutout. The OPF decreases with reduction in cutout area. Mean energy is lower for smaller field size.

PP-12

PLAN ANALYSIS ON SANDWICH TREATMENT IN OESOPHAGUS WITH VERIFIED DOSEMETRIC PARAMETERS

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Introduction: To compare Sandwich treatment in oesophagus Tumour patients Comparing the Dosimetric Parameters such as mean dose, minimum dose, and maximum dose, Uniformity Index, Homogeneity Index, Conformity Index and Dose to Critical organs.
Purpose: The Purpose of the study is to reduce the Heart, lung & integral dose as well to reduce normal tissue in Different Technique With Sandwich Treatment.
Materials and Methods: Data from fifteen consecutive Patients were compared with (CONVENTIONAL PLUS IMRT),(CONVENTIONAL PLUS VMAT), (IMRT PLUS VMAT). For IMRT planning we have used minimum of 5 fields. For VMAT planning we have used minimum of Two ARCS. For CONVENTIONAL planning we have used minimum of TWO fields. The patients were planned for 5040cGy/28fractions/5.3week. The plans were planned in same target volume and inverse planning for IMRT and VMAT. Planning were performed using the treatment planning system (ECLLIPSE 13.7) & Executed in VARIAN TRUE BEAM STX & Verified in Gamma Evaluation (PTW OCTIVIUS with help of 2d array phantom).Integral dose has been calculated by target volumes were subtracted by the Total body volume.
Results: Dose to lung is optimal in CIM & CVM & Dose to Heart & spinal cord has optimized in CIM & CVM. High dose region & Low dose region is reduced in CIM, CVM & IMVM.
Discussion and Conclusion: Dose to Lung has been reduced in CIM & CVM & High dose region Better in CVM, Intergal dose has been reduced in CIM & CVM & Achieving good result in Dosemetric parameters & Gamma Evaluation has been achieved given criteria.

PP-13

REVISITING OF RADIOTHERAPY WITH TELECOBALT BEAM-EFFECT OF TISSUE DEFICIENCY COMPENSATION ON SKIN MORBIDITY IN HEAD AND NECK

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In the north eastern parts of the India, the head and neck cancers form as high as 50% of the total number of patients. We implemented tissue compensation to overcome skin reactions. Lateral opposing portals with Theratron 780E telecobalt machine (80 cm SSD) with custom built Aluminium Tissue Compenstors were used for treatment of head and neck radiotherapy(RT) patients. The skin morbidity in these patients was evaluated in 178 patients treated with and without tissue compensator as a retrospective study (89 patients in each group). About 75% of the H & N patients were in Stage III/IV. 74% of all the patients had concurrent chemotherapy (Cisplatin, Carboplatin and Paclitaxel).
It is observed that in Group A (Orfit uncut, No Tissue Compensation) 12 out of 38 (31%) have not completed dose

upto 60 Gy (more drop outs). In 26 patients who completed >60Gy dose, 9/26 (35%) had absented >5 fractions; 4 patients, (4/38) 11% only received 70 Gy planned dose. In Group B(POP Immobilization, Tissue Compensated), 24 patients (24/29), 83% completed RT above 60 Gy. In these 24 patients, 3(11%) only had interruptions >5 fractions. 7 patients (24%) could complete 70 Gy. Group B patients did not face more interruptions due to treatment morbidity. Also in Group B, there was no skin sequelae in 29 patients, 5 patients had only. In Group D (Orfit Cut, Tissue Compensated), 90% of the patients (54/60), could complete >60Gy dose; whereas in Group C(Orfit Uncut, No Tissue Compensation) only 65% (33/51) could complete >60Gy. In Group D, 28% completed a dose of 70Gy compared to only 6% in Group C. In 33 patients (Group D) who completed >60Gy, 89% of patients (48/54) completed treatments with minimal interruptions; whereas in Group C, only 73% of patients (24/33) completed >60Gy with minimal interruptions. A careful review of all groups brings out an important observation that in 'Uncompensated RT'(A and C) 31% and 35% of the patients could not reach a dose upto 60Gy; in 'Compensated RT' (B and D) 17% and 10% patients only did not complete 60Gy. Grade IV Skin and Mucosal reactions which occurred in Group C reduced in Group D.

Skin reaction appeared minimal or did not occur in most of the 'tissue compensator treated' patients, facilitating dose escalation upto 70Gy. Two radiobiological end points shall be understand in head and neck radiotherapy from this study. Without 'Tissue Compensation', 82% of patients receive 10% to 15% increased dose to tip of the neck, In 88% of patients, 6% to 13% increased dose to chin portion. The spots of increased radiation doses directly correlate the spots of radiation reactions. When the physical dose is more in some regions, it becomes larger fractionation, radio-biologically there are islands of higher effective dose (as high as 2.32 Gy/Fr), thereby inducing excess morbidity in normal tissues both in skin and mucosa.

Due to skin morbidity, when overall treatment time(OTT) is increased from 42 days, the Biologically effective dose (BED) and Equivalent total dose(ETD) for the total regimen reduce; effectively likelihood of less local control. We calculated effect of 60 Gy total dose in 42, 45, 50, 55, 60 days giving effectively BED values 63.6Gy, 61.8Gy, 58.8Gy, 55.8Gy and 52.8Gy respectively; 2Gy/Fr ETD becomes 60Gy, 58.5Gy, 56Gy, 53.5Gy and 51.0Gy respectively; A reduction in Local Control from 100% to 95.8%, 88.8%, 81.8%, 74.8% due to increase in OTT expected. Therefore, it is strongly highlighted that Cobalt RT has a strong role in head and neck RT, if tissue compensation and build up preservation is practiced.

PP-14

MEASUREMENT OF DOSE TO RECTUM DURING HDR INTRA-CAVITARY BRACHYTHERAPY FOR CANCER OF UTERINE CERVIX

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Objective: Brachytherapy ensures good local tumor control and disease free survival. The dose prescription for the HDR application is restricted by the dose tolerance of the rectum and bladder. Hence accurate estimation of rectal and bladder doses are essential to decide upon the dose prescription for each fraction of HDR treatment.

Materials and Methods: At our institute, Carcinoma uterine cervix patients undergo a conventional EBRT followed by 3 fractions of HDR brachytherapy. Dose to rectum was measured using TLDs for twenty five cases where standard Fletcher tandem-ovoid applications were done under local anaesthesia. A total of 5LiF: Mg TL pellets were placed in small plastic tube at a regular spacing of 1 cm and inserted into the rectum and orthogonal radiographs were acquired on a C-arm for treatment planning. The doses measured using the TLD's were compared with the rectal dose calculated on the TPS.

Results and Conclusion: The dose to rectum measured varied between 3.5-4.5Gy for a prescription of 7Gyto point A, (40-45%) and within tolerance. The patients were followed up for a month and no patient was presented with unmanageable early complications. It is also observed that the HDR ICBT applications were well tolerated by the patients while delivering dose for maximum tumor control. The variation between the physically measured and the TPS calculated doses were within 1% which gives us confidence in the accuracy of dose delivery in HDR brachytherapy of cancer uterine cervix.

PP-15

DENTAL RADIATION SAFETY STATUS IN COIMBATORE REGION

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Introduction: To diagnose the oral health, dental x-rays are essential. Dental x-ray machines vary from simple hand held radiographic machine to 3-D Cone Beam Computed Tomography (CBCT) machines. They have a wide range of exposure parameters varies from 60 kV and 2 mA to 90 kV and 20 mA. Ionization radiation can bring two main biological effects mainly stochastic and deterministic. A certain threshold dose is required for deterministic effect to occur and the chance for this effect to arise is very less in dental radiography. Several retake of dental x-ray, use of improper exposure parameters and room design, lack of quality of dental machine and knowledge about radiation are some of the reasons leads to increase the chance of stochastic effect. Estimating the accurate exposure parameters depending on patient size and position of teeth, opting right dental radiography method are some of the guidelines to ensure patient safety. In this research study, a questionnaire regarding dental radiation safety has been prepared and data were collected from several hospitals and clinics and further analyzed to implement safe dental radiography procedures in Coimbatore, Tamil Nadu. Purpose The purpose of this study was to analyze current dental radiation safety protocols and practices followed by dental hospitals and clinics and establish a safe method of practice for dental radiology.

Materials and Methods: This study was carried out in 15 clinics at Coimbatore in Tamil Nadu, where OPG and intraoral machines were installed. The selection of hospitals was done by considering the patient workload. A questionnaire enclosed of 15 questions was prepared to collect data regarding the dental practices and protocols followed by the hospitals and clinics in Coimbatore region. This data helped to record the dental radiation status in Coimbatore region.
Results and Discussion: Among 15 clinics enrolled in this study 5 were having OPG machines and 10 were having intraoral machines. It was observed that limited numbers of clinics were aware about radiation protection protocols. The result discloses that 73 % of the clinics don't have TLD, 87 % of the clinics not registered under eLORA and properly not maintaining calibration as per AERB, 47 % of clinics don't have lead apron and thyroid collar for patient and staff protection. Lack of knowledge about radiation and its consequences constrains dentist to avoid using lead aprons and thyroid collars. Addition to this, radiation dose can be reduced to an adequate level by using fast films or digital detectors instead of normal films. Also the study found that majority of hospitals weren't keen in changing the exposure values by considering patient size, age and sensitivity of detectors. It is mandatory to adopt ALARA and dose reduction standards stringently.
Conclusion: Findings obtained in this research work imply the requirement of sudden attention from authorities towards all dental clinics. Hesitation of several dentists to support this research work points the idleness of authorities to implement stringent regulations. The radiograph can create risks to radiographers, dentists and patients. Knowledge about radiation and its consequences is necessary for everyone who is working in radiation field.
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PP-16

EFFECTS OF NONCONFORMAL RADIOTHERAPY TECHNIQUES IN BREAST CANCER PATIENTS

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Breast cancer is the most prevalent cancer type in women and global best practice in radiation treatment of cancer requires the use of conformal techniques. Inavailability of required equipment in some developing countries result in a deviation from standard practice. This study set out to estimate the ensuing risk.
Twenty (20) breast cancer patients (stages I – III) were planned on a Prowess Panther TPS using a 1.25 MeV cobalt beam of 80 cm SSD. The patients were simulated using both the standard 3D two laterally opposed tangential fields with appropriate wedge angles and a 2D technique in which the field borders were determined using bony landmarks on the DRR images mimicking the scenario in a typical low resource radiotherapy centre. The beam was conformed to the target using cerrobend blocks for the standard 3D technique only. The two techniques were compared in terms of the doses to the PTV and the OARs; the lungs and the heart. The LKB NTCP model was used to assess the possibility of developing radiation pneumonitis and pericarditis in the OARs respectively.
The mean and maximum doses to the PTVs and OARs were significantly higher in the 3D technique for all patients. The NTCP values showed that there was no risk of pericarditis while the risk for pneumonitis was higher in the 3D technique. The doses to the OARs were lower in the 2D technique than the 3D technique however at the expense of the coverage to the PTV.

PP-17

EVALUATION OF PLAN QUALITY OF INTENSITY MODULATED RADIATION THERAPY FOR TWO DIFFERENT BEAM ORIENTATION FOR CARCINOMA CERVIX

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Introduction: Radiotherapy (RT) plays an important role in the adjuvant treatment of gynecologic malignancies, particularly in cervical and endometrial cancer. While RT has greatly improved local regional control of primary tumors, it has come at the cost of significant toxic effects to adjacent non-cancerous tissues. In the late 1990s, the technique of three-dimensional conformal radiation therapy (3D-CRT) emerged as a preferred treatment for gynecologic malignancies, since it gave better target coverage and significantly reduced the radiation exposure to the bladder. However, this technique did not appreciably reduce the amount of radiation exposure to the intestine or rectum. More recent advances in computer technology have led to improvements on the 3D-CRT technique; one, in particular, being the development of intensity modulated radiation therapy (IMRT). In contrast to 3D-CRT, which uses uniform fields, IMRT generates non-uniform fields to achieve better planning target volume coverage, while decreasing unnecessary radiation exposure to normal organs. Therefore, IMRT has become a common strategy for whole pelvic radiotherapy (WPRT), and has been shown to offer more accurate dose distributions and tighter dose gradients to targets and to reduce toxic risk and undesirable side effects to the rectum, bladder, small bowel, and pelvic bones.
Purpose: The aim of this study is to evaluate the effect of beam orientation in Intensity modulated radiation therapy and to evaluate the effect and the plan quality by using Eclipse treatment planning system.
Methods: For this study twenty patients of carcinoma cervix IIB were selected those treated in our institution from the period of Jan 2018 to June 2018. Clinical step and shoot IMRT treatment planning were done using nine beam orientation with Eclipse treatment planning system and was delivered on Siemens Oncor Expression with multi leaf collimators (82 leaf). To ensure the similarity or difference in the plans due to beams orientations, nine beams orientation were planned with certain optimization objectives to achieve the target and OARs dose and the

same objectives were used for the seven beam orientation plan and the plans were evaluated.
Results: The Plan analysis performed based on dose distribution and Dose Volume Histogram for Planning target volume(PTV), the organ at risk (OARs) as well as other physical indices like Mean dose(Dmean), Maximum dose(Dmax), 95% dose (D95), %5 dose (D5), total number of segments, monitor units, Dose homogeneity Index and Conformity Index for the PTV were also evaluated.
Discussion: For all twenty patients both nine beam IMRT and seven beam IMRT technique gave clinically acceptable plans while comparing target doses and dose to critical organs. Dose homogeneity index for 9beam and 7beam IMRT is 1.03 ± 0.01 and 1.03 ± 0.01 and significance difference P=0.02. Significance difference (P=0.002)exist only between the conformity index of PTV CI (1.03 and 1.03) for both plans. Similarly OAR doses for bladder, rectum, bowel, Right femoral head and Left femoral head were evaluated there is much variation in both plans for all twenty patients the significance difference for all critical organs (P<0.0001). Monitor units for 9beams and 7beams (750.84 and 738.11). There is little variation was observed in the segments (79 and 66).
Conclusion: We conclude that it is not necessary to select 9beam IMRT for the treatment of Ca. Cervix we can select 7beam IMRT were we can able to achieve the similar PTV coverage and OARs doses as achieved from 9beam IMRT and also as step and shoot IMRT it will help us to reduce the overall treatment time to the patients.

PP-18

DOSIMETRIC EVALUATION OF FIELD IN FIELD INTENSITY MODULATED RADIATION THERAPY AND INVERSE PLANNING INTENSITY MODULATED RADIATION THERAPY FOR CARCINOMA LEFT BREAST

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Introduction: Breast cancer is the most common cancer in women worldwide as it is also the main cause of cancer death among women globally. The use of radiotherapy in the adjuvant setting has shown to improve both local control and overall survival in early stage breast cancer patients. The most common and traditional whole breast radiotherapy technique uses two tangential fields due to its efficiency in terms of sparing nearby organs at risk (OARs) as well as technical simplicity in which wedge filters are used to compensate patients surface irregularity and reach a homogenous dose distribution. This technique has evolved over the last decade with introduction of multi leaf collimators (MLC) to deliver three dimensional conformal (3DCRT) or intensity modulated radiation therapy.
Purpose: This study is to evaluate the target coverage and Organ at risk (OARs) doses in both Field in Field Intensity modulated radiation therapy (FIF-IMRT) and Inverse planning Intensity modulated radiation therapy (IP-IMRT).
Methods: For this study twenty two patients of left breast cancer cases were selected those treated in our institution from the period of Jan 2017 to June 2018. Treatment plans of 22 patients with left sided breast cancer, in which 10 post mastectomy treated to a prescribed dose of 50 Gy to chest wall with FIF-IMRT and 12 post breast conservative surgery treated to a prescribed dose of 50 Gy to the whole breast in 25 fractions, patients are treated with 8 beam IP-IMRT. For 10 post mastectomy patients 8beam IP-IMRT was planned and for other 12 patients FIF-IMRT monoisocentric plan were created by combining two fields with three to four segments in two tangential beam direction and these plans are compared and evaluated.
Results: The Plan analysis performed based on dose distribution and Dose Volume Histogram for Planning target volume(PTV), the organ at risk (OARs) as well as other physical indices like Mean dose(Dmean), Maximum dose(Dmax), 95% dose (V95), %5 dose (V5), the Dose Homogeneity and Conformity Index to Planning target volume (PTV) and dose received by OARs like both lungs, heart and Contralateral breast were compared in both technique for all 22 patients.
Discussion: All patients both FIF-IMRT and IP-IMRT technique achieved comparable radiation dose delivery to PTV-95% of the prescribed dose covering >95% of the breast PTV. The volume of PTV receiving 110%(V110) of the prescribed dose was 1.12±1.1% for FIF-IMRT and 0.75%±1.2% for IP-IMRT. The dose homogeneity and Conformity indices (HI and CI) were similar for FIF-IMRT and IP-IMRT (1.02 and 0.9). In OARs Ipsilateral lung and heart V30, V20, V5 and Dmean were compared, the low dose volume V5Gy and Dmean in the heart and ipsilateral lung were larger in IP-IMRT than the FIF-IMRT (50.67% and 93%), (15.54Gy and 18.81Gy). In this study, the relative volume of contralateral breast and contralateral lungs volume V5,V2 and Dmean were analyzed. The contralateral lung in FIF-IMRT receive significantly low doses (1.31%±1.4%, 7.38%±4.9%, 1.02Gy±0.3Gy) than the IP-IMRT (66.16%±24.4%, 93.92%±14.7%, 6.96Gy±1.9Gy). Similarly the contralateral breast where in FIF-IMRT receives (12.27%±8.8%, 18.74%±10.26%, 2.79Gy±1.8Gy) low doses than IP-IMRT (62.56%±16.1%, 96.92%±4.9%, 7.19Gy±1.3Gy).
Conclusion: Comparison with IP-IMRT, FIF-IMRT proved to be simple and efficient planning technique for breast irradiation. It provided dosimetric advantage, significantly reducing the size of the hot spot and minimally improving the coverage of the target volume. In addition it was felt FIF-IMRT required less planning time, easy field placements and less time for treatment delivery.

PP-19

COMPARING EUD BASED OPTIMIZATION AND PHYSICAL OPTIMIZATION IN BREAST CASE IMRT DOSE DISTRIBUTION

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Introduction: In the advance radiotherapy technology such as 3D conformal radiation therapy, IMRT and VMAT technique, Breast cases need more involvement with understanding of anatomy. Radiobiological principles and treatment planning. The Main challenge of Breast treatment planning is to reduce the dose to life saving organs of Heart, Lung and Spinal cord is making feel difficult.

Purpose: The Purpose of the study is to reduce the Heart, lung Cord & Contra lateral Breast in IMRT with EUD Based Optimization.
Materials and Methods: Fifteen consecutive Patients data were compared with EUD Based Optimization & Physical Optimization. For IMRT planning we have used 5 fields. For Conventional Planning we have used minimum Four fields. The patients were planned for 4005cGy/15fractions/3week. The plans were planned in same target volume(PTV) and Planning were performed using the Eclipse(V13.7) treatment planning system, Executed in VARIAN TRUE BEAM STX & Verified with Gamma Evaluation method (PTW OCTIVIUS with help of 2D array phantom). Integral dose has been calculated by subtracting target volumes from the Total body volume.
Results: Volume Lung dose (V20) is optimal in EUD Optimization, Dose to Heart & spinal cord has optimized in EUD Optimization.
Discussion and Conclusion: Dose to Lung, Heart & Cord has been reduced in EUD Optimization & Achieving good result in Dosimetric parameters & Gamma Evaluation has been achieved given criteria.

PP-20

NEED OF PUBLIC PRIVATE PARTNERSHIP MODULE IN GOVERNMENT CANCER HOSPITALS

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The Department of Radiotherapy in Shyam Shah Medical College, Rewa was started in the year 2003 but could not become functional due to non-availability of trained staff like Radiotherapy Technologist and Radiological Safety Officer. Dr. Gopa Ghosh was the Head of Department and Radiation Oncologist took lots of effort to make this unit functional but finally department gets closed. This unit was re-started under Public Private Partnership (PPP) Module by Honorable Minister Rajendra Shukla Ji.
Mr. Yougesh Shukla took personnel interest and makes this unit functional after 13 years. Asha Cancer Care got Grand of Rs. 81 Lacs from Department of Atomic Energy (DAE), Government of India for radioactive source replacement. Now the department is working smoothly and got permission from Atomic Energy Regulatory Board (AERB), Mumbai.
The PPP Module is very successful in Government radiotherapy departments. Now, almost all the cancer patients from Rewa and nearby districts getting radiotherapy treatment. The department of radiotherapy is totally different from other medical departments. Most of the time Dean/Head of Institution have less knowledge about the radiotherapy department. In this presentation, different types of challenges and advantages of PPP Modules we will discuss.

PP-21

COMPARISION OF PRE-TREATMENT EPID BASED PATIENT SPECIFIC QA RESULTS WITH DURING-TREATMENT TRAJECTORY LOG FILES ANALYSIS OF TRUEBEAM LINEAR ACCELERATOR

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Introduction: IMRT (Intensity Modulated Radiotherapy)/ VMAT(Volumetric Modulated Radiotherapy) is a complex process which requires a proper QA programme in place in order to ensure a accurate tumoricidal dose delivery. The accuracy of dose delivery must be documented for each course of treatment by irradiating a phantom that contains array of detectors to sample the dose distribution & to verify that the dose delivered is the dose planned.
Aim: To compare EPID based patient specific QA results with Trajectory log files analysis of trueBEAM linear Accelerator.
Materials and Methods: Patient specific dosimetric verification of an IMRT/VMAT plan is an important part of clinical implementation of IMRT/VMAT into any clinic. 10 patients comprising different clinical cases & undergoing IMRT/VMAT treatment on trueBEAM Linear Accelerator (Varian Medical System, Palo Alto, USA) were selected for this study. The pre treatment patient specific QA was performed with a-Si 1200 EPID (amorphous Silicon Electronic Portal Imaging Device). During treatment, the TrueBeam™ system records actual axis positions and MU delivered. After the treatment is completed, this information is stored to a trajectory log file. The truebeam control system generates the trajectory log files at periodic intervals of 20ms. The Trajectory log files analysis QA studies were performed using Assurance QA Software.
Results: For portal dosimetry QA & Assurance QA, the predicted dose distribution and the acquired one are compared using the gamma evaluation criteria of dose to agreement of ± 3% & or distance to agreement of ±3mm. The dose threshold & pass minimum were set at 10% & 90% respectively. The gamma values obtained from Portal Dose Image Prediction (PDIP) software were compared with the Assurance QA software. The (minimum) maximum % variation & (minimum) maximum standard deviation observed was (0.1) 6.15% & (0.07) 4.13 respectively for one patient. The maximum difference was found for one patient because the field size in Y-Direction was 38cm, so some portion of the fluence was out of the EPID active area which resulted in low gamma passing rate as compared to Assurance QA.
Conclusion: The trajectory log file analysis using Assurance QA tool was highly correlated with the Portal dose image prediction software. The trajectory log file analysis is helpful for the cases where treatment field size is more than the active area of phantom used for patient specific dosimetry.

PP-22

ROLE OF SUPERPARAMAGNETIC NANOPARTICLE AS RADIATION THERAPY SENSITIZER

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Introduction: Cancer is one of the leading causes of death worldwide and the number of cancer-diagnosed patients is rapidly increasing, in part due to an ageing population. Radiotherapy is a key treatment and is beneficial in the treatment of about 50% of all cancer patients. Such treatment relies on the deposition of energy (the dose) in tumour cells, typically by irradiation with either high-energy gamma rays or X-rays (photons), or energetic beams of ions, sufficient to damage the cancer cells or their vasculature and thus induce tumour death or nutrient starvation. Photon radiotherapy is non-specific, since a significant dose can be delivered to healthy tissue along the track of the photons, in front and behind the tumour. For radiotherapy, the central pathways to increase the therapeutic index, i. e. the ratio of treatment efficacy to side effects, are enhancement of radioresistance in healthy tissue, increasing radiosensitisation in tumour tissue, and better confinement of the deposited dose to the tumour volume. Increase in radiosensitization of tumor tissue can be done by the use of nanoparticles.

Purpose: Given that radiation therapy is not a selective antitumor treatment, the main challenge for radiation oncologists, medical physicists and radiobiologists is to increase its therapeutic efficacy without increasing damages dealt to the surrounding healthy tissues. Hence, by sensitizing tumor cells, it can be treated with less dose than required so that we can reduce normal tissue dose. To evaluate the efficacy increase in classical radiation biology, it is customary to use the Relative Biological Effectiveness (RBE) which is defined as the ratio of a dose of standard radiation (e. g. photons) to a dose of any other type of ionizing particles (i. e. protons, neutron, etc) to produce the same biological effect. E. g Medical physicists and radiation oncologists would have to deliver 30 Gy with NPs instead of delivering 60 Gy, if the therapeutic strategy "X-rays with NPs" was characterized by a RBE of 2.

Materials and Methods: PEG coated superparamagnetic nanoparticles have been synthesized by chemical co-precipitation method and were characterized by X-ray powder difraction (XRD), Fourier transform infrared spectroscopy (FTIR), Transmission electron microscopy (TEM), Thermogravimetric analysis (TGA), Zeta-Potantial Measurments, Dynamic Light Scattering (DLS) and Magnetization studies.

Results: The XRD pattern reveals the formation of single phase Fe3O4, inverse spinnel structure with lattice constant, a=8.3578 A0, which is very close to reported value of magnetite (JCPDS Card No. 89-4319, a=8.3952 A0). The crystalline size of PEG coated MNP is estimated about 10.42nm from X-ray line broadening using the Scherrer formula. FT-IR spectra shows two characteristic absorption bands from the Fe-O in bare Fe3O4 at 586cm-1 and 626cm-1. 3399cm-1 band probably attributable to stretching vibration of O-H bond. The peak at 1643 cm-1 for PEG coated Fe3O4 and at 1632 cm-1 for bare Fe3O4, represents shifting of stretching vibration of C=O group which confirms the apearance of PEG molecule on surface of Fe3O4.

Conclusion: Size of nanoparticles is enough to penetreate cancer cell lines and PEG coated nanoparticles are hydrophilic and protein rejecting. With the use of nanoparticle as a radiotherapy sensitizer to tumor we can minimize dose to normal tissue.

PP-23

DOSIMETRIC EVALUATION OF FFF PHOTON BEAM FOR CA. LUNG STEREOTACTIC BODY RADIOTHERAPY

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Introduction: Hypofractionated treatment scheme SBRT is an established treatment approach for both curative and palliative indication, which have shown increased local control rates >80% compared with conventional fractionation scheme. Lung SBRT treatments are often prolonged due to high dose per fraction. The extended treatment time can increase the risk of tumour interplay effect during delivery. FFF beams with maximum dose rate results into substantially minimizing the treatment time, which translate into improved patient stability. FFF beam delivery may possibly reduce the dosimetric impact on PTV coverage caused by interplay effect.

Purpose: This study aims to analyse the dosimetric advantages of FFF beam of Varian linear accelerator for SBRT of Lung carcinoma patients over flattened beam.

Materials and Methods: Study group consisted of 9 patients with Lung Cancer who underwent SBRT treatment in Varian Truebeam linear accelerator. PTVs ranged between 13.5 to 100.6 cc. All the plans were generated using Eclipse Treatment planning system (v13.7). For each patient two different plans were optimized using 6MV and 6MV-FFF. All prescription doses, constraints parameter and beam setup were maintained same. The same normalization was used in both plans (80% isodose line covering 95% of the target volume). Both the optimized plan were evaluated and compared for the parameters as criteria defined by the RTOG 0915 protocol: Conformity Indices for 100% and 50% isodose, Max dose at 2cm from PTV, V20Gy of the Lung, Dose to organ at risk, Heterogeneity index for PTV. We also analysed Plan total MUs, Plan max dose and estimated Beam on time.

Results: Dose heterogeneity index for the PTV between plans with flattened and unflattened beams were observed to be the same. Similar comparable values were obtained for both conformity indices CI-100 (0.97-1.12 in FF vs 0.96-1.1 in FFF) and CI-50 (3.06-4.23 in FF vs 3.05-4.18 in FFF). FFF plans required on average 9.1% more MU than flattened plans but the average beam on time was reduced by 52.4% passing from about 4.2 min (with FF modality) to 2.0 min (with FFF modality).The differences in the max dose in the PTV as well as the dose at 2cm from PTV were <1% between 6MV and 6MV-FFF plans. The volume of healthy lung receiving >20Gy was 5.6% for 6MVplans and 5.4% for 6MV-FFF plans. In general 6MV-FFF plan didn't show any significant differences over standard 6MV plan in terms of dosimetric parameter with comparable PTV coverage and small differences in doses to organ at risk.

Discussion and Conclusion: FFF modality yields dose distribution comparable to the standard flat beam in lung SBRT with very small absolute and clinically insignificant differences in OAR doses. Furthermore FFF requires significantly less beam on time which is associated with excellent patient

comfort and reduces the risk of intra-fraction motion. It also increases the feasibility of breath hold and gating techniques in lung SBRT.

PP-24

COMMISSIONING OF VOLUMETRIC DOSIMETER (DELTA 4) AND PRE TREATMENT QA FOR INTENSITY MODULATED RADIOTHERAPY

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Introduction: The IMRT technique is widely used in clinical application to deliver the highly conformal dose to the target and spare the normal structures. To achieve that we need a more accuracy and high precision volumetric dosimeter.
Purpose: The purpose of this study is to perform the commissioning of Delta 4 dosimeter QA system and evaluate the IMRT Pre treatment plans.
Materials and Methods: Linear accelerator(ELEKTA COMPACT),0.6cc Ion chamber, Polymethylmethacrylate (PMMA) Phantom, ScandidosDelta4 Phantom, Solid Phantom, Oncentra Treatment Planning System (TPS) v4.3,. The Delta 4 Phantom is a Diode based detector and that phantom measuring the absolute dose cylindrically. The measurement is synchronized with the linac by detecting the trigger pulse signal from the linac. we performed following tests to ensure the dose is measured accurately.
1. Cross calibration with Ion chamber
2. Relative Array Calibration
3. Directional Response correction
4. Temperature response check
5. Box field plan verification and IMRT Plan verification.

Results and Discussions: Cross Calibration: Absorbed dose was measured in farmer chamber and PMMA Phantom of Delta4. The result of PMMA shows that 0.6% higher than the absorbed dose in water. This difference is due to mass absorption co-efficient and scatter condition of water and PMMA material. **Relative Array Calibration:** In this test shows, 93% of wing units detectors are within ±0.5% and 94% of Main unit detectors are within ±0.5%.The vendor acceptance tolerance was 90% of the detectors should have responses within ±0.5%.This Relative array calibration test was passed. **Directional Response Correction:** The directional calibration increases the accuracy of measurements by determining the detector-to-detector variations according the rotational direction-dependency of the detector. This measurements shows the result within ± 5.0% as per vendor specification. **Temperature Response Check:** The Delta 4 device is diode based detector, it varies with temperature. So that, the temperature need to be entered into the Delta4 software prior to the every measurement and correction for the temperature calculated automatically by the software. For 20° C the dose was 0.9988 Gy and 21°C, the dose was 0.9689 Gy. It was found that dose increases with decrease in temperature. **Box Field Plan Verification:** The 2Gy prescription of Box field were planned in ONCENTRA TPS and executed in Delta 4 phantom. The result of Gamma value shows 99.2% of points pass the criteria of 3% Dose Deviation (DD) and 3mm of Distance to Agreement (DTA) with a dose threshold of 30% of the prescription dose. **IMRT Plan Verification:** The two IMRT Plan were implemented in Delta4 Phantom. The result of gamma value shows 99.7% for prostate plan and 99.8% for esophagus plan. DTA results of both plan were also passed. The Pre treatment QA for two IMRT plans were performed with ion chamber(0.6cc) and solid phantom. The Maximum variation observed between the calculated dose (TPS) and measured dose was 1.30 % and 2.0 % for prostate and esophagus cases respectively.
Conclusion: The Scandidos Delta4 Phantom for 3D dose verification were commissioned and met the criteria to be used clinically. The Pre IMRT Treatment plans were verified and results was passed.

PP-25

DOSIMETRIC CHARACTERISTICS OF OPTICALLY STIMULATED LUMINESCENCE DOSIMETER IN PHOTON BEAMS

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Introduction: Optically Stimulated Luminescence Dosimeter (OSLD), relatively a new dosimeter, recently introduced in medical dosimetry as a potential alternative to TLD. The properties and process that describe OSL are very similar to TLD but differ in read out technique and properties of dosimetric materials. TLDs contribute to transient signal immediately after irradiation and decay away in few minutes and also experiences fading with time. Therefore, it is essential to determine if the OSLD also have unstable traps that might contribute to transient signal immediately after irradiation. Due to the thermal stability of nanoDot OSLDs and the light tight casing, decreased fading is expected when compared to TLD.
Purpose: The objective of the study was to determine the dosimetric characteristics of OSLD in photon beams. The precision and accuracy in measuring dose, field size, reproducibility, signal depletion, dose rate dependency, energy dependency and angular dependency of the detector have been investigated and compared with ion chamber measurements.
Materials and Methods: Nanodot OSLD with MicroStar reader acquired from Landauer Pvt. Ltd., was used for this study. The nanoDots consist of plastic discs of Al2O3: C of 5mm diameter and 0.2mm thick. Irradiations were performed with LINAC and Cobalt machine photon beams. An element correction factor was determined for individual detector and applied to the raw readings of each dosimeter in all tests. Signal depletion per readout of OSL was investigated. The dose range selected for exposure to investigate the linearity of the OSLD was from 0.5Gy to 10Gy. In order to establish the field size dependency, the OSLDs were irradiated with field sizes from 3 x 3 to 40 x 40 cm2. The dose rate dependence of OSLD response was evaluated by varying the dose rate in the range 100 MU/min to 600 MU/min. To find the reproducibility, the OSL detectors were exposed to identical doses. The angular dependency was measured from 00 to 3600 for 6MV photons.

Discussion: It was observed that the OSL response was linear for doses from 50cGy to 300 cGy and a supra linearity was observed for doses greater than 400cGy upto 10Gy. The experimental uncertainty (< 1.6%) found for field size variation with photon beams. For different dose rates, OSL dosimeters were found to have a maximum variation of 1.3% and 1.8% with ion chamber was observed for 6 MV and 18 MV. The maximum percentage difference observed between the bleached and accumulated response was 8% in 6 MV and 9% in 18 MV photon beams. In this work, over 200 readings, nanoDot lost <0.1% signal per readout. Angular dependency of OSLDs for 6MV and 6FFF photon beam was studied. The maximum deviation noticed was 6% for 6 MV and 6FFF.
Results: The results shows that nanoDot OSL dosimeters are suitable for in-vivo dosimetry or continuous routine dosimetry in radiotherapy instead of TLDs or diodes, owing to its properties with regard to handling, small size and good dosimetric response with a relatively prompt read out.
Conclusion: The good reproducibility of OSLD system demonstrated that these nanoDots could be conveniently reused number of times provided optical bleaching in between the irradiations. Yet, OSLDs can be repeatedly used without an intermediate bleaching process by subtracting the previous exposure along with the background response. The measurements with photon beams carried out indicated that this newly introduced OSLD is suitable dosimeter for dosimetric measurements in clinical radiotherapy settings.

PP-26

VOLUMETRIC MODULATED ARC THERAPY PRE-TREATMENT DOSE VALIDATION: A SECOND VERIFICATION OF MONITOR UNITS WITH A DIAMOND SOFTWARE

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Introduction: At the moment it is recommended to perform an independent check of the MUs calculated by the treatment planning system (TPS). In modern complex treatment techniques, it is not feasible to perform these checks by hand, Diamond (PTW Freiburg version 6.2) is a secondary check software that allows independent MU and point dose verification for VMAT treatment.
Materials and Methods: As a part of our QC program all the dose calculations are independently checked, in particular our VMAT pre-treatment protocol establishes that prior to each treatment, calculations are verified at least with:
- Diamond software (PTW Freiburg version 6.2)
- Octavius 4D (PTW Freiburg verisoft version 7.0).

For the MU/point dose verification Dicom files exported from Monaco (version 5.10.02) (dose, plan and structure) are imported by Diamond which compares results against the TPS. The isocenter coordinates and dose are automatically read by Diamond to perform the comparison, but if it is not a representative dose point for all the arcs, extra points must be generated in MONACO and manually introduced in Diamond. We have analyzed the results of the comparisons as well the practical questions that have arisen.
Results: We have calculated more than 25Lung patients since June 2017. Two arcs are commonly used for majority of the plan. The average deviation is **1.53%** with maximum deviation is 8% in diamond and the average passing rate is **98.9%** in Octavius 4D. The standard deviation is **3.7 %** in diamond and **0.97%** in Octavius 4D.
Conclusion: Diamond has proven to be an efficient tool to perform independent verifications of TPS VMAT calculations. From our initial experience we have found that some minor changes in the program such as an improvement in the introduction of all the desired calculation points or the possibility of modification of the calculation slice (removing support structures, adding heterogeneities) would be very helpful to users.

PP-27

EVALUATION OF TREATMENT PLANS FOR BRAIN TUMOUR (GLIOMA) WITH DIFFERENT TREATMENT METHODS

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Introduction: The very basic aim of radiotherapy is to deliver a tumoricidal dose to the target and at the same time spare the normal structures in the vicinity. Intensity modulated radiotherapy (IMRT) in the recent past has established itself as a gold standard for organs at risk (OAR) sparing, target coverage and dose conformity. With the advent of volumetric modulated arc therapy VMAT and 3DCRT, an inter-comparison is needed to address the advantages and disadvantages of each technique.
Purpose: Radiotherapy plays a major role in treatment of brain tumours. The main purpose of the study is to optimize the treatment approach for the GBM. IMRT in the recent past has established itself as a gold standard for organs at risk (OAR) sparing, target coverage and dose conformity. This study attempts to evaluate the treatment plans for brain tumours in 20 patients with different radiotherapy treatment techniques by 3DCRT, IMRT and VMAT.
Materials and Methods: Computed Tomography (CT) images of 20 GBM patients with 3mm slice thickness were used in this study. The contouring and treatment planning was performed in the Monaco treatment planning system version with 6 MV photons (Elekta Infinity LA) available in our Department. The dose to 95% tumour volume, dose received by eye lens, eye ball, optic nerves, and optic chiasm were calculated using the DVH from Monaco treatment planning system. For all the selected patients,3DCRT, IMRT and VMAT treatment plans were generated. Plan comparison was done in terms of target coverage, dose homogeneity index (HI), dose conformity index (CI), OAR dose, monitor units (MUs) and Integral Dose (ID).
Results: The dose to 95% to the Planning Target Volume (PTV) were maintained for all three treatment techniques. PTV coverage is comparable in all three treatment techniques. However, VMAT give better sparing of critical structures such as optic nerve, optic chiasma and brainstem than IMRT and 3DCRT. whereas, 3DCRT technique gave better sparing in

eye and eye lens but the PTV coverage is less than IMRT and VMAT. Monitor Units (MU) for VMAT is more when compare than IMRT and 3DCRT plans.

Discussion: Radiotherapy is usually delivered with 3D-conformal techniques but several improvements in the technologies led to more complex delivery technique (IMRT and VMAT) used to treat different types of solid tumours with a considerable outcome, allowing to deliver dose with excellent conformation around the tumour and a better sparing of normal structures. VMAT is an advanced radiation treatment modality. It has a potential to generate treatment plans which are comparable with the corresponding IMRT and 3DCRT plans in terms of OAR sparing, plan quality with better treatment efficiency.

Integral dose (ID) and the volume receiving low-dose radiation for non-target volume, represented by ID of low-dose regions, were compared between IMRT plan, VMAT plan and 3DCRT for all the 20 patients. The study also showed that 3DCRT scored less ID than IMRT and VMAT. However, the IDs for VMAT and IMRT showed not much difference, with VMAT plans showing very minimal decrease in IDs when compared with IMRT.

Conclusion: This study shows achievement of better treatment of GBM cases with IMRT and VMAT techniques (except increase in IDs) when compared with 3DCRT technique. VMAT had additional advantage of lesser treatment time when compared with IMRT.

PP-28

PLANNED VERSUS RECEIVED DOSE IN SBRT LUNG CASES: A STUDY ON DOSIMETRIC INFLUENCE OF DAILY IMAGE-GUIDED RADIOTHERAPY CORRECTIONS

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Purpose: To study the daily variations in delivered doses in Stereotactic body radiotherapy lung cancer patients, using Cone Beam Computed Tomography (CBCT) images acquired before treatment to correct for target position.

Materials and Methods: Ten patients treated with volumetric Modulated Arc Therapy (VMAT) to the Lung cancer patients were studied. CBCT performed on all patients before treatment for all fractions. Patients were localized after CBCT by fusing the CBCT with the planning CT to evaluate the corrections that closely matches the patient treatment position with the planning position using bony land marks. Then CTV was superimposed on both scans for final corrections or daily deviations. Initially lasers match with external fiducial markers; later localization point changes with respect to external fiducial markers due to inter-fraction variations. Patients received 50 Gy of SBRT using 6X unflattened beam in 5 fractions. Actual dose delivered were calculated on CT for contour after editing the normal structures and PTV according to the fused CBCT on that day in Treatment planning system. The mean, maximum and minimum doses received by the planning target volume and mean doses of oesophagus, trachea and maximum dose of spinal cord were evaluated. Calculations were performed on each day on edited CT for contour. For this study 5 fractions for 5 patients (total 25 study sets) were created. Planning CT fused with daily CBCT for all 5 fractions to delineate and adjust the OAR contours.

Results: Localization was performed to optimize the target coverage. Over the whole treatment, most patients experienced Significant deviations in dose and displacement for Spinal cord, trachea and Oesophagus. Compared with the planning values, the mean dose for PTV was-5% % to-0.2 %, for trachea was-20 % vs +20 % and for Esophagus was 2% to >20 %. The dose maximum in spinal cord changes from 0.2 % to 10%. For PTV, deviations in maximum dose and minimum dose were observed; whereas mean dose variations observed less than 3%.

Discussion: In general, we have been concentrating on tumor localization and its position compared to other normal structures. Our aim is to deliver the maximum dose to the tumor and minimum dose the surrounding normal structures. As we are concentrating on only tumor the OARs are neglected. The dose planned versus the actual dose delivered were different due to its position with respect to the tumor or isocenter in most of the cases. If the Actual dose delivered to the OARs were near to the prescription or within the limits, then there will not be any issue. Problem comes only if the dose exceeds the limit to the OARs. To know this first we need to get the actual dose to the OARs. This method shows the solution for this task. This study can avoid hazards due to excess dose to normal structures or critical structures due to their mobility, Inter-fraction variation and Intrafraction variations.

Conclusions: This study shown the actual dose delivered to the PTV and normal structures while localization was performed to optimize the target coverage in daily IGRT corrections. A detailed study on few more number of patients yet to complete to give more meticulous results on doing daily shifts for tumor localization.

PP-29

DOSIMETRIC COMPARISION OF FIELD IN FIELD AND IMRT TECHNIQUES IN BREAST CANCER TREATMENT

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Introduction: The curative potential advantage of radiation therapy in the management of Breast cancer is greatly enhanced by the use of Intensity Modulated Radiotherapy (IMRT). The success of IMRT requires the high radiation dose delivery to the tumour, while sparing the surrounding normal tissues. The aim of this study is to compare the feasibility of 3DCRT, Field in Field (FiF) 3DCRT, IMRT plans to improve the treatment quality and optimize the treatment approach for the Breast cancer.

Purpose: The present study is aimed at comparing the planning and delivery efficiency of FiF 3DCRT and IMRT in radiotherapy of cancer of breast. Treatment planning using 3DCRT technique without any subfields was also performed for dosimetric comparison.

Materials and Methods: Treatment plans of 20 patients with left sided breast cancer and 5 right sided breast Cancer was used for this study. The 25 patients who had breast

conservative surgery received a prescribed dose of 50Gy in 25 fractions to the whole breast. FiF, IMRT and 3DCRT plans were compared for doses in the planning target volume (PTV), the dose homogeneity index (HI), conformity index (CI), conformation number (CN), dose to the ipsilateral lung, dose to the left and right breast irradiation and the monitor unit counts (MU) required for treatment. In the 3DCRT technique, the beam arrangement consists of two parallel opposed tangential beams with dynamic wedges. TheFiF plans were created by using two open tangential beams and four to five subfields. Five beam angles were chosen to create IMRT plans and were inversely optimized.

Results: The HI, CI and CN were similar for 3DCRT and FiF whereas IMRT plans had better CI and HI and CN. The low-dose volumes (V10) in the heart and lungs were lowest in FiF plans than in the other techniques. The mean dose to the heart and ipsilateral lung was higher with FiF and 3DCRT than with IMRT. The Heart dose in the case of right breast irradiation is negligible in all three techniques. In the current study, the relative volume of contralateral breast receiving low dose (1Gy) was significantly lower with the FIF plans than in the other plans. Also, 3DCRT and FiF techniques required fewer monitor units (MU) to deliver a given dose compared to IMRT.

Discussion: Target is more efficiently covered in the IMRT plans, compared to 3DCRT and FiF plans. The doses to critical structures i. e. lung, heart and contralateral breast is higher with 3DCRT technique compared to the other techniques. The IMRT and FiF techniques significantly reduced the maximum dose and the volume receiving greater than 110% and 107% of the prescription dose. The volume of contra lateral breast receiving dose of 1 Gy (V1) is found to be high in IMRT plans compared to the 3DCRT and FiF plans.

Conclusion: The 3DCRT technique without field-in-field though is simple to plan results in higher maximum dose to the target. The IMRT technique for breast radiotherapy enables significantly better dose distribution in the PTV with reduction in the doses to the organs at risk. However, the FiF technique is simple and efficient planning technique for breast irradiation. It significantly reduces the doses in low dose regions and it requires lesser planning time. Data analysis based on the dose volume histogram (DVH) shows that both FiF and IMRT techniques provided good dosimetric results.

PP-30

TPS COMMISSIONING AND VALIDATION OF SRS CONES BY USING TECHNICAL REPORT SERIES 483 PROTOCOL

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Introduction: Success of radiotherapy is not only depends on the planning, dosimetry also plays a vital role in modern radiotherapy, because of the complex treatment technique. It is very essential to take care in the small field dosimetry, because of these factors i. e. Lack of lateral charged particle equilibrium (LCPE), occlusion of the source and detector size.

Purpose: Aim of this study is to implement the Technical Report Series 483 protocol in the commissioning of SRS cones and its dosimetric impact.

Materials and Methods: This work was carried out in Clinac iX (Trilogy) which has 6MV, 15MV and 6SRS and five electron energies. It has equipped with radio surgical cones of diameter ranging from 5mm and 10mm to 30 mm in steps of 2mm for the SRS treatment technique. The beam data requirements for the commissioning of the cone are TMR, Total scatter factor and Off Axis ratio (OAR). The TMR for the 5mm and 10mm diameter cones were measured using Scantiditronix stereotactic diode. And for the larger cones 12 to 30mm Wellhofer CC01 ionization chamber. The OAR were measured at the depth of 5 cm for the cones 5, 10,12,14,20 and 30mm at three different SSDs 90,100, 110 cm. In this study we have taken 18mm cone as reference field as a MSR (machine specific reference field) as specified in the code of practice TRS 483. The total scatter factor was measured with SSD of 100 cm at the depth of 5 cm for the available cones and normalized to 18mm cone size. The reference dosimetry has been carried out using 18 mm cone as a reference field. Reference dose for 18mm cone was measured in water phantom with 10g/cm2. The correction factor for reference dosimetry for the machine specific reference field, **KQmsr, Q0fmsr, fmsr** has been applied.

The formula for the refence dosimetry using the MSR is and the Corrected output factor for the MSR has been calculated by a new beam data has been generated using these parameters. To evaluate the beam data, a plan has been created using cones. Same plan has been delivered and the dose measured using CC01 chamber.

Results: We have measured the dose for each cone and compared with the TPS calculated dose. The TPS calculated MU are compared with manually calculated MUs.

Discussion and Conclusion: We found there is a good agreement between the TPS calculated dose and the measured dose. And also the manually calculated MUs are matched with TPS calculated MUs. The commissioning of SRS cones in the TPS has successfully done by using Technical Report Series 483 protocol.

PP-31

DOSIMETRIC EVALUATION OF CARDIAC AND LUNG DOSES FOR LEFT SIDED POST BREAST CONSERVATIVE SURGERY PATIENTS UNDERGOING HYPOFRACTIONATED RADIOTHERAPY USING 3DCRT

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Purpose: To evaluate cardiac and lung doses in left sided breast conservative surgery undergoing adjuvant radiotherapy with hypo fractionated 3DCRT.

Materials and Methods: Between January 2012 to December 2015, 61 patients of Left sided breast cancer undergoing adjuvant hypo fractionated radiotherapy were included in present analysis. Clinical target volume (CTV), heart and ipsilateral lung and total lung were delineated on plan CT scan. 3DCRT plans with field in field techniques were generated for all patients. All dose calculations were done

using AAA algorithm in Eclipse planning system version 8.9. Heart, lung and CTV doses were evaluated using dose volume histogram (DVH).
Results: Sixty one patients were included in analysis. The median age of cohort was 55yrs (range 35-76 years). The prescribed dose was 40 Gy in 15 fractions over period of 3 weeks. The mean CTV D95 was 36.5 Gy (Range 34.8-39.5). For heart mean and V25 were 4.7 Gy and 5.6% respectively. For ipsilateral lung (left lung) Mean, V5, V20, V30 was 7.8%, 28.3%, 15.45 %, 12.07% respectively. For total Lung mean, V5, V20 and V30 was 3.79%, 12.88%, 7.07%, 5.46% respectively.
Conclusion: Hypo fractionated 3DCRT with field in field technique for left sided post BCS radiotherapy provides adequate coverage of CTV keeping heart and lung doses within accepted tolerance limit.

PP-32

DOSE VOLUME PARAMETERS OF BONE MARROW PREDICTING HAEMATOLOGICAL TOXICITIES IN PATIENTS WITH CARCINOMA CERVIX TREATED WITH VOLUMETRIC MODULATED ARC THERAPY TECHNIQUE

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Aim: Purpose of this study is to predict haematological toxicities in patients with squamous cell carcinoma of the cervix from dose volume parameters undergoing concurrent chemoradiotherapy by volumetric modulated arc therapy (VMAT) technique.
Materials and Methods: patients diagnosed with carcinoma of the cervix presented to the hospital between Jan 2017 till Dec 2017 were prospectively analyzed in this study. All were treated with concurrent chemoradiation by VMAT technique. Patients were assessed at baseline and every week during treatment for acute haematological toxicities. Dose volume parameters of VMAT plans from treatment planning system were correlated with RTOG grade of haematological toxicities.
Results and Discussion: A total of 34 patients diagnosed to have carcinoma of cervix were treated by radical radiotherapy by VMAT technique and concurrent chemotherapy (weekly cisplatin 40mg/m2). Median age of presentation was 54 years (39-73 years). The most common stage of presentation was stage IIB (61.7%). Out of thirty-four patients twenty-nine (85.2%) completed five cycles of weekly cisplatin whereas four received four cycles and one received three cycles of chemotherapy. Statistical analysis was performed using ROC curve to find sensitivity and specificity of dosimetric parameters. The t test was used to find the probability for bone marrow toxicity. Mean dose to the bone marrow more than or equal to 28.85Gy was significantly associated with bone marrow toxicity (sensitivity – 82.4%, specificity-70%). Incidence of grade 2 or higher toxicity was increased if mean dose to bone marrow exceeded 31.2Gy and was negligible if mean dose was less than 27.9Gy. Analysis of different dose volume parameters showed that volume of bone marrow receiving 20Gy, 30Gy and 40Gy (V20, V30 and V40) more than or equal to 71.75%, 49.75% and 25.7% respectively were significantly associated with increased bone marrow toxicity.
Conclusion: It is important to consider bone marrow as an organ at risk and limit its radiation absorbed dose to decrease haematological toxicities in pelvic malignancies.

PP-33

PRETREATMENT VERIFICATION USING PORTAL DOSIMETRY AND ION CHAMBER ARRAY DETECTOR

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Introduction: The complexity of intensity modulated radiotherapy (IMRT) demands through verification of the planned dose before treatment delivery. Traditional method of film dosimetry for pre-treatment verification of patient specific IMRT dose distribution is gradually being replaced by two-dimensional (2D) array detector and portal dosimetry system due to their ease of use and immediate readout of the result.
Purpose: to use the ion chamber array detector (I'MatriXX) and portal dosimetry for IMRT patient pre-treatment verification. To analysis the gamma scaling parameters like γ (γ max), γ (γ avg) γ % $\leq$1. To compare the gamma indices used in the dosimetry system. To analyse the effect of gamma indices with respect to gantry rotation.
Materials and Methods: Twenty five IMRT plans (10H&N,9 Brain and 6 Cx**)** were selected for this study, Eclipse TPS used for IMRT planning and UNIQUE Linear Accelerator was used to deliver the IMRT plans. The high resolution aSi-1000 EPID with Portal dose prediction (PDP) software and 2D ion chamber Array detector (ImatriXX) with OmniPro IMRT software was used in this study. For each IMRT plans, a portal dose verification plan was created in eclipse TPS using PDIP algorithm and same was exposed on EPID which is placed at SSD of 105cm. the images were acquired in integrated mode and processed to determine the photon fluence. This processed fluence was then compared with corresponding predicted fluence in eclipse TPS. The same plan was verified with I'MatriXX with OmniPro IMRT software. Fluence of every plan was projected separately at SSD 100cm.
Results: The PD predicted and EPID measured photon fluence are in well agreement with overall mean values of γ max, γ avg and γ % $\leq$1 with1.63, 0.24 and 99.4% respectively. Independent verification using MatriXX showed comparable overall mean values of γ avg and γ % $\leq$ 1 is 0.26 and 99.80%. However, in all plans, MatriXX showed significantly lower γ max with an overall mean value of 1.37. Both MatriXX 2D ion chamber array and portal dosimetry showed comparable results**.**
Discussion: The agreement of PD predicted and EPID measured photon fluence/dose distribution were evaluated using gamma (γ) index set at 3%/3 mm distance to point agreement (DTA). Three gamma scaling parameters, maximum γ (γ max), average γ (γ avg) and percentage of points with γ % $\leq$1 were estimated for each field. An independent measurement was carried out with the MatriXX 2D ion chamber array detector and γmax, γ avg and γ % $\leq$ 1 were estimated using the OmniPro IMRT analysing software. The effect of gantry rotation on PD was also investigated for 5 IMRT plans.

Conclusion: the overall result of patient specific IMRT fluence verification using portal dosimetry and MatriXX 2D ion chamber array is comparable except for gamma max, which is higher in portal dosimetry. However, all parameters are well within the clinically acceptable values. Based on the result of range of the plans studied, portal dosimetry can be considered as an alternative method of 2D detector array or vice versa for pre-treatment verification IMRT plans.

PP-34

POSITRON EMISSION TOMOGRAPHY/COMPUTED TOMOGRAPHY IMAGING FOR RADIATION THERAPY: OUR EXPERIENCE IN QUALITY ASSURANCE PROGRAM

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Introduction: In the last few years, there has been significant advances in radiation treatment planning (RTP) software of the treatment planning system (TPS) calculation algorithms and it is able to combine the biologically guided Positron emission Tomography (PET) data or Magnetic Resonance and imaging (MRI) data and anatomic Computed Tomography (CT) data with five registrations methods namely, Manual approach (MA), Landmark, Identity, Surface Matching, and Mutual Information (MI) for precise three dimensional (3D) computer based dose calculation. Combined PET/CT based treatment planning has an advantage over CT alone in the standardization of target volume delineation (Gross tumour volume (GTV), Clinical target volume (CTV), and Planning target volume (PTV) margins), in reduction of risk for geometric misses and in minimizing radiation dose to the non-target organs.

Purpose: To identify and minimize the sources of uncertainties and errors, a rigorous quality assurance (QA) protocol of these imaging tools is mandatory for its proper functioning and effective image integration and safe use for patients. In this paper, QA procedures necessary for the success of PET/CT imaging for radiation therapy will be discussed.

Materials and Methods: INHS Asvini, a premier Indian Naval Hospital has installed an integrated PET/CT unit (Discovery Elite VCT 690) of M/s Wipro GE Healthcare make in Apr 2014. Till now optimum number of patients have undergone whole body PET/CT scans successfully. Prior to the actual clinical use, various acceptance testing and Quality Assurance (QA) tests related to radiation safety and proper calibration of the unit were carried out using 200 mCi of radioactive 18F-fluorodeoxyglucose (FDG) (half life 110 minutes), scatter fraction, image quality, sensitivity and spatial resolution phantoms, Ge-68 VQC phantom (solid polyethylene cylinder with line sources) as per the Atomic Energy Regulatory Board (AERB) proforma and National Electrical Measurement Association (NEMA) protocol. The QA program is generally divided into daily, weekly, and quarterly checks. The PET/CT scanner has a radioactive rod Ge-68 pin (half life 270.8 days) source mounted in a shielded container behind the scanner and is used for daily calibration. It monitors the image quality of the scanner. Tests like single events, coincidence, dead time and peak energy spectrum of the detectors are measured. In weekly QA, all detectors are irradiated and corrections are made for the detector outputs. The quarterly calibration provides the system with a benchmark for counting variations and optimizes the system performance. The type of measurements includes the position of single events, update gain, and energy. The detector coincidence timing characterization, 2D normalization, 3D geometric and 2D/3D well counter calibration checks are also done. The vendor performs QA of image acquisition and data transfer and a standard disease specific image acquisition protocol is developed, optimized, and used routinely, and is confirmed by routine inspection of clinical procedures. The standard uptake values (SUV) forms the basis for quantitative use of the imaging data and automated segmentation. The delineation of target volumes and contours in radiation therapy is usually done by: (a) Visual interpretation; (b) By using a threshold SUV; (c) Threshold percentage of the maximum uptake; and (d) The source-to-background ratio. A rigorous validation tests and procedures are followed in tumor volume definition, by ensuring the consistency of SUV.

Conclusions: PET/CT imaging plays an important role in oncology. To ensure safe and effective use of this latest technology, a comprehensive QA program should be followed for checking overall performance of the scanner, thereby minimizing uncertainties and errors during treatment planning of radiation therapy patients.

PP-35

DOSIMETRIC COMPARISON OF 6MV FLATTENING FILTER FREE BEAMS AND 6MV FFF FOR SINGLE FRACTION STREOTACTIC RADIOSURGERY TREATMENT

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Introduction: Stereotactic Radiosurgery is widely used in radiotherapy to treat single or multiple brain metastatic tumor. There are many treatment technique for Brain SRS such as such as Gamma Knife, Cyber Knife, helical tomotherapy and linear accelerator. SRS treatment started with Gamma Knife but it was more time consuming and cumbersome, now days SRS treatment are, completely non invasion and frameless, that make patients more comfortable. Many publication shown that Rapid arc (VMAT) significantly reduced the treatment time compared with conventional IMRT techniques. The dose rate of FFF are substantially higher than FF that make shorter treatment time.

Purpose: The purpose of this study was to investigate the dosimetric plan quality and delivery efficiency in flattening filter free beams (FFF) and with flattening filter for volumetric arc therapy in Stereotactic radiosurgery.

Materials and Methods: Ten no. of patients were selected for this study all are single metastatic lesion average size in 12.26 cc, (2.72cm equivalent square in cm). All patients were treated with rapid arc plan, and all plans has been made in Varian Eclipse 10.0v treatment planning system. The plans was made with coplanar as well as non-coplanar beam depends upon tumor location. The prescription of dose is depend up

on location and size of the tumor, average dose prescribed was 20Gy. X-ray energy of 6 MV FFF and a dose rate of 1400 MU/min. were used for all plans. The plans were delivered on a True Beam STx (Varian Medical Systems) equipped with an MLC with 2.5 mm Leaves in the center 8 cm and outer leaves of 5 mm width. We had kept the FFF (Flattening Filter Free) plan as a base plan, while doing plan with 6 MV FF (Flattening Filter) and dose rate of 600 MU/min. All the planning parameters used for 6MV FFF beam with rapid arc kept as it is including objective function and priority's also, only energy 6MV and dose rate 600 MU/min. changed for FF plans.

Results: Dosimetric evaluation performed on the basis of, Beam on time, Total monitor units, Homogeneity index, Conformity index, Dose Gradient Index, Body mean dose, Max dose in PTV, Low dose Spillage, and PTV Dose Coverage, Gama Passing Criteria. We found the significant difference between FFF and FF is beam on time (4.33 ± 0.53 Vs 8.97± 2.71, $p < 0.00015$). There was no significant difference between Total MU (5445.46 ± 979 *Vs* 5126.21 ± 1697.50 $p < 0.40$), HI (1.22±0.08, *Vs* 1.26± 0.09 $p < 0.03$), CI *(*1 ±0.01 *Vs* 1± 0.01 $p < 0.46$), GI (3.37± 0.76 *Vs* 3.86 ± 1.33 $p < 0.05$), body mean dose (49.36 ± 16.26 *Vs* 51.0±16.9 $p < 0.15$), Max dose (110.0± 7.0 *Vs* 113.28± 7.85 $p < 0.03$*),* low dose spillage (98.53 ±49.95 *Vs* 107.65± 52.17 $p < 0.09$). PTV Coverage (93.2 ± 3.67 *Vs* 95.19± 4.9, $p < 0.09$) and gamma passing criteria (96.88 ± 1.4 *Vs* 96.81 ± 1.04,$p < 0.88$).

Discussion: A comparative evaluation of two different treatment techniques using FF and FFF beams for single brain metastasis was addressed in our study. Dosimetric superiority was shown in VMAT_FFF plans, and a time efficient treatment was also provided in 6X FFF beams which it was a good choice for single fraction SRS treatment. However, dose distributions achieved with FFF beams are similar or comparable to those with FF beams. Our investigation shows that FFF beams delivers faster dose in shorter treatment time is the biggest advantages over FF beams.

PP-36

QUANTITATIVE AND QUALITATIVE DOSIMETRIC ANALYSIS OF FLATTENING AND FLATTENING FILTER FREE BEAM FOR TRUE BEAM STX: OUR INITIAL COMMISSIONING EXPERIENCE

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Introduction: True Beam STx is the advanced RT equipment with its stereotactic counterpart, have many unique features, including high-dose-rate flattening-filter-free (FFF) X ray modes, updated KV onboard imaging option, hardware/software, and a novel control system with High Definition Multileaf Collimator for best tumour conformality.

Aim and Objective: Current study presents the compared Quantitatively and Qualitatively analyzed Dosimetric beam data on a Varian True Beam Stx, Medical Linear Accelerator, the beam characterization and evolution of Dosimetric properties for 6, 10 and 15 Mega voltage beam and 6, 10 flattening filter free Mega voltage beam has been carried out as well as the comparison of photon beam data for two standard FF and FFF photon energies has been done.

Materials and Methods: Measurement of all the Dosimetric data done with the PTW Beam Analyzer with different detectors were compared and evaluated for all photon energies: 6MV, 10 MV, 15MV, 6MV FFF and 10MV FFF. The ionization chambers Pin Point CC01, Semiflex CC13 and FC 65 and Roos chamber by PTW dosimetry were used to determine and compare the parameters like PDD, Depth dose profile, symmetry, flatness, penumbra, quality index, transmission factor, relative output factor DLG in addition to degree of un-flatness and off axis ratio of FFF beam.

Results and Conclusion: It was observed that, the reduction in surface dose due to Removal of flattening filter which not only causes softening of the resulting beam but decreases scattering and electron contamination from flattening filter. PDD curve for FFF beam has lower down beyond the region of TCPE due to the loss of beam hardening effect as well as Dmax is more specially function of beam quality and design of the head of the treatment machine. output factor (Scp) at a smaller field sizes for FFF beam slightly higher in magnitude compare to that of FF beam, variation between FF and FFF slowly decreases with rise in field size and an output factor converges to unity at field size of 10 × 10 cm2. The Quality Index in case of FFF beam is lesser than the magnitude of FF beam. Removal flattening filter alters various commissioning associated parameter as Field flatness, Field penumbra, Beam quality, Surface dose, Transmission factor, off axis energy variation and Homogeneity need to be redefined for FFF beam other than FF beam. Since, the concept of homogeneity cannot be applied to FFF beam special attention need to be given while treatment planning. Due to smaller variation of head scatter, off axis energy distribution, electron contamination, leaf transmission the dose calculation accuracy expected to increase. Availability of FFF beam provides additional clinical advantage over flat beam.

PP-37

PLANNNIG AND SHIELDING CALCULATION FOR TELETHERAPY AND BRACHYTHERAPY INSTALLATIONS

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Introduction: The primary aim of radiation protection is to provide an appropriate standard of protection for humankind against harmful effects of ionizing radiation, without unduly limiting the beneficial practices of such exposures of individuals to primary and secondary radiations can be reduced by one or more combination 1.Time 2. Distance 3.Shielding. Where it is impracticable to adopt the methods of distance and time to ensure acceptable low radiation level at work place, method of radiation shielding is adopted.

Objective: To provide a document for the standard practice in radiotherapy department to be a reference and guide for establishing teletherapy and brachytherapy room facilities by theoretical room shielding calculations and its experimental validations based on the International protocols (NCRP) and the recommendation of national level regulatory board (AERB).

Materials and Methods: In teletherapy Co-60 room calculation and the linear accelerator having the nominal photon beam energies 6MV, 10MV, and 15MV were used in the present work and for brachytherapy facilities of HDR room both Ir-192 and Co-60 room designing were executed. For the photon measurements, GM based and ion chamber based counters have been used and for the neutron measurements a neutron detector with a polyethylene moderator was used. The work also includes a literature study of different international protocols explains about the room shielding calculation for the radiotherapy facilities were presented.
Results and Discussions: All the wall thickness have been calculated for teletherapy and brachytherapy rooms and tabulated. The measured doses of the radiation shielding in teletherapy and brachytherapy outside the walls were below the acceptable radiation limits per week and year for both the primary and secondary walls. In the discussion part, compared all wall thickness of the facilities between the theoretical calculated and the original layout values. Based on these comparisons the difference was very minimal and the planned facilities were well adequately shielded in order to achieve the radiation limits of the radiation workers and the public.
Conclusion: It has been concluded that, the present work can be used as a reference guide to establish a new radiotherapy department in the country as per the AERB protocol.

PP-38

SETUP ERROR ANALYSIS OF TREATMENT FIELDS BY ELECTRONIC PORTAL IMAGING IN PELVIC RADIATION THERAPY

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Introduction: The aim of radiation therapy is to reliably maximize the dose to the target while minimizing the toxicity to the normal tissues. Therefore, daily treatment setup is considered as a critical requirement in radiotherapy for an accurate dose delivery. Setup uncertainties can creep in day to day radiation treatment and are divided into two categories: systematic errors and random errors.
Purpose: The aim of this study is to assess set-up errors for carcinoma of cervix and stomach patients undergoing radiotherapy treatment using an electronic portal imaging device (EPID).
Materials and Methods: The study was carried out on a sample of 20 patients treated for Ca Cervix and Ca Stomach between Jan 2017 and June 2018. Before treatment, the patients were immobilized using thermoplastic immobilization device of three fixed points. A computed tomography (CT) scan was acquired with CT simulator (Somatom Scope-Siemens) using a 3-mm slice thickness. CT images were imported into the Oncentra (v.4.3-Elekta) treatment planning software for 3 Dimensional Conformal Radio Therapy (3D CRT) treatment planning. The clinical target volume (CTV) and organs at risks (OARs) were contoured by the physician. For pelvic cancer cases, planning target volume (PTV) margin of 10 mm to 15 mm were added all around to the defined CTV. The digitally reconstructed radiographs (DRRs) were generated and stored as reference images. The set-up errors were defined as the displacement of the coordinates of the bony land marks on the beam film from those on the DRR films. Since parallel opposite fields were used in all the pelvic sites, the displacement errors are shown in 'X' direction and 'Y' direction. Set-up errors were corrected if they exceeded 5mm in any direction. Patients were imaged weekly. For pelvic cases, the systematic errors were defined as deviations between the planned patient position and simulated patient position before starting treatment. The random errors were defined as deviations between different treatment fractions taken weekly during a course of the treatment.
Results and Discussion: Patient set-up was evaluated and corrected via manual matching using the 3D bony anatomy. We measured the shifts in the anterior-posterior fields for pelvis. In pelvic cases, the 'X' and 'Y' direction errors represent lateral (X-axis) and longitudinal (Y-axis) shifts. The aim of the study was to determine the field setup errors and since parallel opposite fields were used for treatment, the displacement errors are shown in 'X' direction and 'Y' direction. As discussed in literature it was assumed that the mean and standard deviations represent the systematic and random errors respectively. The average mean errors (systematic errors) along X and Y directions were 1.22 and 1.66 mm and standard deviation in X was 1.0 mm and Y was 2.9 mm for pelvic cases. It was observed that the mean and standard deviation errors were greater in longitudinal direction compared to those in the 'lateral direction. It was assumed that this may be due to the lack of accuracy accepted on comparison of bony landmarks of matched images along the longitudinal direction compared to that along the lateral during the setup verification of fields.
Conclusion: The retrospective study has shown the probable range of systematic and random errors that occur in the field setup during the course of radiotherapy treatment. EPID is a useful tool for fast and reliable assessment for verification of field set up and correction of various errors during the course of radiotherapy treatment. From this study, it is suggested to obtain pre-treatment portal images weekly for managing random and systematic errors effectively.

PP-39

DOSIMETRIC STUDY OF ELONGATED FIELDS IN MEDICAL LINEAR ACCELERATOR

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Introduction: With the state of the art techniques now Radiotherapy is a proven means to cure and improve the quality life of cancer patients. Success of advanced radiotherapy highly depends upon the precession and accuracy. For accurate and precise delivery of the prescribed dose to the target volume, it is necessary to calculate Monitor Units correctly.
Purpose: Aim of the study is to evaluate the deviation of output between a rectangular field size and its corresponding equivalent square field size calculated using Sterling's

formula and analysis the deviation versus elongation ratio(Y/X ratio of a field).

Materials and Methods: Percentage depth dose and electrometer reading were measured for various rectangular field sizes of four set of X and Y combination i. e. Y values were fixed(10 cm,15 cm,20 cm and 25 cm) and X was varied from 4 cm to 25 cm. Meter reading of square field sizes(from 4x4 cm2 to 25x25 cm2) were also taken. Output of all rectangular field sizes included in this study were calculated and simultaneously output of all the square field sizes were also calculated using PDD from BJR Supplement No-25.For measurement of PDD, PTW Radiation Field Analyser and PTW 0.125 cc thimble chamber were used. For electrometer reading PTW 0.6 cc Farmer chamber and one dimensional water phantom were used and chamber was placed at 10 cm depth and 100 MU was fired for each reading and two sets of reading were taken for each field.

Results: Deviation of output increases as the Y/X ratio increases. Two medical LINACs were used in this study(Elekta Synergy and Siemens Primus). In Elekta Synergy maximum deviation is 1.57% and in Siemens Primus it is 1.3%.

Discussion: In Elekta Synergy, the measured output is lower than the calculated output. In Siemens Primus, in most of the field sizes the measured output is higher than calculated output.

Conclusion: Since the deviation is not greater than 2% across all field sizes included in this sizes, so Sterling's equivalent square formula can be used for Monitor Unit calculation.

PP-40

RETROSPECTIVE ANALYSIS OF ELECTRON BEAM DATA MEASUREMENTS AT A TERTIARY CARE INDIAN NAVAL HOSPITAL

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Introduction: Electron beams generated by a modern linear accelerator (LA) is widely used in external beam radiation therapy. The treatment head design of the LA has a primary collimating device and various scattering foils (made of stainless steel and gold having thickness from 0.002 to 0.008 inches). The output factor measurements of the electron beams comprises of air fluence profiles (without applicator) along the in plane and cross plane directions at two Source to Detector distances (SDD), 70 cm and 90 cm (normalize to 20x8 cm2) and percentage depth dose (PDD) profiles in water and absolute dose measurement in water at 100 cm source to surface distance (SSD) at reference depth for 100 MU. A retrospective analysis of electron beam output data measurements for various electron energies used for 3D (dimensional) treatment over a span of ten years at this premier tertiary care Indian Naval hospital were carried out and is discussed in this paper.

Materials and Methods: The electron beams has energies 6, 9,12,15,18 and 21 MeV generated by a dual energy LA (Siemens) commissioned in 2007. Routine, quality assurance (QA) tests as per IEC Protocol recommended by AERB are done and the machine is calibrated for 1MU= 1cGy and practical range (Rp) for all energies and reference depth (Zref) are determined as per Siemens protocol. Parallel plate (PP) ionization chamber (Markus Type) & Semi flex ionization chambers, Mephysto (MP3-M software) Radiation field Analyser (RFA) and slab phantom (RW3) and Unidos electrometer (all PTW make) have been used. The PP chamber is placed at the depth of dose maximum on this slab phantom and absolute dose measurements for 100 MU for each applicator (cones) for all energies at 100 cm are carried out as per IAEA, TRS-398 protocol. Air measurements were performed without any build up cap in an empty RFA phantom with field size 40x40 cm2 and for point dose measurements as well as profiles scans were performed for a set of rectangular and square field sizes (8x8,20x8, 30x8 & 30x30 cm2) at two SSD 70 cm (upper measurement plane) and 90 cm (lower measurement plane) for each cone sizes and repeated for all electron energies. The relative PDD measurements in water (without applicator) is done for maximum field size 40x40 cm2 and profiles measurement (with applicator) at two different depths (normalization depth 1-3 cm and bremsstrahlung depth 5-10 cm) for all the above electron energies.

Results: The electron beam characteristics namely, maximum dose measurement (in plane and cross plane), profiles (flatness and symmetry), stability of flatness, radiation field penumbra, output factors, all generated by the RFA phantom in air at various energies at two SDDs were found to be within the tolerance values as per AERB protocol. The nominal energies of electron beams, measured using "range-energy" relationship and the energy distribution at the surface of the medium, characterized by model energy, Ep,0 (MeV) which is related to the extrapolated practical range, Rp (cm) in water were found to be 6 $\pm$ 0.42 MeV, 9 $\pm$ 0.21 MeV, 12 $\pm$ 0.19 MeV, 15 $\pm$ 0.04 MeV (except 18 and 21 MeV presently not in use) and reference depths for 6,9,12,15,18 and 21 MeV were found to be 1.4, 2.1, 2.7, 2.8, 2.9 and 3.0 $\pm$ 0.1 cm respectively. The air-gap corrections factors measured were found to be $\leq$ 2% with the baseline data obtained at commissioning.

Conclusions: The overall uncertainties in these periodical QA tests and electron beam data used for treatment planning over a span of ten years are well within the tolerance limits as prescribed in the protocols and guidelines used to carry out these tests.

PP-41

DOSIMETRIC STUDY OF UNFLATTENED 6MV X-RAY BEAM VMAT PLANS FOR THE TREATMENT OF HEAD AND NECK CANCERS

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Introduction: Volumetric Modulated Arc Therapy (VMAT) or RapidArc® treatment technique is an advanced radiotherapy delivery technique. It delivers continuous intensity modulated radiation beams as "radiation beamlets" in a very short time as the dose is sculpted in a 3D view to the target. Conventionally,

medical linear accelerator produces flattened beams where as currently unflattened beam gains momentum for clinical use due to its inherited beam characteristics. The unflattened beam has clinical advantages and it is characterized by high dose-rate, conical-shaped beam profile, beam softness, higher superficial dose and reduced out-of-field dose.

Purpose: To study the dosimetric characteristics of 6MV X-Ray photon beam of flattened and unflattened beam by VMAT treatment delivery technique using Varian-Eclipse Treatment Planning Systems (TPS) for fifteen Head&Neck cancer patients.

Materials and Methods: Varian-TrueBeam® medical linear accelerator and Varian-Eclipse™ TPS was used to create VMAT plans for treatment delivery of 6MV X-Ray photon of flattened and unflattened beams. The VMAT treatment plans were created to deliver the prescribed dose of 66Gy in 33 fractions to planning target volume (PTV). The fifteen Head&Neck cancer patients VMAT treatment plan of both flattened and unflattened beams were selected for dose-volume-histogram (DVH) analysis and plan evaluation parameters such as homogeneity index, conformity index, monitor units(MU) and "beam-on" time were also compared. Gamma(γ)-index analysis was performed among TPS calculated and PTW-2DArray-729 detector with OCTAVIUS®-4D-phantom measured fluences for flattened and unflattened beam VMAT treatment plans.

Results: The plan analyses show that dose delivery to the PTV in both the flattened and unflattened beam VMAT treatment plans are identical (*p*value-D50%=0.0721, D2%=0.0893, D98%=0.0878) and also it shows similar homogeneous dose distribution (*p* value-0.0835) and dose conformity (*p* value-0.0667) to the PTV, but the dose delivery to OAR's differs significantly. The unflattened beam VMAT treatment plans outscore over flattened beam VMAT treatment plan in terms of sparing the organ-at-risks structures like optic-nerve, optic-chiasm, spinalcord, brainstem and parotids. The dose received by optic nerve is 47.60±4.91Gy & 50.41±5.11Gy, optic-chiasm is 40.10±10.5Gy & 44.92±9.75Gy, brainstem is 44.30±1.77Gy & 49.30±3.77Gy and spinalcord is 36.50±2.89Gy & 41.50±3.89Gy for unflattened and flattened beam VMAT treatment plans respectively. The number of MU's in the unflattened beam shows significantly higher (695±65MU) than the flattened beam (450±50MU) VMAT plans. The "beam-on" time in unflattened beam has less (2.1±0.2mins) than the flattened beam (2.5±0.3mins) VMAT plans. The pre-treatment plan verification by γ-index analysis with criteria of 3mm DTA and 3% DD were found to be good agreement between flattened and unflattened beam VMAT plans.

Discussion: The unflattened VMAT treatment plans of fifteen Head&Neck cancer patients plan evaluation dosimetric parameters like PTV dose distribution, conformity and homogeneity indices found to be similar to the flattened beam VMAT treatment plans. The unflattened beam VMAT treatment plans has low out of filed dose, hence it demonstrated great improvements in OAR's sparing from radiation dose. Almost 5% to 15% more sparing of OAR's were observed in unflattened beam VMAT plans compared with flattened beam VMAT plans. The reduction of normal-tissue doses and more number of MU's were observed in unflattened VMAT treatment plans compared with flattened VMAT treatment plans. Due to the higher dose-rate property of unflattened beam, the "beam-on" time is less compared to the flattened beam VMAT treatment plans. For patient specific QA, γ-index analysis showed good agreement between the planned and delivered dose for unflattened and flattened VMAT plans.

Conclusion: The unflattened beam of VMAT treatment plan is the choice of treatment for Head&Neck cancer patients to achieve the clinical objective of minimum possible dose delivery to OAR's with clinically acceptable level dose distributions to PTV.

PP-42

DEVELOPMENT OF IN HOUSE DOSIMETRIC PHANTOM FOR GAMMA KNIFE RADIOSURGERY AND COMPARISON OF TPS WITH DELIVERED DOSE BY USING GAFCHROMIC FILM

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Introduction: The Gamma Knife 4C model was installed in 2006 and being treated with various brain lesions like Vestibular Schwannoma, Meningioma, AVM, etc. the GKRS clinical responses are above 95% and have treated more than 2500 cases till now with this unit. Considering the present workload and quality assurance test tools. we are unable to monitor the accuracy of dose delivery with automatic positioning System.

The aim of this study is to compare the TPS calculated and delivered dose by using customized hemispherical phantom and Gafchromic film. In regular radiotherapy, the multi-fractioned dose delivery method will have an advanced patient-specific quality assurance test tools for verification of planned and delivered dose.

Materials and Methods: The gamma knife treatment delivery is a single fractionated treatment delivery and no margin added to GTV where we do not have the essential QC tools to verify the dose conformity. So, to overcome this issue, we had an idea to develop an acrylic dosimetric phantom for comparison of TPS vs delivered dose.

A study has been performed earlier to verify the dose delivery by trunnion (manual coordinates setting) method and achieved the accuracy of Gamma Knife iso-centre with the result of 3% deviation by using Radiochromic films vs. Treatment Planning System The study was carried out with Automatic Position System by using a customized phantom. The film is sandwiched into phantom and irradiated with a treatment plan, the films will be scanned and their optical density will be converted to dose, the dose from film compared with TPS calculated dose.

Result and Conclusion: Customized phantom has been developed for APS and the study has been performed for ten cases and the measured dose are compared with TPS calculated dose for patients treated with different brain lesions. this study will represent a step forward to understand the Gamma Knife dose delivery and a visual agreement will be observed in this project.

PP-44

ESTIMATION OF THE DOSE RECEIVED BY THE PATIENT UNDERGOING CHEST X-RAY EXAMINATION IN DIGITAL RADIOGRAPHY

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Introduction: All over the world, the use of x ray for diagnostic purpose is ever increasing. Although there are other modalities available like MRI and ultrasound, but due to various safety practices, quality assurance test of x ray machines, implementation of regulatory guidelines accepted worldwide and good quality images, makes diagnostic x ray most widely used and essential modality in diagnostic radiology. But as ionizing radiation is used for diagnostic purpose. There are several health hazards associated with it, if proper precaution and safe practices are not implemented. Therefore it is essential to follow recommended Dose Reference Level to ensure if the dose received by the patients are well beyond the accepted level and does more good than harm to the patients.

Purpose:

1. Check consistent performance of DR machine
2. Measure and compare the quality control parameter
3. Output of the DR machine
4. To estimate the effective dose and determine the dose reference level for patient undergoing chest X ray examination in Digital Radiography.

Materials and Methods:

1. The SAMSUNG (make), GU60A (model) machine QA is done with the help of IBA makes Magic Maxx semiconductor dosimeter

Patient specific incident air kerma is calculated from various exposure factors by the formula:

2. Incident air kerma = Output factor*(100/focus to skin distance)*mAs
3. PCXMC-2.0 Monte-Carlo simulation software is used to determine effective dose
4. The variation of effective dose in terms of Body Mass Index, age and other radiological factors like mAs is verified
5. Dose reference level for digital radiography is estimated and verified with the value given by IAEA.

Results: A total of 81 patients data were collected and the statistical analysis of Age, Height Weight, mAs, Thickness, BMI Average Dose was done to determine the Standard Deviation, Mean, Median, Minimum and Maximum value. From the 2D-fit plot of Effective Dose versus BMI, with BMI in X axis and Effective Dose in Y axis. We have obtained an empirical formula relating BMI and Effective Dose for chest radiography: $Y=0.01223+0.00148*X$. Similarly, from the 2D-fit plot of Effective Dose versus mAs, with mAs in X axis and Effective Dose in Y axis. We have obtained an empirical formula relating mAs and Effective Dose for chest radiography: $Y=0.00457+0.01729*X$.

Discussion and Conclusion: From our study we have found that effective dose increases with increasing BMI(body mass index) and mAs. We have also obtained an empirical formula relating effective dose with BMI as well as mAs. Therefore from the empirical formula we can calculate the effective dose prior to X ray examination. For radiography, effective dose is recommended DRL quantity The dose reference level in our study wasfound to be (0.0432 +/-0.01527) mSv and the third quartile value was found to be 0.0553215 mSv. Thislimit is well under the accepted DRL (dose reference level.) as found by comparing the DRL in this study with the DRLs of other publications.

PP-45

INSTALLATION AND COMMISSIONING OF CARDIOVASCULAR X-RAY IMAGING SYSTEM

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Introduction: The medical equipment producing ionizing radiation using for patient diagnostic, intervention procedure or therapeutic application needs regulatory approval from the radiation safety point of view to protect and to minimize unnecessary radiation exposure to Patient, Health care professionals and Public before put in to clinical application. The commissioning of new equipment for clinical use to ensure the functionality of equipment through the procedure of quality assurance performance testing as per the National/ International protocol and compliance with technical specification of equipment.

Objective: To install and commissioning of cardiovascular X-Ray system for clinical use.

Materials and Methods: The newly procured Philips Allura Xper FD10 X-ray system with flat detector installed for the imaging study of coronary angiography for functional evaluation of cardiac and cardiovascular system. The quality assurance tools RTI, Piranha were used to evaluate functional performance of the X-ray system. The generator and X-Ray system was tested for accuracy of operating potential and timer, total filtration, image quality, radiation safety of equipment and layout integrity from radiation safety point of view, ion chamber based survey meter Fluke 451P was used for radiation surveillance.

Result and Discussion: Measured value of operating potential are 50.71, 100.21, 125.83 kVp for set value of 50, 100, 125 kV respectively. The difference between them is less than 0.1 kV for the tolerance of $\pm$ 5 kV. The measured value of time of exposure are 0.0507, 0.1009, 0.4015 s for set value of 0.05, 0.10 and 0.40 s respectively. The measured value of total filtration thickness is 3.5 mm Al and HVL 5.39 mm Al at 125 kVp. The coefficient of linearity of mA loading station at 60kVp and timer at 70 kVp is 0.0008 and 0.0006 respectively, which is less than tolerance limit of < 0.1. The consistency of radiation output produced by X-ray system at 60 kV and 70 kV is 0.0009 and 0.0002 for tolerance limit of ≤ 0.5. The system passed the low contrast resolution test with resolving 2.0 mm hole and high contrast resolution test resolved the 1.8 lp/mm pattern resolved for image quality instead of 1.5 lp/mm. The Table top exposure measured at 120 kVp and 8.6 mA is 6.338 cGy/min at 70 cm from focal point with AEC for tolerance limit of $\leq$ 10 cGy/min and measured level of leakage radiation at 1m from tube housing and collimator at 125 kVp, 50 mA is 0.0086 mGy and 0.0048 mGy in one hour respectively for the tolerance limit of $\leq$ 1 mGy (114 mR) in one hour. The level of

exposure at the patient entry door which is lined with 2 mm of Pb exceeds the permissible limit due inadequate overlapping of Pb. Then modified the door lead lining properly, radiation exposure level brought down to 0.75 mR/week within the permissible limit of 2 mR/week.

Conclusion: The results of acceptance test protocol confirms the functional, integrity status and radiation safety of equipment to acceptable level. The cardiovascular X-ray system commissioned for clinical use after obtaining license for operation from regulatory authority of India, AERB.

PP-46

SAFETY REVIEW AND PERFORMANCE EVALUATION OF HALCYON MEDICAL ACCELERATOR

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Introduction: Atomic Energy Regulatory Board (AERB), Mumbai carries out the safety review with respect to the performance of the medical accelerators before its use in radiotherapy purposes in India. During review, the applicable standards are referred. With rapid advancements in technology aimed at faster and accurate treatment delivery, new features are regularly incorporated in radiotherapy units. In some instances, standards are not available for testing the new features for acceptance. In such cases, it is required to arrive at a value which is practical, achievable and in-line with the supplier's protocol without compromising the patient safety. In the present work, the safety review and acceptance criteria of several new features of the medical accelerator model Halcyon which are not available in the applicable standards are discussed.

Materials and Methods: Recently, Varian Medical Systems International India Pvt. Ltd., India approached AERB for obtaining the requisite regulatory clearances of Halcyon unit. AERB has carried out the safety review of documents pertaining to performance of the Halcyon unit and its type approval testing. The major difference that were observed compared to the other approved models of Varian make medical accelerator are (i) higher gantry speed (ii) dual layer of multileaf collimator (MLC) with higher leaf speed (iii) No tertiary collimator (secondary beam collimation system) iii single photon energy (6 MV Flattening Filter Free (FFF)) (iv) higher collimator rotation speed (v) no optical fields, (vi) no optical distance indicators (ODI), (vii) restricted field size (maximum 28 cm x28 cm), (vii) head design as a single block etc. As collimators are not accessible, the collimator angles were verified with help of portal imager. As no ODI was available, the SSD for the radiation field analyzer (RFA) was set using the portal imaging system. The complete acceptance tests were carried out. As the treatment planning system (TPS) for Halcyon unit is delivered with the preset factory data, the TPS data was also compared with the measured data for consistency.

Result and Discussion: It was observed that the gantry speed and the collimator speed of the Halcyon unit are found to be 24º per second and 14º per second which exceeds the limit prescribed by relevant IEC standards i. e 7º per second. The higher gantry speed was achievable due to the presence of magnetic tracks. On further analysis of the safety features available, it was found that the positional accuracy of the gantry and collimator are meeting the acceptable tolerances as per the IEC standards. The verification of collimators angles were performed by using the portal imager and found to be within 0.5º of the expected value. The accuracy off gantry angles was also found to be within 0.5º. For setting of the RFA, the image of the water tank taken at 84.3º gantry angle was found to be optimum. As relevant IEC standard values are not available for beam quality, PDD, surface dose value of 6 MV FFF, those measured values were accepted after judicious discussion in-line with the supplier protocol. Several tests such as matching of PDDs, profiles and off axis ratios etc., were suggested for inclusion in the acceptance test report. Due to the specific design of the head and MLC, the leakage radiation was found to significantly less in the unit.

Conclusion: Safety review of the radiotherapy equipment is essential in order to ensure the safety in radiotherapy**.** It is essential to ensure that advanced features available with the radiotherapy units are checked and accepted as per the applicable protocols and standards. New features of the Halcyon unit were tested as per applicable standards and manufacturers protocols were found acceptable.

PP-47

STABILITY ANALYZATION OF THE PHOTON AND HIGH ENERGY ELECTRON BEAM OF LINEAR ACCELERATOR USING DAILY QUICKCHECK DEVICE

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Introduction: Treatment delivery systems are capable of complex simultaneous motions which have led to increased quality assurance (QA) requirements. Multiple simultaneous motions along different axes increase flexibility in treatment delivery and can decrease the total time a patient is on a treatment table. These increasingly complex systems require new QA tests and procedures. AAPM Task Group 142 (TG 142) provides guidance tolerance values for individual components of linear accelerators based on the treatment delivery type [conformal, IMRT/volumetric modulated arc therapy (VMAT), SRS]. It is recommended that quality assurance (QA) of the beam energy of radiotherapy treatment machines is carried out at regular intervals, daily, weekly and monthly.

Purpose: The main purpose of the study was to assess the energy stability of a 6 and 15 MV Photon and 12 and 15MeV high energy electron beams in Varian Clinac-IX linear accelerator. The stability of the linear accelerator energy over a period of several months the results will be useful for estimation of the required tolerance values for the beam quality factor (BQF) of the PTW QUICKCHECK webline® daily checking device.

Materials and Methods: Multi-detector daily-checking devices are effective tools for performing quick and convenient quality assurance tests to determine several

useful quantities, e. g., central-axis radiation dose, penetrative quality, beam flatness and symmetry, wedge angle (fixed, dynamic) and field size of linear accelerators. The quick check setup for daily measurements on the Varian Clinac iX linear accelerator-the quick check consists of 13 air-vented ionization chambers. Readings of nine chambers are used for calculating the central-axis dose, flatness, wedge angle and symmetry. The QUICKCHECK also calculates a BQF as an energy index. Measuring the energy is carried out by the other four chambers, where the reading of one of these energy chambers is used for calculating the BQF.

Over a 6 month period of routine clinical service, 180 readings of BQF were taken and then analyzed for a 10×10 cm2 field for 6 and 15 MV photon and 12, 15 MeV high energy electron beams. The measurements were performed in the mornings immediately after the warm-up procedure, which is recommended by the linear accelerator manufacturer. As specified in the QUICKCHECK user manual, a 10×10 cm2 field size was used to obtain BQF values. The usual source-to-surface distance (SSD) was 97.3 cm fixed for QUICKCHECK setup.

Results: No decreasing or increasing trend in BQF was observed over the study period. The mean BQF value was estimated 5.954 and 14.970 for 6 and 15 MV photon. Similarly for 12 and 15MeV electron 11.982 and 14.983.

Conclusion: The conclusion of this stability study of the linear accelerator energy showed that 98% of the observed BQF values were within ±1% of the baseline value. This can be considered to be within the recommended tolerance for linear accelerator photon beam and high energy electron beam. As per the TG-142 suggest that the BQF tolerance may be upto 3%. In our hospital study for a period of six month, we found that the BQF with in ±2%.

PP-48

DOSIMETRIC ASSESSMENT OF RICE AS A TISSUE EQUIVALENT BOLUS MATERIAL AND COMPARED WITH SUPERFLAB AND SENFLAB

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Introduction: In radiation therapy, bolus is frequently used for treating uneven surfaces of a patient such as around the nose, hand, foot or ears, to make up for missing tissue or to provide build-up and thus elevate the dose to the skin surface. For filling the air cavities in treatment area the rice can be used. To our knowledge, the dosimetric properties of rice have not been documented with regard to physical density, mass density, electron density and attenuation.

Purpose: The main purpose of this study was to assess the dosimetric assessment and usefulness of readily available uncooked rice as a bolus material and compared with superflab and SENflab.

Materials and Methods: In order to analyze uncooked rice as a bolus, there are various varieties of rice available, we selected two types of rice's namely Ponni and Basmati. Ponni rice is a variety of rice developed by Tamilnadu Agricultural University in 1986. It is widely cultivated in Tamilnadu a state in India, and is a hybrid variety of taichung65 and myang Ebos 6080/2. Basmati is a variety long, slender-grained aromatic rice, which is traditionally from the Indian subcontinent. A uniform 15X15 cm2 rice bolus slab with a 1cm thickness was created for both the rice's. The rice bolus was used to measure the physical density, electron density, transmission factor and PDD compared with superflab (universally accepted bolus material) and SENflab (Indian Made). CT image of both the rice bolus were acquired to analyze the mass and electron density. Transmission factor of rices was obtained for 6, 15 MV high energy photons and 12,15,18 MeV high energy electron beams. Transmission factor of rice bolus was obtained using 0.6cc Farmer ionization chamber by measuring the dose (electric charge) with and without rice. Marcus parallel plate chamber was used for the PDD measurement in RW3 slab phantom.

Results and Discussion: The rice bolus physical properties, mass, electron density was obtain and compared with the superflab and SENflab. Both the rice bolus has the transmission factor of 0.97. Rice bolus has the transmission similar to the superflab and SENflab with less than 3%, 2.5% for both photon as well as electron beams. Rice bolus has the build-up(PDD) similar to the superflab and SENflab with less than 3%, 2.5% for both photon as well as electron beams.

Conclusion: Ponni rice bolus and Basmathi rice bolus can be used as bolus material for Radiotherapy. Rice is fairly inexpensive and easily available worldwide. If rice is used as a bolus material for radiotherapy, it is mandatory to verify dosimetrically the density, CT number, transmission, effect on surface dose and depth dose curve for the effective treatment delivery.

PP-49

DOSIMETRIC COMPARISON OF ION CHAMBER AND EPID IN DAILY OUTPUT CONSTANCY CHECK

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Introduction: A quality assurance (QA) is essential to guarantee quality and safety of patient treatment in radiotherapy department. The daily QA tests were very essential for all radiotherapy units like LINAC, Brachytherapy, etc. The daily QA tests include dosimetric, geometric, and safety issues. The monitoring of output constancy is one of the major test in daily QA for Linear Accelerator unit. There are several detectors can be used for measuring output constancy like Ion chambers, Diode detectors, Scintillators and EPID. The traditional way to measure output constancy by using cylindrical ion chamber. EPID is not only acquire treatment portal images for verification and also we can used for dosimetric QA purpose. In this study, investigate daily photon output constancy check with ion chamber and EPID in our LINAC unit and our result provide evidence to support that an aSi EPID can be a stable dosimeter for daily photon output constancy checks.

Purpose: In this study, we compared thedaily photon output constancy with 0.6cc ion chamber and EPID (Electronic Portal Imaging Device) in our LINAC unit (Varian, Unique Power).

Materials and Methods:

1. Electronic Portal Imaging Device (Varian, aSi-1000 amorphous silicon panel): In this study, daily output

constancy measurement were performed in varian unique power Linear Accelerator. Varian unique power unit havesingle 6MV photon energy with EPID aSi-1000. EPID effective measurement area was 40X30 cm2 and pixel size was 1024x768 with 0.39mm spatial resolution. The EPID was set at the distance of 105cm. We were placed a markers on both side of EPID cover for daily setup and repeatability of position accuracy. The field size opened at 10x10cm2. The EPID was irradiated with 100MU by a 6MV photon energy at a dose rate of 400MU/Min. The portal images were acquired every morning for 100 days. After acquisition of portal image, the portal dosimeter software reads in calibration unit (CU) values over an ROI of 2x2cm2 around the central axis and provide in cGy/MU 0.6cc Ionization Chamber (PTW):

2. We were measured the daily output constancy by using 0.6cc ion chamber (PTW, TM30013/8396) in our LINAC unit. The 0.6cc ion chamber were placed in solid phantom at the depth of 10 cm and the SSD was 100cm. The field size opened at 10x10cm2. The 0.6cc ion chamber were exposed daily with 100 MU at the dose rate of 400MU/Mins and output were calculated in cGy/MU. Both outputs were compared.

Result: In this dosimetric comparison study we measured daily output constancy with both 0.6cc ion chamber and EPID for 100 days. The output constancy for 0.6cc ion chamber ranges from 0.976 cGy/MU to 0.9990 cGy/MU and output constancy average is 0.987 cGy/MU. The output constancy in EPID ranges from 0.9786 cGy/MU to 1.0016 cGy/MU and average is 0.989 cGy/MU. The ion chamber and EPID outputs percentage deviation ranges from-1.621 to1.902.

Discussion: Now a days the EPID dosimeter replace the 0.6cc ion chamber and film dosimetry in quality assurance program in LINAC unit. In our study the daily output constancy vary only in the third decimal between ion chamber and EPID. It may be due to set up error. Both Ion Chamber and EPID daily outputs are within the tolerance limits (± 3% as per the AERB safety code AERB/RF-MED/SC-1(Rev1.1) and TG-40. The EPID reduce the physicist workload in daily QA and also reduce the set up error.

Conclusion: In this study that the use of EPID for daily output constancy measurements has the potential to become a viable and efficient tool for daily routine LINAC QA, thus eliminating weather Temperature & Pressure correction and human setup variability and increasing efficiency of the QA process.

PP-50

DEVELOPMENT OF FLUORESCENCE-BASED PATIENT ISOCENTER SETUP MARKER, FIELD CORNER MARKER AND RADIATION BOARDER MARKER FOR ACCURATE AND PRECISION PATIENT POSITIONING IN RADIOTHERAPY

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Introduction: The success of radiotherapy depends on the accuracy of patient setup for each fraction. A significant problem arises from reproducing the same patient position during treatment for every fraction of the treatment process. During a course of radiotherapy, skin markings play a key role in terms of the reproducibility of treatment setup and accuracy of treatment delivery. The protocols for skin markings vary according to different institutions' protocols. However the available marking devices and protocols lack accuracy and precision in positioning due to varied reasons. Hence there exists a need in the state of art to develop a novel field setup marker for accurate and precise patient positioning in Radiotherapy.

Purpose: The main purpose of this study was to indigenously develop novel fluorescence-based patient isocenter setup marker, Field corner marker and radiation boarder marker for accurate and precision patient positioning and compare with the regular patient marking in radiotherapy treatment.

Materials and Methods: The fluorescence-based patient isocenter setup marker, Field corner marker and radiation boarder marker was developed indigenously. The fluorescence-based field setup marker comprises of fluoreSEN patient centre marker, plurality of fluoreSEN patient filed corner marker, and plurality of fluoreSEN patient line marker. The size of the patient isocenter setup marker was 25mm circular with extra half circular provision for easy pickup. 1.2mm of cross lines were provided with the florescence material and the other areas were in dark colour. The size of the field corner marker was 15mm circular with extra half circular provision for easy pickup. 1.2mm of L shape lines were provided with the florescence material and the other areas were in dark colour. The size of the field border marker was 1.2mm width and 50mm length were provided with the florescence material and the other areas were in dark colour. The dark colour should not reflect the field light and the positioning cross line lasers, So the fluorescence helps to position precisely. These markers have a 1.5mm central axis hole to make a mark on the patient or over the mask, which will help to identify the original initial setup position in the case of knowingly or unknowingly removed the marker from the patient or mask.

Results and Discussion: This novel fluorescence-based marker addresses virtually all the shortcomings of traditional markers. These markers are highly visible on field light and the positioning cross line lasers due to the fluorescence material and help to facilitate a quick and accurate patient setup.

Conclusions: The precision of these markers are catching up to the repositioning of the radiation delivery with high precision, easily identifiable, save time, improve accuracy, provide a better patient comfort without any difficulty in patient setup and radiotherapy technologist satisfaction.

PP-51

REGULATORY AND RADIATION SAFETY ISSUES IN DIAGNOSTIC RADIOLOGY PRACTICE-TRAINING AND EDUCATION VIEW POINT

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Introduction: Diagnostic X-rays are the most widely used application of radiation in medicine. Number of existing X-ray

institutes/facilities worldwide are highest among all medical radiation facilities. Regulatory control in diagnostic radiology (DR) practice in India is a challenging task to the regulatory body. AERB, the national regulatory body has established framework for effective regulation of x-ray facilities which includes simplifications of regulatory requirements without compromising radiation safety using concept of graded approach, launching of e-licensing of Radiation Applications (e-LORA) in 2013 for DR practice, spreading of awareness on radiation safety and initiated special regulatory inspection for enforcement actions. This paper brings out the regulatory and radiation safety issues in DR Practice with respect to training & education of the personnel involving in this practice and the initiatives taken by Regulatory Body to address the same.

Radiation Safety and Regulatory Concern in DR practice: Radiation safety & regulatory concern in diagnostic X-ray practice can be discussed as follows:

1. **Radiation safety:** Radiation Safety in X-ray facility includesbuilt-in Safety andOperational Safety. Built-in safety for X-ray facility can be ensured by procuring type approved X-ray equipment and installation of X-ray equipment in a room with proper shielding. However, operational Safety is a combined responsibility of the employer, licensee and the operator. The employer and licensee need to ensure availability of protective accessories, periodic QA, personnel monitoring services and qualified operators in the facility where as following safe work practice is the responsibility of the RSO and operators. Radiation Safety can be ensured only when the facilities are in compliance with licensing requirements. Hence, strong motivation is appealed for spreading public awareness through periodic notices in newspapers and advertisements in health magazines regarding the licensing requirements. Enforcement actions are being taken against several DR facilities spread all over the country due to major regulatory non compliances during special regulatory inspection and till date several DR equipment have been either sealed or issued warning for seal by AERB
2. **Occupational exposures:** Even though dose limits are prescribed by AERB for occupational workers as 20 mSv average in a year. By analyzing the TLD dose records for the year 2014 of radiation workers in India, average annual dose was recorded as 0.3 mSv. It is also found that medical diagnostic x-ray facilities in India contribute significantly higher to the reported excessive exposures cases compared to facilities with high hazard potential. However, on investigation, it is found that most of these cases are non-genuine due to improper handling and inappropriate use and storage of TLD badge and/or undergoing medical examination wearing TLD badge. Hence, safety awareness in proper use of protective accessories and the TLD badges is essential to minimize the exposures in diagnostic radiology practice. AERB regularly circulates Radiation Safety Posters to all the registered radiation professionals and X-ray facilities for sensitizing towards radiation safety
3. Training and manpower requirements: Employer is responsible for appointing qualified staff for safe handling of diagnostic X-ray equipment including assigning the responsibility to a person for ensuring radiation safety in the institution with approval of regulatory body to discharge the role of Radiological Safety Officer (RSO). But, most of the time it is seen that the diagnostic X-ray equipment are being operated and serviced by persons without training and also have lack of adequate knowledge about radiation safety. Moreover, it is noted that several types of training courses for X-ray technologist/radiographers are being conducted by Institutions/Board/Universities in our country without adequate infrastructure such as non availability of adequate faculties, inadequate radiation equipments, QA gadgets, no specific entry level of candidates, no specific course duration and improper syllabus etc.

To address these issues, AERBhas established some mechanism which includes 1. Prescription of radiation safety syllabus for x-ray technologists/radiographers, 2. Harmonization in the training programs for radiographers in the country (Ministry of Health and Family Welfare, Government of India has brought out in March 2016, the national guidelines for education and career pathways of x-ray technologists/radiographers, with inputs from AERB addressing the minimum entry level qualifications, course curriculum and duration), 3. Assessing the training courses for x-ray technologists/radiographers conducted by various University/Institution/Board as per radiological safety view point, 4. Publishing training module for diagnostic X-ray facilities which is available in its website, and 5. Conducting awareness program on radiation safety & protection during regulatory inspection.

Conclusion: Appropriateeducation and training is very important aspects for performing the intending tasks of every individual. Radiation safety in the User's institution can be ensured by availability of trained personnel. It is also the responsibility of every safety professional to continuously enhance his/her knowledge and skills to keep abreast with the advancement in the field, with the aim as impressing the quality of services and care offered to patients. All the course conducting University/Institution/Board should adopt the above said national guidelines to ensure the uniformity in the courses for x-ray technologists/radiographers and should approach AERB to asses their course for recognition. There is always a need for active participation between professional bodies and AERB to address the regulatory & radiation safety issue of diagnostic X-ray facilities with respect to training & education aspects.

PP-52

WIRELESS ROBATIC PHANTOM FOR QUALITY ASSURANCE OF 4D GATED RADIATION THERAPY

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High precision Radiotherapy Technique such as Intensity Modulated Radiotherapy (IMRT) and Volumetric Arc Therapy (VMAT) requires accurate targeting of Tumour, however due to cardiac and respiratory motions, achieving precise targeting is ambiguous in cases of intra-thoracic tumours due to varying magnitude of displacement with respect to patient, respiratory pattern and size of the tumour. These displacement results in an increased treated volume and distribution of the dose

delivered does not match with the intended dose distribution. To evaluate the accuracy of radiation dose delivery during gated radiation therapy with the Varian Realtime Position Management (RPM) System using an in house developed wireless respiratory phantom.

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QUANTITATIVE ANALYSIS OF PLAN EVALUATION USING INDICES: COMPARISON OF HDR INTERSTITIAL BRACHYTHERAPY VERSUS IMRT AS A BOOST IN CARCINOMA BREAST

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Introduction: Combinations of external beam radiotherapy and interstitial or intracavitary brachytherapy have been effectively used in variety of clinically settings since the introduction of megavoltage beam therapy in the 1950s. Generally, Brachytherapy is used to administer high doses to unresected or residual primary tumor while external beam radiotherapy is used to deliver more modest doses to larger volumes of adjacent tissue.
Purpose: The Aim of the study is to Quantitative analysis of plan Evaluation using Indices and to Compare HDR Interstitial Brachytherapy with IMRT as a Boost in Carcinoma Breast.
Materials and Methods: Consecutive 8 patients were selected who underwent radiotherapy after breast-conserving surgery (BCS) in patients with early stage breast cancer. The brachytherapy boost was started on third post operative day of BCT followed by EBRT to whole breast of 50 Gy in 25 fractions. For all patients, a dynamic IMRT planning was carried out for Varian Clinac 2300 CD with Five fields in six MV photon beam using Varian Eclipse Treatment Planning system (V6.5) with the prescription of 15Gy/6 fraction. The interstitial brachytherapy treatment planning was done for all patients using Plato BPS Version 3.1.(Nucletron, The Netherlands) with same prescription. The dose Homogeneity Index (HI),Conformal Index(CI),COIN and External volume index were Calculated for both IMRT and Quantitative evaluation of the implant dosimetry.
Result: In IMRT, the average of the maximum and Minimum doses occurred in the PTV is 16.54±0.41 cGy and 13.43 ± 1.16 cGy respectively. The conformity index ranging from 0.9712±0.024, the heart dose is 9.37±5.97 Gy and 12.38±7.68 Gy for IMRT and HDR-IBT respectively. no significant difference has been found for the 10 Gy and 15 Gy lung volumes, the average COIN value was around 0.84, EI was calculated within 0.19 for IMRT and 0.08 for HDR-IBT.
Discussion and Conclusion: External IMRT plans produce highly conformal and uniform dose distributions. Similarly, HDR-IBT produces better conformal plans. Heart and lung doses were reduced with HDR-IBT. HDR-IBT plan was superior in target coverage than external IMRT plan. In addition, HDR-IBT can be performed in clinical situations with the less equipped or to the facilities less than ideal conditions.

PP-54

ARC PLANNING METHODOLOGIES FOR STEREOTACTIC RADIOSURGERY OF SCHWANNOMAS A DOSIMETRIC COMPARATIVE STUDY

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Purpose: Stereotactic Radiosurgery (SRS) is a procedure that involves the precise three-dimensional targeting of ionizing radiation to obliterate abnormal tissues such as vascular malformations, malignant or benign tumors. We treated schwannomas like Acoustic, Trigeminal, Vestibular, Glossopharyngeal (GP) for pain relief and while preserving the functionality of the adjacent brain tissue and normal Organs at Risk (OAR). This work represents the efficiency of stereotactic radiosurgery (SRS) in the management of schwannomas by volumetric modulated arc therapy using Rapid Arc (RA) in 6MV Flattening Filter Free (FFF) beams on the Truebeam STx platform during the years year 2012 to 2018.
Materials and Methods: We used Varian Eclipse (version 13.7) and Anisotropic Analytical Algorithm (AAA) treatment planning system (TPS) which allows planning in 6MV FFF beams for delivery on Truebeam STx linear accelerator equipped with HD 120 MLC. Brainlab Iplan (version 4.5) software allows fusion of DSA and MRI with planning CT. We evaluated 31 Schwannomas (Acoustic, Vestibular, Trigeminal, Glossopharyngeal [GP]) cases from our patient population who underwent Rapid Arc SRS treatment with partial and full arcs. Each RA Plans were generated with coverage of at least 95% to PTV. Normal tissue dose was evaluated by using the parameters Normal Brain 10cc, V5, V10, V12 and V20 in the cumulative dose-volume histogram for the following structures: Brainstem, Brain, Cochlea, Chiasm and Optic Nerves. Conformity Indices CI and Homogeneity Indices HI are evaluated to validate the plan quality.
Results and Discussion: Rapid arc (VMAT) plans had PTV coverage (D95%) of average 98.68% (S. D±1.03) of prescription dose. Homogeneity of dose distribution in target volume was an average of 0.09 (S. D±0.03). The conformity index evaluated was an average 1.09(S. D±0.03. The 10cc normal Brain received 89.47% (S. D±9.84) of the prescribed dose with Rapid arc plans. The greatest effect of RA FFF SRS Beams was the treatment delivery beam on time was reduced by 4 times compared with conventional conformal dynamic arc beam on time.
Conclusion: Linear accelerator based radiosurgery is promising treatment option for brain AVMs in majority of cases with reasonable adverse effect profile. Rapid Arc (VMAT) with FFF beams using partial or full arcs for the treatment of schwannomas provide improved target volume coverage, highly conformal and more homogeneous dose distribution in the PTV.

PP-56

VERIFICATION OF DOSE AT JUNCTION BETWEEN BREAST/CW AND SUPRACLAVICULAR FIELD DURING DIBH TREATMENT

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Aim: Verification of dose at junction between Breast/CW & SCF field during DIBH treatment.
Purpose: In DIBH treatment dose at junction is depended on the breathing of patient. As such uncertainties may be introduced due to improper breathing. We have to tried to a film based dose measurement at junction of fields treated by DIBH.
Materials and Methods: Breast patients requiring supraclavicular field(SCF) treatment were selected for this study. Patients were treated on Varian TrueBeam machine. For tracking the Patient breathing pattern Varian based RPM system was used, reflecting marker was placed at the sternum level on the patient body. proper immobilization devices is used to reproduce the patient positioning (same at the time simulation) for the treatment. We performed film based dose measurement for 10 breast cancer patients receiving radiotherapy to the Breast/CW and SCF region. Gafchromic EBT film (5cm * 10cm) was placed at the junction between upper boarder of Breast/CW & lower boarder of SCF field. The patients were treated with the film placed on the skin. EPSON perfection V800 scanner was used to scan the film to measure the profile. We performed the consecutive measurement for five days to find out the accuracy of the setup and reproducibility of breathing cycle.
Results: For 20% of the patients, the ratio of measured and calculated dose along the junction were greater than 1(i. e. overlapping between the junction fields). We observed that whenever breathing pattern was reproducible, the intended gap(i. e. 5mm was used) between the fields was maintained and was visible on the film. For patients who could not follow the instructions correctly the gap on the film seemed to reduce i. e. chances of overlapping occur. however upon further coaching these patients when they followed instructions the gap was maintained well.
Conclusion: Breast patients having SCF field can be safely treated with DIBH protocol provided patient breathing is reproducible. For patients who cannot follow the breathing instruction properly, should be coached and junction dose should be confirmed with in-vivo dosimetry method.

PP-57

EVALUATING AND IMPROVING PATIENT-SPECIFIC QA FOR IMRT BY USING INDIAN MADE MULTI-ROTATIONAL PHANTOM

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Purpose: The main purpose of this study was to increase confidence level in the clinical IMRT verification by Design and develop the new patient specific QA phantom which is able to measure the dose to the point in different regions in and outside of the target. And Verify the IMRT Treatment Plan by the comparing dose calculated in TPS and the dose measured in the thorax multi rotational phantom using semi-flexible chamber.
Materials and Methods: PMMA (Poly Methyl Methacrylic) water equivalent phantom was used in this study. Its density is 1.18 g/cm3. Semi-flexible chamber were used for measuring the point dose. This setup was scanned using a GE Light Speed 16 slice CT scanner. IMRT verification plans were generated by the Varian Eclipse treatment planning system (TPS) version 13.6. The measurement was carried out on Varian Clinac iX (Linear Accelerator). The Varian clinac iX linear Accelerator provides X-rays and Electron beams. It is 6 MV & 15 MV Linac. The multiple electron beam energies (6, 9, 12, 15, and 18) are available.
Result and Discussion: Our result demonstrates a strong correlation between the dose calculated in TPS and the dose measured in the phantom using semi-flexible chamber. The obtained results showed a good agreement between dose calculated in TPS and dose measured in the phantom. The percentage variation between dose calculated in TPS and dose measured in the phantom is less than 2% for most of the points and only two points showed less than 3% variation.
Conclusion: The results showed that the thorax rotational phantom can be used in patient specific QA measurements for IMRT. The percentage variation between dose calculated in TPS and dose measured in the phantom is less than 3% variation. Therefore we can use the thorax rotational QA phantom with semi-flexible chamber for IMRT patient Specific QA. The phantom is a very reliable tool for the fast and precise verification of IMRT fields. These tests have resulted in an understanding of the rotational phantom limitations and increased confidence in its use for clinical IMRT verification.

PP-58

DEVELOPMENT OF ARTIFACT FREE NON LEAD BASED NONMETALLIC CT BREAST SCAR MARKER

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Introduction: In Breast Radiotherapy CT marker wires are frequently used to identify the breast scar area for the accurate treatment. The placement of such markers is usually on the skin surface. CT marking wires should therefore exhibit the following features such as clear visibility, should not produce any artifacts and should be easy to use. Most commercially available CT marking wire are made of high-Z materials, which typically cause streaking artifacts, decreasing image quality of the subsequent reconstruction. In this work I have developed a new non metallic artifact free CT breast scar marking wire for Radiotherapy.
Purpose: The main purpose of this study was to indigenously develop artifact free non lead based non metallic breast CT scar marker for Radiotherapy.
Materials and Methods: Non lead based non metallic artifact free CT breast scar marking wire were developed using various combination of low atomic number materials. The materials are in the powder form which can be modifiable to versatile shape and size according to the needs. Lead based

CT scar marking wire and newly fabricated non metallic CT breast scar marker wire were used to evaluate the visibility of marker wire, CT number and artifact. Both the marker wire were placed in a 30x30x30cm3 sheets of solid phantom (SMART) and imaged on a Toshiba multi slice CT scanner for quality analysis. The phantom was scanned using the similar imaging parameters such as 2 to 3mm slice thickness, as commonly used in the simulation. For the visibility test I have done the CT scan topographic as well as in axial section. The CT artifact of marker were analysed using a J-image software.
Results and Discussion: On analyzing the CT scan of both the marker wire on phantom, it has been found that the newly fabricated CT breast scar marker wire has the equal visibility and almost no CT artifact when compared with the commercially available marker wire. The metallic marker wire produced bright streak artifact on the CT image but non metallic CT breast scar marker wire were not producing any streak artifact.
Conclusions: The newly fabricated breast scar marker wire density has nearly equal to human bone density so, it appears as bright spot on CT without streak artifact. To conclude that the newly fabricated CT breast scar marker wire will be an alternative to the existing commercially available marker wire with almost no artifact and also cost effective, which can be used for the clinical CT simulation for mainly breast scar marking without producing any metal streak artifact and also can be used all the other anatomical sites during CT scan for Radiotherapy purpose.

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A METHOD TO PREDICT ACHIEVABILITY OF CLINICAL OBJECTIVES IN IMRT

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Purpose: A data-driven method to predict the achievability of clinical objectives before performing the IMRT optimization is proposed.
Materials and Methods: In our approach, "Geometric Complexity (GC)" is computed to estimate the achievability of clinical objectives. Here, GC is the measure of the number of "unmodulated" beamlets or rays that intersect the Region-of-interest (ROI) and the target volume. The geometric complexity ratio (GCratio) between the GC of a region of interest (ROI) in a reference plan and the GC of the same ROI in a given plan is computed. The GCratio of a ROI indicates the relative geometric complexity of the ROI as compared to the same ROI in the reference plan. Hence, by using GCratio it is possible to predict the achievability of clinical objective associated with the ROI optimizer. Basically the likelihood for the optimizer to achieve the clinical objective defined for a given ROI is inversely proportional to GCratio. We have evaluated the proposed algorithm on six Head and Neck cases using Pinnacle3 (version 9.10.0) TPS.
Results and Discussion: Out of the total of 42 clinical objectives from six cases accounted in the study, 37 were in agreement with the prediction, which implies an agreement of about 88% between predicted and obtained results. The Pearson correlation test shows a positive correlation between predicted and obtained results (Correlation = 0.81, r2 = 0.66, $p < 0.005$).
Conclusion: The study demonstrates the feasibility of the proposed method in head and neck cases for predicting the achievability of clinical objectives with reasonable accuracy.

PP-60

DETERMINATION OF THE PHOTON BEAM ATTENUATION BY THE TREATMENT COUCH AND VARIOUS IMMOBILIZATION DEVICES

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Introduction: Light weight carbon fiber has been used in Radiation Therapy for making table tops because carbon fiber has high specific strength with high beam transmission when compared to other materials commonly used in Radiation Therapy. Despite the good characteristics of carbon fiber table tops, the beam attenuation is not accounted in treatment planning; this can be result in under dosage of the target volume. Beam absorption by the tabletop can also be significant thus increase in skin toxicity. Photon beam attenuation properties of carbon fiber couch inserts have been studied by several investigators. The studies are that the focus has mainly been performed with a range of energies, field size, gantry angles, and couch-tops.
Purpose: The gantry angle plays the major role in the attenuation because the pathway of beam increases when the gantry angle in posterior and posterior oblique. So the attenuation of the photon will be more in the posterior and posterior oblique fields. It can cause unacceptable shift in the dose distribution, which goes unnoticed in the treatment planning systems. The purpose of this study is to measure the attenuation of carbon fiber couch with different base plate, different gantry angles and different energies.
Materials and Methods: Elekta Synergy Platform Linear Accelerator which has 4MV,6MV & 15MV and iBeam Evo Carbon fiber couch used for this study. Independent dosimetric studies were carried out to evaluate attenuation due to couch, couch along with carbon fiber base plate, couch along with Acrylic base plate and couch along with base plate and vacuum cushion. Dose measurements were carried out with A12 (Exradin) ionization chamber with Max 1000 Electrometer. And all dose measurements were carried out with different gantry angles with range of 300 each, for all three energies (4 MV, 6 MV & 15 MV) and for the field sizes of 5x5cm2 and 10x10cm2.
Results: The ionization chamber with build-up cap was placed at isocenter in air to measure charge without couch. Readings were taken at gantry angles from 00 to 3600 of 300 intervals. Attenuation due to couch (Carbon fiber couch) alone was studied. Attenuation was high at gantry angles from 120 Degree to 240 Degree, with maximum value at gantry angle of 180 Degree.
Measurements were also done for following setups:
- Carbon fiber couch + Carbon fiber base plate
- Carbon fiber couch + Acrylic base plate
- Carbon fiber couch + Vacuum Cushion.

In all these case, attenuation was high at posterior gantry angles, with maximum value at gantry angle of 180 Degree. The results for all photons beams are tabulated and plotted the graphs for all results.
Discussion and Conclusion: It has been concluded that the gantry angle plays the major role in the attenuation because the pathway of beam increases when the gantry angle in posterior (1800) and posterior oblique (120 Degree, 150 Degree, 210 Degree, 240 Degree). In posterior oblique field the thickness of the medium increases. So due to back scatter factor more charges are collected. Thus, couch attenuation correction factor needs to be taken into account.

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AN EMPIRICAL METHOD FOR SELECTING BEAM GEOMETRIES IN IMRT

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Purpose: The purpose of this study is to introduce a simple and practical algorithm for selecting beam angles in IMRT.
Materials and Methods: In the recent past, different beam angle ranking techniques have been proposed for fast selection of beam angles in IMRT. These methods use some metric to evaluate the value of a given beam direction. The metric is evaluated for each beam of a set of candidate orientations and the top ranking orientations are used for final optimization. This approach is significantly faster than the other exhaustive search approaches. However, such ranking techniques ignore the interplay effects between the beams. In addition, the ranking function is different from the cost function used for the final plan optimization, which could result in a sub-optimal plan. We are proposing a novel beam angle algorithm that uses the cost function for ranking the candidate beams. As a prerequisite to our ranking approach, a first optimization is performed with the user defined candidate beams (say 20 beams). Subsequently, the top ranked candidate beams are retained while the other beams are removed from the plan, with which a final optimization is performed. An important advantage in our approach is that the interplay effects between the beams is incorporated in our ranking making it more accurate than the other ranking approaches. In this work, we used Pinnacle3 Auto plan to perform optimization. To study the efficacy of the algorithm, it has been applied to one simulated phantom case and three clinical cases: Abdomen, Prostate, and Lung case. Basically, two set of plans were created. In the first set, the beam angles were defined using conventional logic (equiangular beams). In the second set, the beam angles were decided using the proposed algorithm. In both plans, we did optimization using same Objectives (Clinical Goals).
Results and Discussion: We compared the dosimetric parameters of the plans that employ the proposed algorithm with the corresponding plans that employ equiangular beams. On the average, about 16% and 5% reduction in the mean dose and maximum dose (respectively) to OARs is observed in the plans employing the beam angle selection algorithm with equal target coverage, conformity and uniformity as compared to the plans employing the equiangular beam geometries.
Conclusion: It is evident from the study that the proposed algorithm can be effectively applied to IMRT to get fast and case specific beam geometries.

PP-62

CONFIGURATION OF SMALL FIELDS BY USING THREE DIFFERENT DETECTORS AND COMPARISON WITH GOLDEN BEAM DATA AND DOSIMETRIC VALIDATION

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Purpose: To configure the beam algorithm in treatment planningsystem (TPS) for small fields by using 0.125cc, pinpoint chamber(PP), EBT3 gafchromic film and its comparison with Varian medical systems (VMS) beam data and validate the beam models dosimetrically in clinical cases.
Materials and Methods: Anisotropic analytical algorithm needs beam profiles (BP), percentage depth doses (PDD), output factors (OF) and absolute dose at calibration depth for modelling the beam in Eclipse (VMS Ver 11). BP, PDD and output factors were measured for 6MV by using 0.125cc and pinpoint chamber from the field size (F.S) of 1 x 1 cm2 to 40 x 40 cm2. OFs were measured by using 0.125cc (For F.S 2 x 2 cm2 to 40 x 40 cm2), pinpoint chamber (For F.S 1 x 1 cm2 to 40 x 40 cm2) and EBT3 gaffchromic film (For F.S 0.5 x 0.5 cm2 to 30 x 30 cm2). Separate beam modelling was done with individual detector measured data and Varian golden beam data (VBD) in Eclipse. Modeled and deduced beam parameters from these beam configurations were compared. Beam spectrum (BS), intensity profile (IP), mean radial energy (MRE), electron contamination (EC), collimator back scatter factor (CBSF) and secondary source parameters were compared between above mentioned beam models. For dosimetric validation, metastatic brain case with single lesion of volume 0.4cc and 5 lesions of total volume 6.37cc was planned. For IMRT and VMAT plans dose calculation were performed by using each model and compared. Dose volume histogram (DVH) was compared. Patient specific quality assurance was performed by using EBT film and gamma evaluation was done.
Results and Discussion: Difference in output factors were observed between the detectors. Difference in secondary source size was 8.35 mm (PP vs. 0.125cc), 4.31 mm (PP vs. EBT3) and 0.01 mm (PP vs. VBD). No difference in beam spectrum was observed. Modelling the flattening filter, calculated MRE was compared between the models. IP over medial to lateral direction was plotted for four beam models and difference were calculated. Calculated CBSF was compared). Dose difference between above beam models were calculated in mid uniform dose region and it was 0.73% (PP vs. 0.125cc), 2.12% (PP vs. EBT), 1.06 (PP Vs VBD) for single metastatic lesion IMRT plan and in VMAT the dose

difference were 1.47% (PP vs. 0.125cc), 0.155% (PP vs. EBT), 0.92 (PP Vs VBD). For 5 lesion case, the dose difference were 2.51% (PP vs. 0.125cc), 1.14% (PP vs. EBT), 0.81% (PP Vs VBD) and 1.92 (PP vs. 0.125cc), 0.71 (PP vs. EBT), 1.2% (PP Vs VBD for IMRT and VMAT respectively. Comparison of 2 dimensional dose analysis, beam profiles and DVHs shows the significant variation in the dose gradient regions.

Conclusion: Active measuring volume of the detector is crucial for modelling the small filed. In our study, the smaller volume chamber and EBT 3 film bema model can provide the adequate accuracy for dose calculation. When EBT 3 film is used for modelling and patient specific QA, consideration to be given for scanner resolution, sensitivity over the area, irradiation time and scanning time.

PP-63

CLINICAL IMPLEMENTATION OF TOTAL BODY IRRADIATION WITH MULTI ISOCENTRIC VOLUMETRIC MODULATED ARC

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Introduction: Total Body irradiation (TBI) is conditioning regimen in conjunction with chemotherapy before Bone Marrow Transplant (BMT) for a patient with hematological malignancies. TBI kills malignant cells and suppresses the immune system which helps to prevent transplant rejection. Various dose and fractionation schemes were used in the past treatments but in general dose fractionation schemes for TBI is 12-15 Gy given in 6-12 fractions over 3-6 days. Several publications reported various treatment techniques such as left and right side treatment with sitting patient on chair, AP-PA technique with extended SSD, Translational technique and sweeping beam technique with column mounted Linac. All these techniques required dedicated equipments & accessories for treatment, shielding materials for critical OARS and larger size room which is not feasible in regular linear accelerator. In recent years publications reported that Helical Tomotherapy was implemented the TBI treatment as an approach of reducing dose to critical organs especially lungs.

Purpose: The purpose of this paper is to implement the Total Body Irradiation (TBI) clinically feasible with purely on multiple Iso-centric VMAT technique with the help of SBRT Multi-board Base plate used as rotating pivot technique.

Materials and Methods: A Patient of 15 year old boy was reported and admitted for the TBI treatment in our hospital before going for the BMT. Immobilization was done for the patient with the help of thermoplastic mask of 5 clamps for head and shoulders, 4 clamps for pelvis and vaclocs for the extremities. Whole body splitted into two set of CT scans, one with head first supine position from base of skull to mid thigh and second one with feet first supine from feet to mid pelvis. Reference marker placed on mid thigh for dose coverage junction for both scans. SBRT Multi board base plate from Macro Medics used as rotated pivot technique can rotate the patient without disturbing the setup for feet first scan. Whole body is prescribed as CTV excluding lung and kidneys with 12Gy in 6 fractions over 3 days (2 fractions per day). PTV generated with margin of 5 mm from CTV. Treatment planning performed using VMAT (Rapid Arc) technique in Eclipse 13.7 TPS from Varian Medical systems. Treatment planning consisted of totally 9 isocenters, 5 isocentre in head and neck, chest and pelvis with 10 arcs of 21480 angle and 4 isocentres in left and right legs with 4 half arcs of 7160 arc angle. The best treatment plan was performed with 6 MV photon beam to ensure 95% CTV dose coverage with the prescription dose and mean dose to lungs and kidneys were restricted to 10.5 Gy. Lens reduced to 6 Gy. Treatment executed with Vital Beam Linear accelerator with OBI, CBCT used as Image Guided Radiation Therapy (IGRT) for each VMAT delivery. Quality assurance performed with IBA iMatrixx Evolution with Miniphantom and Point dose measurement done with slab phantom and CC13 ion chamber followed by in vivo dosimetry via OSLD nano dots on the patient while on treatment.

Results: The time required for contouring and planning was 15-20 hrs and quality assurance took 4-5 -hrs. CTV coverage of 95% achieved with VMAT technique with reduced OAR doses of lungs and kidneys to 10.5 Gy and lens restricted to 6 Gy. The couch time for treatment on day one was 2.5 hrs including setup and mounting of OSLD chips and irradiation. Further fraction reduced to 1.5 hrs & actual beam on time was 550 s. Three CBCT performed for head first with setup error of ±0.5 mm and two CBCT scans performed for feet first with setup error of ±0.3 mm. The Gamma analysis of 3%/3 mm of all isocentres passed more than 95% with tolerance dose of 10%. Point doses between calculated and measured dose resulted ±2% deviation. OSLD dosimeter readings showed the results of ±5% deviation from prescription dose of 2.0 Gy.

Discussion and Conclusion: Volumetric Modulated Arc Therapy (VMAT) provides the benefit of satisfactory dose distribution within PTV and reducing the dose to the OARs. Moreover VMAT guarantees a homogenous dose to the total body and allows 3D conformal high Precision radiotherapy treatment.

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FIRST CLINICAL EXPERIENCE WITH IMAGE GUIDED RADIATION THERAPY ON SOUTH EAST ASIA'S FIRST HALCYON LINEAR ACCELERATOR: AN INNOVATIVE RING MOUNTED LINEAR ACCELERATOR

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Introduction: Halcyon is an innovative new ring mounted linear accelerator designed by Varian Medical Systems, USA. South East Asia's First Halcyon was Installed, Acceptance Tested, Type Approved and Licensed for patient treatment at Sterling Cancer Hospitals, Rajkot. The machine has a new design with no optical field light or Optical distance indicator. The machine has a bore laser fitted which are not on the plane of isocentre. The ring design has a one meter bore in the centre to position the patient. All these features make the setup of the patient different from that of a conventional

linear accelerator. The setup and treatment of the patient is extremely simple and fast in the Halcon Linac.

Materials: Varian Halcyon linac is a ring mounted linear accelerator with a single energy of 6MV Flattened Filter Free photon delivered at 800 MU/min dose rate at 1 m Source to Axis Distance (SAD). Halcyon has a 28 cm x 28 cm field size defined by a new innovative dual layer MLC (Multileaf Collimator). There are 28 pairs on the distal and 29 pairs in the proximal layers with the proximal layer aligned with an offset of 5 mm to cover the inter-leaf gap of the distal layer. Each leaf has a width of 1 cm at isocentre and a full overtravel distance of 14 cm. With the proximal layer also participating in the fluence creation, the treatment plan is created with an effective 5 mm resolution. The Varian Eclipse Treatment Planning System is the only planning systems for Halcyon treatment planning. The interface for planning is same as that of other conventional linac and hence has a fast user adaptability. The calculation algorithm supported is only AAA (Analytical Anisotropic Algorithm) and for optimization PO (Photon Optimizer) only. Even the intermediate dose and the portal dose predictions use the AAA algorithm for calculation. In this study, the experience of patient simulation, setup, treatment and quality assurance is detailed.

Methods: The CT Simulation was performed using Siemens Go Up CT Simulator with Gammex Blue Moving lasers. The immobilization of the patient was done using the same setup as done for a conventional linear accelerator treatment. The Contouring and Planning was done in Somavision and Eclipse Planning Systems. After planning, the patient specific QA was done using SunNuclear ArcCheck.

Discussion: The treatment plans quality was very much comparable with the quality of conventional linear accelerators. All the treatment plans were clinically acceptable as per international protocols. Even with a 1 cm resolution plans, the organ doses were comparable with high resolution MLCs. With the proximal leaves moving into the field, superior quality plans were generated with far better conformity than with only the distal leaves creating fluence. This confirms with the proposition than plans are created with 5 mm effective resolution. When comparing RapidArc plans, the monitor units were comparatively more in Halcyon but the integral body dose was comparable. The plan delivery is very fast due to the four RPM gantry rotation and 5 cm/sec MLC speed. Also, collimator rotation is also faster and hence multiple beams with different collimator angles are also delivered fast.

Conclusion: Halcyon is capable of delivering high quality treatment plans with its novel design and innovative MLC. With the mandate of daily QA checks and imaging for each and every fraction, the superiority of the treatment delivery is assured on each fraction. The inclusion of imaging dose into the plan ensures the safety of the patient.

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COMPARISON OF AUTOMATIC AND POINT REGISTRATION TECHNIQUES FOR BRAIN TUMOURS

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Introduction: Correct determination of tumor localization and extension is of major importance in radiation oncology. This is especially true from the perspective of modern radiation treatment techniques such as inverse planning and intensity-modulated radiotherapy. The precise delineation of gross tumor volume is one of the quality assurance aspects that have to be dealt with when applying these techniques. For brain cases imaging techniques such as computed tomography (CT) and magnetic resonance (MR) imaging provide specific and essential information. Correct interpretation of this information requires an accurate image registration, so that they can be used for delineation of targets.

Purpose: This paper describes the implementation of point registration method and compared it with automated registration procedure for treatment planning of brain tumors.

Materials and Methods: Fifteen patients with various brain tumors was taken retrospectively for this study who had computed tomography (CT) and magnetic resonance (MR) imaging before the start of radiotherapy. We analysed the two registration methods available in our Monaco contouring workstation on these image sets. Automatic Registration was done by mutual information (MI) method where software automatically aligns the image sets and gives numeric MI value which convey the extent of matching. Another registration method called point registration displays CT and MR images as blended view on the screen and needs atleast three pair of points as input for both image sets. We identified at least five non coplanar pairs of matching (conjugate) anatomical landmarks points within the two image sets, such as the Superior border of frontal sinus, fornix, left and right mandibular head, superior border of clivus bone. Alternating between the two images sets, we will mark landmark points. The software links these points together with lowest possible root mean square error among them for best fusion. The translation shifts along x; y and z axes and the time taken for registration were noted and compared for both the registration techniques.

Results and Discussion: The Absolute mean coordinate differences between automatic and point registration along x, y and z axis were 0.08 cm, 0.22 cm and 0.16 respectively with standard deviation less than 0.2 cm in all axes. The absolute mean of the rotational difference in x, y and z axis were 2.5°, 0.95° and 1.23° with maximum standard deviation of 3.12 in x axis. There are larger differences in rotational axes.

Conclusion: Automatic and point registration methods can provide comparable registration as evaluated by the coordinate differences between the shifts obtained in both methods. But more time and human intervention is required for the point registration method. Further studies needed to be be carried for the effect on target volumes.

PP-66

AN EFFECTIVE DEEP-INSPIRATION BREATH-HOLD RADIOTHERAPY TECHNIQUE FOR THORAXIC OESOPHAGEAL CANCERS

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Purpose: Thoraxic oesophageal cancer being highly morbid and mortal led us a challenge in developing and applying the accurate and safe delivery of radiotherapy. We prospectively evaluated a novel deep-inspiration breath-hold (DIBH) screening and delivery technique to spare & optimize organs at Risk (OAR). The impact of set-up and dose variables upon (OAR) dose in DIBH RT was investigated.

Materials and Methods: All patients with thoracic oesophageal malignancies referred between 2015 and 2018 of all disease stages, set-up variations, and dose prescriptions were included. We used simple screening criteria at CT simulation, to systematically assess patients for obvious DIBH benefit and capability. The study was performed on a Truebeam STx system, which is equipped with Varian Real-time Position Management (RPM) system (Version 1.7). Five oesophageal malignancies patients were immobilized in supine position with All in one (AIO) Systems from Orfit Industries. 2.5 mm slice thickness of FB & DIBH CT scans were taken on a GE Discovery 16 Slice PET CT scanner. Contouring was done on both FB and DIBH CT Scans Selected patients received Intensity-modulated RT (IMRT), Rapid Arc (RA)/Volumetric Modulated Arc Therapy (VMAT) based on a DIBH CT scan. A 3D-surface monitoring system with visual feedback assured reproducible DIBH positioning during gated radiation delivery. Patient, target set-up, and OAR dose information were collected at treatment. Target volumes for primary lesions (54 & 60 Gy) and electively treated regions (45& 50 Gy) were contoured. OAR such as heart, lungs, spinal cord, liver and kidneys were evaluated. Every patient had 2 dose-plans, one with DIBH CT and other with FB CT with IMRT/ VMAT techniques. For each technique, we evaluate the coverage target, homogeneity index of PTV (HI), conformity index (CI), monitor units and DVH metrics of lungs, heart and spinal cord.

Results and Discussion: DIBH IMRT/VMAT plans reduced total lung volume treated above 20 Gy (V20) and mean lung dose (MLD), but volume treated above 5 Gy (V5) was higher in both DIBH & FB CT. Gated IMRT/VMAT plans improved total heart volume treated above 20 Gy and 40 Gy (V20, V40) and maximum dose to cord. HI and CI were evaluated. Coverage target was very high with both schemes. Statistical differences were observed in DIBH & FB CT plans.

Conclusion: Our results suggest that gated IMRT/VMAT for radical treatment of oesophageal cancer is useful for decreasing dose in organs at risk and with high conformity and homogeneity of the target. Nevertheless, VMAT/IMRT increases low-doses in lung and this may contribute increase pulmonary complications.

PP-67

STUDY THE QUALITY ASSURANCE TESTS IN MOBILE C-ARM FLUOROSCOPY SYSTEMS USING NOMEX MULTIMETER

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Introduction: Fluoroscopy was the first real-time imaging equipment which imaged the motion organ of the human body in a lively manner. Later comes the c-arm innovation which made the work easier. Mobile C-arm is a compact unit designed for real-time imaging which is used in the operating room, emergency departments, physicians' offices, and in some cases healthcare facility. C-arm is a smaller size, simplicity of use and lower cost. It is very important that quality assurance to be carried out because the exposure time is comparatively more than that of normal X-ray imaging exposure.

Purpose: To perform quality assurance (QA) tests as per the Atomic Energy Regulatory Board (AERB) regulation in mobile C-arm fluoroscopy systems. The QA tests include beam alignment, focal spot size, accuracy of tube voltage and tube current, half value layer (HVL) assessment, total filtration (TF), output consistency, image intensifier tube (IIT) assessment and tube housing leakage radiation.

Materials and Methods: The instruments used for QA study includes Multimobil 5E (Siemens Medical Systems, Germany), PTW-NOMEX multimeter (PTW-FREIBURG, Germany), low and high contrast pattern and pressurized ionization chamber based fluke survey meter. The AERB safety code no. AERB/RF-MED/SC-3 (Rev. 2) was followed for the measurement of all tests in this study. The beam alignment test tool and focal spot pattern were kept above the IIT one by one for central beam alignment and focal spot size measurement. The multimeter was properly connected to laptop and detector sensitive area position within the X-ray beam at 50 cm. The accuracy of tube voltage was verified between 60 kVp to 90 kVp at 10 kVp intervals except for 80 kVp (Siemens vendor only have 81 kVp option). The linearity of mAs was verified at 10 mAs, 20 mAs, and 50 mAs. The measurement of HVL and TF was done using aluminium filters for the operating parameter of tube voltage 81 kVp tube current 20 mAs. The low and high contrast pattern was fixed into IIT, we have noted diameter of the smallest size hole and bar strips line clearly seen on the monitor. The radiation protection survey of tube housing leakage was measured at 100 cm distance from the focal spot after blocking the exposure.

Results: From this study, we noticed that titled central beam alignment is 0.5°. The effective focal spot size observed 1.5 mm X 1.5 mm on the monitor. An x-ray tube kVp accuracy error is 61.95±1.95 for 60 kVp, 71.63±1.63 for 70 kVp, 82.51±1.51 for 81 kVp and 93.02±3.02 for 90 kVp. The mAs linearity was measured and the coefficient of linearity value is 0.0185. In output consistency, the COV values are 0.0023 for 60 kVp, 0.0022 for 70 kVp, 0.0028 for 81 kVp, 0.0001 for 90 kVp. HVL value is 4.27 mm of Al and TF value is 6.4 mm of Al. The diameter of the low contrast is 3 mm and the resolution of bar strips frequency is 0.8 lp/mm. The patient table top exposure is 2.03 mR/min at 90 kVp and 10 mAs. The X-ray tube housing leakage radiation is 1.44 mR in one hour.

Discussion: The measured value of beam alignment is within the acceptance limit of 1.5°. The kVp acceptance is done by varying the operating voltage the differences is well within the permissible limit of ± 5%. Likewise, all the QA tests values are within the permissible limit.

Conclusion: The C-arm equipment for which QA test performed was in safe working condition since all the values are in good agreement with the AERB recommendation.

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COST EFFECTIVENESS OF SILVER NANOPARTICLE OVER GOLD NANOPARTICLE IN NANO-PARTICLE AIDED RADIOTHERAPY

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Introduction: The prime aim of radiotherapy is to deliver adequate dose to tumor tissue while sparing surrounding normal tissue and the organ at risks. One of the major problems associated with these techniques is the lack of selectivity between the tumor and the surrounding healthy tissue, thus the performance is limited by the tolerance dose of normal tissues and organ at risks. The tumour region can be made radio-sensitive with the infusion of nanoparticles (NPs) which will improve the therapeutic benefit by selectively differentiating tumor and healthy region. The gold NPs are used as radio-sensitizer due to its high atomic number, bio-compatibility and it is well explored for its suitability in dose enhancement. Presently silver NPs are also being explored in radio sensitization like other high Z materials. The cost of silver NPs is almost 10 times less than the gold NPs.

Purpose: The prime aim of this study was to calculate the dose enhancement factor in the tumor with gold and silver NPs for mono-energetic photons having energy above the absorption edge energy of both NPs using analytical as well as Monte Carlo method and to compare the cost effectiveness of both NPs in order to achieve the same level of dose enhancement.

Material and Methods:

DEF (Analytical Method): The dose enhancement factor (DEF) which is defined as the ratio of the dose absorbed in the tumor region with the infusion of NP to the dose absorbed in the tumor without NP is calculated as,

$$DEF = \frac{\left\{ w_{NP} * (\mu en/\rho)_E^{NP} \right\} + (1 - w_{NP}) * \left\{ (\mu en/\rho)_E^{tissue} \right\}}{\left\{ (\mu en/\rho)_E^{tissue} \right\}} \quad (1)$$

where the $\left(\frac{\mu_{en}}{\rho}\right)^{\text{tissue}}$ and $\left(\frac{\mu_{en}}{\rho}\right)^{\text{NP}}$ are the mass energy absorption coefficients of tissue and the NP respectively; w_{NP} and (1- w_{NP}) are the fraction by weight of NPs in the tissue and the fraction by weight of the tissue respectively. The DEF were calculated at concentration levels of 7mg NPs per gram of tumor with mono-energetic photons ranging from 20 KeV to 500 KeV for both gold and silver NPs.

DEF (Monte Carlo Method):

The material composition of the tumour and normal tissue was assumed to be the same having 10.1% Hydrogen, 11.1% Carbon, 2.6% Nitrogen and 76.2% Oxygen. Only difference in the tumour and tissue is that the composition and density of the tumour were altered by varying the concentration levels of NPs inside the tumour. The EGSnrc/DosRZnrc Monte Carlo Code was used to estimate the DEF. The mono-energetic photons with energy 50 and 100 keV were used for calculation and 10^9 particle histories were simulated.

Result: The DEF of gold and silver NP inside the tumor region for photon of energy 50 keV was found to be 2.07 and 2.06 respectively using analytical method whereas with Monte Carlo method it was 2.13±0.008 and 2.10±0.008 respectively. For photon of energy 100 keV, DEF of gold and silver NP inside the tumor using analytical method was found to be 1.57 and 1.31 respectively while with Monte Carlo method it was 1.63±0.006 and 1.40±0.005 respectively.

Discussion: The result demonstrates that, for the same concentration of gold and silver NPs inside the tumour region, it is possible to achieve the same level of dose enhancement when the treatment is given via photon of energy 50 keV. It was also noticed that the dose enhancement is almost similar for the photon energies ranging from 50-75 keV.

Conclusion: The study shows that optimum energy in order to achieve the similar level of dose enhancement with silver and gold NPs is found to be around 50 keV which indicates that, the silver NPs in place of gold NPs can be used as a cost effective option without compromising the clinical outcome.

PP-69

EVALUATION OF VOLUMETRIC MODULATED ARC THERAPY FOR THE CARCINOMA OF LUNG

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Introduction: In patients with locally advanced non metastatic carcinoma of lung with large Planning Target Volume (PTV) eligible for radical radiotherapy, meeting dose constraints for organ at risks (OAR) with Three Dimensional Conformal Radiotherapy Therapy (3DCRT) is not possible and in these patients VMAT is necessary to achieve this.

Purpose: The main goal of the study is to analyse the dosimetric parameters of radiotherapy planning with reference to International Commission on Radiation Units and Measurements (ICRU 83) for carcinoma of lung treated using Volumetric Modulated Arc Therapy (VMAT) on Varian Eclipse Treatment Planning Systems (TPS) version 15.1.

Materials and Methods: Thirty patients of Lung Cancer with Median Volume of (PTV) 784.71 cc were planned using the technique VMAT, in the Eclipse version 15.1 Anisotropic Analytical Algorithm (AAA). These plans were evaluated using dosimetric parameters Conformity Index (CI), Homogeneity Index (HI) as recommended in (ICRU 83).

Results: The median CI and HI for the VMAT plans were 0.89, 0.11 respectively. The Median Mean lung doses (MLD) was 15.84 Gy. Lung Median V20Gy, V10Gy, V5Gy were 29.88%, 46.6%, 64.74%. Heart Median V30Gy was 25.54%. Heart Median Mean doses was 18.13 Gy. Spinal Canal PRV Median Max Doses were 43.84 Gy. Esophagus Median Max dose were 60.36 Gy. Esophagus Median V15Gy was 52.76%.

Discussion and Conclusion: Even though We could achieve the good values in dosimetric parameters like CI, HI for the PTV Coverage normal tissues constraints for the lesser PTV volumes in the Field-in-Field Plans, VMAT plans seems to be better when the PTV volumes were larger and if were very much close to the Spinal Cord and concavity nature. VMAT enables delivery of radical doses of radiotherapy even in

patients with very large PTVs where dose constraints could not be met with 3DCRT.

PP-70

MEASUREMENT OF DEPTH DOSE IN MAMMOGRAPHY UNIT USING MOSFET

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Introduction: The Metal Oxide Semiconductor Field Effect Transistor (MOSFET) dosimeter has been studied in the past for organ dose measurements and effective dose evaluation in the mammography unit. The depth dose measurements are required to determine the dose absorbed by females while performing Mammography examination.
Purpose: To measure the depth dose in a homogeneous Mammography polymethyl methacrylate (PMMA) phantom using MOSFET dosimeter.
Materials and Methods: We have fabricated a mammography slab phantom which consists of 25 slabs of PMMA, each slab has 2 mm thickness. The total thickness of the phantom was 5 cm when comprising the slab. The phantom was placed between the cassette holder and compression paddle of the Sophie Classic S (Planmed Oy) mammography unit. The portable MOSFET dosimeter (TN-RD-91, Best Medical Canada) S1 & S2 (TN-502RD-H) probes were placed on the phantom at 1 cm gap and horizontally 3 cm interval was marked. The operating parameters of 30 kVp and 90 mAs were set for Mo/Mo combination of Target/filter to measure the depth dose.
Results and Discussion: From this study, it is inferred that the average dose on the surface of the PMMA phantom is 9.16 mGy, 7.21 mGy at 1 cm depth dose, 3.51 mGy at 2 cm depth dose, 0.88mGy at 3 cm depth dose and 0.26mGy at 4 cm depth. AGD limit of 3 mGy.
Conclusion: The depth dose varied at the different location of the breast is well within the American College of Radiology (ACR) recommendation.

PP-71

DOSIMETRIC STUDY OF COPLANAR AND NON-COPLANAR INTENSITY MODULATED RADIOTHERAPY AND VOLUMETRIC MODULATED ARC THERAPY TREATMENT TECHNIQUES USING FLAT AND UNFLAT BEAMS FOR GLIOMA

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Introduction: There are groups of patients with high-grade brain tumors that can now be identified with prolonged survival. As survival outcomes improves, Intensity Modulated Radiotherapy Techniques are used to minimize treatment related long term toxicities and to improve therapeutic ratios.
Purpose: The aim of the study was to compare coplanar and non-coplanar Intensity Modulated Radiotherapy (IMRT) and Volumetric Modulated Arc Therapy Treatment Techniques (VMAT) using Flat and unflat beams for Glioma.
Materials and Methods: Five patients were chosen and Patients were immobilized with a thermoplastic mask in the supine position followed by computed tomography (CT) scanning. A consensus set of contours were generated for target and OARs. The prescribed dose was 60 Gy in 30 fractions. The treatment plans were created using the Eclipse TPS version 15.5 which employs Acuros XB algorithm. The plans were generated using the following techniques: Coplanar IMRT (IMRT C), Non-coplanar IMRT (IMRT NC), both using Flat and Unflat beams (FFF IMRT C, FFF IMRT NC), Coplanar VMAT (RA C), Non-coplanar VMAT (RA NC), both using Flat and unflat beams (FFF RA C and FFF RA NC).
Results and Discussion: All the eight radiotherapy treatment techniques were compared using various dosimetric parameters. The mean PTV dose averaged for all techniques were 5987.425cGy with a standard deviation of 53.8387.
IMRT demonstrated more improved sparing of Ipsilateral and Contralateral optic nerve (difference of 55.145cGy and 146.08 cGy respectively) compared to rapid arc techniques. There is an increased sparing of Ipsilateral eye and lens, Contralateral eye and lens doses in rapid arc techniques. There is no significant variation in the case of Brain stem, Optic chiasm and the volume receiving 35Gy in brain excluding PTV (Brain – PTV). There is no significant variation in the case of flat and unflat beams for brain stem, Ipsilateral and Contralateral lens doses, unflat beams shows an improved variation in the case of both optic nerve doses (Ipsilateral optic nerve: difference of 32.775cGy and Contralateral optic nerve: difference of 110125cGy). The volume receiving 35Gy is comparatively less in unflat beam (variation of 2.77cc) with flat beams. Unflat beams demonstrate a reduction in optic chiasm (difference of 13.57cGy)and contralateral eye doses (44.83cGy). Non coplanar technique shows better results in contralateral lens (1056.765 vs 959.38). There was no significant variation in dose to Ipsilateral lens (1133.5 vs 1097.2) and Ipsilateral optic nerve but a considerable reduction of dose can be noted in Contralateral optic nerve (difference of 107.275cGy) for non-coplanar technique. When eyes and optic chiasm is concerned, coplanar techniques shows improved sparing. There is no comparable variation in brain stem and volume receiving 35Gy in Brain excluding PTV. There was no significant variation in homogeneity index with flat vs unflat beams and coplanar verses non coplanar techniques. But IMRT plans are more homogenious (0.05559) in comparison with rapid arc (0.07254). There is a significant variation in conformity index. Rapid arc shows better conformity (1.0828) compared with IMRT (1.2495). But there was no significant variation with flat vs unflat beams and coplanar vs non coplanar techniques. The volume receiving 95% dose other than PTV shows a better result in Rapid arc techniques (7.5284cc) compared with IMRT (21.1384cc). Unflat beams shows more sparing (13.19786 vs 15.3922) compared to flat beams. While coplanar and non-coplanar is concerned, non -coplanar shows a better result (13.263 vs 15.392). Rapid Arc techniques required fewer MUs (434 vs 818.4) in comparison with IMRT. But non coplanar technique require higher MUs (643.5 vs 608.9) than coplanar. Unflat beams shows higher MUs compared with flat beams (753.1 vs 499).
Conclusion: VMAT shows better dosimetric advantage than IMRT except for optic nerves and homogeneity index. In all

dosimetric parameters, unflat plans gives more sparing of OAR except increased MU. Compared to coplanar techniques, non -coplanar shows a better sparing of critical organs with a slight increase in treatment MU. Overall, from this study, we concluded that Non-coplanar flattening filter free VMAT technique may be the better technique for the treatment of Glioma.

PP-72

PATIENT SPECIFIC QUALITY ASSURANCE USING SUNNUCLEAR ARCCHECK FOR RAPIDARC TREATMENTS DELIVERED ON VARIAN HALCYON LINEAR ACCELERATOR

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Introduction: Halcyon is an innovative new ring mounted linear accelerator designed by Varian Medical Systems, USA. South East Asia's First Halcyon was Installed, Acceptance Tested, Type Approved and Licensed for patient treatment at Sterling Cancer Hospitals, Rajkot. The machine has a gantry rotation speed of 4 rotations per minute (4 RPM) and MLC speed of 5 cm/sec. Also, the MLC has an innovative dual layer design with 28 pairs of distal and 29 pairs of proximal leaves. The proximal MLC leaves also participate in the fluence distribution to create an effective 5 mm fluence delivery resolution. With all the new design and technology, the patient specific qa is an integral part of evaluation for every patient.

Materials and Methods: Varian Halcyon linac is a ring mounted linear accelerator with a single energy of 6MV Flattened Filter Free photon delivered at 800 MU/min dose rate at 1 m Source to Axis Distance (SAD). The Varian Eclipse Treatment Planning System is the only planning systems for Halcyon treatment planning. The interface for planning is same as that of other conventional linac and hence has a fast user adaptability. The calculation algorithm supported is only AAA (Analytical Anisotropic Algorithm) and for optimization PO (Photon Optimizer) only. Even the intermediate dose and the portal dose predictions use the AAA algorithm for calculation. SunNuclear ArcCheck 3D patient QA dosimetry phantom was used to perform patient specific QA. The 3D phantom consists of 1386 helically aligned SUNPOINT diodes which measures both at the entry and exit points. The planned dose was delivered on the ArcCheck and the results were evaluated on the SNCPatient software. The phantom setup is done using the external bore lasers and then the isocentre position is verified using Image guidance. A total of 25 patients were planned with RapidArc with two or three arcs and the plans were delivered in the Halcyon linac.

Results and Discussion: All the plans delivered on the ArcCheck showed excellent pass rate both in the relative and absolute dose values. The maximum pass rate was 97.5% relative dose and 97.3% absolute dose for a head and neck RapidArc plan with 3%/3 mm gamma passing rate and 10% threshold. The same plan passed with a 95% relative dose when evaluated with 2%/2 mm passing rate.

Conclusion: The patient specific QA for RapidArc plans on the Halcyon Linear Accelerators showed superior delivery quality. This ensures that the preloaded beam data commissioned on the Eclipse TPS is accurate. Also, this provides confidence on the machine that the system can deliver even complex treatment plans with high accuracy and high precision. A future study is recommended to study the quality of treatment in multiple isocentre delivery. This study hence proves that ArcCheck is an ideal device to perform patient specific QA in Halcyon linear accelerators.

PP-73

ACCEPTANCE TESTING AND COMMISSIONING OF RADIXACT™ X9 TOMOTHERAPY UNIT: INITIAL EXPERIENCE

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Introduction: Helical Tomotherapy is recognized as modern solution for radiotherapy to sculpture highly conformal dose to the target and minimal toxicity to OARs. A 6 MV linear accelerator is mounted on a ring gantry for image-guided intensity-modulated radiation therapy treatment. The major advantage of Radixact™ X9 system from its predecessor is that it offers increased dose rate of about 1000 cGy/min at isocenter and 10 rpm gantry rotation for faster image acquisition with reduced imaging dose rate. Like CT technology, gantry rotation and couch longitudinal translation are simultaneous that permits helical dose distribution up to 135 cm treatment length. A fan beam created by the collimator and jaws produces a maximum of 40 X 5 cm2 field size at the isocenter. The linac can be operated at a lower voltage (3.5 MV) to produce CT images, which are used for patient image verifications. Radixact™ X9 tomotherapy unit was commissioned for clinical use at our center in June 2018.

Objective: In this study we aim to present the mechanical and dosimetric test performance carried out on Radixact™ x9 Tomotherapy unit recently installed at our institution.

Materials and Methods: Acceptance testing of the unit was carried out with guidance of vendor specific protocols and that of AAPM TG 148 report. Among various performance tests Radixact™ X9 tests involves some unique procedures compared to C-ARM linacs say mechanical tests such as Linac alignment test, Transverse, Longitudinal beam profiles and Central axis depth dose and dosimetric test comprising dose rate measurement, IMRT dose verifications, MVCT imaging dose verifications were presented.

Results: Linac alignment in IEC-X and Y was found 0.09 and 0.009 mm (tolerance: $<\pm0.34$ mm and $<\pm0.2$ mm), Y-Jaw divergence offset was -0.04 mm (tolerance: <0.5 mm), jaw twist angle 0.03º (tolerance: <0.5º), MLC Center offset of 0.05 mm which was well within acceptable (tolerance:1.5 mm), The MLC twist angle was found 0.01° (tolerance: <0.5º), Field Center versus Jaw Setting Test verified and result was 0.22 mm (tolerance: <0.5 mm).The measured transverse, longitudinal beam profiles field width and gamma were evaluated and then compared with the factory data. Depth dose comparison between measured and manufacturer quoted value at 10 cm depth for 40 x 5 cm2 field agreed of $<1\%$ dose difference. Dose rate-(output) at 85 cm SSD (1.5 cm buildup) for 5 x

40 field width was found 1009.9 cGy/min, the manufactured specifications 1000cGy/min (Tolerance: ±5%). Radixact™ System MVCT has no variation in the noise, uniformity and measured dose during MVCT procedure was found 1.8137 cGy (tolerance: < 3 cGy).

Discussion and Conclusion: The overall performance evaluation of the Radixact™ Tomotherapy delivery system installed at our institution was found satisfactory. The mechanical and dosimetric performance presented in the study was well within the tolerance limits specified by both the protocols. Based on our experimental results, Radixact™ X9 Tomotherapy unit expected to fulfill the requisites of high precision IGRT with fastest mode of MVCT imaging and increased dose rate to reduce the overall treatment time and increased machine throughput with desired dosimetric accuracy.

PP-74

EFFECT OF GANTRY ANGLES ON PHOTO-NEUTRON DOSE MEASUREMENTS IN A MEDICAL LINEAR ACCELERATOR

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Purpose/Objective: Cancer remains one of the greatest threats and clinical challenges to human health despite the vast therapeutic actions in medicine. However, high energy radiation therapy is one of the highly effective modes for treating cancer either alone or in combination with other modes i.e. Surgery or Chemotherapy. Nevertheless, one of the concerns in radiation therapy is the photoneutron field as by-product in a medical accelerator when using high energy, which produces mainly through photonuclear giant dipole resonance reactions as a function of photon energies. The objective of this study is to determine out-of-field Photoneutron dose equivalent (PNDE) as a function of gantry angle for clinical linac operating at 6-15 MV photon beam.

Materials and Methods: BD-PND is a passive detector which is used to measure out-of-field PNDE more accurately and dose can be read immediately when compare with other detectors. The sensitivity of BD-PND dosimeter use in this study is 1.2 bubbles per μSv.

In the current study, irradiations were carried out using an Elekta Versa HD linear accelerator with a collimator angle at 0o. The detector was set to 100 cm distance from source to surface distance (SSD). The total dose of 200 MU was delivered for 6MV, 10MV (FF & FFF) and 15 MV beam. The out-of-field PNDE were measured as a function of gantry angles of 450 increments over a (00-3600) rotation by placing the BD-PND detector along axis on the patient plane at a distance of 50 cm, 100 cm and 150 cm from the geometric field edge of 5 x 5 cm2.

Results and Discussion: The measured photoneutron were normalized to photon dose measured at isocenter and is given by μSv/Gy. The contamination of PNDE varies with respect to energy as a function of gantry angles at all respective positions and the results observed were as follows: (1) Gantry angle at 900 & 2700 show high PNDE when compared with to other angles and low PNDE were noticed at a gantry angle at 1350 & 3150 at respective distances. (2) The measured PNDE for the gantry angle 900, 2700, 1350 & 3150 were 64, 63 & 48, 48 μSv/Gy for 10 FF, 60, 55 & 43, 42 μSv/Gy for 10 MV FFF and 148, 146 & 113, 111 μSv/Gy for 15 MV photon beam at a distance of 50 cm. (3) As a function of gantry angle, the ambient neutron dose varies within ± 20μSv/Gy at all distance respectively. (4) Contribution of PNDE was high in 10 MV FF beam compare to FFF beam which may be due to the photons interacting with FF produce additional secondary neutrons than FFF beam. (5) The study shows that 15 MV photon beam contribute high PNDE compared 10 MV FF and FFF photon beams at different gantry angle and the ambient fast neutron dose equivalent gradually decreases by increasing the distance from the primary photon beam.

Conclusions: In the current study, it is observed that for 6 MV photon beam, there is no sign of secondary neutron production. Whereas 15 MV photon beam shows higher photoneutron contamination than 10MV photon beam. It is also confirmed that the PNDE is independent of the gantry angle for all energies.

PP-75

STUDY OF COLLIMATOR EXCHANGE EFFECT IN TELETHERAPY UNIT

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Introduction: The dose to a point in a medium is analyzed into-primary component and scattered component (collimator & phantom).Variation of the scattered photons from different parts of the head of the treatment machines with different collimator settings is described by collimator scatter factor (Sc). For rectangular fields, the interchange of upper and lower collimator jaws affects the numerical value of Sc. This is known as the collimator exchange effect (CEE) and is dependent on the design of each particular accelerator/ machine.

Purpose: To study CEE in Linear Accelerator (Elekta-Synergy) and telecobalt unit (Bhabhatron-II) at two depths, dmax and 5 cm using wax miniphantoms.

Materials and Methods: The measurements of this project study were taken in two treatment units-linear accelerator (Elekta Synergy) with 6MV photon beam and a telecobalt machine (Bhabhatron–II) with 60C0 beam at depths of dmax and 5 cm. The equipments used for the measurement are –Wax Phantom, 0.125cc Ionization chamber, PTW Unidose Electrometer. Two mini phantoms of different thickness i.e. dmax for 6MV photon beam and 6 cm (equivalent to 5 cm of water) were made using dental wax of 0.85 gm/cm3 density. The miniphantoms were kept on the treatment couch in such a way that the central axis of the beam or the cross wire matches the axis of the phantoms which corresponds the center of the active volume of the ion chamber. The in air measurement for 60Co gamma beam at dmax was performed using build up cap of thickness 0.5 cm (dmax for 60Co gamma beam). SSD was kept at 100 cm, for LINAC, and 80 cm for telecobalt unit. Gantry and collimator were kept at 0o. First, (10 x 10) cm2 field size was opened and the

ion chamber was irradiated for 1 min for 60C0 beam and for 100MU with 6MV photon beam. X jaw was fixed at 5 cm, while Y jaw was opened from 5 cm-30 cm for 60C0 beam and to 35 cm for 6MV photon beam. Next, Y jaw was fixed at 5 cm and the X jaw was opened from 5 cm-30 cm and 35 cm for 60Co beam and 6MV photon beam respectively. Three sets of electrometer readings were taken for each field size and the average of the readings was used to calculate Sc and CEE was studied.

Results: The value of Sc increased with elongated field size. The value of Sc was higher for the collimator setting of varying X jaw (MLC in case of Linear Accelerator) than compared with the value of Sc for the collimator setting of varying Y jaw. The maximum percentage difference between the Sc of the corresponding collimator settings for the Bhabhatron-II unit for depths dmax (0.5cm) and 5 cm are 0.79% and 1.87% respectively and for Linac (Elekta Synergy) at the depths, dmax (1.5 cm) and 5 cm it is 1.40% and 2.65% respectively.

Discussion: The values of Sc and the maximum percentage difference obtained for both the units at two different depths is purely machine specific. This data may not be compared with the commissioning data or any baseline data.

Conclusion: If the value of Sc is not accounted for the corresponding exchanged fields, then it may produce certain error in the dose calculation ultimately leading to error in treatment delivery. Therefore, it is required to use a two dimensional table accounting for the Sc values for every rectangular field sizes.

PP-76

EVALUATION OF OPTIMAL COMBINATION OF PLANNING PARAMETERS (FIELD WIDTH, PITCH, MODULATION FACTOR) IN HELICAL TOMOTHERAPY FOR BILATERAL BREAST CANCER

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Introduction: Breast cancer is the most common malignancy among the women in the world, synchronous bilateral breast cancer is uncommon with the incidence of 2.1%. Bilateral Breast planning is time consuming and challenging because of the huge volume and nearby critical structures. Helical Tomotherapy is capable to deliver well tolerated homogeneous dose to the bilateral breast without field overlapping.

Purpose: Aim of this study is to evaluate the influence of tomotherapy treatment planning parameters on plan quality and treatment time for bilateral breast cases and to find the optimal combination of planning parameters.

Materials and Methods: We have evaluated 5 patients with 90 plans. For each patient, 18 plans were created using the combination of planning parameters (Field width (FW) of 2.5 cm, 5 cm; Pitch of 0.215, 0.287, 0.43; Modulation Factor (MF) of 2, 2.5, 3. For every patient initial plan was created with FW 5cm, Pitch 0.287, MF 2.5 and the PTV was prescribed to 50Gy in 25 fractions. Using helping structure we have blocked the beam from posterior direction to reduce the low dose spillage. We have optimized the plan to achieve 50Gy to 95% of the PTV, without increasing 107% dose more than 2% volume. After achieving acceptable OAR results this plan was copied with its optimization constrains and 17 more plans were created by changing only its plan parameters. Plans were evaluated by dose volume histogram (DVH) analysis. Plan quality of target was quantified using Homogeneity Index, Conformity Index, Dmin by D98%, Dmax by D2%, and coverage by D95%. Organ at risk (OAR) doses were evaluated by mean dose, V5Gy, V25Gy for heart and mean dose, V5Gy, V20Gy for both the lungs. Treatment time also evaluated for all the 90 plans.

Results: PTV: When field width lowered from 5 cm to 2.5 cm the CI and HI of PTV improved from 0.997 to 0.999 and 0.07 to 0.04. HI decreases with (more homogeneous) decreasing the pitch or increasing modulation factor. With the effect of pitch (0.215, 0.287, 0.43) D98% and D2% were 49.2Gy, 49.4Gy, 49.5Gy and 51.8Gy, 52.1Gy, 53.2Gy respectively. Increasing modulation factor slightly improved all the PTV indices. OAR: Average value of Heart and lung mean doses were 4.89Gy, 5.17Gy and 10.5Gy ,10.7Gy for field width 2.5 cm and 5 cm.V5Gy of, Heart was 21.4%, 23.1%, 24.8% and lung was 45.6Gy, 46.7Gy, 47.8Gy for pitch value 0.215, 0.287, 0.43. Increasing Modulation factor improved all the OAR indices. Treatment Time: As expected FW of 2.5 cm (~10 min) had a higher treatment time than 5 cm (~6 min). Pitch value didn't affect the treatment time. Increasing modulation factor increased treatment time by 2-3 mins.

Discussion and Conclusion: Comparison of dosimetric indices showed that the lower Field width (2.5 cm) improved all the indices but increased treatment time 40–50% than the 5 cm FW. Pitch value 0.43 didn't offer any dosimetric advantage. An optimal pitch appears to be 0.215 or 0.287. While analyzing low dose as well as high dose OAR volumes it was evident that the pitch value of 0.215 showed better results. Increasing modulation factor increased plan quality as well as treatment time. By applying small FW, tighter pitch and large MF values, it is possible to get a sophisticated treatment plan with a very long treatment time. However, this results in two adverse outcomes: patient discomfort (to lie down static during irradiation) and inherent organ movement due to breathing. Considering all these and on the basis of our analysis plan with FW 5cm and pitch 0.215, MF 2.5 can be considered as a optimal combination of planning parameters for bilateral breast irradiation in Helical Tomotherapy Technique.

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DOSIMETRIC COMPARISON OF VARIOUS PARAMETERS USING SEGMENTED (FIELD-IN-FIELD) TECHNIQUE AND CONFORMAL TANGENTIAL BREAST IRRADIATION: A PLANNING STUDY ON RADIOTHERAPY TREATMENT CONCEPT FOR THE EARLY STAGE BREAST CANCER

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Aim: Most of the patients with early stage breast cancer undergo postoperative radiotherapy to reduce the risk of

local recurrences and improve outcome in long term survival. In early days breast tangential irradiation technique was the standard approach that matched to a direct supraclavicular field depending upon the stage of the tumor. Achieving the homogeneous dose distribution inside the target volume was the difficult task for a planner. In recent past, the field–in–field (FIF) technique has been widely used for delivering tangential breast technique for conservative whole breast treatment. The aim of this study is Dosimetric comparison of various parameters using segmented field-in-field technique and conformal tangential breast irradiation for early stage breast cancer as well as to discuss the "how-to technique" for the FIF technique procedure.

Materials and Methods: A total of 10 left sided breast cancer patients with breast conservative surgery were included for our study. The patients were immobilized with an inclined breast board on the CT-simulator. The scanned images were transferred to the contouring system. The whole breast was contoured as the CTV and the PTV was created by adding 5 mm margin to it and by editing 5 mm below the skin surface of the breast. Regarding the organ at risk (OARs), the ipsilateral lung, heart, spinal cord, liver and contra lateral breast were contoured for the dose reporting. Then the image sets were transferred to the CMS-XIO (Release V5.10.00.4) treatment planning system. All the patients were planned with two plans using 6MV photon beam for 50 Gy in 25 fractions, one with two standard opposing tangential beams with wedge and another with segmented FIF technique .The medial tangent field enters the breast medially at the edge of the sternum and the opposite edge with 1.5-2 cm air flashing to the skin and for lateral field with one edge enters at axiliary line where medial field exits and the opposite edge with 1.5-2 cm air flashing to the skin. With the help of Beam's Eye View (BEV) the gantry angle were chosen in such a way that OAR's like heart, contralateral breast, ipsilateral lung were maximally avoided. We use the MLCs for the shielding of all OARs which were nearby PTV to achieve a good plan. We use the motorized wedge to reduce the dose inhomogeneity across the target volume. And for the Field–in-field (FIF) technique, initially the calculation was done with the same tangential photon beams with same gantry angle as used for conformal tangential RT with two equally weighted and open beams. Then the medial field was copied to create the first subfield. The MLCs were used to block the isodose level of 1-2% lower than the Dmax shown in the plan. Then the dose calculation was done. Initially the weightage setting for the first subfield was set as Zero and an optimum weight was given to the subfield as required. Then the lateral main field was copied as the second subfield. The MLCs were used to block the isodose cloud of 1-2% lower than the dose blocked at the first subfield. Again the dose calculation was performed and optimum weight setting of the subfield was added. Again the medial main field was copied as the third subfield. The MLCs were used to block the isodose level of 2-3% lower than the dose blocked at the second subfield. The coverage of PTV was verified after final dose calculation was performed. In total all the plans were done with five fields including the two main fields. The subfields were merged to the main tangential field portals.

Results and Discussion: The isodose coverage to the PTV with standard conformal tangential plan and FIF technique plans were compared using D95, D93, Dmax and mean doses. Where D95 = 95% of the volume receiving the dose value, D93 = 93% of the volume receiving the dose, Dmax = maximum dose value in the plan. Regarding to OARs like contra lateral breast, ipsi lateral lung and for the heart various percentage of volumes like D5, D10, D20, D30 and mean doses to that organ were recorded. Where D5, D10, D20, D30 are the 5%, 10%, 20% and 30% percentage of volumes receiving the dose respectively. The Monitor units (MUs) for both the plans for all the patients were compared.

Conclusion: In conclusion, with the segmented field technique or FIF technique the dose homogeneity in the target is significantly improving. The dose to the OARs is also significantly less in FIF technique as compared to conformal tangential plan. The Monitor units required were also significantly less in FIF plans. So the FIF technique can be a suitable technique to improve the dose homogeneity across the target volume for early stage breast conservative irradiations.

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ANALYSIS OF THE VARIATION OF INTERNAL TARGET VOLUMES OF A MOVING PHANTOM USING FOUR DIMENSIONAL COMPUTED TOMOGRAPHY

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Introduction: To analyse probable variation of internal target volumes (ITV) with variable longitudinal displacement of different standard shapes of tumor in the moving phantom with the constant breath rate and sine wave breath pattern using a programmable Quasar phantom and Four- Dimensional Computed Tomography (4DCT).

Materials and Methods: The programmable motion Quasar was used with variable displacement in longitudinal displacement of CT image cylinder phantom insert containing 2 cm diameter, 1 cm diameter spheres and 3cc cube tumor density as tumor were used and sine wave in rotational mode with 1 cm amplitude platform with 6 dot marker and constant 4 seconds were set per breath (SPB). The same procedure was repeated with known displacement values of 4 mm, 6 mm, 8 mm and 10 mm respectively in constant breathing period of 4 SPB. The whole procedure were repeated five times at each displacement level and the variation in the volumes recorded for consistency. 4DCT was acquired with 1/10th of the breathing period set as time between images and cine duration set at 5 seconds (breathing period + 1 second). The images were sorted into 10 phases based on the temporal correlation between surface motion and data acquisition with an Advantage Workstation. The binned 10 phase images, Maximum Intensity Projection (MIP) were imported in Varian Eclipse version 15.1. From MIP set, the ITV (spheres resulted in a spherocylinder volume and cube in a cuboid volume) structure created under -210 HU window width to estimate the volume in CC.

Results: The observed variation in the internal target volume was ±3% error in the 3 cm cuboid and 2 cm diameter spherocylinder and ±11.5% error in 1 cm diameter spherocylinder of MIP volumes to calculated physical with

variable displacement motion induced volumes in the 10-bins 4DCT image protocol.
Conclusion: There is significant error in 1 cm spherocylinder due to loss of volume information in superiorly and inferiorly with the normal breath rate leads to over or under estimate the volume with higher displacement of the smaller volume tumor. There was no significant error in 3 cm cuboid and 2 cm diameter spherocylinder target volumes due to encompass the MIP volumes were able to consistent by encompass in 4 seconds per breath in 2.5 mm slice thickness during 4DCT imaging.

PP-79

ACCEPTANCE TESTING AND QUALITY ASSURANCE OF NEWLY INSTALLED ORTHOPANTOMOGRAPHY

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Introduction: People with the dental problem are an increasing number in present days because of their lifestyle and hereditary. Same as general diagnostic equipment, dental medicine has also come up with diagnostic equipment with advanced features in it. Orthopantomography (OPG) is imaging equipment used to image the teeth structures. The dentist uses this equipment to find the hidden dental structures, malignant or benign masses, bone loss, and cavities of the human mouth. Quality Assurance (QA) is an important aspect when we talk about radiation procedure imaging technology. So, QA protocol to be carried out in accordance with Atomic Energy regulatory body (AERB) and American Association Physicist in Medicine (AAPM) task group report no. 175 which will ensure the safety procedure of the equipment handling.
Purpose: To evaluate some of the acceptance and quality assurance tests like central beam alignment, focal spot size, accuracy of accelerating voltage, output consistency, half value layer (HVL), total filtration (TF), and tube housing leakage radiation in Orthopantomography.
Materials and Methods: Orthopantomography (Hyperion X7) is a product of Cefla Dental Group, Italy. Small focal spot verification was carried out by placing the line pattern object near to the detector and the operating parameters are 70 kVp and 2 mA. This system has a specification of an automatic timer with respect to mA. PTW-NOMEX multimeter is used to measure the accuracy of kVp, output consistency, HVL, and TF. The kVp is varied between 70 kVp and 78 kVp with an interval of 2 kVp, keeping focus to detector distance (FDD) 62 cm and 6 mA for measuring the accuracy of accelerating voltage. Output consistency test is done by keeping constant tube current 26.4 mAs and a varying tube voltage of 60, 70 and 80 kVp. With this measured value, the coefficient of variation (COV) is calculated. To see the tube leakage, the tube is fully closed by radiation blocking material and by setting 70 kVp, 6 mA then values are measured at 100 cm distance in all sides like left, right, front, back and top side of the tube using fluke survey meter.
Results: It is observed that deviation of beam alignment is 0◦. The stated value for the focal spot is 0.6 mm X 0.6 mm and the observed value is 0.8 mm X 0.8 mm which is within the limit. The maximum and minimum values of standard deviation in the tube voltage accuracy is 70.36±0.21 for 70 kVp and 76.00±0.00 for 76 kVp and the remaining deviations are within this range. The output consistency is given by COV that is 0.000261 for 60 kV, 0.000385 for 70 kV, 0.000408 for 80 kV and the limit <0.05. TF is found to be 2.1 mm of Al. Tube leakage is more in the front side of the tube of 7.9 mR/hr which is within the accepted limit.
Discussion: We have performed our study in a newly installed OPG in which there is no significant deviation from the accepted level. However, in the case of old machines, there is a possibility of exceeding the tolerance because of sear and tare property. Hence, it is mandatory to do the QA on a regular basis as per AERB norms.
Conclusion: Orthopantomography successfully passes the QA criteria within the tolerance limit.

PP-80

DOSIMETRIC COMPARISON FOR NASOPHARYNGEAL CANCER PATIENTS WITH COPLANAR AND NON-COPLANAR VMAT ARC TREATMENT TECHNIQUE

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Introduction: Carcinoma Nasopharynx is one of the complicated radiation treatment in head and neck cancers. Though regular Intensity-modulated radiation therapy (IMRT) can provide better treatment and sparing the normal structure, arc therapy have some flexibility in dose delivery from full range of gantry angles with variable dose rate. But still it is more challenging to achieve the full dose to the tumor which lies close to the Organ at risk.
Purpose: The purpose of this study was to evaluate the dose distribution and normal tissue sparing in the radiation treatment for the nasopharyx patients with coplanar and noncoplanar VMAT arc treatment.
Materials and Methods: A retrospective study was carried out for the five Nasopharynx cancer patients, earlier treated by dynamic IMRT techniques, in which the tumor extended to intra cranial, located close to the eye and optic nerve. The high risk and low risk planning target volumes (PTV) were contoured along with other related organ at risk OAR structures as per the guidelines of Radiation Thearpy Oncology Group (RTOG). As per the NCCN guidelines, the dose of 7000cGy and 5940cGy in 35 fractions was prescribed to high risk PTV (PTV1) and low risk PTV (PTV2) has a simultaneous integrated boost treatment (SIB). The Monaco Treatment Planning system for Elekta Versa HD machine with 6MV, 80 pair's agility MLC was used for the planning. Two plans were evaluated with each patient, In coplanar VMAT technique, 3 full arc was used. In non coplanar VMAT plan, 2 full arc with one partial arc has a non coplanar beam was used. The monte carlo algorithm was used to reach the maximum dose to the Target and minimal dose to the Organ at risk (OAR). The dosimetric evaluation included: PTV homogeneity index (HI), conformity index (CI), delivery time, monitor unit, mean and maximum dose to eye, eye lens, brain stem, optic chaism, optic nerve, oral cavity, parotid, larynx, and spine.

Results and Discussion: The coplanar and non coplanar VMAT plans had similar PTV coverage 95%. There was no much difference in dose homogeneity in both coplanar and no coplanar VMAT plans. The non coplanar VMAT plans provided improved conformity index. There is no larger difference in parotid, larynx, oral cavity, spinal cord sparing in both the plans. When compared to coplanar VMAT plans, non coplanar plans had better sparring in Eye lens, Eyes, brain stem dose. There is no mush difference in delivery time, since the number of arcs has been reduced in the non coplanar VMAT plan.

Conclusion: Our result shows that the non coplanar VMAT plans provides better sparring of normal tissue, homogeneity and conformity when compared to coplanar VMAT plan, however the technique selection is depends on the patient clinical need and requirement.

PP-81

EVALUATION AND VALIDATION OF IBA I'MATRIXX ARRAY FOR PATIENT SPECIFIC QUALITY ASSURANCE OF TOMOTHERAPY

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Introduction and Objectives: A very sophisticated IMRT can be planned and delivered using Tomotherapy treatment system. It uses fan beam technology and is modulated by a binary multi leaf collimator. This modulation results high degree of homogeneous and conformal dose distribution. As like other IMRT treatments, patient specific quality assurance is most important in this helical approach also. Because of its dynamic nature, it is a great challenge for physicists to achieve QA goals. Helical Tomotherapy users practice with film and a specially designed cylindrical phantom called cheese phantom. Currently, there is also a lot of interest in using electronic array dosimeters, because of their instantaneous readout of results. These array detectors have been proved reliable and the results are comparable with films and also better in some cases. There are several 2D array dosimeters commercially available. These detectors have shown to be adequate when used by linear accelerators. But their applicability to helical tomotherapy is not much discussed in the literature. One of such 2D array which has been existing for IMRT verifications for many years is I'MatriXX 2D array with blue phantom. S Xu *et al*. tested this matrix for helical tomotherapy IMRT plans of head and neck cases. But, its dependency on pitch and field width of tomotherapy was not discussed. Also this study was limited to a single treatment site. Hence, our objectives of this study were to examine and validate the response of I'MatriXX to different pitches and field widths commonly used in planning and to evaluate this device for IMRT/IGRT/SBRT plans of different cancer lesions.

Materials and Methods: I'MatriXX is a two-dimensional array with 1020 ion chambers, arranged in a square. The pitches ranged from 0.1 to 0.5 were used for all the three different filed widths.16 plans were created with different possible pitch values and field widths. 3% dose differences and 3 mm distance to agreement was the gamma-index criteria used in our study. All plans created with the virtual target were then delivered using multicube set up. Then, Patient DQA plans were executed and the fluence was recorded. Patient plans: 23 quality assurance plans of different treatment sites of the body were used in this study. Plans were chosen in such a way that, different body lesions were covered. All types of treatments like conventional fractionated plans, Hypofractionated plans, SBRT plans were covered in the selection. Same passing criterion was used in these cases also.

Results and Discussion: All the plans were analysed as per the above procedure. Using the 3% and 3 mm criteria, plans with various pitches , field widths and modulation factors showed good agreement, with the percent of points less than 1 being more than or equal to 99%. These results are clearly indicating that, matrix response is independent of filed width, pitch and modulation factor of tomotherapy and is validated successfully for performing PSQA.

All the patient plans showed very acceptable passing rates with matrix irrespective of cancer site. High passing rate ranging from 99.7 % to 90.7% was observed. Pitches, field widths were selected as per the requirements of better planning results. This shows PSQA with matrix gave good agreement for most of the treatment lesions of the body.

Conclusions: 2D array can be utilized for easy and quick Tomotherapy dosimetry. I'MatriXX response is independent of field width, pitch and modulation factor of Tomotherapy. Hence, it is a good and suitable option for patient specific QA for any conformal technique possible with Tomotherapy.

PP-82

PATIENT DOSE MANAGEMENT IN COMPUTED TOMOGRAPHY SCAN

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Introduction: Computed Tomography (CT) examinations have rapidly increased in number over the last few years. Increasing applications causes increase in collective radiation dose to the population. But it can be controlled as long as individual CT examination is clinically justified and doses are optimized to be not more than what is necessary. But experience shows that individual patient doses are increasing mainly because of repeated CT scans. We can reduce the patient dose in ct scan by following certain Quality control protocols such as: Justify the procedure – Ask the patients for records of previous diagnostic procedures – Plan the procedure (right patient, right contrast) – Know well about your equipment settings – Ensure only qualified and trained operator should operate the equipment –Handover procedure records (CD/disc and reports) – Ensure that daily and periodic QA are performed and equipment performance is satisfactory.

Purpose: The present study is to present the improvements implemented at our hospital to reduce the patient's dose from repetition of CT examination. CT exams should not be

repeated without clinical justification and should be limited to the area of interest.

Materials and Methods: The basic way to manage dose is by accurately assessing dose by examination and comparing with national dose reference levels or comparing with the facility averages. Our PET/CT machine model is GE Discovery ST 16 Slice. It can create dose reports with volume CTDI (CTDIvol) and DLP. DLP can be multiplied with conversion factors to calculate effective dose. DLP is the most important value to monitor and optimize dose. The dose reports are saved in PACS which can be frequently monitored. Radiation doses received from radiographs will vary according to patient size, examination area, and examination views. For CT, doses will vary between 2-20 mSv depending on the examination area and protocol. Dose Length Product: DLP accounts for the length of radiation output along the z axis (the long axis of the patient). DLP=CTDI*vol*/*.nT.* Volume Computed Tomography Dose Index (CTDIvol) is a standardized parameter to measure Scanner Radiation Output. CTDIvol is reported in units of mGy. Where n is the number of slices acquired, T is the slice thickness. nT is therefore the total scan length. We sampled four patients aged 18 and older in the month of JAN-MAY 2018 who had undergone Repeated CT due to various reasons. For each patient, the technical parameters and dose report data (scan area, scan range, kVp, mAs, and dose length product) were abstracted from the CT images. E = DLP * k, E = Effective Dose in mSv, DLP = Dose Length Product in mGy*cm, k = conversion coefficient in mSv/mGy*cm), k values are based on ICRP 60 organ weights. We found out the reasons for repeating the CT scan for those patients and improvements were implemented.

We sampled around 12 patients in June & August 2018 and calculated the patient doses.

Results: We found that the doses received by the patients were much less. Good practice requires the use of patient size specific protocol and techniques that minimize dose without adversely affecting diagnostic performance.

Discussion and Conclusion: The risk associated with medical imaging procedures refers to possible long-term or short-term side effects. Most imaging procedures have a relatively low risk. Hospitals and imaging centers practice ALARA (As Low As Reasonably Achievable). This means they make every effort to decrease radiation risk. Therefore, it could be said that the benefit from medical imaging (an accurate diagnosis) is greater than the small risk that comes with using it. The dose reports provided by CT examinations are only estimations and not true measurements. These dose values are reported on the basis of calculations using phantoms. Therefore, it is not possible to know the exact dose the patient was exposed. There can be no limit to individual radiation dose when used for medical imaging purposes. If the examination is medically justified, the imaging should be performed.

PP-83

CAN CONTROL POINTS BE AN EFFECTIVE TOOL FOR MONITOR UNIT ESTIMATION IN IMRT?

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Objective: A dynamic delivery IMRT field file will contain several control points that are defined MLC shapes at a marked fraction of the delivered monitor units. The size of this file and the fidelity of the deliverable fluence are proportional to the number of control points defined. The aim of this study is to estimate the MU per subfield in dynamic IMRT by exploiting control points.

Materials and Methods: The monitor unit calculations were performed for Eclipse treatment planning system (TPS) version 13.8.0 for dynamic IMRT. Optimization was performed for 20 plans for various sites by photon optimizer (PO) algorithm. The number of control points and leaf motion were calculated by the leaf motion calculator (LMC) algorithm. The MU per beamlet was calculated by the difference between two successive meter set weights of the control point over the total MU. The total MU can be estimated for with the number of control points and MU per beamlet. The dose delivered per beamlet to the reference point and overall dose to the reference point were also estimated.

Results: The parameters estimated by manual method with the control points were compared with the TPS calculated parameter. All the parameters were within the percentage of deviation of +/-3%.

Conclusion: The control points can be used as an effective tool for estimating the significant parameters for dynamic IMRT delivery.

PP-84

COMPARISON OF THREE-DIMENSIONAL CONFORMAL RADIOTHERAPY VERSUS INTENSITY-MODULATED RADIOTHERAPY PLANNING FOR WILM'S TUMOUR

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Introduction: Wilms tumor (WT) (also called Wilms' tumor or nephroblastoma) is a type of cancer that starts in the kidneys. WT is the commonest pediatric renal tumor, predominantly seen in children. National Wilms' Tumor Studies (NWTS) have laid down the guidelines for standardized treatment of WT. Three-dimensional conformal radiotherapy (3D-CRT) and intensity-modulated radiotherapy (IMRT) are 2 recently developed radiotherapy techniques. IMRT is believed to be more effective than 3D-CRT in target coverage, dose conformity and reducing toxicity to normal organs. In this study we compared 3D-CRT versus IMRT plan of WT in terms of dose–volume histograms (DVHs), Organs-at-Risks(OARs).

Purpose: The purpose of this study is to achieve higher conformal doses to the tumor, while avoiding OARs and WT is the rare case seen in children less than five years of age.

Materials and Methods: For this study we have taken one WT patient whose age is 2 yrs and 4 months. The patient was scanned in the CT simulator. The slice's thickness was 1.2 mm and then images were imported to Eclipse treatment planning system (TPS) version 13.7. In contouring section oncologist delineated the target volumes and OARs. In planning section both techniques 3D-CRT and IMRT plans were planned using 6 MV Energy and compared using dynamic multileaf

collimator (DMLC). 3D-CRT planning technique was done using four field box and IMRT planning technique was done using 5 fields and dose was calculated using anisotropic analytical algorithm (AAA) version 13.07.16. DVHs and OARs doses were evaluated.

Results: Dose prescription for WT was 12 Gy in 7 fraction. 3D-CRT versus IMRT planning Comparison was done which includes DVHs, mean and maximum dose of OARs and Monitor units (MUs). It was observed that the doses in DVHs ,the mean and max doses of spinal cord, liver and contra lateral side LT kidney in cGy for all OARs are lower in IMRT technique than in 3D-CRT but MUs are higher in IMRT technique and compared values were tabulated.

Discussion: IMRT plan substantially gave more conformal dose to the target and structures like liver, spinal cord, contra lateral side LT kidney received lower doses. 3D-CRT is forward planning which mostly depends on geometric relationship between the tumor and nearby sensitive structures. IMRT is Inverse planning and is less dependent on the geometric parameters but more on specification of volumes of tumor targets & sensitive structures, as well as their dose constraints.

Conclusion: IMRT plan was more efficient than 3D-CRT in Wilms Tumor in terms of dose distribution and OARs sparing.

PP-85

ARC PLANNING METHODOLOGIES FOR STEREOTACTIC RADIOSURGERY OF SCHWANNOMAS: A DOSIMETRIC COMPARATIVE STUDY

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Purpose: Stereotactic Radiosurgery (SRS) is a procedure that involves the precise three-dimensional targeting of ionizing radiation to obliterate abnormal tissues such as vascular malformations, malignant or benign tumors. We treated schwannomas like Acoustic, Trigeminal, Vestibular, Glossopharyngeal (GP) for pain relief and while preserving the functionality of the adjacent brain tissue and normal Organs at Risk (OAR). This work represents the efficiency of stereotactic radiosurgery (SRS) in the management of schwannomas by volumetric modulated arc therapy using Rapid Arc (RA) in 6MV Flattening Filter Free (FFF) beams on the Truebeam STx platform during the years year 2012 to 2018.

Materials and Methods: We used Varian Eclipse (version 13.7) and Anisotropic Analytical Algorithm (AAA) treatment planning system (TPS) which allows planning in 6MV FFF beams for delivery on Truebeam STx linear accelerator equipped with HD 120 MLC. Brainlab Iplan (version 4.5) software allows fusion of DSA and MRI with planning CT. We evaluated 31 Schwannomas (Acoustic, Vestibular, Trigeminal, Glossopharyngeal [GP]) cases from our patient population who underwent Rapid Arc SRS treatment with partial and full arcs. Each RA Plans were generated with coverage of at least 95% to PTV. Normal tissue dose was evaluated by using the parameters Normal Brain 10cc, V5, V10, V12 and V20 in the cumulative dose-volume histogram for the following structures: Brainstem, Brain, Cochlea, Chiasm and Optic Nerves. Conformity Indices (C.I) and Homogeneity Indices (H.I) are evaluated to validate the plan quality.

Results and Discussion: Rapid arc (VMAT) plans has PTV coverage (D95%) of average 98.68% (S.D±1.03) of prescription dose. Homogeneity of dose distribution in target volume was an average of 0.09 (S.D±0.03). The conformity index evaluated was an average 1.09 (S.D±0.03. The 10cc normal Brain received 89.47% (S.D±9.84) of the prescribed dose with Rapid arc plans. The greatest effect of RA FFF SRS Beams was the treatment delivery beam on time was reduced by 4 times compared with conventional conformal dynamic arc beam on time.

Conclusion: Linear accelerator based radiosurgery is promising treatment option for brain Schwannomas in majority of cases with reasonable adverse effect profile. Rapid Arc (VMAT) with FFF beams using partial or full arcs for the treatment of schwannomas provide improved target volume coverage, highly conformal and more homogeneous dose distribution in the PTV.

PP-86

DOSIMETRIC COMPARISON OF INTENSITY MODULATED RADIOTHERAPY AND VOLUMETRIC MODULATED ARC THERAPY PLANS FOR PANCREATIC STEREOTACTIC BODY RADIOTHERAPY USING FILTER FREE BEAMS

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Introduction: Stereotactic body radiotherapy (SBRT) delivers higher biological dosage of radiation with accuracy and precision in few fractionated treatments. SBRT plays a major role in treatment of several cancers. Pancreatic cancer is an aggressive malignancy with high mortality rates. Over the last decade, SBRT has come out as a novel treatment option in pancreatic cancer care.

Purpose: To compare the dosimetric differences between Intensity modulated radiotherapy (IMRT) plans and Volumetric modulated arc therapy (VMAT) plans using filter free beams for pancreatic cancer.

Materials and Methods: Ten patients with pancreatic cancer were selected for this retrospective study. All patients were immobilized in supine position, with arms above head using whole body Vacloc system. The CT images were acquired at 1.25 mm thickness and the CT data sets were transferred to the eclipse treatment planning system. The gross tumor volume (GTV) was delineated by radiation oncologist and PTV is expanded by giving 3 mm margin over the GTV. The organs at risk (OAR) such as duodenum, stomach, left and right kidneys, liver and spinal cord were contoured. The prescription dose was 35Gy in 5 fractions to PTV. IMRT plans were created with 12 equidistant beams whereas VMAT plans were generated with 2 full arcs (CW 181°-179°, CCW 179°-181°) using 6 FFF photon beams. An anisotropic analytical algorithm was used to compute the dose calculation for both the plans. The planning criteria is to achieve 95% of the target volume receives the prescription dose while all the oars were kept within the tolerance limit as per TG101. For PTV the dose volume histogram parameters

such as V95%, D98%, D2% and mean dose were analyzed. The conformity index, homogeneity index and gradient index for both the plans were evaluated. The DVH parameters such as D1%, D5% and Dmean to organs at risk were analyzed. The monitor units and treatment time delivered were compared.
Results: The D98% was 97.23 ±0.74% and 97.77±0.66% for IMRT and VMAT plans. The homogeneity index for IMRT was 1.17± 0.037whereas it was 1.12 ± 0.036 for VMAT plans. The conformity was better in VMAT 0.99±0.03 plans than IMRT 0.93±0.29 plans. The gradient index is lesser in VMAT (4.73) than IMRT (4.96).The mean dose was higher in IMRT plan (38.39±0.75 Gy) compared to VMAT plans (37.36±0.75 Gy). The D1% and mean dose to the oar's were similar in both techniques. The D5% of duodenum was lesser in VMAT plans (18.83±8.82) than IMRT (20.51±8.05).The maximum point dose to the spinal cord was higher in IMRT (12.56±2.35Gy) compared to VMAT (11.30±2.26Gy).The D5% of the left kidney shows reduction in VMAT plans (10.1 ±4.1Gy) than IMRT (12.9±3.99Gy).The monitor units delivered for VMAT plans (2134.1±286) was lower than the IMRT plans (2214.6±509).
Discussion and Conclusion: The PTV coverage was almost similar in both the plans. There was a better conformity and homogeneity in VMAT plans. VMAT plans showed better gradient compared to IMRT plans. All the OAR doses were comparable for both techniques except D5% of duodenum and left kidney. VMAT plans exhibit slightly better organs at risk sparing and, lower MU's with shorter treatment time compared to IMRT plans.

PP-87

OUT OF FIELD DOSE MEASUREMENT AND SECOND CANCER RISK ESTIMATION IN CARCINOMA CERVIX RADIOTHERAPY TREATMENT-PHANTOM STUDY

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Purpose: To measure the scatter and leakage dose received by out of field organs while delivering the carcinoma cervix external beam and brachytherapy treatment in a humanoid phantom and to estimate the risk of second cancer (SC).
Background: The increasing survival rate of cervix cancer patients steadily warrants the SC risk estimation based on out of field dosimetry, since the Treatment Planning System (TPS) is not commissioned for this purpose.
Materials and Methods: The dose to out of field organs was measured using the LiF-100 dosimeter while delivering 3D Conformal Field in Field technique by 6 MV (Varian – Clinac 2300CD) photon beam and also during intracavitary brachytherapy treatment by Co-60 beam. Following that the Excess Absolute Risk (EAR) of SC was estimated for stomach, colon, liver, lung, breast, kidney and Excess Relative Risk (ERR) for thyroid based on BEIR VII report.
Results: The out of field organ dose varies with respect to distance between the organs. The organ received the highest dose with external beam and brachytherapy per fraction was colon = 11.23cGy and kidney = 23.55cGy respectively. The equivalent dose (per fraction) to nearby organs was higher for brachytherapy than external beam therapy. For the cumulative dose the highest EAR estimated was for kidney (21.3) and stomach (12.9) and the lowest for liver (0.2) per 10000 populations.
Conclusion: Out of field phantom dosimetry should be encouraged to provide a solid database on the estimation of radiotherapy induced cancer incidence for various treatment sites.

PP-88

CALIBRATION OF EBT3 FILM FOR ITS USE AT I-125 ENERGIES

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Introduction: Gafchromic EBT3 film is widely used for dose measurement in radiotherapy due to its higher spatial resolutions, low energy dependency, dynamic range and easy handling. This film can be used for dose evaluations up to 8 Gy in red channel and upto 40 Gy in the green channel.
Purpose: In the present study, EBT3 films were calibrated at 60Co and 70 kV X-ray (effective energy is 30.5 keV) which is comparable to the mean energy 28.37 keV of I-125 source. Calibration results were compared to find its use for dosimetry at I-125 energies.
Materials and Methods: The EBT3 film is a self-developing radiochromic film. It is composed of an active radiochromic layer of thickness 30 m, which is laminated between two 125 m matte polyester layers. Strips of EBT3 films (3 cm x 20 cm) were placed in air at the centre of 10 15 cm2 X-ray field, at 1 m distance from the focal spot. The X-ray machine was operated at 70 kV potential and 30 mA tube current. The films were irradiated to doses of 0.5, 1.0, 2.14 and 5.1 Gy. The air-kerma rate of the X-ray machine was 0.115 Gy/min at 1 m. The value of ratio of mass energy absorption coefficient water to air, 1.015 calculated at I-125 energies was used to convert air-kerma into absorbed dose to water. The films could not be irradiated for doses more than 510 cGy at 70 kV X-ray energy due to limitation on exposure time. A telecobalt unit was used to calibrate the EBT3 films. The output of machine was 1.98 Gy/min at 80.5 cm in water. The films (size 3 cm x 20 cm) were kept at depth of dose maximum in perspex phantom of size 30 x 30 x 20 cm3. Films were irradiated to doses of 0.5, 1.0, 2.14, 5.1, 9.46, 16.54 and 30 Gy using10 □ 10 cm2 field size. The irradiated films were scanned using the EPSON Expression 10000 XL scanner with a resolution of 72 dpi after 24 h of irradiation. Films were scanned prior to irradiation to measure the optical density (OD) of the background image. All film pieces were scanned in the same orientation throughout scanning. Net optical density (NOD) was calculated by subtracting the OD of an unexposed film piece from the OD from exposed film. Irradiated films were analysed using ImageJ software. The data of red channel were used to determine OD. The energy response, R is the ratio of the NOD for a given dose of the 70 kV X-ray beam and the NOD for the same dose for 60Co beam.
Results: NOD of EBT3 Gafchromic films as a function dose to

water was compared. The value of R is 0.92 for 50 cGy dose and 0.98 for dose range of 100-510 cGy.
Discussion and Conclusion: The dose response is within 2% for 60Co and 70 kV X-ray for dose range of 100 - 510 cGy. The variation up to 8% was observed for dose of 50 cGy. Higher variation at lower dose may be attributed to lower sensitivity of EBT3 films. Hence, EBT3 films calibrated at 60Co energy with dose more than 50 cGy are suitable for dosimetry of I-125 sources.

PP-89

RADIATION SAFETY AND STRUCTURAL INTEGRITY OF THERATRON 780E MACHINE HOUSING OVER THE PERIOD OF 12 YEARS: A RETROSPECTIVE STUDY

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Introduction: Use of ionizing radiation in the field of medicine is well established. Cancer incidence in India is steadily increasing. While planning radiation installations, it is extremely important to ensure radiation safety of radiation worker and public at all levels. Radiation protection survey values recorded in our Department for the period of 12-yearshave been analyzed for radiation safety and structural shielding integrity of radiation installation.
Purpose: The objective of this study is to assess the radiation safety and structural stability of remodeled telecobalt room housing Theratron 780E machine over the span of 12-years.
Materials and Methods: A Theratron 765 telegamma machine having a maximum source capacity of cobalt-60 of 333 TBq/9000Ci was installed in March 1977 and decommissioned in 2004. Theratron 765 is designed to treat at a source to axis distance (SAD) of 65 cm and maximum field size at 65 cm SAD is 30 x 30 cm2. In Theratron 780E machine, maximum source capacity of cobalt-60 of 444TBq/12000Ci and designed to treat at a SAD of 80 cm and maximum filed size at 80 cm SAD is 35 x 35 cm2. Almost thirty year old existing telegamma room has been remodeled/modified to house Theratron 780E machine. The existing structure has been studied and inspected extensively by the various agencies before modification of the old room. Concrete core has been taken from existing old walls as well as roof slab to investigate and determine the (a) compressive strength (b) density (c) condition of embedded reinforced steel (d) corrosion potential from carbonation test (e) general assessment on the concrete density. After ensuring structural stability and performance warranty from architect and structural designer, a modified layout plan to house Theratron 780 E has been prepared and duly approved by the competent authority of India. Theratron 780E unit was installed and commissioned for patient treatment on 8th August 2005 after obtaining approval. Radiation protection survey has been carried out on Theratron 780 E at regular intervals as per regulatory guidelines using calibrated digital advanced radiation survey meter model ASM-900 with GM probe. The measured values were recorded for (a) Head leakage of telecobalt when source is in OFF position (b) Radiation survey of telegamma installation. The measured and recorded values from 2006 to 2018 have been taken for our study to evaluate and assess radiation safety and structural integrity. We have also measured exposure levels at 5 m and 10 m away from the radiation installation to check stray radiation. The observed exposure levels are not exceeding background levels in these areas.
Results and Discussion: The radiation surveillance tests have been done as per RPAD/Telecobalt/QA/2006 protocol. It has been observed that the measured average exposure rate at 5 cm from the surface of source head varies from 10.88 μSv/hr to 27.4 μSv/hr. The average exposure rate at 1 m from the source of head varies from 1.73 μSv/hr to 5.74 μSv/hr. The average exposure rate measured for shielding adequacy of primary barrier varies from 0.286 μSv/hr to 3.19 μSv/hr. The average exposure rates measured for shielding adequacy of secondary barriers at various locations were well within the limits prescribed by the competent authority.
Conclusion: From this retrospective study, we conclude that the modified structural shielding designed to house Theratron 780 E machine is adequate. There are no notable radiation exposure levels due to stray radiation in the vicinity of telegamma installation. Theratron 780 E is very safe to use for patients treatment.

PP-90

IS NON COPLANAR BEAM BENEFICIAL FOR SPINE STEREOTACTIC RADIOSURGERY?

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Introduction: Nearly 40% of cancer patients develop spine metastases resulting in poor quality of life. There are several treatment options for spine metastases like surgery, augmentation and radiotherapy. Stereotactic Radiosurgery (SRS) to spine lesion is an emerging technique delivering high radiation dose in single fraction.
Purpose: The purpose of our study is to compare the dosimetric differences in treatment plan between three techniques: Cyberknife (CK), Volumetric Modulated Arc Therapy (VMAT), and Helical Tomotherapy (HT) and analyse whether non coplanar beams are beneficial for spine SRS.
Materials and Methods: 8 CT data sets of slice thickness 1.25 mm with single spine lesions from C3 to L4 level were included in this study. A total of 24 plans were generated for the three comparison techniques: CK, VMAT and HT. The contouring and optimization objectives were based on RTOG0631 protocol. Spinal cord, cauda equina, esophagus, blood vessels, intestines, kidneys, were contoured depending on the location of PTV. All plans were prescribed to dose of 18 Gy in 1 fraction. The major priority was given to achieve adequate dose coverage to PTV while limiting maximum dose (0.035cc) to cord to $\leq$ 14 Gy and cauda equina to $\leq$ 16 Gy. The CK plans were created in Multiplan treatment planning system (TPS) using two or three fixed collimators. HT plans were optimized using the VoLo TPS. Beam width 1 cm, pitch

of 0.215 and modulation factor ranging from 1.8 to 2.2 was used for optimization. For VMAT plan, 6 FFF beam with two full arcs (CW from 181–179° with collimator 30°, and CCW from 179–181° with collimator 330°) were used in Eclipse TPS. Parameters of comparison include target volume coverage, Conformation Number (CN), homogeneity index (HI), high-dose spillage index (HDSI), intermediate-dose spillage index (IDSI), dose received by 0.035cc, 0.35cc and 1.2cc of spinal cord and 0.035, 0.5cc and 1.2cc of cauda equina, low dose volume V2Gy and V5Gy, Beam On Time (BOT), and monitor units (MU) per fraction.

Results: The target volume coverage was evaluated by comparing D2%, D98% and mean dose to PTV. D2% and mean dose was higher for CK (22.30±1.10Gy and 19.73±0.72Gy) compared to VMAT (20.84±1.36Gy and 18.96 ± 0.79Gy) and HT (20.21±1.44Gy and 18.94±0.75Gy). D98% was similar in three techniques. The mean CN ± SD values of PTV were 0.75 ± 0.05, 0.84 ± 0.11 and 0.83± 0.19 for CK, VMAT and HT respectively. The mean HI± SD values of PTV were 1.27±0.06, 1.20±0.08 and 1.16±0.08 for CK, VMAT and HT respectively. HDSI were 0.08 ± 0.01 for CK, for VMAT 0.08 ± 0.01 and 0.03± 0.01 for HT respectively. IDSI characterized by gradient index was lower for CK (3.54± 0.35) than for VMAT (4.08 ± 0.88) and HT (4.45 ± 0.56). Spinal cord and cauda dose constraints were achieved in all three techniques. The low dose volume V5Gy in CK plans was approximately 18.1% higher than HT plans and 19.12% higher than VMAT plans. Similarly V2Gy in CK plans was approximately 22.8% higher than HT plans and 29.67% higher than VMAT plans. CK (41.4±4.9 min, 24821 ±2940 MU) had the longest beam on time and MU per fraction compared to VMAT (5.3 ±0.7 min, 6674±1035 MU) and HT (16.3 ± 3.2 min, 13658 ± 2719 MU).

Discussion and Conclusion: CK, VMAT and HT plans achieved conformal target coverage while limiting cord and cauda tolerance. Highly conformal distribution was achieved in both VMAT and HT plans compared to CK as both techniques are MLC based delivery whereas CK is cone based delivery. Dose heterogeneity was larger in CK compared to other two techniques. IDSI was least in CK plan compared to VMAT and HT plans. VMAT required the least BOT and MU because of higher dose rate. Sharp dose gradient was achieved with CK at the cost of low dose spillage. CK for spine SRS showed additional dosimetric benefits compared to VMAT and HT.

PP-91

DOSIMETRIC REPRODUCIBILITY AND ACCURACY OF THE INDIAN MADE 1D WATER PHANTOM IN RADIOTHERAPY

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Introduction: A phantom is a material, which absorbs and scatters the radiation in the same way as tissue. The phantom material should have the same density as tissues and contain the same number of electron per gram. The water phantom is the most similar to the human body that is used for the quality control of the absorbed dose management in the telecobalt and linear accelerator. Quality assurance (QA) in radiotherapy is all procedures that ensure consistency of the medical prescription and safe fulfillment of that prescription, as regards the dose to the target volume, together with minimal dose to normal tissue, minimal exposure of personnel and adequate patient monitoring aimed at determining the end result of the treatment. It is recommended that quality assurance (QA) of the beam energy of radiotherapy treatment machines is carried out at regular intervals, daily, weekly and monthly to deliver proper treatment.

Purpose: The main purpose of this study was to assess the long-term dosimetric reproducibility and accuracy of the Indian made 1D water phantom.

Materials and Methods: The PMMA material was used to fabricate the Indian made 1D water phantom and the dimension of the 1D phantom is 30 cm × 30 cm × 30 cm. The all side walls are nominal to 1 cm thick. The clear water phantom provides extra visibility of the light field and facilitates its leveling and setup by using the treatment machine's patient positioning lasers. The water phantom consists of a manually controlled, precision probe positioning mechanism mounted on the wall of the phantom and fabricated as per the recommendation of TRS-398. Counter meter used to display the chamber position during the movement. It also has the water draining provision with ON/OFF tap. It also has the provision to fit the Farmer type chamber and also for the parallel plate chamber for all type of dosimeters. Chamber holder also fabricated with same PMMA material. The water phantom was fabricated as for recommended by ESTRO BOOKLET – 3. The reproducibility and accuracy of the 1D water phantom was measured mechanically using the standard scale with the counter meter of the 1D water phantom. The counter meter readings of 1D water phantom such as 1, 2, 3, 4, 5, 10, 15, 20 and 25 cm were compared with standard scale reading. Similarly, dosimerical output, PDD reproducibility of water phantom was carried out in clinac iX. The irradiation was carried out for 6MV and 15MV photon beams as well as 6, 9, 12, 15MeV electron beams. The Indian made 1D water phantom is kept on the treatment couch and alignment done with laser light, such that the beam should normally incident on the phantom surface plane, also central axis of the beam should pass through the sensitive region of the chamber. Initially the chamber was irradiated for different depth such as 1, 2, 3, 4, 5, 10, 15, 20 and 25 cm. The same measurement was repeated for year with the interval of month.

Results and Discussion: The mechanical and dosimetric reproducibility and accuracy of Indian made 1D water phantom was working satisfactory. The result of the study was forward and backward movement of the counter meter and scale found ± 0.1 mm for year. The dosimetrically results was also found less than ±1%. The dosimetric values were good in agreement when compared with 3D RFA measurements.

Conclusion: From the dosimetric measurements performed Indian made 1D phantom and the results compared with 3D RFA, it was evident that the long term dosimetric and mechanical reproducibility looks good and within the recommended limit. The phantom setup time is less than 5 minute. So, the Indian made 1D water phantom can be used for regular radiotherapy output measurement, PDD and QA programs.

PP-92

EFFECT OF COLLIMATOR ANGLE IN SPINE STEREOTACTIC BODY RADIATION THERAPY-PLANNING STUDY AND DOSIMETRY VERIFICATION

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Introduction: Stereotactic body radiation therapy (SBRT) is an EBRT method that very precisely delivers a high dose of radiation to an extra cranial target. SBRT is highly effective in early stage primary and Oligometastatic tumors at locations throughout the abdominopelvic and thoracic cavities, and spinal and paraspinal sites. SBRT varies from conventional RT is the delivery of large doses in a few fractions, which results in a high BED. In order to minimize the normal tissue toxicity, conformation of high doses to the target and rapid fall-off doses away from the target is critical.
Purpose: IMRT or VMAT is required to create concave dose distributions. Due to the advancement of Technology VMAT delivers more faster Treatment. The cylindrical symmetry of vertebrae favors the use of volumetric modulated are therapy in generating a dose "hole" donut shape on the center of the vertebrae limiting the dose to the spinal cord. we have studied the improvement of plan quality and deliverability with respect to collimator angle.
Materials and Methods: Ten patients with single vertebral mets were included in the study. Planning CT was acquired with 1.25 mm slice thickness in GE Discovery imaging system. Target Volume (TV) and OAR Contouring was done as per ISRCC & RTOG 0631 protocol. Two Dose Prescription protocols were followed (TV to Spinal Cord (SC) Distance <3 mm - 24Gy in 3#, TV- SC Distance more than 3 mm 16Gy in single Fraction). Treatment Planning system- Eclipse 13.7 was used for Planning. 6MV-FFF beams with 5 mm Agility MLC were used for all plans. Four Plans were generated with 4 Collimator angle combinations of 0-180 (C0), 30-330 (C30), 60-300 (C60) & 90-270 (C90) with two arcs. High Resolution Grid lines i.e 1.25 mm kept for Optimization and Calculation. Photon Optimizer (PO) algorithm for Optimization and Anisotropic Analytical Algorithm (AAA) for calculation was used. All the Plans were normalized to cover 95% of TV to 100% Dose. Gamma analysis were made to check the deliverability of plans.
Results: In all the plans, the Dmin, Dmax and Dmean were found to be relatively similar and irrespective of the prescription doses (either 24 Gy/3# or 16 Gy/1#). Conformity index (CI) for each collimator combinations such as C0-180, C30-330, C60-300 and C90-270 were found to have a value 1.3, 1.1, 1.1 and 1.2 respectively. Marginal increase in CI observed in the C0-180 and C90-270 combinations could be due to cumulative low dose contributions from the overlapping interleaf leakages in all opposing gantry projections. Identical gradient indices (GI) and OAR (heart, liver and kidneys) doses observed among all the collimator combinations showed that the dose fall-off outside the target was not dependent on collimator angles. However, important finding in our study is that the C0 and C90 combinations resulted in increased SC dose of about 10% in comparison with C30 and C60 combinations. Gross difference in total MU was also observed between the four collimator settings, the C90 combination was found to have the lowest value. For all the four collimator combinations, more than 95% dose voxels were passing the standard gamma criteria (3%/3 mm DD and DTA).
Discussion and Conclusion: Selection of optimum collimator combination is essential in SBRT of spine mets thereby reducing the maximum dose to spinal canal and limits the total MU required to deliver the prescription dose. Further investigation on the various collimator combinations with large sample size yields statistical significance of the same.

PP-93

A NOVEL COUCH BASED THREE DIMENSIONAL TREATMENT TECHNIQUE FOR TOTAL BODY IRRADIATION

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Aim: Purpose of this study is to dosimetrically evaluate the novel and simple couch based three-dimensional treatment technique for Total Body Irradiation (TBI).
Materials and Methods: Patient immobilised on a vacuum cushion. Whole body computed Tomotherapy images acquired in head first supine position at 5 mm slice thickness. Care was taken to strap the scrotum towards the anterior body surface. Target delineated by shrinking the skin by 2 mm. Treatment plan generated on CMS XiO planning system using 4 MV photon beam from Elekta Infinity linear accelerator. A 90% of the planning target volume (PTV) prescribed (Rx) to 90% (of 12Gy) over 6 fractions in 3 days. Since the dimension of the target is more than the maximum field size, we adapted 4 adjacent fields with extended SSD (135 cm). Junctions were matched using feathering technique. Boost fields added to compensate the deficit dose in the brain and chest region. Bilateral lungs were partially shielded to reduce the toxicity. Target and organ at risk (OAR) doses found acceptable.
Results and Discussion: PTV D90% is 1156cGy (96% of Rx) and PTV Dmean is 1242cGy (103.5% of Rx). As a result of partial lung shielding mean lung are 964cGy & 948cGy for right and left lung. For rest of the critical structures the mean dose ranging from 1165cGy, 1285cGy. Junction doses were achieved between 93% and 112% of the Rx dose. Most of the high dose areas found in the perineum, the area between the arms. This is due to missing tissue and the air gap in and around the target volume. Optical shadows of the anterior fields are used to cross verify the junction on the patient surface. The dose distribution was considerably uniform over the entire target volume.
Conclusion: Dosimetric evaluations shows that, this technique provide adequate target coverage and acceptable OAR doses. Three dimensional planning improves the geometric accuracy and enhance the confidence in treatment

delivery. Parameters needed for precise patient setup can be obtained from TPS. Image guidance is possible.

PP-94

COMPARISON OF POINT DOSE VERIFICATION AND PORTAL DOSIMETRY FOR HEAD AND NECK INTENSITY MODULATED RADIOTHERAPY PLANS

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Introduction: Intensity Modulated Radiotherapy (IMRT) can deliver optimal prescribed dose distribution to the target volumes, while reducing doses to normal tissues. The planning process of IMRT is having complex planning and delivering mechanisms and needs accuracy in dose planning and delivery. Errors can lead higher doses to critical organs lying close to the targets. So, advanced radiotherapy demands a high level of quality control of machine and treatment delivery. There are two different way of performing IMRT specific Quality Assurance (QA) - Point dose verification and Absolute and fluence verification using gamma analysis.
Purpose: Purpose of this study is to compare the deviations in results between point dose verification and area gamma values of portal dosimetry in Head and Neck IMRT plans.
Materials and Methods: Ten Head and Neck IMRT plan were taken each being treated with 7 Fields. QA was done for all plans by point dose verification and portal dosimetry methods in Varian True Beam (version 2.6) Machine. Point dose Measurement - RW3 slab Phantom aligned for 95.0 cm Source to Skin Distance with 0.13cc chamber at the depth of 5.0 cm and connected to dose 1 electrometer. Meter reading (in nC) where taken for every individual field in all 10 IMRT plans. Meter readings were converted to cGy unit to compare with Treatment Planning System (TPS- Eclipse 13.6 version) calculated value. Portal dosimetry - Mega Voltage Electronic Portal Imaging Device is aligned at 105 cm Source to Imager Distance. All the portal dosimetry verification plans were performed for every same individual field. Absolute values are converted to Portal Calibration Unit (CU) to compare with predicted portal dosimetry results. The tolerance of area gamma is 3.0% and Distance To Agreement 3.0 mm.
Results: Point dose measurement: Cumulative TPS Calculated/cumulative point dose measurement values for 10 IMRT plans are 2.298Gy/2.26Gy, 1.467Gy/1.504Gy, 2.269Gy/2.286Gy, 1.315Gy/1.351Gy, 2.093Gy/2.096Gy, 1.816Gy/1.807Gy, 1.181Gy/1.203Gy, 1.214Gy/1.159Gy, 1.259Gy/1.250Gy, and 2.142Gy/2.145Gy. The percentage deviation between cumulative TPS calculated and cumulative point dose measured values are 1.6%, 2.52%, 0.1%, 2.7%, 0.1%, 0.49%, 1.81%, 4.5%, 0.7% and 0.1% respectively. Portal Verification - Area gamma analysis values of 10 IMRT Plans are 98.1%, 99.3%, 99.0%, 99.1%, 99.7%, 99.3%, 98.1%, 97.9%, 99.0% and 99.0%. The deviation from TPS calculated values are 1.9%, 0.7%, 1.0%, 0.9%, 0.3%, 0.7%, 1.9%, 2.1%, 1.0% and 1.0% respectively.
Discussion: Point dose verification shows less than 3.0% deviation in 9 IMRT plans and portal dosimetry shows more than 98% area gamma values in the same IMRT plans. The deviation between portal dosimetry and point dose verification is negligible in 7 IMRT plans and deviation of 2% in other two IMRT plans. Only one plan had point dose verification of 4.5% deviation though area gamma value was 97.9%. The reason for failing point dose verification in one plan is due to larger field size.
Conclusion: The Area gamma values of the portal dosimetry were comparable to the point dose verification values for head and neck IMRT Plans. Thus, both the verification method can be used for patient specific QA.

PP-95

IMPROVED ARTEFACT REDUCTION IN OPTICAL COMPUTED TOMOGRAPHY BASED BRACHYTHERAPY GEL DOSIMETRY USING A DUAL CATHETER SYSTEM

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Introduction: Three-dimensional (3D) dosimetry has become easily accessible due to the development of radiochromic gel dosimeters and optical computed tomography (CT) scanners. These dosimeters have been used widely for external beam radiation therapy (EBRT), but use for high dose rate (HDR) brachytherapy has been limited. One reason for the limited use of radiochromic gels within HDR brachytherapy is the streak artifacts produced by the catheters during the CT reconstruction process by standard Feldkamp-Davis-Kress (FDK) reconstruction algorithms. In our previous work we presented a modified iterative algebraic Ordered Subsets Convex reconstruction algorithm with Total Variation minimization regularization and ray rejection (OSC-TVRR). While this work showed promising results with artifact removal in volumes from gels with catheters inserted irradiated via EBRT, results from HDR brachytherapy irradiations were difficult to obtain. When attempting to deliver HDR irradiations it was found that the limited length of catheter protruding from the gel would cause the catheters to be perturbed when connecting them to a HDR after loader, limiting the accuracy of the method.
Purpose: This work aimed to develop an improved catheter insertion technique for radiochromic gels to allow for easier connection of the HDR afterloader to the catheters. Doing so would allow for reliable accurate 3D dosimetry for HDR brachytherapy.
Materials and Methods: The radiochromic gels used for this work were leuco crystal violet (LCV) micelle gels prepared according to the recipe by Babic *et al.*[1] in 1 L vessels. The OncoSmart Comfort Catheter System (Elekta Ltd., Stockholm, Sweden) was used within the gels. The OncoSmart system consisted of an outer catheter that was suspended within the gels as they set and trimmed to fit within the gel vessels, and an inner catheter that could be connected to the after loader and inserted into the outer catheter during irradiation. The gels were scanned using a Phillips Brilliance Big Bore CT scanner (Philips Medical Systems, Cleveland, OH) and the x-ray CT scans were imported into the Oncentra Brachytherapy treatment planning system (TPS) (Elekta Ltd., Stockholm, Sweden) for catheter tracking and treatment planning. The planned treatments were then delivered with a Flexitron

remote afterloader with a Flexisource Ir192 source (Elekta Ltd., Stockholm, Sweden). The gels were scanned with optical CT with the Vista 15 scanner (Modus Medical Devices Inc., London, ON) both before and after irradiation, and then a change in optical attenuation ($\Delta\mu$) volume was reconstructed using an inhouse implementation of the OSC-TV algorithm both with ray rejection (OSC-TVRR). The reconstructed $\Delta\mu$ volumes were then calibrated and registered to expected dose volumes exported from the TPS for comparison according to the methods given by Alexander *et al*.[2]

Results: The use of the OncoSmart catheter system was shown to provide an easy method to delivery HDR brachytherapy irradiations to radiochromic gels, with a 100% delivery success rate compared to a 50% success rate with previous methods. The comparison of the reconstructed dose volumes with the OSC-TVRR algorithm showed removal of the streak artifacts found in volumes reconstructed by the FDK algorithm and close agreement with the expected dose volumes from the TPS.

Conclusion: The work demonstrated that using the OncoSmart catheter system provided an improved method for performing HDR brachytherapy radiochromic gel dosimetry. By combining this method with optical CT read-out and the OSC-TVRR reconstruction algorithm, cost effective, reliable, and accurate 3D dosimetry for HDR brachytherapy is now possible.

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PP-96

A STUDY ON SURFACE DOSE OF FLATTENED AND FLATTENING FILTER FREE PHOTON BEAM OF MILLENNIUM TRUE BEAM ACCELERATOR

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Aim of Study: The aim of this study is to report the variation of surface dose of different field sizes by flattening filter free (FFF) photon beams generated by millennium True Beam medical linear accelerator used for cancer treatment and its variation with respect to flattened beams (FB).

Materials and Methods: Surface doses were obtained for field sizes 3 × 3 40 × 40 cm2. For depth dose curves ionization chambers and radiation field analyser were used and data were taken at a sourcetosurface distance (SSD). Consistency of depth dose data was checked for one year.

Results and Discussion: Surface doses were higher in FFF beam compared with FB up to 20 × 20 cm2 field size. But in higher field size 40 x 40 cm2 surface dose in both 6XFFF and 6 MV FB beams are equal. But in 10 MV, surface dose is higher than 10XFFF beams in higher field size 40 x 40 cm2. FFF beams showed good data consistency in one year duration.

Conclusion: The surface dose, consistency of FFF beams and FB photon beams were derived and the data showed good consistency during a year duration.

PP-97

A DOSIMETRIC ANALYSIS OF RADIATION DOSE TO NORMAL STRUCTURES IN HEAD AND NECK CANCERS TREATED WITH THREE-DIMENSIONAL CONFORMAL RADIOTHERAPY AND INTENSITY MODULATED RADIOTHERAPY

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Objective: A retrospective dosimetric analysis of individual Central Nervous System (CNS) structures like posterior fossa (cerebellum), brainstem and spinal cord was performed and the results were compared for 3DCRT and IMRT treatment plans.

Materials and Methods: The posterior fossa (PF), brainstem (BS) and spinal cord (SC) was delineated for 20 head and neck cancer patients treated with 3DCRT or IMRT. Alternate treatment plan was generated for all patients and summary statistics and dose–volume atlases were reviewed for dosimetric parameters like GTV95%, CTV95%, PTV95%, GTV HI, CI and Maximum dose and Mean dose for CNS structures and compared.

Results: An increase in maximum and mean doses to posterior fossa, brainstem and spinal cord was observed for IMRT plans compared to 3DCRT plans. Dmax for PF and BS ranged between 3.1 and 42.62 Gy and 16.7 - 47.96 respectively for IMRT. Dmax for PF and BS ranged between 3.1 and 12.8 Gy and 21.34 – 44.76 respectively for 3DCRT. Median Dmean for PF is 7.885 Gy in IMRT and Median Dmean for PF is 1.13 Gy in 3DCRT plan. In aspect of spinal cord median Dmean is 41.6 Gy in IMRT plan which was found 45Gy in 3DCRT plan. Both maximum and mean doses were higher for the posterior fossa, brainstem and cerebellum for the IMRT plans and both maximum and mean doses were found higher for spinal cord in 3DCRT.

Conclusion: IMRT delivers higher radiation dose to CNS structures compared to 3DCRT. Dose–volume atlases of the same structures indicate that regions representing larger volumes and higher doses to each structure are consistent with a higher incidence of acute fatigue in patients treated with IMRT for head and neck squamous cell carcinoma during phase III parotid sparing radiotherapy trial PARSPORT. So this needs further prospective studies correlating the clinical effects (fatigue) with the dose to CNS structures.

PP-98

VALIDATION OF RAPID ARC DELIVERY SYSTEM USING A VOLUMETRIC PHANTOM AS PER TASK GROUP REPORT 119 OF AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE

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Introduction: RapidArc (RA) is one of the most sophisticated technologies available in radiotherapy departments worldwide. It more precisely targets a cancerous tumor while

sparing healthy surrounding tissues. It also significantly reduces patient treatment times and radiation exposure. In the RA technique, optimal dose distribution with efficient treatment delivery can be achieved with the interplay of various modulation parameters such as dose rate, gantry rotation speed, multi-leaf collimator (MLC) movement, and number of control points. However, owing to physical limitations of the hardware operation and misalignment between dosimetric and mechanical components of the linear accelerator, dose discrepancies can occur in the radiation beam delivery. Thus, it is desirable to employ appropriate and extensive quality assurance at the RA planning and delivery level, because errors at these stages may alter treatment outcomes. However, it is tedious and laborious to perform RA quality assurance at an individual level because of the various complex parameters involved.

Purpose: This study validated RA delivery using a volumetric ArcCHECK phantom as per the guidelines proposed in the TG 119 report. This study also investigated the impact of the AXB algorithm on RA plan dose calculations in the homogeneous medium of an ArcCHECK phantom.

Materials and Methods: A filtered beam (FB) of 6 MV from the Clinac-iX linac machine and, a filtered beam (FB) and flattening filter-free beam (FFFB) 6MV from the TrueBeam-STx were used for planning purposes. The dose rates were 600 MU (6MV_FB) and 1200 MU (6MV_FFFB) per minute, respectively. Eclipse TPS and aria version 11 (Varian Medical System, Palo Alto, USA) was used for RA planning and for record and verification. Gamma criteria of 3 mm distance-to-agreement (DTA) and 3% dose difference (DD) were used for evaluation of RA plans, with a threshold value 10%. A gamma passing rate of ≥ 90% and absolute dose +5% was considered as acceptable.

Results: RA planning results were comparable and satisfying the planning criteria stated in AAPM TG 119 for all test cases. The average percentage gamma passing rate for AAA calculated plans were 98.5 (SD: 0.6), 98.5 (SD: 1.3), 98.1 (SD: 2.0) and for Acuros XB calculated plans were 95.1 (SD: 1.8), 96.1 (SD: 1.3) and 94.0 (SD: 0.9) for Clinac-iX (6MV) and TrueBeam-STx (6MV_FB & 6FFFB) respectively. For ion chamber measurements, the average percentage dose difference for AAA calculated plans were 1.5 (SD: 2.5), 2.7 (SD: 1.4), 1.4 (SD: 2.7) and for Acuros XB calculated plans were 2.3 (SD: 1.6), 3.2 (SD: 1.5) and 2.3 (SD: 2.0) for Clinac-iX (6MV) and TrueBeam-STx (6MV_FB & 6FFFB) respectively.

Discussion: Treatment planning benchmark is necessary to investigate planning ability and to facilitate a review of the accuracy of treatment planning systems under relevant conditions. This may reveal the unidentified errors of local treatment and delivery system which leads to improve in quality of treatment.

Conclusion: The AAPM TG 119 test cases were successfully applied on an ArcCHECK phantom. This phantom has been proven to be an easy, quick, and reliable system for RA delivery verification following the TG119 recommendations. The AXB has the potential to perform dose calculations comparable to the AAA for RA plans in the homogeneous medium of the ArcCHECK phantom. Therefore, the AAPM TG 119 report can be used as an effective tool for the quick evaluation of RA planning and delivery systems.

PP-99

PERCENTAGE OF ATTENUATION FOR VARIOUS IMMOBILIZATION DEVICES USED IN RADIOTHERAPY

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Introduction: Radiotherapy treatment demands high precision in patient set up for reproducibility. To achieve this, various immobilization devices are used. Ideally, an immobilization device should have 0% attenuation, which is not practically possible. So, the tolerance for attenuation is less than 3%.

Purpose: Purpose of this study is to measure the attenuation of various immobilization devices used in radiotherapy.

Materials and Methods: The Immobilization devices used for measurement of attenuation were 3 Carbon fiber and 3Perspex Head and Neck base plates, 2 Perspex pelvic base plates, 6 neck rest, 2 indexer bars, 3 Thermoplastic cast and Vacloc supplied by different vendors along with indigenously prepared devices. All the measurements were performed on Varian TrueBeam Linear Accelerator (version 2.5). RW3 Slab phantom (Water equivalent) size 30 x 30 x 20 cm3 used with 0.65 cc farmer ionization chamber and Dose 1 Electrometer. RW3 Slab Phantom was aligned for 10 x 10 cm2 field size at SSD 100 cm. 0.65CC Farmer chamber placed at 10 cm depth in slab phantom. This set up was exposed with 500 MU's of 6MV Photon beam for warm up. Meter readings were taken for 100MU's in nC unit. All the above-mentioned immobilization devices were introduced one by one on the slab phantom and the respective meter readings were noted in the nC. Percentage of the attenuation was calculated using the following formula: *Percentage of Attenuation = [(Measured Value-Calculated Value)/Calculated Value] × 100.*

Results: The Percentage attenuation of different immobilization devices are -3 carbon fiber (2.21%, 1.54% and 0.88%) 3 head and neck Perspex base plate (6.5%, 5.15% and 5.0%) 2 Perspex pelvic base plates (5.0% and 4.78%) 6 neck rests (0.29%, 0.66%, 0.37%, 0.37%, 0.66% and 3.75%) 2 indexer bars (8.38% and 5.0%) 3 Thermoplasticcast (2.13%, 0.81% and 0.81%) and Vacloc (1.47%).

Discussion: Carbon fiber materials, Thermoplastic cast and Vacloc attenuation was within the tolerance limits. Out of 6 Neck rests 5 had attenuation with in tolerance limits. The sixth neck rest had attenuation of 3.75%, the reason being seemed to be made of high density material (Probably Car –cushion material). Indexer bar attenuation is more than 5.0% but it will not affect our treatment, since it is placed outside the irradiated area. The Perspex base plates for head neck and Pelvis shows higher attenuation which will affect the quality of treatment delivery. Therefore, attenuation factors in MU Calculation and assigning HU Values for immobilization contours should be considered which will improve our quality of treatment delivery.

Conclusion: Attenuation factors should be measured for all immobilization devices to verify for tolerance limits and be utilized in dose calculations.

PP-100

REDUCING THE CARDIAC AND PULMONARY DOSE WITH DEEP INSPIRATION BREATH HOLD TECHNIQUE AS COMPARED WITH FREE BREATH FOR LEFT-SIDED BREAST CANCER RADIOTHERAPY TREATMENT

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Aim: The purpose of this dosimetric study was to find a suitable treatment & planning technique, which can serve as an optimized technique with respect to PTV coverage and better sparing of concerned OAR's.

Introduction: Referring to the previously available literature of DIBH studies, it is clearly showed that DIBH has an advantage over FB in case of left-sided breast cancer radiotherapy treatment in terms of reduced risk of cardiovascular-related morbidity and mortality. DIBH is now a well-established technique in case of left-sided breast cancer radiotherapy treatment. This dosimetric study explores the benefit of using a suitable treatment & planning technique in case of left-sided breast cancer radiotherapy treatment.

Materials and Methods: In this study, we have taken 10 patients of left-sided breast cancer (7 MRM + 3 BCS) treated with DIBH technique at our Centre. The Varian's RPM respiratory gating system (Varian Medical System, Palo Alto, CA) was used for respiratory motion monitoring. All patients were coached for three to four days for obtaining the desired respiratory breathing cycle. Once the patient was coached successfully, CT scans were acquired, one with conventional free breath (FB) and also three random scans with deep inspiration breath hold (DIBH) i.e., gated CT scans on SOMATOM Sensation Open CT simulator machine (Siemens Medical System's). On importing the acquired CT images in TPS, it showed that left lung volume increment in DIBH technique as compared to FB was significant. Patient contouring and treatment planning performed on Eclipse V13.5 and a dosimetric comparison was made between two treatment & planning techniques i.e., ((DIBH VS FB) for (3DCRT VS IMRT) and it is for PTV coverage, left lung, heart, left anterior descending coronary artery (LAD), left ventricle and contralateral breast.

Results: Left lung volume increment in DIBH technique as compared to FB was 69.375% showed that there was a significant increment in left lung volume, which results in a larger separation of heart and the PTV chest wall. **FB Case:** Dose Volume Histogram (DVH) analysis of 3DCRT VS IMRT plans for PTV coverage found that PTV coverage of V95% (95.37% vs 99.61%), for left lung's V20Gy (14.17% vs 33.3%), for heart mean dose Dmean (3.93 Gy vs 12.8 Gy), for LAD max dose Dmax (46.75 Gy vs 38.96 Gy), for Left ventricle max dose Dmax (46 Gy vs 41.16 Gy), and for contralateral breast V4Gy were (0.1941% vs 4.741%). **DIBH Case:** Dose Volume Histogram (DVH) analysis of 3DCRT VS IMRT plans for PTV coverage found that PTV coverage of V95% (95.37% vs 99.206%), for left lung's V20Gy (14.98% vs 24.44%), for heart mean dose Dmean (2.635 Gy vs 9.455 Gy), for LAD max dose Dmax (37.124 Gy vs 33.499 Gy), for Left ventricle max dose Dmax (36.746 Gy vs 28.336 Gy), and for contralateral breast V4Gy were (0.5455% vs 11.912%).

Conclusions: This dosimetric study showed that IMRT has better PTV coverage and LAD, left ventricle sparing, but on the other hand more doses to left lung, heart and contralateral breast as compared to 3DCRT technique. DVH evaluation concluded that 3DCRT plans have been a preferable technique in case of left-sided breast cancer radiotherapy treatment, as PTV coverage was adequate in both the techniques and left lung, heart, contralateral breast doses were lesser in case of 3DCRT plans, although relatively little higher doses to the LAD and left ventricle. On comparing FB and DIBH techniques, DIBH is showing drastically dose reduction for left lung, heart C/L breast, LAD and left ventricle. From the data of DIBH and FB, we can conclude that DIBH technique in many respects has an advantage over FB, which is solving the purpose of reducing cardiac and pulmonary doses without compromising the PTV coverage.

PP-101

IMPACT OF DYNAMIC JAW TRACKING TECHNIQUE DURING FLATTENING FILTER FREE BASED VOLUMETRIC MODULATED ARC THERAPY - STEREOTACTIC RADIATION THERAPY DELIVERY – A RETROSPECTIVE DOSIMETRIC STUDY

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Introduction: Volumetric Modulated Arc Therapy (VMAT) delivery technique has proven its capability in sparing critical and normal tissues when administering small volume target plans especially in sites like Brain with multiple metastatic cancers. VMAT with Flattening Filter Free (FFF) using high dose rate Stereotactic Radiation Therapy (SRT) became a standard treatment approach in multiple brain metastasis cancer radiotherapy due to the ability of dose escalation to the tumor and high dose fall off with reducing doses to critical structures. Normal brain volumes receiving doses of 12Gy, 10 Gy and 5Gy lead to radio necrosis, cognitive dysfunction, etc as reported in literature and efforts in reducing these volumes (V12, V10, and V5) are underway by various methodologies.

Purpose: Study of Dosimetric benefits of Dynamic Jaw Tracking in FFF based VMAT-SRT technique for multiple brain metastatic patients.

Materials and Methods: Five previously treated Multiple Brain Metastatic patients were taken up for this retrospective dosimetric study in giving 20 Gy in a single fraction to the multiple targets. SRT- VMAT plans (6 MV FFF - Dose rate 1400 MU/min) were generated using ECLIPSE Treatment Planning Systems (TPS), ver 13.0 (M/S Varian Medical Systems, Palo Alto, USA) with Dynamic Jaw tracking (DJT) and as well as with fixed jaw (FJ) technique by keeping the same constraints and priorities for a particular patient. Target conformity and normal Brain dose volumes (V12Gy, V10Gy and V5Gy) were evaluated. Verification phantom plans are created with 4D Octavius phantom equipped with 729 array of chambers and Prediction Dosimetry (Varian). True Beam Linac (Varian

Medical Systems, Palo Alto, USA) equipped with 120 Millenium MLC, capable of jaw tracking technique delivered the verification plans. All patient QA plans are evaluated using PTW Verisoft Software Ver 4.0 and Varian Portal Dosimetry Software (aSi-1200 DMI EPID Systems).

Results: TPS Generated VMAT-SRT plans are compared using plan evaluation portal in Eclipse TPS, shows surprisingly with lesser Monitor Units(MU) in DJT when compared with FJ but not significant. For the study group with similar target coverage, averaged V12 Gy showed hardly any variation. Averaged V10 Gy and V5Gy for DJT plans was 2.5% and 3.5% lesser than FJ plans respectively. 4D Octavius Phantom measured results ranged from 97% till 99% gamma pass for 3% and 3mm Distance to Agreement (DTA) for the study group. Its Excellency in evaluating multiplanar dose distribution , 4D volume analysis gamma pass results provided an additional confident of delivering the DJT technique with high dose rate FFF plans. Portal dosimetry system plan verification also showed gamma pass 99% for DD 3%, DTA 3mm.

Conclusion: In DJT, the jaws can move at the maximum speed of 2.5 cm/s, during the VMAT dose delivery as close as possible to the MLC aperture, minimizing the leakage and transmission through the MLC. This was evident and observed in our planning comparison study.

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OPTIMAL FIELD MARGIN FOR PANCREAS STEREOTACTIC BODY RADIOTHERAPY USING FLATTENING FILTER FREE PHOTON BEAMS

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Introduction: As high precision stereotactic body radiotherapy (SBRT) uses higher dose per fraction, high degree of conformity and dose gradient are essential. The conformity and dose fall-off into the normal tissues are mostly influenced by the beam margin around the target volume. Further, the choice of beam margin is important to reduce maximum high dose to nearby critical organ as well as to reduce low dose spread in order to avoid the development of secondary cancer.

Objectives: To find optimal multileaf collimator (MLC) beam margin for VMAT based SBRT treatment using high intensity FFF beam for pancreas cancer.

Materials and Methods: VMAT based SBRT treatment plans were generated for 10 pancreas patients using 10X-FFF of Truebeam STx linear accelerator (Varian medical systems, USA), modeled in Eclipse Treatment Planning System (Version13.6). For each patient, SBRT plans with different MLC margin to PTV viz. -2, -1, 0, 1, 2 mm were generated. 35 Gy in 5 fractions (7Gy per fraction) was delivered to the target volume using 1 full arc (1790 - 1810) with collimator angle of 300. The maximum available dose rate of 2400 MU/min for 10X-FFF was used. Dose calculation was performed with Anisotropic Analytical Algorithm (AAA). All plans were normalized to 95% of target should cover 100% of dose. Comparison of plans generated has been established in terms of various dosimetric variables. ANOVA test was performed for statistical significance analysis.

Results and Discussion: The PTV parameters like conformity, homogeneity, gradient indices and volume receiving 110% were showed statistically similar results ($p > 0.1$) and better value achieved with 1, 1, -1, 0 mm respectively. Whereas, dose to 98% PTV volume ($p=0.03$) and MU ($p<0.0001$) were showed statistically significant results among plans and better coverage achieved with 0 mm. The MU was increased linearly as the margin reduced. The homogeneity and volume receiving 110% were higher with -2 mm margin plan. The organs at risk showed similar results for all plan ($p> 0.9$). The duodenum V10Gy, V15Gy were less in 0 mm plan.

Conclusion: The investigation of dosimetric performance and treatment delivery efficiency suggests that 0 mm margin to PTV for 10X-FFF is optimal for pancreas SBRT.

PP-103

ANALYSIS OF THE EFFECTS OF IONIZING RADIATION ON PREGNANT WOMEN WITH REFERENCE TO ICRP-PUBLICATION-84

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Introduction: Pregnant women are at risk of exposure to non-ionizing and ionizing radiation, resulting from necessary medical procedures, work place exposure and diagnostic or therapeutic interventions before the pregnancy is known. Pregnancy is most-contra-indication to radio diagnostic procedures. During these procedures, embryos usually receive less than 100 mrem during 9 months gestation. The most common effects of Ionizing Radiation on fetus in pregnant women are Malformation of organs, Microcephaly, Mentally retardation, Lower Intelligence Quotient, Leukemia and Cancer.

Objectives: To evaluate the various dose levels to study the effect of Ionizing Radiation on pregnant women. We also outline the precautions for pregnant women during any medical procedure using Ionizing Radiation.

Materials and Methods: The effects of ionizing radiations are stochastic and deterministic. Stochastic effects are those that occur without any threshold by chance and consist primarily of cancer and genetic effects. Deterministic effects have a limit and sufficiently a large dose is required. However radiation safety to pregnant women is a challenging job. In a pelvis exposure, radiation risk are most significant during organogenesis Early fetal period < 2nd trimester, least in the 3rd trimester. Threshold of 100-200mGy or higher are typically associated CNS problems/ malformations. But fetal doses of 100mGy are not reached even with 3 pelvic CT scans or 20 conventional diagnostic X-ray examinations. These levels can be reached with fluoroscopically guided interventional procedure of the pelvis and with radiotherapy. Leukemia and cancer: Radiation has been shown to increase the risk of Leukemia and many types of cancer in Adults & children through most pregnancy, the embryo or fetus is assumed to be at about the same risk for carcinogenic effects as children. The relative risk may be as high as 1.4 (40% increase over

normal incidence) due to a fetal dose of 10mGy. For an individual exposure in utero to 10mGy the absolute risk of cancer at ages 0-15 is about 1 excess cancer death per 1700. The probability of bearing the healthy children is as a function of radiation dose. Animal data suggest that possibility of prenatal death at 5-10 cGy. Animal and NBS data suggest this is a most sensitive stage for intrauterine growth retardation (20-25 cGy) major organogenesis NBS data indicate small head size those posed at < 8 weeks did not display intellectual deficit ever with small head most sensitive time for induction of childhood cancer. Rapid neuron development and migration (> 10 cGy) results in small head size, seizures, decline in intellect. When CT abdomen is taken, the dose will be 3000 mrem. The various fetus dose chat is presented. X-ray exam of abdomen is 250 mrem.

Conclusion: A common warning notice should be displayed in a predominant place in front of radiation room. Each one of the applications of Ionizing Radiation should be justified all women in the age group of child bearing age and should be informed about the harmful effects of the Ionizing radiation. During a standard radiotherapy protocol may be justified for a 50 year old female but the same protocol may not be justified in pregnant women of 25 years old without more consideration and perhaps modification. All pregnant women are entitled to counseling before any imaging procedure using Ionizing Radiation. They should be explained about the effects of radiation related to the effects of risks. A detailed explanation shout be provided, if the expected fetal dose exceeds 0.01 Gy. Implementations of ALARA principle will be more effectively reduce the fetal dose. Alternatively the patient can be referred to MRI scan or Ultrasonography.

PP-104

IMPACT ON DOSE COVERAGE FOR LUNG TUMOURS DUE TO GEOMETRICAL DIFFERENCES IN TARGET VOLUMES BETWEEN SLOW CT AND 4D CT IMAGING IN STEREOTACTIC BODY RADIOTHERAPY

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Introduction: The outcome of radiotherapy patient's treatment fully depends on target delineation, optimising plan and precise delivery. The Stereotactic body radiotherapy(SBRT) Lung tumour is very challenging site for radiation treatment due to respiratory motion during imaging and treatment delivery. SBRT technique for Lung tumour was started long time ago and used widely at present. This special technique helps oncologist to escalate the tumour dose with help of high precision tumour delineation using high quality images and advanced treatment delivery techniques of Intensity modulated radiation therapy(IMRT), Volumetric modulated arc therapy(VMAT) along with Flattening filter free(FFF) beam.

Purpose: Aim of our study was to quantify the geometrical differences of SBRT-Lung tumors volume in routine Slow-CT and 4D-CT imaging and how its impact on dose coverage of Gross Target Volume(GTV) when motion margin not accurately incorporated while treating advanced treatment technique.

Materials and Methods: For this study twelve SBRT-Lung patients were selected. The selected patient's with Vac-Loc immobilization, routine Slow-CT was acquired and immediately thereafter using Varian Real-time Positioning Management (RPM) system with external marker, retrospective 4D-CT image were acquired in patient free breathing and both image series were acquired in 2mm slice thickness. Acquired Slow-CT images directly transferred to Eclipse (Varian) Treatment planning system V-11.0 and phased 4D-CT image series were transferred to Focal 4D to generate maximum intensity projection(MIP) image. Slow CT and MIP images from Focal 4D system were fused to delineate target volume. After the image registration two GTV volumes were contoured on Slow CT images, one GTV target volume(TVslow CT) using Slow CT images another GTV(TV4D CT) using MIP images. From the two volumes tumour motion range were analysed in all direction for every patients. The plans were generated in technique of IMRT and VMAT on slow-CT images and plan optimised for TVslow CT using 6MV FB and FFF beams. Planning goal was 95% of TVSlow CT should receive prescription dose of 50Gy in 5 fraction. The plans were made using 120 HD MLC for TrueBEAM(Varian) machine, available dose rate for flatten beam and FFF beam is 600MU/Min and 1400MU/Min respectively. Dose were calculated using Acuros® XB Algorithm with grid size of 1mm, different plans were analysed dose coverage for target volume TV4D -CT.

Results: The geometrical difference of target volume on slow-CT and 4DCT images were analysed for every patient. The mean + standard deviation motion ranges were 7.8+4.2, 8.2+7.0 and 6.8+4.0mm in the Right-Left(RL), Anterior-Posterior(AP) and cranial-caudal(CC) direction respectively. In every patient plans, 95% of TVslow CT volume was receiving 50Gy dose . The Mean+S.D of D95 of TV4D CT is 36.9+14.6, 36.2+16.1,34.7+16.2 and 33.7+15.9Gy in FB-IMRT, FFF-IMRT, FB-VMAT and FFF-VMAT plans respectively. And the mean+S.D of V100 for TV4D CT is 71.7+15.5, 71.9+15.7, 70.8+14.8 and 71.0+14.5% for FB-IMRT, FFF-IMRT, FB-VMAT and FFF-VMAT plans respectively.

Discussion and Conclusion: The motion range of GTV in slow CT and 4DCT were analysed and the results were clear that lung tumor motion varíes from patient to patient and not consistent it due to patients respiratory pattern varies in frequency, amplitude and waveform shape. SBRT plan results representing that if plan made on TVslow ct without referring 4DCT images, the actual GTV volume(TV4D CT) will receive dose of D95=36Gy and V100=71%. The standard uniform margin around the GTV for motion doesn't help to cover prescribed dose due to lung motion vary patient to patient and it causes either under dose to GTV region or over dose to normal tissue. So the conclusion is SBRT-Lung treatment goal can be achieved with any techniques when tumours are delineated using 4DCT images.

PP-105

COMPARE THE TPR20, 10 PHANTOM BY USING WATER AND GELATIN GEL

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Introduction: Medical linear accelerator is critical gadget used in radiotherapy departments global. Measurement of beam exceptional of high-energy X-rays generated via a clinical linear accelerator is needed for 3 one-of-a-kind purposes, namely, (i) to confirm the stated specification of the vendor, (ii) to decide the ideal beam-pleasant–correction element for the ionization chamber and (iii) to determine the defensive thickness of the number one and secondary obstacles of the accelerator housing. Recently, some times of enormous mismatch among quoted nominal X-ray-beam power (6 MV) and measured X-ray–beam power, therein, it is essential to observe that one of the beam-exceptional signs (TPR20,10) indicated a particular fee of nominal X-ray energy at the same time as the measured dosimetry information indicated a appreciably different nominal strength. Such observations create confusion at some stage in the medical use of the accelerator, and the user will become unsure about whether to apply the dosimetry data measured regionally or to apply the standard information set available in the literature corresponding to the measured satisfactory of the X-ray beam.
Purpose: The present study is to show the application of the IAEA TRS-430 QA procedures of TPS for photon 6 MV energy. In addition, the trends of the deviations found in the conducted tests were determined using gelatin based TPR20, 10 phantom.
Materials and Methods: In high precision radiotherapy treatment 3D dose verification is very important aspect in giving a quality treatment to patients. One of the beam quality specifications is TPR20,10. This is the ratio of absorbed dose at 20 cm and 10 cm depth , in water phantom with SCD (source to chamber distance) of 100 cm and the field size of 10X10 cm2 on the plane of the chamber and with this we compare water phantom and gelatin based phantom.
Results and Discussion: The linear models for TPR(20,10)(s) and exponential models for PDD(10)(s) as a function of the (equivalent) square field size can reproduce the beam quality within 0.3% and beam quality correction factors within 0.05% for square field sizes ranging 10X10 cm2 and nominal photon energies from 6 MV. For higher energy beams the errors are only slightly worse but for %dd(10)(X), an additional uncertainty component has to be considered for the electron contamination correction. Based on this report, we have measured the data using TPR 20/10 gelatin based phantom and then compare above mentioned results.
Conclusion: The models proposed here can be used in practical recommendations for the dosimetry of small and nonstandard fields. Based on above discussion, the gelatin gel based phantom was better for 3D dose verification a quality treatment to patients.

PP-106

EVALUATION OF AN INDIGENOUSLY DEVELOPED SINGLE WATER PHANTOM USED FOR BOTH THE OUTPUT MEASUREMENT IN EXTERNAL BEAM AND AIR KERMA STRENGTH MEASUREMENT IN BRACHYTHERAPY

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Introduction: Water phantom measurement was strongly recommended for output measurement in External beam radiotherapy, an attempt was carried out to perform brachytherapy source calibration using the same phantom.
Purpose: The main purpose of the study was to evaluate the indigenously developed water phantom used it for both external beam measurement and air kerma strength measurement and in water measurement.
Materials and Methods: The phantom made up of Perspex and the size 30 x 30 x 30 cm3, 0.6cc chamber holder provided at a depth of 10cm. utilizing the same phantom and modified it for brachytherapy measurement by placing two plastic Source applicator in the phantom at 10 cm depth and 10 cm adjacent to the chamber. For External Beam output Measurement was carried out as per the protocol TRS 398 for 6 MV Photon using this phantom and compared the value with 1.00 cGy. In air measurement for air kerma strength for Ir192 and Cobalt-60 source were carried out as per the IAEA-TECDOC-1274 protocol in the same phantom and compared with corresponding air kerma strength value on that day. The same procedure was repeated for in water measurement.
Results: For External beam output measurement percentage variation is ± 0.2% and in air kerma strength measurement for brachytherapy the percentage variation for Ir192 source is ±0.3 % and Cobalt 60 source is ±0.8 %.
Conclusion: The Single unique water phantom for external beam and brachytherapy can be used for three measurements in one single Phantom. For Brachytherapy measurement in air measurement and absorbed dose to water measurement can be done and implemented in routine dosimetric measurement in Hospitals.

PP-107

EVALUATION OF THE INTENSITY MODULATED RADIOTHERAPY TREATMENT PLANS COMPUTED USING PHYSICAL AND BIOLOGICAL OPTIMIZATION ALGORITHM

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Introduction: The main goal of radiation therapy is to deliver adequate high dose to the tumor so that all tumor cells are killed while avoiding the radiation induced damage to the surrounding normal tissue. Radiobiological models are used in the radiobiological treatment planning to estimate the tumor control probability (TCP) and the normal tissue complication probability (NTCP). TCP-PoissonLQ model is used to estimate the TCP and two models namely NTCP-PoissonLQ and NTCP-LKB model are used for the computation of NTCP. The TCP-PoissonLQ model and the NTCP-PoissonLQ model are based on the cell survival model and the Poisson statistics. The NTCP-LKB model is based on the probate function.
Purpose:
1. Evaluation of the Intensity Modulated Radiotherapy Plans using physical and biological evaluation tool

2. Generationof IMRT plans using biological optimization algorithm in terms of probability for Complication Free Tumor Control, Tumor Control Probability and Normal Tissue Complication Probability
3. Comparison of IMRT plans computed using physical optimization algorithm and the same using biological optimization algorithm.

Materials and Methods: In this study we have used the Eclipse Treatment Planning System Version 13.7 (Varian Medical Systems, Inc.,USA). It uses Anisotropic Analytical calculation algorithm (AAA) with a calculation grid of 2.5 mm for dose calculation. It has both physical and biological optimization algorithms for the generation of treatment plans and uses Dose Volume (DV) as well as Biological evaluation tools to evaluate the plans. Biological based evaluation tools are developed by the Ray Search Laboratories (Suveavagen25 111 34 Stockholm, Sweden).20 numbers of patients with Head and Neck cancers treated with Intensity Modulated Radiotherapy technique were selected. Treatment plans of these cases were already performed by the AAA algorithm using a calculation grid of 2.5 mm. In each plan, the physical parameters such as maximum, minimum and mean dose for both Planning Target Volume (PTV) and Organ At Risk (OAR) were obtained from the Dose –Volume Histogram (DVH) generated. At first, these plans were evaluated by using Biological Evaluation tool. Secondly these same patients were re-planned using Biological based Optimization algorithm which calculates the biological parameters such as TCP and NTCP. Results were obtained in terms of probability for complication free tumor control, Tumor Control Probability and Normal Tissue Complication Probability. The't-test' was carried out to find out whether the values of P+, TCP and NTCP have significantly changed for both physical optimization and the biological optimization.

Results: From the 't-test' values it was found that the 'p' values obtained from the comparison for P+,TCP and NTCP were 0.001,0.034,0.04 respectively. Since these values are less than 0.05 we conclude that there is a significant change in the result of biological optimization when compared to that obtained from physical optimization. The average value of P+ for the Physical Optimization was 14.58 and for Biological Optimization was 32.34. Hence complication free tumor control has increased when Biological Optimization is used. The average value of TCP for the Physical Optimization was 38.18 and that for the Biological Optimization was 62.47.This shows the probability for tumor control has increased when Biological Optimization is used.The average value of NTCP for the Physical Optimization was 54.75 and the same for Biological Optimization was 46.10. Hence the probability of normal tissue complication is relatively less when Biological optimization is used.

Discussion and Conclusion: It is evident from this study that there is a significant increase in the probability of complication free tumor control as well as Tumor Control Probability anticipated when we use the biological optimization.There is also significant decrease found in the probability of normal tissue complication while we used biological optimization. Hence it is concluded that the biological optimization is necessary to enhance the complication free tumor control while reducing the normal tissue complication.

PP-108

IN-VIVO ENTRY DOSE MEASUREMENTS FOR THE ASSESSMENT OF SCALP DOSE IN PATIENTS UNDERGOING CRANIAL IRRADIATION BY VMAT

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Objective: To measure entry dose in the scalp region in-vivo using optically stimulated luminescent detectors (OSLDs) for patients undergoing VMAT treatment for intracranial tumors and compare it with calculated dose in the TPS.

Introduction: Epilation (Hair loss) is a possible side effect of radiation therapy since follicles are sensitive to radiation. Hair loss may be temporary or permanent phenomenon depending on the dose received in the scalp region which may vary from patient to patient. In this context the evaluation of dose to the scalp by in-vivo measurements and comparing the measured dose with the calculated dose in TPS assume significance.

Materials and Methods: 10 patients who are treated by VMAT for intracranial tumours were considered for this study. These patients were planned by VMAT technique in MONACO TPS (Version 5.11.02). Scalp region surrounding the PTV was contoured for all these cases. The entry point which is closer to the isocenter is taken as a point of in-vivo measurement for comparison with calculated dose in TPS. These patients were treated in Elekta/Axesse Linear accelerator with 4mm MLC thickness. Aluminum oxide (Al2O3) OSLD chips were placed at the entry points marked for in-vivo dose measurements. To generate a dose response curve OSLD measurements were taken for the first five fractions of treatment. These chips were earlier irradiated with doses in the range of 20 to 1000 cGy for generating a calibration curve.

Results and Discussion: The entry dose to the scalp region is observed to be more than 50% of the tumour dose in 8 out of 10 patients. In two patients it is less than 40% because the isocenter is at a larger depth. The measured OSLD doses were found to be in agreement with the TPS calculated doses below 8.6 % in 9 out of the 10 patients and in one patient the variation was observed as 15.3%.

Conclusion: Entry dose measurements in scalp regions for patients who are treated for intracranial tumours using VMAT technique were measured with OSLD and compared with the TPS calculated dose at the same points. The results are found to be in agreement in 90% of the cases. It was observed that OSLD is an effective tool for in-vivo Dosimetry.

PP-109

RADIATION AWARENESS AMONGST THE RADIATION PROFESSIONALS AND IMPORTANCE OF TRAINING PROGRAMMES: EVALUATION (A PILOT STUDY)

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Introduction: Due to its distinctive properties and multiple uses, ionizing radiation (radiation) has found wide-spread applications in the field of medicine and healthcare. However, with an increase in the use of radiation, the probability of occurrence of radiation injuries and hazards (in case of inadvertent accidents or malpractices) also increases. Hence, proper training and education of the radiation professional is a pre-requisite for the smooth and safe functioning of a radiation department, be it therapy or diagnostics. This training, however, should not be restricted to learning the functioning of a department but must encompass the radiation protection and safety aspects. Inclusion of radiation safety with special emphasis on safe work practices and safety protocols instills confidence in the radiation professionals and reduces the anxiety and fear that surrounds radiation usage.
Purpose: Although the radiation workers and professionals are trained to work in radiation field, constant reassessment and updating is also required to keep them abreast with the technological and safety advances. Moreover, it is a responsibility of the RSO as per Atomic Energy Radiation Protection Rules (RPR) 2004 to periodically train the staff in radiation safety. Medical Physicists too play a significant role in spreading awareness and knowledge about radiation safety as they are the experts in the subject. Hence this training programme was organized at our institute as a pilot study to assess the status of radiation professionals, train them and highlight the importance of such training sessions in radiation safety. The impact of such programmes was assessed through evaluation questionnaires (Pre and Post). We plan to extend this study over the radiation professionals in Jaipur in the next phase and it is in progress.
Materials and Methods: A questionnaire comprising of 30 basic questions related to radiation protection, safety, regulatory norms and safe practices was formulated. The radiation professionals were asked to fill it to evaluate their skills and knowledge in radiation safety. They then underwent a training programme on radiation safety and were again asked to submit same questionnaire. A comparative analysis was done about their knowledge and practices and the improvement through the training programme.
Results: On comparing the results of pre and post questionnaires, an increase in the score was seen for almost every participant. The average score of the pilot group increased from 67% to 78%. The median score increased from 22 to 25 while the mode value of score increased from 24 (scored by 7 participants) to 26 (scored by 8 participants). Each participant showed some appreciation in the radiation safety knowledge.
Discussion and Conclusions: Although the radiation professionals have undergone training for radiation safety, they were found to be less confident in applying it in routine practice. A lacuna was also observed in the awareness about regulatory aspects and dose limits. The training programme showed some improvement but it threw light on the importance of regular and periodic training sessions. As an RSO or medical physicist, it is our responsibility to take on this role and disseminate knowledge about radiation safety to promote safe practices. We aim to extend this study and conduct training programmes across the various hospitals in Jaipur city. Our plan is to include not only the Radiation therapy Professionals (Radiation Oncologists & Radiation Therapists) but also the radiologists and other medical professionals who deal with radiation (Cardiologists, Orthopedics, Anesthetists, Gastroenterologists, etc. who perform interventional radiology procedures). The crux of this study is to bring focus on the role of medical physicist in radiation protection and safety.

PP-110

COMPARISON OF PHANTOM AND TPS BASED DOSE DISTRIBUTION IN 3DCRT-TBI

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Introduction: 3D- CRT based TBI is done with an extended SSD of 120 cm and covering the whole body in AP-PA fields within +/-10% variation in the prescribed dose while shileding the OAR with MLCs.
Purpose: It is important to verify the dose delivered to the patient, so the same is verified using RFA. The study involves comparing the dosimetric values in the water phantom and the tps calculated dosimetric distributions for the given field.
Materials and Methods: Liquid water phantom is CT scanned and the volume is contoured for planning. Extended SSD technique of 120cm is used. Planning is done through the XIO 5.1 and the whole phantom is covered with a homogenous distribution with a variation of +/-10%. 6MV Elekta compact and a PTW RFA is used to collect the dosimetric values on different depths on all the three axis.
Results: Manually calcualted dose and the TPS calcualted dose are compared on different points in the phantom using the RFA.
Discussion and Conclusions: A matrix of 5cm is taken in the RFA in all 3 axis and the manually calculated dose values are compared in each matrix points with the TPS calculated values. The resulting dose profile is compared with that of the TPS generated one and the results are found to be within +/-3% variation.

PP-111

EVALUATION OF POSITIONAL ACCURACY OF EPID USING IMRT GRATICULE PHANTOM IN EXTENDED SOURCE TO IMAGER DISTANCE SETUPS: FORMALISM OF QA

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Introduction: In this modern era of Radiotherapy the Imaging technology now plays very important role in the delivery of radiation with accuracy up to the order of millimeter. Therefore, their performance should also be evaluated in different patient settings especially in nonstandard.
Purpose: The aim of the present study was to evaluate the utility of IMRT graticule phantom to check the positional accuracy of EPID (amorphous silicon flat panel detector, retractable arm) and to develop a quality assurance program for geometrical verification.
Methods: The radiographic images of graticule phantom were acquired using computed tomography (CT) and beam

shapes for desired dose distribution was generated using computer-based treatment planning system. A known shift of 0.5 cm, 1.0 cm and 1.5 cm were introduced in longitudinal, lateral and vertical directions, respectively w.r.t. treatment couch of medical linear accelerator. The EPID images were taken for each shift at different source to imager distance (SID) and beam orientations.

Results: The maximum and minimum shift between the expected and observed value in all the direction were found to be 3 mm and zero respectively. In longitudinal and vertical directions, maximum error of 2 mm was obtained for SID 179.9 respectively, while in lateral direction the 2 mm maximum error was obtained for imager distance 149.9 cm and 179.9 cm. However, the maximum error of 3 mm was found to be most frequent in the longitudinal and vertical directions for SID 1 respectively.

Discussion: The study was carried out to find the effect of sag in EPID due to gravity at extended imager distances and varying beam orientations. Rowshanfarzad et al. found that the sag in EPID was found to be 0.3 mm and 2.5 mm in cross-plane and in-plane direction. Although the large deviation was observed for in-plane as that of cross plane direction and the accepted criterion for non-stero tactic linac is 2 mm as per AAPM TG 142 report. The on-board imaging of patients suffering from different types of tumors is done at different imager distances. This is because of limitation of imaging system, location of tumor and coverage of larger target volumes. For example, the patient suffering from cervix carcinoma and having anterior posterior separation more than 30 cm, the image cannot be acquired at 140 cm. This is due to more possibility of collision between imager and the treatment couch.

Conclusion: The methodology used in the present study is very effective to check the mechanical characteristic and consistency of the retractable arm EPID and can be used routinely in radiotherapy units. The effect of EPID sag due to gravity was not significant for detection of shift in patient's position.

PP-112

EFFECT OF COLLIMATOR ANGLE IN SPINE STEREOTACTIC BODY RADIATION THERAPY-PLANNING STUDY AND DOSIMETRY VERIFICATION

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Introduction: Stereotactic body radiation therapy (SBRT) is an EBRT method that very precisely delivers a high dose of radiation to an extra cranial target. SBRT is highly effective in early stage primary and Oligometastatic tumors at locations throughout the abdominopelvic and thoracic cavities, and spinal and paraspinal sites. SBRT varies from conventional RT is the delivery of large doses in a few fractions, which results in a high BED. In order to minimize the normal tissue toxicity, conformation of high doses to the target and rapid fall-off doses away from the target is critical.

Purpose: IMRT or VMAT is required to create concave dose distributions. Due to the advancement of Technology VMAT delivers more faster Treatment. The cylindrical symmetry of vertebrae favors the use of volumetric modulated are therapy in generating a dose "hole" –donut shape on the center of the vertebrae limiting the dose to the spinal cord. we have studied the improvement of plan quality and deliverability with respect to collimator angle.

Materials and Methods: Ten patients with single vertebral mets were included in the study. Planning CT was acquired with 1.25 mm slice thickness in GE Discovery imaging system. Target Volume(TV) and OAR Contouring was done as per ISRCC & RTOG 0631 protocol. Two Dose Prescription protocols were followed (TV to Spinal Cord (SC) Distance <3mm - 24Gy in 3# , TV- SC Distance more than 3mm 16Gy in single Fraction).Treatment Planning system- Eclipse 13.7 was used for Planning.6MV-FFF beams with 5mm Agility MLC were used for all plans. Four Plans were generated with 4 Collimator angle combinations of 0-180 (C0), 30-330 (C30), 60-300 (C60) & 90-270 (C90) with two arcs. High Resolution Grid lines i.e 1.25mm kept for Optimization and Calculation. Photon Optimizer(PO) algorithm for Optimization and Anisotropic Analytical Algorithm(AAA) for calculation was used. All the Plans were normalized to cover 95% of TV to 100% Dose. Gamma analysis were made to check the deliverability of plans.

Results: In all the plans, the Dmin, Dmax and Dmean were found to be relatively similar and irrespective of the prescription doses (either 24 Gy/3# or 16 Gy/1#). Conformity index (CI) for each collimator combinations such as C0-180, C30-330, C60-300 and C90-270 were found to have a value 1.3, 1.1, 1.1 and 1.2 respectively. Marginal increase in CI observed in the C0-180 and C90-270 combinations could be due to cumulative low dose contributions from the overlapping interleaf leakages in all opposing gantry projections. Identical gradient indices (GI) and OAR (heart, liver and kidneys) doses observed among all the collimator combinations showed that the dose fall-off outside the target was not dependent on collimator angles. However, important finding in our study is that the C0 and C90 combinations resulted in increased SC dose of about 10% in comparison with C30 and C60 combinations. Gross difference in total MU was also observed between the four collimator settings, the C90 combination was found to have the lowest value. For all the four collimator combinations, more than 95% dose voxels were passing the standard gamma criteria (3%/3 mm DD and DTA).

Discussion and Conclusion: Selection of optimum collimator combination is essential in SBRT of spine mets thereby reducing the maximum dose to spinal canal and limits the total MU required to deliver the prescription dose. Further investigation on the various collimator combinations with large sample size yields statistical significance of the same.

PP-113

MONTE CARLO INVESTIGATION OF ELECTRON BEAM CHARACTERISTICS AND ITS VARIATION WITH THE INCIDENT ELECTRON AND COMPARISON WITH PHASE SPACE BEAM CHARACTERISTICS

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Introduction: Monte Carlo simulation is considered to be the most accurate technique to understand the beam transport and interaction of radiations with matter. A linear accelerator model is developed using the GEANT4 software. Monte Carlo simulations are performed to understand the variation in beam characteristics of the electron beams by varying the incident electron and tried to match with the electron beams produced by the phase space file provided by the IAEA.
Purpose: The aim of the study is to establish a relation between electron beams produced by varying the incident electron and those produced by phase space file given in IAEA.
Materials and Methods: Monte Carlo model of the linear accelerator capable of producing electron beams of energy from 6 MeV and 9 MeV is developed. Linear accelerator model is designed in accordance with the configuration provided by the Varian Medical Systems Inc., Palo Alto, CA. Monte Carlo simulations of 6 MeV and 9 MeV electron beams with applicator size of 10-10 cm2 and 15-15 cm2 are preformed and dosimetric data is recorded which is compared with the dosimetric data obtained using the phase space file provided by the IAEA for the same beam energies and applicator sizes. The initial beam energy of the electron is varied from 6 MeV with the increment step of 0.1 MeV to get the comparable percentage depth dose curve within 1% and lateral dose profile within 2% as of the Phase space from IAEA.
Results and Discussion: More the number of particles run more accurate is the result. As it is time taking due to system limitation and all other parameters.

PP-114

A FUTURISTIC TOOL FOR THE TUMOUR CHARACTERISTICS: THE RADIOMICS

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Introduction: Images are not just images they are data. Basically, images are the mathematical representation of intensity patterns distributed over a volume in 3D. Radiologically, tumours can be differentiated from the normal tissues in terms of some characteristics like shape, intensity and texture. From the idea it can be justified that the mathematical data of the images are different for tumours and that for normal tissues in respect of some mathematical functions. These functions are known to be the Radiomic features. Various tumours are also different from others in terms of their nature and biology. Thus, a pattern is to be created in between them so that nature of tumour, its origin as well as kinetics of the tumour can be studied and furthermore may be helpful in finding the survival of the patient and also the effectiveness of the treatment given to them individually.
Purpose of Study: The aim of the study is to find some characteristics features in terms of mathematical functions (Radiomic features) of the tumours as well the normal tissues.
Materials and Methods: The pre-treatment CT scans of 422 non-small cell lung cancer (NSCLC) patients available at The Cancer Imaging Archive (TCIA) were included in this study. The manual delineations of gross tumour volumes as marked by radiation oncologists were used for accuracy purposes. The radiomic features including Global textures, first order and higher order texture features were calculated in Matlab. Additionally, wavelet band-pass filtering, isotropic resampling, discretization length corrections and different quantization tools can be used along with a mathematical algorithm to further study delta-radiomics.
Results and Discussion: A few radiomic features including Global textures, Grey level co-occurrence matrix (GLCM) features, Grey level run length matrix (GLRLM) features, Neighbourhood grey tone difference matrix (NGTDM) features and Grey level size zone matrix (GLSZM) features were extracted.
Conclusion: Radiomics holds great (promises in future. Since it is easy to perform, non-invasive and achievable at low cost, it is a revolutionary tool that can be used to study tumour growth, its proliferation and differentiation. This might need a good collaboration with clinic to obtain scans acquired on each follow-up.

PP-115

DOSIMETRIC COMPARISON FOR TREATMENT OF CA. BRAIN USING INTENSITY MODULATED RADIATION THERAPY AND VOLUMETRIC MODULATED ARC THERAPY TECHNIQUES

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Introduction: *Dosimetric Comparison* in Intensity Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) was compared, and the advantages and disadvantages of different radiotherapy plans were evaluated. Volumetric Modulated Arc Therapy (VMAT) is a novel form of IMRT optimization that regulates the radiation dose with enhanced degrees of freedom, by continuously modulating the Multi Leaf Collimator (MLC) field shape, gantry rotation speed and dose rate. VMAT enables for additional flexibility in dose delivery and could further improve dose conformity and sparing of vital tissues. Compared with IMRT, the potential advantages of VMAT include a large reduction in treatment time and a concomitant reduction in the number of monitor units (MUs) required to deliver a given fraction size. For each patient, three treatment plans, including a dIMRT, Single Arc VMAT and Double Arc VMAT plan were generated. The dose prescription was set to 60 Gy delivered over 30 fractions. The dose distributions for the planning target volume, organs at risk (OARs) and normal tissue were compared. The MUs were also evaluated. The dose distribution of target (Dmax, Dmin, Dmean, dose Conformity and Heterogeneity index), OARs and normal tissue were compared among the three plans.
Materials and Methods: A total of 30 patients with Ca. Brain were selected from between June 2016 and July 2018 to be included in the present study. The median age was 52 years the target volume was delineated according to the no. 50 and 62 reports of the International Commission on Radiation Units and Measurements. For the gross tumor volume (GTV) was defined MRI Scan and the CTV was defined as the GTV plus a margin. The CTV was expanded by 5 mm to produce

the PTV. Using Monaco 3DTPS software (version 5.1 Elekta Medical Systems, Crawley, UK). dIMRT and VMAT plans were produced using 6MV photons, and the dose prescription was set to 60 Gy in 30 fractions. The dose constraints to the OARs were determined using a Radiation Therapy Oncology Group protocol. The dIMRT plans consisted of six coplanar fields at gantry angles of 51˚, 102˚, 153˚, 204˚, 255˚ and 306˚. The VMAT plans consisted of a single arc and double arc starting at a gantry angle of 180˚ and rotating counterclockwise through 360˚. The Three plans adopted the same approach during optimization. The upper limits of the dose rate for the 6MV beams were 600 MU/min, respectively. The dose volume histogram included the Dmax, Dmean and Dmin of PTV. Conformity index was calculated as follows: (PTVref/VPTV) x (PTVref/Vref). Heterogeneity index (HI) was calculated as follows: D5/D95. To quantify the dose distribution on OARs and normal tissue (NT) at different dose levels, the percentage volume of the OARs and NT receiving a dose of 20, 10 and 5 Gy were evaluated and compared.

Results and Discussion: PTV coverage, the Dmax and Dmean of PTV in dIMRT were increased compared with that in the both VMAT plans. During the process of VMAT the parameters, including the dose rate, the gantry rotation speed and the site of MLC change dynamically. Two types of products are currently in clinical use, Varian RapidArc and Elekta VMAT. As the application develops, the VMAT plan may become equal or superior to IMRT. Compared with IMRT the VMAT plan may increase the scattering of NTs, reduce the MUs and reduce the treatment duration. OARs, including pituitary gland, optic nerve and chiasma were more improved in the dIMRT plan compared with VMAT. The reason for this is primarily due to the spatial association between the location of the Ca. Brain and OARs. In an identical ray model, the differences in dose distribution to OARs between the three plans the positioning accuracy and the leakage ray, and as a result the Dmax of the pituitary gland and chiasma in VAMT was increased compared with dIMRT. In the past few years, the VMAT plan has been gradually applied in clinical treatment. The VMAT plan should be considered as the treatment duration may be reduced with dIMRT Treatment duration.

PP-116

DOSIMETRIC STUDY OF SMALL CIRCULAR CUTOUTS FOR ELECTRON BEAM THERAPY

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Introduction: Electron applicators has an important role in electron beam therapy. Electrons undergo significant scattering in the air between the scattering foils and the patient. Superficial tumours having small area are commonly treated using megavoltage electron beams. Depending on the type and the shape of tumour, cast cerrobend alloy cutouts are used.

Purpose: The main objective of this study is to dosimetric effects of cerrobend cutouts of smaller area in megavoltage electron beam and find out how the dosimetric parameters such as mean energy output factor and range of electron changes with the use of small area cerrobend cutouts, and to fit the values of R100, R90, R80, R50, E0 (mean), and OPF changes on a curve and formulizing these changes as a function of cutouts cavity area.

Materials and Methods: In this study, measured the dose profile and output of electron beam with applicator sizes *5×5, 10×10, 15×15 and 20×20 cm2* and without applicators for different energies 4, 6, 9, 12, 15 and 18 Mev for Varian 2300 C/D Acccelerator. Circular Cerrobend cutouts of smaller area, having circular diameter of 2 cm, 3 cm, 4 cm, 5cm, 6 cm 7 cm and 8 cm were made with the help of a Styrofoam cutter. Electron applicator of 10 x 10 cm2 field size was mounted to the linear accelerator. RFA was set at SSD of 100 cm, using parallel plate ionization chamber as field detector and semi flex ionization chamber as reference detector. Beam profile and PDD curve of reference field (10 x 10 open field) and all cut outs for all available electron energies (4 MeV, 6 MeV, 8 MeV, 12 MeV, 15 MeV) were taken using RFA. Data analysis was done using MEPHYSTO MC2 software.

Results: R100, R90, R80, R50, Rp E0mean and Output factor for all cut outs for six different energy is found. The obtained data is analyzed and curve for each energy is plotted as cutout area versus the dosimetric parameter. Curve fitting is done using GNU plot software. Equations for each parameters for all energy is found as a function of cutout area with minimal reduced chi square value.

Discussion and Conclusion: This work explores the impact of use of small area cut outs for electron beam therapy, which is usual practice in radiotherapy treatment for superficial tumors. This study concludes that there are some changes in the dosimetric parameters occurred due to the placement of cutouts in the megavoltage electron beams. The effects are decrease in output factor, decrease in mean energy and shifting of PDD curve to the surface. Variation in the values showed almost same trend, each parameter for each energy is fitted and equation is made as a function of cavity area, and the equation is given by

$P = a/(+b*\exp(-c*A))$

Any of the dosimetric parameter R100 R90 R80 R50 output factor and E0 mean can be found using this equation for any cutout with known cutout area, so there is no need of doing dosimetry for each patient specifically.

PP-117

DOSIMETRIC EVALUATION OF INDIAN MADE BOLUS AND COMPARED WITH SUPERFLAB AND RW3 SLAB

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Introduction: Bolus material is used in photon and electron energy of radiation therapy to correct for anatomical irregularities and deliver the prescribed dose to the patient skin surface. The common treatment site bolus required such as ear, nose, breast, chest, and vulva. There are various tissue equivalent bolus material used as bolus in radiotherapy.

Purpose: The main purpose of the present work was to perform the dosimetric evaluation of the Indian made bolus

(SENflab) and compare with that of the commercially available superflab and RW3 slab using RW3 slab phantom with high energy photon and electron beams.

Materials and Methods: The Indian made bolus was used to measure the transmission factor, Electron Density and compare with superflab and RW3 slab using RW3 slab phantom. For two megavoltage X-rays, 6 and 15 MV & all electron energies, the transmission factor of the Indian made bolus was measured by means of a 0.6cc Farmer ionization chamber. The Home made was placed on top of the slab phantom and irradiated by 6 and 15 MV photons and repeated for other boluses. Afterward, the boluses was removed and the irradiation repeated for both photon as well as electron energies. Computed tomography data from the boluses were acquired to assess electron densities with various techniques (mA and kVp). Circular ROIs were delineated on CT DICOM images and densities were calculated using CT numbers.

Results and Discussion: Evaluation of our results are evident that showed that mass electron densities are similar to those of water and soft tissue. Furthermore, transmission factors are close to those of water.

Conclusions: The Indian made bolus is a reasonable alternative to tissue-equivalent bolus. Bolus is equivalent to tissue in photon attenuation, conforms well to the irregular contours. It should be considered a viable alternative to common bolus materials such as Bee's wax and Paraffin wax. Its need further study to use clinically.

PP-118

AN IN-HOUSE SPREAD SHEET FOR ANALYSIS AND VERIFICATION OF DOSE ACCUMULATION FOR CARCINOMA CERVIX PATIENTS TREATED WITH EXTERNAL BEAM THERAPY AND BRACHYTHERAPY

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Introduction: Cancer of cervix is a major cause of cancer morbidity and mortality among women worldwide. The radiotherapy treatment includes external beam radiotherapy and brachytherapy. Brachytherapy enables the delivery of a high dose, in a small volume, during a short period of time. The continuing interest in brachytherapy stems from enhanced technological capabilities to place radiation sources accurately within and/or adjacent to tumors, usually allows a high tumor to normal tissue dose ratio and a reduction in the volume of irradiated normal tissue.

Materials and Methods: A retrospective analysis of radiation dose accumulation for 60 patients who have received radiotherapy with EBRT and Brachytherapy was carried out. 50 Gy was delivered by external beam radiotherapy in 25 fractions and 3 fractions of HDR Brachytherapy of 7 Gy were delivered. The treatments were performed on Bhabhatron TAW II and Bebig multisource HDR Brachytherapy. The Biologically Effective Dose (BED) was calculated for the prescribed doses. An equivalent dose in 2 Gy per fraction (EQD2) was estimated for both external beam and brachytherapy dose delivered. For brachytherapy, EQD2 calculation must take into account the dose gradient and has to be cautiously applied as it's a mathematical one. We have formulated an excel spread sheet to incorporate these dosimetric parameters according to the linear quadratic model using alpha/beta 3 Gy. The EQD2 for external beam radiotherapy, and doses to point A, bladder point and rectum point for brachytherapy were estimated separately using the spread sheet and analyzed.

Results and Conclusion: The in-house spread sheet is reliable to analyze the dose accumulation to normal structures in radiotherapy of carcinoma cervix (bladder and rectum). The doses to bladder and rectum were within tolerance dose limits for all patients treated. This spread sheet appears as a useful tool for EQD2 analysis between the dose delivered through EBRT or brachytherapy.

PP-119

A PRELIMINARY VALIDATION STUDY ON THE DOSE PREDICTION ACCURACY OF PENCIL BEAM CONVOLUTION AND COLLAPSED CONE CONVOLUTION ALGORITHMS

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Introduction: Study investigated the effect of air gaps on depth dose calculations computed by pencil beam convolution algorithm (PBC) and collapsed cone convolution (CCC) algorithm.

Materials and Methods: A phantom (30 x 30 x 30 cm3) containing rectangular solid water blocks and two 5cm air gaps was used for central axis dose calculations computed by collapsed cone convolution algorithm (CCC) and Pencil Beam Convolution algorithm (PBC).

Results: The point dose measured by collapsed cone convolution was within ±1.1% in the first water medium. After the second air gap, the CCS continued to under predict the dose , and the difference ranged from -3.3% to -3.1% for 3 x 3 cm2, from -2.1% to -5.3% for 5 x 5 cm2, from -2.1% to -6.4% for 10 x 10 cm2, and from -1.3% to -5.4% for 15 x 15 cm2. The results of PBC were within ±1.7% in the first water medium. After the second air gap, the PBC continued to over predict the dose, and the difference ranged from -3.3% to -3.9% for 3× 3cm2, from -2.6% to -5.6% for 5 × 5 cm2, from -2.5% to -6.0% for 10 × 10 cm2, and from -1.6% to -5.6% for 15 × 15 cm2.

Conclusion: The PBC over predicted and collapsed cone convolution under predicted the dose in water medium after the photon beam traversed the air gaps at different depths.

PP-120

PATIENT SPECIFIC QUALITY ASSURANCE OF RAPIDARC PLANS IN HEAD AND NECK CANCERS USING 3DVH SOFTWARE IN NEW AGE DOSIMERY

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Introduction: Patient Specific Quality Assurance is defined as a mandatory procedure to ensure the proper delivery of

modulated treatment plans. The advancement in technology has ensured in developing newer algorithms in evaluating the plan delivery quality. The standard followed across the world in gamma evaluation defined by standard algorithms being followed by all vendors. With more robust machines coming in the market, we have more tools to dig deep into evaluating each control point for error. With standard gamma evaluation methods all being in 2D, there are chances of missing few data or sometimes data getting integrating where errors are cancelled out in final result. In this study, we have made an effort to understand the use of 3D evaluation of patient qa using Sun Nuclear ArcCheck and 3DVH, in head and neck cancers.

Materials and Methods: For the purpose of this study we have considered 18 patients with head and cancer. All these patients were treated with RapidArc and the QA was done using Sun Nuclear Arc Check. The treatment planning was done using Eclipse Treatment Planning Software and the plans were delivered in TrueBeam STx SVC linear accelerator equipped with HDMLC with 2.5 mm leaf thickness at isocentre. Further, the delivered plans were evaluated using SunNuclear 3DVH software for 3D dose evaluation. The PTV doses, viz a viz, maximum, minimum and mean dose and the coverage to 95% and 98% volumes were compared. The protocol was defined as 95% as the pass rate as per department standards. Additionally, the DVH was used to compare the Organ At Risk (OAR) dose values also.

Results: The gamma passing rate for all the plans were above 98% and in general all plans cleared the department tolerance for pass rate. This indicates that all plans are good for delivery. But, the DVH analysis showed varying results. Two of the plans showed failure in 3DVH analysis with values less than 95%. The max dose to the PTV was more compared to the planned dose and finally these patients were replanned before treatment. For the same patient, the OAR doses were also not comparable to the planned OAR doses.

Conclusion: Gamma analysis can predict the failure of a plan in most of the cases and is proven to be a reliable tool for patient plan qa evaluation. But, it can miss some information at some time due to integration of errors. For the evaluation of plan delivery with higher precision we need to evaluate all the plans in 3D and the 3DVH performs the same with high accuracy.

PP-121

MEASUREMENT OF OUTPUT FACTORS FOR SMALL FIELDS OF BHABHATRON II TELECOBALT UNIT

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Introduction: The recent technological advancements in radiation therapy have led to a significant increase in treatment techniques involving small fields such as SRS, SRT, SBRT etc. Presently machines dedicatedly designed for these sophisticated techniques are also used in the therapeutics. However, measurement in small fields using ion chambers is a challenging task due to several factors such as absence of charge particle equilibrium, low signal to noise ratio, volume averaging effect and source occlusion. To overcome these difficulties IAEA recently published a technical report series (TRS-483). One of the recommendations of this report is the use 5 x 5 cm2 field sizes as reference field in case of unavailability of 10 X 10 cm2 field size. Radiochromic films can also be used can be used for this purpose due to its high spatial resolution.

Purpose: In the present study, output factors for small field using Bhabhatron-II Teletherapy machine were measured using Radiochromic film for two different reference fields namely 5 x 5 cm2 and 10 x 10 cm2 and the results were compared.

Materials and Methods: Radiochromic film pieces (EBT 3 Film) were used for the calibration as well as output factor measurements. Calibration procedure was carried out by exposing the films with known doses from 25 cGy to 500 cGy using Bhabhatron-II Teletherapy unit. The films were scanned with Epson 1000 XL scanner and pixel density for each film was measured using ImageJ software. A calibration curve was plotted using the pixel density obtained from ImageJ against known doses. For output factor determination, radiochromic films were exposed for field sizes of 1 x 1 cm2, 2 x 2 cm2, 3 x 3 cm2, 4 x 4 cm2, 5 x 5 cm2 and 10 x 10 cm2 with the same treatment time (2 min). By using the calibration curve obtained above, dose corresponding to each field size was obtained.

Results: The output factors for different field sizes were normalized to reference fields (10 x 10 cm2 and 5 x 5 cm2) in accordance with TRS 483. The output factors obtained with reference field of 5 x 5 cm2 were found to be 0.36, 0.85, 0.97 and 0.99 for field sizes of 1 x 1 cm2, 2 x 2 cm2, 3 x 3 cm2, 4 x 4 cm2 respectively and for that of 10 x 10 cm2 were 0.33, 0.77, 0.87 and 0.90 for field sizes of 1 x 1 cm2, 2 x 2 cm2, 3 x 3 cm2, 4 x 4 cm2 respectively. The relative percentage variations up to 11.5% were found for these two reference fields.

Conclusion: The variation in output factors using two different reference fields can be attributed to the fact that a low scatter dose at the smaller reference field (5 x 5 cm2) would lead to smaller total dose as compared to larger(10 x 10 cm2) reference field, which in return lead to higher output factor for the smaller reference field. It also emphasizes on the fact that due to very high uncertainty at small field a particular detector may give large variation and hence it should be verified against other detectors.

PP-122

VERIFICATION OF DOSE AT JUNCTION BETWEEN BREAST/CW AND SUPRACLAVICULAR FIELD DURING DIBH TREATMENT

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Aim: Verification of dose at junction between Breast/CW & SCF field during DIBH treatment.

Purpose: In DIBH treatment dose at junction is depended on the breathing of patient. As such uncertainties may be

introduced due to improper breathing. We have to tried to a film based dose measurement at junction of fields treated by DIBH.

Materials and Methods: Breast patients requiring supraclavicular field (SCF) treatment were selected for this study. Patients were treated on Varian TrueBeam machine. For tracking the Patient breathing pattern Varian based RPM system was used, reflecting marker was placed at the sternum level on the patient body. Proper immobilization devices is used to reproduce the patient positioning (same at the time simulation) for the treatment.

We performed film based dose measurement for 10 breast cancer patients receiving radiotherapy to the Breast/CW and SCF region. Gafchromic EBT film (5 cm * 10 cm) was placed at the junction between upper border of Breast/CW & lower boarder of SCF field. The patients were treated with the film placed on the skin. EPSON perfection V800 scanner was used to scan the film to measure the profile. We performed the consecutive measurement for five days to find out the accuracy of the setup and reproducibility of breathing cycle.

Result: For 20% of the patients, the ratio of measured and calculated dose along the junction were greater than 1 (i.e. overlapping between the junction fields). We observed that whenever breathing pattern was reproducible, the intended gap (i.e. 5 mm was used) between the fields was maintained and was visible on the film. For patients who could not follow the instructions correctly the gap on the film seemed to reduce i.e. chances of overlapping occur. However upon further coaching these patients when they followed instructions the gap was maintained well.

Conclusion: Breast patients having SCF field can be safely treated with DIBH protocol provided patient breathing is reproducible. For patients who cannot follow the breathing instruction properly, should be coached and junction dose should be confirmed with in-vivo dosimetry method.

PP-124

A STUDY OF LUNG VOLUMES AND DOSES IN LUNG LESIONS, MULTIPLE VOLUMETRIC IMAGES OF RESPIRATION CYCLE ON CT

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Introduction: Introduction of respiratory motion management into the radiation therapy practice to accomplish target or organ motions. Using an infrared camera tracker the external marker on the patient is tracked. This will help in generating a respiratory cycle of the patient.

Purpose: The purpose of this study is to find out the change in volume of the lungs throughout the 4DCT of the thorax patient on image sets.

Materials and Methods: We have taken 6 patients for the study. There are lot of vendors available with respiratory-gating devices. We have used the Varian Real-time Position Management (RPM) system. A marker is placed on the abdominal region between the xyphoid process and umbilicus to account for the maximum amplitude of the patient motion. Patients are trained for reproducible and regular breathing pattern. Phillips Big bore CT-Simulator, along with real-time position management (RPM) system (Varian Medical Systems, USA) were used to acquire 4D-CT image set. The upper and lower portion of the signal represents the inhaled and exhaled phase. This respiratory cycle represents a complete period and is divided into a number of phases of equal duration. All the lung volumes were contoured along with other OARs on all phases of the multiple images of the respiration cycle on the individual patients. Our stude we have compared only the ipsi lateral lung volumes and the dose received by them.

Results: In 6 patients 83% were male and 17% female ratio. 50% were from Right lung and 50% ration were from left lung. The ratio of upper, middle and lower was equal with anteriorily situated tumors were 66% and remaining were posteriorily situated. The average lung volume of all the phases is compared with the averaged CT and mip (maximum intensity projection).

Discussion and Conclusion: We noticed that among 6 patients the ipsi lateral lung received least V20 dose in the 0 phase of the cycle when a tumor PTV was done on the ave CT, the mip received the less dose for max in 50% of the cases. Our superior to inferior lung volume length changed between 1.5 to 2 cm and AP in between 0.4 mm to 0.7 mm and in lateral direction found to be 0.2 mm to 0.5 mm. It is well within the published result from many authors and our most of the patient general condition for treatment was also a favorable factor. We conclude that each institution must carry their own margins to be given in thorax lesions. And while deciding a plan one must carefully choose the plan by checking the doses in all the phases.

PP-125

FLUENCE SCALING FACTOR FOR VIRTUAL WATER PHANTOM IN HIGH ENERGY ELECTRON BEAMS

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Introduction: Plastic phantoms may be used under certain circumstance in electron beam dosimetry for beam qualities R50 < 4g/cm2 as per IAEA TRS-398 report. Though the fluence scaling factor (hpl) for various plastic phantoms is listed, the value for virtual water phantom is not available in the report. This study was aimed to estimate the hpl factor for virtual water phantom in available electron energies at our institute.

Materials and Methods: Virtual water phantom (density=1.030 g cm-3) in the form of solid slabs of size 30 x 30 cm2 with different thickness ranging from 0.2 cm to 5 cm were used for measurements. The chamber holder plate for Advance Markus Chamber (PTW TM34045) was made of acrylic material of 2 cm thickness. The measurements were taken for electron beams with energies 6, 9, 12 and 15MeV generated by Truebeam STx LINAC. Initially absorbed dose was measured according to IAEA TRS-398 protocol in 1D water phantom (PTW) at Z ref,w for all the four electron energies. On the same day, dose was measured again in virtual water phantom at Z ref,pl as derived from the below

Table 1: Fluence scaling factor hpl for virtual water phantom

Energy (MeV)	*hpl*					*Average (hpl)*
	Day 1	*Day 2*	*Day 3*	*Day 4*	*Day 5*	
6	1.0137	1.0137	1.0138	1.0136	1.0138	1.0137
9	1.0135	1.0141	1.0137	1.0135	1.0140	1.0137
12	1.0228	1.0230	1.0230	1.0229	1.0232	1.0230
15	1.0265	1.0267	1.0268	1.0264	1.0265	1.0267

expression. **Z ref,pl** (g/cm2) = **Z ref,w** (g/cm2)/**Cpl.** Where Cpl is depth scaling factor. Cpl value for virtual water phantom is 0.946 (ref in TRS-398). Z ref,pl (cm) = Z ref,pl (g/cm2)/ρpl (g/cm3). Where ρpl is density. The ρpl value for virtual water phantom is 1.030 g cm-3 (ref in TRS-398). Entire measurements were repeated on different days and hpl factor is estimated from the average of the observed results. The estimated hpl factor were used in the other LINAC for the corresponding electron energies to measure the dose in virtual water phantom and compared with liquid water phantom results.

Result: The fluence scaling factor (hpl) was calculated as the ratio of absorbed dose in water to dose in plastic, for all four electron energies generated by LINAC Truebeam STx using the expression hpl = D w,Q(Z ref,w)/D pl,Q(Z ref,pl). Calculated values of hPl from dose measurement on different days is shown in Table 1. Repeatable results were observed and hpl factor were estimated. Measured absorbed dose in virtual water phantom with the estimated hpl values in the other Linac for the corresponding electron energies, was found to be consistent with the liquid water phantom results.

Conclusion: As per IAEA TRS-398 report, plastic phantoms can be used for routine quality assurance measurements, provided the relationship between dosimeter readings in plastic and water has been established for the user beam at the time of calibration. In a busy clinical setup, a quick measurement setup with virtual water phantom compared to liquid water phantom will be useful for routine quality assurance checks.

PP-126

VOLUMETRIC-MODULATED ARC THERAPY FOR HIPPO-CAMPAL SPARING IN WHOLE BRAIN RADIOTHERAPY: A NEW APPROACH FOR MANAGEMENT OF BRAIN METASTATIC CASES

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Introduction: Whole brain radiotherapy (WBRT) with two lateral opposed portals has long been considered the standard treatment of choice for patients with brain metastases, because of its wide availability, ease of delivery and its effectiveness for most of the patients. Although this was the main treatment option available and is still widely used, many toxicities, particularly cognitive impairment resulting from WBRT remained a major concern. With the advancement in imaging and treatment delivery techniques, the probability of improved outcomes has increased for many patients. With the improvement in outcomes and the higher expectations of patients regarding better quality of life, the routine use of WBRT has been scrutinized, considering the impact of neuro cognitive functions and quality of life of the patients. The Hippocampus is responsible for memory and cognitive function. Hippocampal sparing whole brain radiotherapy (HS-WBRT) is a technique that aims to reduce the neuro-cognitive side effects of whole brain radiotherapy. In this regard, hippocampus sparing WBRT is an improved technique that aims to spare critical hippocampus region without compromising the tumour control. The aim of this study is limited to planning, feasibility and efficiency of using volumetric modulated arc therapy (VMAT) to spare the hippocampus and all other OARs.

Materials and Methods: A total of 5 patients were planned for hippocampus sparing using VMAT according to the RTOG 0933 protocol. The OARs (Both lens, optic chiasm, both optic nerves) were considered as dose constrained structures. The hippocampi were contoured and hippocampus PRV structures were created using a 5 mm volumetric expansion around the hippocampus. The whole brain planning target volume was defined as the whole brain tissue minus hippocampus PRV regions. All the plans were done with VMAT for the prescription of 30 Gy in 10 fractions. The VMAT plans were created in Elekta Monaco treatment planning system (Version -5.00.04) with 6MV photon beam for the Elekta Synergy Linear accelerator. Plans were evaluated using D2% and D98% for the whole brain PTV (whole brain tissue minus hippocampus PRV structure region). D100% and the maximum dose to the hippocampus region and also maximum dose to the optic nerves, optic chiasm and lenses were recorded.

Results: The whole brain PTV D2% mean value was 3368 cGy (ranges from 3251 to 3429 cGy), D98% mean value was 2457cGy (ranges from 2407cGy to 2507 cGy) and the D95% mean value was 2851cGy (ranging from 2797cGy to 2897cGy). The hippocampus D100% mean value was 833cGy (ranging from 768 cGy to 897cGy) and hippocampus maximum dose mean value was 1470cGy (ranging from 1408cGy to 1539 cGy).The maximum dose to optic nerves and optic Chiasm for all patients were noted and did not exceed 37Gy. The mean number of monitor units was 1482MU (ranging from 1347MU to 1608 MU). Quality assurance of the plan delivery (Gamma evaluation) for all the plans passed the 3%, 3 mm criteria with more than 93% measurement points.

Conclusion: The results indicate that VMAT planning allows significant sparing of the hippocampus with acceptable target coverage and homogeneity, and meet the RTOG 0933 criteria, consequently reducing neuro-cognitive decline as shown in Preclinical and clinical studies, and potentially improving quality of life.

PP-127

COMPARISION BETWEEN THE NANODOSIMETER AND GAS CHROMATOGRAPHY AND MASS SPECTROMETRY TO DIAGNOSE CANCER

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Introduction: In the modern field of nanodosimetry, the Printed Circuit Board (PCB) technology based positive ion detector has been identified as a device to detect cancer in lungs and breast region. The gas chromatography and mass spectrometry (GCMS) is one of the techniques to analyze the gas molecules released by liquid samples. By this technique, malignant cells can be diagnosed by the exhalation of specific volatile organic compounds (VOCs) which serves as eminent source biomarkers for malignant diagnosis.
Purpose: To compare the cancer diagnosing capability of the Nanodosimeter and GCMS using lung and breast malignant biopsy tissues of all stages.
Materials and Methods: Multilayer PCB technology based Nanodosimeter was designed to capture positive ions produced by the interaction of ionizing radiation with low pressure gas medium. After the validation, the normal breast tissues were placed inside the chamber and it was evacuated in order to remove all molecules present in the chamber. Then, it was allowed to exhale molecules at various pressures in order to measure the amplitude, rise time, fall time, and number of pulses of the signal. Later, these normal tissues were replaced with breast cancer tissues of all stages (Stage 0, 1, 2, 3a, 3b, and 4) in the evacuated medium and the same was allowed to exhale Volatile Organic Compounds (VOCs) to capture signal at various pressure ranging from 1 to 10 Torr. All the measurements were repeated for 10 times to improve consistency in measurements. The mean amplitude, rise time, fall time, and frequency of pulses and number of pulses produced by normal and malignant lung and breast tissue were compared. The GC-MS sample analysis was performed as per the direction given in the Agilent GCMS instrument manual.
Results and Discussion: In the Nanodosimeter, the signal amplitude, frequency, rise time, fall time and number of pulses have been increased gradually when the normal breast and lung tissue converted into various stages of malignancy. For the stage 0, 1, 2, 3a, 3b and 4, the mean amplitude of the pulse produced by normal breast tissue was increased upto 2.82, 6.59, 14.78, 20.02, 21.64, 22.98 % and for lung tissue 2.45, 6.18, 10.89, 12.12, 15.12, and 17.84 % respectively and the mean frequency of the signal emitted by normal breast tissue was shifted from 38.4 Hz to 83.2, 183.5, 281.2, 454.5, 494.5, 569.6 Hz and for lung tissue 16.6 Hz to 21.15, 24.8, 28.7, 33.8, 35.6, and 43.02 Hz respectively. Similarly, rise time and fall time of the stage 0, 1, 2, 3a, 3b and 4 of breast and lung malignancy signal is higher than that of normal tissue. The GCMS spectrum shows different VOC molecules in variable number depending upon the type of tissue and stage. But, it does not show any signal at stage 0, 1 and 2. Hence, it was inferred that GCMS can only be used to detect cancer at stages 3a, 3b and 4. However, it requires gas molecules at pressure ranging from 4000- 5000 Torr.
Conclusion: Nanodosimeter shows better response than GCMS to detect breast and lung malignancy in addition to its cost effectiveness, simple processing, reproducibility and capability to detect low level signal. However, the present Nanodosimeter should be upgraded to identify the gaseous molecules.

PP-128

EVALUTION OF DOSMETRIC PROPERTIES OF HAFNIUM OXIDE NANOPARTICLES FOR RADIOTHERAPY APPLICATIONS

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Purpose: Thermoluminescence dosimeters play an vital role in invivo dosimetry. Hafnium Oxide nanoparticles (HfO2 NPs) has found wide-ranging in numerous fields of interest, such as control rod in nuclear reactor, UVR dosimeters and Scintillators. In this regard, the current study aim's to examine the thermoluminescent properties of HfO2 NPs and to evaluate its application in high energy gamma dosimetry.
Materials and Methods: HfO2 NPs were synthesized by precipitation method and pellets were prepared by using hydraulic pellet pressing machine. Before irradiating the samples in 60Co beams they were annealed at 300 degree C for 10 minutes in order to erase the residuals. Theratron phoenix 780C cobalt-60 unit were used for irradiating the sample at SSD=80 cm for Field size =10 × 10 cm2 and the sample were kept at dmax =0.5 cm by varying the dose. In order to determined the dosimetric characterization such as glow curve, linearity, reproducibility and fading, the TL glow curves were recorded by Nucleonix TL reader (1009I), from room temperature to 350 degree C at heating rate of 5 degreeC/s.
Results and Discussion: The prepared samples were exposed to 60Co gamma beam at an absorbed dose of 100cGy and the observed glow curve have a single peak and well defined dosimetric peak centered at around 310 degree C.TL response of HfO2 NPs for gamma irradiations as a function of absorbed dose varying from 5 to 1000 cGy were carried out which shows a linear response. The fading studies were carried out by irradiating the samples for the dose of 100 cGy which is stored at room temperature and the fading parameter were measured for

the period of 1 month at interval of 5 days for reading the sample at higher temperature shows higher stability due to emission from deeper traps. The reusability parameter is also one of scale to measure the sensitivity of TL detector. Hence the measurements were carried out by ten cycles of repeated irradiation and annealing the samples and no significant changes in the intensity of the glow curve were observed.

Conclusion: The observed results shows that HfO2 NPs have very high linearity, their fading properties shows that it can be read even after 5 days, where there is not much difference in the observed result. As for as their reusability is concerned. The results shows that it has a longer lifetime and it can be used for longer period of time. Hence, HfO2 NPs can be used as TL material in radiotherapy.

PP-129

DOSIMETRIC COMPARISON BETWEEN TG-43 AND TG-186 IN LIP AND BUCCAL MUCOSA BRACHYTHERAPY IMPLANTS

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Introduction and Purpose: TG-43 dose calculation formalism for photon emitting radionuclide sources used in brachytherapy, is based on the parameterization and superposition of single source dose distributions, obtained in liquid water under fixed geometry. Although, it is easy, fast and practically applied in clinics, it inherently lacks considerations for tissue and applicator heterogeneities, differences between absorbed dose in water and tissues, inter-seed attenuation, finite patient dimensions and dose contributions from electrons, can lead to under or overestimation of dose calculation. Model-based dose calculation algorithms (MBDCAs) have recently been emerged as a potential formalism for dose calculation in brachytherapy which involves tissue-inhomogenities and lack of scatter. It offers the possibility of departing from water-only geometries by modelling radiation transport in non-water media (tissues, applicators, air-tissue interfaces), resulting in a much more accurate dose distribution delivered to the patient. The present work provides the comparison between the dose calculation between TG-43 and TG-186 formalism for lip cancer and buccal mucosa brachytherapy Implant.

Materials and Methods: Five lip cancer and three buccal mucosa Brachytherapy implant patients previously treated in our hospital using TG-43 formalism (Oncentra Brachytherapy TPS v 4.5.3) were taken for this retrospective analysis. The mean (sd) of catheters in lip and buccal mucosa implants were 7 (2), and the number of implant planes were 2. CT images were transferred to TPS, followed by catheter reconstruction. The source activation was based on the clinical examination/or using the implanted markers. Dose prescription was done on basal points followed by geometric optimization on volume. Plan evaluation was carried out jointly by the treating physician and the physicist. Plans were made using TG 186 algorithm (Oncentra Brachytherapy TPS v4.5.3), keeping all the other parameters constant. A total of 16 plans were made. For this dosimetric analysis, a single brachytherapy fraction was considered. Dose prescription was 4Gy per fraction. The isodose volume covering 240%, 200%, 150%, 120%, 100% and 85% and 50% of prescription isodose were evaluated for TG 43 and TG 186 plans. The difference between these volumes in absolute difference was evaluated. In addition, Dose Homogeneity Index (DHI) was calculated and the difference between these plans were compared.

Results: The mean (±sd) of absolute differences of various isodose volumes was found to be 0.6 (±0.2) cc and 1.0 (±0.5) cc for lip and buccal mucosa implant respectively. Interms of percentage variation, the mean (±sd) difference was found to be 49 (±21) and 30 (±23)% for lip and buccal mucosa implant respectively. It was observed that TG 43 overestimates the dose more in higher isodose volumes as compare to lower isodose volumes. TG 186 plans were more homogeneous as compared to TG 43. The mean (sd) DHI of TG 43 vs TG 186 was 0.66 (0.06) vs 0.76 (0.08) and 0.73 (0.02) vs 0.76 (0.01) for lip and buccal mucosa respectively.

Conclusion: The difference between TG 43 and TG 186 algorithm was dosimetrically evaluated for brachytherapy implants such as lip and buccal mucosa. The difference between these two algorithms for the evaluated implants was found to be subtle. The clinical significance of these differences is not yet known.

PP-130

AN IN-VITRO STUDY FOR DETECTION OF BREAST, LUNG AND COLON MALIGNANCIES USING THE PRINTED CIRCUIT BOARD TECHNOLOGY BASED NANODOSIMETER

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Introduction: The International Agency for Research on Cancer estimated 14.1 million new cancer cases and 8.2 million cancer deaths worldwide in 2012. The WHO estimated 8.8 million cancer deaths in 2015 which included cancer of lung, liver, colorectal, stomach, and breast in the order of 1.690, 0.788, 0.774, 0.754, and 0.571 million respectively. Earlier studies reported that malignant cells can be diagnosed by the exhalation of specific volatile organic compounds (VOCs) which serves as eminent source biomarkers for malignant diagnosis. Lungs emit various VOCs include benzene, ethylbenzene, cyclohexane, methanol, ethanol, dodecane and tridecane, and the breast emit alkanes, alkenes, ketones, halogenated hydrocarbons, aldehydes, alcohols, esters, unsaturated hydrocarbons, terpenes, siloxanes, and aromates. Based on these, we have put forth an attempt to confirm the suitability of an indigenously fabricated multilayer printed circuit board (PCB) technology based hole type 3D positive ion detector to detect breast, lung and colon malignancy.

Purpose: To analyze the suitability of the indigenously fabricated multilayer PCB technology based nanodosimeter to detect breast, colon and lung malignancy by collecting the air exhaled by its biopsy tissues.
Materials and Methods: The normal lung, breast and colon tissues were collected from a biopsy center with the approval human ethical clearance committee. The normal lung, breast and colon tissues were placed separately inside the chamber and it was evacuated in order to remove all other molecules present in the chamber. Then, it is allowed to exhale molecules at various pressures in order to measure the amplitude, rise time, fall time, frequency and number of pulses of the signal. Later, these normal tissues were replaced by cancerous tissues of stage 4 in the evacuated medium and the same was allowed to exhale VOCs to capture signal at various pressures ranging from 1 to 10 Torr. This procedure was repeated for 5 sets of both normal and cancerous tissues of breast, lung, and colon at stage 4 to assure reliability.
Results and Discussion: It is observed that the signal amplitude, rise time, fall time, frequency and number of pulses of normal lung, breast and colon tissues was found to be 72.9 Volts, 2.4 ms, 480 μs, 16.6 Hz, 581; 74.1 Volts, 2.4ms, 480μs, 38.4 Hz, 781 and 79 Volts, 2.9 ms, 490 μs, 45.2 Hz, 963 respectively. Similarly, the signal amplitude, rise time, fall time, frequency and number of pulses at stage 4 of lung cancer tissues was found to be 86.3 Volts, 1.3 ms, 430 μs, 43.02 Hz, and 3008 and from breast cancer tissues: 91.5 Volts, 2.9 ms, 480 μs, 569.6 Hz, and 4077 and from colon cancer tissues: 98.9 Volts, 3.3 ms, 520 μs, 586.3 Hz and 6077 respectively. From this data, it is inferred that the signal amplitude, rise rime, fall time, frequency and number of pulses are high in presence of the colon cancer tissues followed by Ca. breast, and lung tissues. This may be due to the higher rate of emission of VOCs from colon cancer tissues than the breast, and lung cancer tissues.
Conclusion: The indigenously fabricated multilayer PCB technology based nanodosimeter would be used to detect breast, colon and lung malignancies. The intensity of VOCs present in colon malignant tissues is higher than breast and lung malignant tissues.

PP-131

CHARACTERISATION OF A PRINTED CIRCUIT BOARD TECHNOLOGY BASED 3D POSITIVE ION DETECTOR

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Introduction: Nanodosimetry is a new technique for the qualitative and quantitative description of ionizing radiation at nano level. A new hole type 2D position sensitive positiveion detector based on the multilayer printed circuit board (PCB) technology was used to develop a compact track structure detector with nanometric resolution. This technology combines the working principle of thick gas electron multipliers and resistive plate counter. To achieve localized events in nanometric resolution, positive ions rather than electrons were registered in these detectors. The measuring method of these positive ion detectors is based on the detection of single ionization in a gas of low pressure, simulating target volumes of about 1 μg cm$-$2 mass per area.
Purpose: Characterize the indigenously fabricated 3D positive ion detector to understand its capability for further applications and its comparison with Geiger-Mueller (GM) counter.
Materials and Methods: The Multilayer PCB technology based nanodosimeter was designed to capture positive ions produced by the interaction of ionizing radiation with low pressure gas medium. In order to confirm the signal, the present signal captured under propane medium at 1 to 10 Torr pressure at analyzed thickness of the detector 3.483 mm with optimized cathode was analyzed using the same nanodosimeter experimental setup using the Co-60 source. The parameters such as rise time, fall time, dead time, resolving time, amplification factor, and operating voltage of 3D positive ion detectors and GM counter are compared here.
Results and Discussion: From this study, it is confirmed that the novel 3D positive ion detector that has been upgraded using gold as strip material, tungsten coated copper as the core wire, gold coated ceramic as cathode, and thickness of 3.483 mm showed 9.2% efficiency under methane medium at 0.9 Torr pressure using an Am-241 source that is approximately five times higher than the reported one. The maximum efficiency of the nanodosimeter was ~12% in presence of μCi activity Co-60 source under propane medium at 1 Torr pressure using 3.483 mm thick detector. In this case, the observed pulse height, rise time, fall time, ion drift time, dead time, resolving time, and amplification factor of the detector signal was found to be approximately 156V, 2.5ms, 495μs, 13μs, 2.5ms, 1.24ms, and 1.8 x 105 respectively. The response time of the detector was observed in the order few sec. In this case, the observed rise time, fall time, dead time, resolving time, recovery time amplification factor, operating voltage of GM counter is 150μs, 150μs, 300μs, 450μs, 600μs, 1010, 450V to 850V respectively. Since dead time, recovery time, resolving time and operating voltage of this indigenously fabricated nanodosimeter is small, it is found to be a better instrument than GM counter.
Conclusion: The indigenously fabricated nanodosimeter would be an effective detector for low energy and low activity alpha, beta and gamma sources while GM counter is only used to detect gamma and beta sources. Further the present detector can be used in the field of radiation protection, radiation dosimetry for low and high radiation measurement, gamma spectrometry, radiation biology and oncology.

PP-132

FABRICATION OFA NOVEL ROUND BOTTOM MICRO- WELL ARRAY CHIP FOR 3D TUMOR CULTURE

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Introduction: 3D tumor culture platforms are emerging tools to investigate the fundamental cell biology, drug development, and in many medical applications. The 3D tumor cultures can reproduce the *in vivo* tumor microenvironment in terms of mass transport, communication with their environment, and cellular heterogeneity. In spite of many

developments in tissue culture, the malignant phenotypes, the mechanotransduction between extracellular matrix and cells remain crucial. Hence, biomaterial-based tissue culture platforms that can mimic human physiological conditions have been evolved as an effective technique. Even though there are many techniques such as hanging drops array, coating with organic or inorganic matrices on plastic substrates, and paper-supported scaffoldsto demonstrate the 3D tissue culture, each technique has its own challenges include complexity, poor reproducibility, cell wastage, poor accessibility in cell motility and matrix invasion etc.

Purpose: To fabricate a round bottom micro well array chip using Polydimethylsilicone (PDMS) to culture tumor spheroids from MCF7 and MDA- MB- 231 cell lines, analyze the cell attachment via biomimetic nano-cilia (triblock copolymers) and optimize it's physical and biological characteristics to investigate the bystander effects of radiation and to collect volatile organic compounds (VOCs) exhaled by tumor spheroids.

Materials and Methods: To fabricate the μ- U well array chip, a sheet of PDMS was prepared and a hydrophobic material with array of holes was formed. Then the hydrophobic material was patterned on a glass plate followed by pipetting 4 and 5 μl of deionized water. In continuation to this, PDMS gel was poured into the mold and cured for 1 h at 120°C and μ- U well array chip was formed when the glass plate was removed. The ultraviolet sterilized chips were coated with triblock copolymers and known number of MCF7 and MDA- MB- 231 cells along with culture medium were seeded in each well of the chip followed by covering its surface with membrane for incubation over a period of 24 h.

Results and Discussion: The novel round bottom micro well array chip that can culture tumor spheroids in 2 days was fabricated successfully. From this study, it is inferred that the tumor spheroid formation efficiency of 5 μl well is better than 4 μl well. If the number of cells seeded is increased, the time taken to form spheroid is also increased. The 3D spheroid formation efficiency of MCF7 cell line is better than MDA- MB-231 cell line. The spheroid formation efficiency of polycarbon membrane is better than nylon membrane due to the leakage of medium with nylon membrane. It is also observed that it is possible to transfer the cultured tumor spheroid to a dish without disturbing it. But, these spheroids are stable for 20–30 h in the culture dish as the tumor cells start to migrate in the medium.

Conclusion: The PDMS based round bottom micro well array chip is proved as a simple, economic, reproducible and rapid tool to culture MCF7 and MDA- MB- 231 tumor spheroids. The spheroid formation efficiency of the present technique depends on the volume of the well, type and number of cells seeded, size of pores and material of the cover membrane. From this study, it is assured that the present novel round bottom micro well array chip can be used to investigate the bystander effects of radiation and also for VOC collection.

PP-134

INDIRECT ESTIMATION OF ABSORBED DOSE TO WATER FOR CO-60 TELETHERAPY MACHINE

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Introduction: Radiotherapy treatment involves the precise delivery of the prescribed radiation dose to a defined target volume in the cancer patient. The success of radiotherapy depends on the accuracy, precision and conformity of the desired dose distribution over the tumour volume and organs at risk. Therefore high accuracy of dose determination is crucial. In the field of ionizing radiation the absorbed dose is one of the basic quantities used in dosimetry. Ionometric measurement is one of the method based on absorbed dose to water is determined. So far, we do not have absorbed dose to water standard as primary/reference standard in our country. By keeping in view, here efforts were made to derive the absorbed dose to water for Co-60 teletherapy machine using existing absolute air kerma standards available in the laboratory. This paper describes the methodologies adopted to estimate indirectly absorbed dose to water from the charge collected using air kerma standard.

Materials and Methods: The air kerma absolute standard of 7.88 cc air volume for Co-60 gamma beams has been designed, fabricated and characterized earlier.[1] For estimation of absorbed dose to water using the air kerma absolute standards, the ionisation chamber was placed in air at 100 cm distance from the teletherapy source and was aligned perpendicular to the central beam axis of the Co-60 beam in 10x10 cm2 field size. The chamber was irradiated continuously for a longer duration and the charge was collected using DOSE-1 electrometer. Based on charge vs applied voltage characteristic curve, the chamber was operated at 500 V. The collected charge was corrected for the variation in environmental conditions and other correction factors described below. By applying Bragg-Gray and large detector cavity theories, the formalism was derived to estimate the absorbed dose to water rate, $\dot{D}_{\mathrm{w}}$ at 10 cm depth in water phantom from the charge collected in air medium:

$$\dot{D}_{\mathrm{w}} = \left\{ \frac{q}{\rho_{\mathrm{air}} V_{\mathrm{air}}} \left(\frac{\bar{w}}{e}\right)_{\mathrm{air}} \left(\frac{\overline{\mu_{\mathrm{en}}}}{\rho}\right)_{\mathrm{c}}^{\mathrm{air}} \left(\frac{\bar{S}}{\rho}\right)_{\mathrm{air}}^{\mathrm{c}} \prod k_i \right\} \times$$

$$\left(\frac{1}{\beta}\right) \times \left(\frac{\bar{S}}{\rho}\right)_{\mathrm{air}}^{\mathrm{w}} \times \left(\frac{100}{80.5}\right)^2 \times PDD_{Co-60,10\times10\ \mathrm{cm}^2,10\ \mathrm{cm}}$$

where q is the measured charge collected for one minute; ρ_{air} = 1.205 kg/m^3, density of air (20 °C and 1013 mbar); $\left(\frac{\bar{w}}{e}\right)_{\mathrm{air}}$ =33.97 J/C; β is the air kerma to absorbed dose to air conversation factor; $\prod k_i$ are the product of correction factors (recombination factor k_s, stem scattering k_{st}, polarization factor k_{pol}, wall attenuation k_{wall}, axial uniformity k_{an} and radial uniformity k_{rn}); V_{air} is the sensitive air volume of the chamber; $\left(\frac{\bar{S}}{\rho}\right)_{\mathrm{air}}^{\mathrm{c}}$ and $\left(\frac{\bar{S}}{\rho}\right)_{\mathrm{air}}^{\mathrm{w}}$ are the unrestricted mass electronic stopping power graphite to air and water to air media respectively and $\left(\frac{\overline{\mu_{\mathrm{en}}}}{\rho}\right)_{\mathrm{c}}^{\mathrm{air}}$ is the mass energy absorption coefficient air to graphite medium.

Results: The $\dot{D}_w$ estimated using above formalism was found equal to 0.1607 Gy/min whereas the $\dot{D}_w$ measured at Radiation Standards Section by using 0.6 cc cylindrical ionization chamber calibrated at BIPM, France was equal to 0.1561 Gy/min. The values of the absorbed dose to water rate measured using two independent methods are in good agreement to one another within 2.86%. The expanded uncertainty in the measurement of absorbed dose to water using 7.88 cc air volume ionization chamber is 3.2% (k=2).
Conclusions: It is concluded that absorbed dose to water can be derived indirectly using air kerma standards in Co-60 gamma beam. It is further stated that the present chamber of air volume 7.88 cc qualifies to be a absolute standard for measurement of absorbed dose to water.

References

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PP-135

MONTE CARLO STUDY OF RESPONSE OF SOLID STATE DETECTORS FOR RADIOTHERAPY ELECTRON BEAMS

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Purpose: For radiotherapy photon beams Compton scattering is the predominant mode of interaction. Hence, the response of the detector can be understood by using electron density information of the detector materials. However, in case of electron beams, electron density information of the detector materials is not sufficient to understand the response of the detector as the electrons will undergo multiple scattering in the detector materials. Hence, for electron beams, investigation of cavity theory is important to understand the response of the detector. Such investigations can be done using Monte Carlo (MC) methods. Thin detectors mostly behave like an ideal Spencer-Attix cavity and intermediate size detectors which fall in neither large nor small category cavities, general cavity theory proposed by Burlin holds good.
Materials and Methods: The electron beams investigated in the present study were 6 MeV, 9 MeV, 12 MeV, 15 MeV and 18 MeV. The incident electron beam is circular with a radius of 5.64 cm (equivalent field size of 10x10 cm2) at the depth of measurement in the phantom. The energy response correction factor is defined as the ratio of the medium to detector dose ratio for an electron beam energy E, to the medium to detector dose ratio for 60Co beam. In the MC calculations, absorbed dose to each detector was scored as a function of central axis in the water phantom using the MC-based DOSRZnrc user-code of EGSnrc code system. Absorbed dose to water, Dwat and absorbed dose to detector, Ddet were scored as a function the above-mentioned depths in the water phantom for the investigated radiotherapy electron beams. The detector response i.e., the numerator of equation 1 was calculated by taking the ratio of absorbed dose to water and absorbed dose to detector for a given electron beam energy. For calculation of the denominator of equation 6.1 a realistic 60Co spectrum from a telecobalt unit was used. The 60Co beam was parallel and had a radius of 5.64 cm at the front face of the phantom. The MC calculations were carried out to find the water to detector dose ratio for 60Co beam with the same phantom and detectors as used in the calculations for the investigated radiotherapy electron beams. The statistical uncertainties on the calculated values of response of the detector were less than 0.4%.
Results: Energy response corrections and detector response of the investigated detectors were calculated as a function of depths (dmax, dref, 0.1R50, 0.2R50, 0.3R50, 0.4R50, 0.5R50, 0.6R50, 0.7R50, 0.8R50, 0.9R50 and R50) for the radiotherapy electron beams 6 MeV, 9MeV, 12 MeV, 15 MeV and 18 MeV, respectively.
Discussion and Conclusion: The response of the detector does not change significantly with depth for the radiotherapy electron beam energy. These calculated detector responses were compared with the Spencer-Attix mass collision stopping power ratios. For thin diamond detector, 300 keV was found to be the most suitable at which the diamond detector response agrees well with the Spencer-Attix mass collision stopping power ratios. For other solid-state detectors, the values of electron fluence perturbation correction factors were significantly different from unity for the investigated radiotherapy electron beams. Hence for these detectors electron fluence perturbation correction factors should be applied in order to determine absorbed in a medium for radiotherapy electron beams.

PP-136

POLYMERASE CHAIN REACTION- OPTIMIZATION AND TROUBLESHOOTING FOR TP-53 GENE

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Introduction: Polymerase chain reaction (PCR) is a technique used to amplify a desire size of DNA in a large amount of magnitude. Failure in exact size of amplification in PCR leads to the reproduction of multiple orders of undesired products. Literature shows anomaly in P-53 tumor suppressor gene leads 50% of cancer patient. Outcome of radiobiological significance in p53 is still controversial.
Purpose: To optimize the PCR procedure to study the TP-53 gene.
Materials and Methods: The designed TP-53 (Avantor-IDT, Agri Genome Lab Pvt Ltd, Kerala-30) gene primers details along with its sequence and size of the base pair are following
Exon 4 Forward: 5'TGA GGA CCT GGT CCT CTG AC 3' (413bp)
Exon 4 Reverse: 5'AGA GGA ATC CCA AAG TTC CA 3'
Exon 5 Forward: 5'TTC AAC TCT GTC TCC TTC CT 3' (248bp)
Exon 5 Reverse: 5'CAG TGT CGT CTC TCC AG 3'

Exon 6 Forward: 5'GCC TCT GAT TCC CTG AT 3' (181bp)
Exon 6 Reverse: 5'TTA ACC CCT CCT CCC AGA GA 3'
Exon 7 Forward: 5'CTT GCC ACA GGT CTC CCC AA 3' (237bp)
Exon 7 Reverse: 5'AGG GGT CAG AGG CAA GCA GA 3'
Exon 8 Forward: 5'TTC CTT ACT GCC TCT TGC TT 3' (231bp)
Exon 8 Reverse: 5'AGG CAT AAC TGC ACC CTT GG 3'
One ml of healthy volunteer blood was collected in EDTA tube (K3, EDTA-2ml) and the DNA was isolated by the standard method of a simple salting out procedure (S. A. Miller, D. D. Dykes and H. F. Polesky, Nucleic Acid Research, 1988). Melting temperature (Tm) of the individual primers was calculated by the following equation.
Tm = 2 (A+T) + 4 (G + C)
The 20 µl reaction of PCR was performed with various Tm with respect to the individual primer sequence with initial denaturation of 95oC/5 min, followed by 35 cycles of denaturation at 95oC/1 min, the primer Tm was varied for Exon 4 (F and R) (53oC/1 min and 55oC/1 min), Exon 5 (F and R) (53oC/1 min and 61°C/1 min), Exon 6 (F and R) (55oC/1 min and 57oC/1 min), Exon 7 (F and R) (59oC/1 min and 59oC/1 min) and Exon 8 (F and R) (53oC/1 min and 57oC/1 min) with a final extension of 72oC/10 min. Apart from Tm variation, PCR conditions were similar for all amplified regions. The PCR amplified TP-53 gene sequencing sizes were analyzed with 1% of agarose gel electrophoresis. The gel photograph was taken in Syngene gel documentation unit.
Results: The 1% gel image shows, no amplification for all non-DNA PCR reaction. All the exons from 4-8 with 20µl PCR with DNA were successfully amplified with its exact size.
Discussion: Five different Tm were used for the optimization and troubleshooting of exact amplification of TP-53 gene primers of exon 4- 8. The exact size amplified melting Tm for exon 4-8 is 55oC/min, 53oC/min, 57oC/min, 59oC/min and 53oC/min respectively.
Conclusion: The protocol to perform PCR of the tumor suppressor gene TP-53 was optimized successfully in terms of optimizing its melting Tm. This optimized PCR reaction would be useful to find the mutation of TP-53 tumor suppressor gene in human genome research.

PP-137

VALIDATION OF TISSUE PHANTOM RATIO OBTAINED FROM PERCENTAGE DEPTH DOSE WITH TPR FROM DIRECT MEASUREMENT IN A WATER PHANTOM

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Aim: To validate the TPR data derived from PDD with TPR from direct measurement in water phantom.
Materials and Methods: The PDD and TPR measurements are done using TRUEBEAM STx Linear accelerator (Varian) at energies 6X,10X,15X,6FFF,10FFF for field sizes 5 x5cm 2,10x10cm2,20x20cm2,30x30cm2,40x40cm2.Both PDD and TPR was measured from surface to depth of 20cm. Water scanning system used was 3DScanner (sun) and detector was semiflex 0.125cc (PTW). The 3D scanner system consists of 3D TPR sensor, 3D reservoir for direct measurement of TPR. PDD was measured at SSD 100cm and TPR was measured at SSD 80cm. The measured PDDs were converted to TPR by SNC dosimetry system (sun). The software generated TPR was compared with direct measured TPR. The statistical significance was calculated with paired students *t*-test.
Results: For 6MV, mean variation in direct measured and system calculated TPR was 1.25-1.81%, 0.14-1.95%, 0.76-1.5%, 0.7-1.36%, 1.15-1.19%for fs of 5x5cm2,10x10cm2, 20x20cm2,30x30cm2,40x40cm2 respectively. For 10MV, mean variation in direct measured and system calculated TPR was 0.07-2.86%,-0.21-1.95%,0.12-1.77%,-0.05-1.36%,0.05-1.86%for fs of 5x5cm2,10x10cm2,20x20cm2,30x30cm2,40x40cm2 respectively. For all fs was found statistically significant with *P* value. For 15MV, mean variation in direct measured and system calculated TPR was -0.35-2.8%,-0.52-2.99%,-0.21-1.24%,-0.46-1.8%,-0.21-1.23%for fs of 5x5cm2, 10x10cm2,20x20cm2,30x30cm2,40x40cm2 respectively. For all fs was found statistically significant with *P* value. For 6FFF, mean variation in direct measured and system calculated TPR was 0.33-1.8%,-0.17-1.74%,0.46-1.37%,0.3-1.38%,-0.43-1.4%for fs of 5x5cm2,10x10cm2,20x20cm2,30x30cm2,40x40cm2 respectively. For all fs was found statistically significant with *P* value. For 10FFF, mean variation in direct measured and system calculated TPR was -0.5-2.14%,-0.61-0.95%,-0.39-0.73%,-0.77-1.73%,-0.64-1.30%for fs of 5x5cm2,10x10cm2,20x20cm2,30x30cm2,40x40cm2 respectively. For all energiesit was found statistically significant with p value.
Conclusion: From our study we found that average dose error is 1% for6X,10X,15X,6FFF,10FFF.so,if TPR is not measured directly on machine it may induce 1% uncertainty in dose calculation.

PP-138

AMPLIFICATION OF NRAS GENE BY POLYMER CHAIR REACTION

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Introduction: NRAS gene is a proto-oncogene. The protein symbol of the NRAS gene is P01111-RASN_HUMAN. The NRAS gene provides instructions through a process known as signal transduction, the protein relays signals. When mutated, oncogenes have the potential to cause normal cells to become cancerous. Polymerase chain reaction (PCR) is a technique used to amplify a single copy or a few copies of a segment of DNA. PCR permits early diagnosis of malignant diseases such as leukaemia and lymphomas. PCR assays can directly performed on genomic DNA samples to detect the translocation of specific malignant cells. Since it allows for the isolation and application of tumour suppressors, it is very much used in medical field.
Purpose: To optimize the temperature during the PCR procedure and to find the melting temperature for exact size (230bp) amplification of a proto-oncogene NRAS.
Materials and Methods: The standard DNA isolation technique (S. A. Miller, D. D. Dykes and H. F. Polesky, Nucleic Acid Research, 1988) were used for DNA isolation from EDTA(K3, 2ml) Collected blood samples. Finally we eluted

with 30μl of DNA with TE buffer. We synthesise NRAS gene (IDT, AVANTOR PERFORMANCE MATERIALS, New Delhi-20) as following

Exon 1- Forward Primer: 5'-CCA AAT GGA AGG TCA CAC TA-3' (230bp)

Exon 2- Reverse Primer: 5'-AGA GAC AGG ATC AGG TCA GC-3'

After that a major optimization procedure involves in the DNA amplification by PCR. The melting temperature of the primer was calculated by the following equation.

Melting temperature (Tm) = 2 (A+T) + 4 (G+C)

The PCR steps involves from initialisation heat activation for reaction chamber at a temperature of 95oC/5mins and then denaturation is a heating of reaction chamber by increasing the temperature of 95oC/1min followed by melting temperature for forward primer and reverse primer is 53oC/1minand 97oC/min respectively and finally elongation/ extension at 72oC/10min where the length of the strand gets elongated. This denaturation, annealing, elongation is for a single cycle. Likewise we have done 30cycles. In order to identify the PCR amplification we ran gel electrophoresis for PCR samples. The gel was photographed with syngene gel documentation unit.

Results: The agarose gel result shows the exact size amplification (230pb) in melting temperature of 49oC. At the same time the non DNA control sample in PCR shows no amplification. Our result shows very good agreement with literature.

Discussion: Two different melting temperatures (Tm) were used for the optimization of NRAS gene primers amplification by PCR. From this data, it was found that the melting temperature Tm for exact size (230bp) amplification of a proto-oncogene NRAS is 49oC/min.

Conclusion: The protocol to perform Polymerase chain reaction of a proto-oncogene NRAS was optimized successfully in terms of optimizing its melting temperature. This optimized PCR reaction would be useful for mutation detection in the field of oncology.

PP-139

ANALYZE THE SUITABILITY OF THE NANODOSIMETER TO DETECT BREAST CANCER FROM EXHALED BREATH

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Introduction: According to the World Health Organization (WHO) cancer fact 2017, cancer is the second leading cause of death and it causes nearly 1 in 6 deaths globally. Breast malignancy is the second leading cause of deaths in women. It is estimated that the chances of 5 years survival rate of breast malignant patients were 96% in localized condition and 86 % in metastases stage in 2017, which increased to 98.3% in localized condition. Hence, early detection of breast malignancy is the urgent need of today to decline the rate of mortality. Even though there are many techniques such as biopsy, mammography etc., to detect breast malignancy, each technique has its own limitations which necessitate developments in the area of early cancer detection.

Purpose: To analyze the suitability of the indigenously fabricated multilayer PCB technology based nanodosimeter to detect breast malignancy from the breath exhaled by the patients in order to enhance the efficacy of breast cancer treatment and to avoid carcinophobia among public.

Materials and Methods: A medium sized air bag (43cm X 28cm) was taken and a small hole was made at its bottom so that a 6 mm gas flow tube can be inserted inside the hole and can be fitted tightly inside the vacuum chamber of the nanodosimeter experimental setup. In the present study, breath sample from normal persons (below 30 age), Ca. breast (Stage 4) patients and smokers were collected in an air bag. Then, the air bag was connected with the nanodosimeter through a T bent gate valve. To start the experiment, the chamber was evacuated to remove all the molecules present inside the chamber. Then, the exhaled air collected from each person was allowed into the vaccum chamber to reach 1 to 10 torr pressure. The DSO signal captured in presence of the air collected from normal, smoker and cancerous patients were analysed in terms of its amplitude, rise time, fall time, frequency and number of pulses of the signal.

Results and Discussion: It is observed that the signal amplitude, rise time, fall time, frequency and number of pulses corresponds to the normal person was found to be 48 Volts, 420 μs, 1.2 ms, 36.2Hz, and 760 respectively. Similarly, the signal amplitude, rise time, fall time, frequency and number of pulses corresponds to the cancerous patient was found to be 100 Volts, 495 μs, 2.5 ms, 470.6 Hz, and 3795 respectively and for smoker is 121.2 Volts, 520 μs, 2.9 ms, 590.8 Hz, and 6079 respectively. The signal amplitude, rise rime, fall time, frequency and number of pulses are higher with smoker breath sample followed by cancerous patients and normal persons. This may be due to the higher rate of emission of VOCs from smoker breath than the cancerous and normal persons.

Conclusion: The indigenously fabricated multilayer PCB technology based nanodosimeter would be used as an economic, non-invasive, convenient and simple instrument to detect breast malignancy using the breath exhaled by patients and human population. However, the present study needs further investigation to distinguish molecules exhaled by various cancerous patients of all stages, other related diseases like asthma, pneumonia, persons who have taken antibiotics, smokers, drinkers and people who have taken non-vegetarian food at different time internal.

PP-140

MEASUREMENT OF ENTRANCE DOSE AND PERIPHERAL DOSE USING THERMOLUMINESECENT DOSIMETER DURING BREAST RADIOTHERAPY

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Introduction: *In vivo* dosimetry was performed using thermoluminescent dosimeters (TLD) in order to evaluate the entrance dose measurements and peripheral dose (thyroid and skin) was measured during breast radiotherapy for different treatment techniques. *In vivo* dosimetry can be divided into three classes: Entrance dose measurements, exit

dose measurements and intracavitary dose measurements. Entrance dose measurements to check the output and performance of the treatment apparatus as well as the accuracy of patient set-up. Exit dose measurements to check the dose calculation algorithm and to determine the influence of shape and density variations of the patient body on the dose calculation procedure a variety of detectors including TLD, diodes and MOSFET are currently available methods.

Purpose: This study was to determine the role of *in vivo* dosimetry with TLD as part of quality control in radiotherapy procedures. In this study we investigate the entrance dose for Ca. Breast radiotherapy treatment using photon beams (6 &15 MV) and measure skin and thyroid doses.

Materials and Methods: TLD measurements were made using from Rexon TLD System. The TLD 100 Chips are made LiF: Mg, Ti with dimension of 3.2×3.2×0.9 mm3 which have high sensitivity for radiation dosimetry. All TLDs were annealed in annealing oven. The read out for TLD-100 at a 100°C preheat temperature and the signal acquired from 100°C to 300°C for TLD-100 with a heating rate of 10°C/s. All measurements have been performed using a 6 & 15 MV X-ray beam produced by Varian Triology Machine.

TLD Calibration: The TLDs are calibrated in a Plexiglas phantom 30x30x30 cm3 at a depth of 1.5 & 2.7 cm using 6 &15 MV. The field size of 10x10 cm2 at phantom surface and SSD of 100 cm is employed during the calibration. The accelerators are calibrated according to the IAEA TRS 398.

In vivo Dose Measurements: Entrance Dose Measurements: Totally 14 patients was taken for the measurements. The expected dose at Dmax was calculated using TPS and the dosimetric data obtained from linear accelerator calibration for each field. The dose evaluation that had sensitivity in the range of ± 3 % from the average response.

Peripheral Dose Measurements: Thyroid and skin dose were measured during breast radiotherapy. The TLDs are packed in plastic foil and attached on the surface of the thyroid and at the entrance of the beam at the skin surface during breast radiotherapy. To have high accuracy of dosimetry results for each patient, three TLD chips were placed and the absorbed dose was obtained the average dose by three TLD chips. Three TLD chips were formed as a triangle shape and positioned on the thyroid gland of each patient. Therefore, in this calculation we used surface dose as a thyroid dose.

Result and Discussion: The measured entrance dose for the different patients for 6 MV beams is found to be within the ±2.3% compared to the dose and normalized dose at Dmax. The same measurements for 15 MV beams are found to be ±2.8 %. An average thyroid skin dose of 3.2% of the prescribed dose was measured per treatment session while the mean skin dose breast treatment session is estimated to be 40% of Dmax, for both internal and external fields. This result has shown reasonable agreement between measured and expected doses.

Conclusion: Entrance dose and doses to organ at risk such as thyroid should be carefully evaluated. The risk of thyroid dose due to breast cancer is considerable.

PP-141

AMBIENT DOSE EQUIVALENT H* (10) MEASUREMENT FROM SECONDARY STRAY NEUTRON AND PHOTON AROUND PROTON THERAPY FACILITY

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Introduction: Proton therapy (PT), especially with pencil beam scanning (PBS) technique, offers several advantages compared to photon radiotherapy owing to better dose conformation, lesser normal tissue dose and integral organ dose. However, proton interaction with beam production system, beam transport element and human tissue leads to production of secondary radiation predominantly neutrons of wide energy spectrum and photons through intra nuclear cascade and evaporation and hence demand massive shielding of the facility.

Designing the neutron shielding for a PT facility presents several major challenges due to uncertainties in proton usage estimates, neutron production and attenuation calculations. Even with the best available predictive tools, it remain large and difficult to estimate. Therefore a detail measurement of total ambient dose equivalent H*(10) need to be carried out around the PT facility so as to ensure that the dose limit to occupational workers and public is within the stipulated limits of AERB. In this study, we have carried out an extensive measurement of ambient dose equivalent from secondary stray neutron and gamma radiation around a PT facility. To our knowledge, no literatures are available addressing stray neutron and gamma radiation around PT facility.

Materials and Methods: Our center is the first PT facility in South East Asia. It is a multi-room facility equipped with Proteus Plus consisting of C230 isochronous cyclotron, beam transport system (BTS), dedicated nozzles, 6axis robot and 3D image guidance. Proteus Plus can deliver proton beam of 70-228 MeV energies at nozzle exit in PBS mode. The shielding thickness of our facility was calculated using Monte Carlo MCNPX 2.7 code and mix clinical cases.

The H*(10) measurement were carried out around the cyclotron vault (CV), BTS and first treatment room (GTR1) using extended-range neutron rem meter WENDI-2 for neutron and SmartIon survey meter for gamma. We have chosen WENDI-2 detector due to its sensitivity from thermal up to 5GeV and well-balanced fluence-to-H*(10) conversion function from ICRP Publication 74.

For the measurement of H*(10), worst case scenarios were simulated to produce maximum secondary neutrons and gammas around CV, BTS and GTR1 i) by setting high beam current, ii) intentionally allowing 228 MeV proton to bombard on nickel beam stopper located at beam degrader and behind deflecting magnet of GTR1 and iii) completely absorbing 228 MeV beam to a 35x35x35 cm3 phantom positioned at isocenter of GTR1. The H*(10) measurement around GTR1 was carried out for four cardinal gantry angles of 0°, 90°, 270° and 180°. A total of 198 measurement positions were identified by mapping MC simulated dose distribution, fundamental physics principle and importance of the zone based on occupancy. For each position, H*(10) from neutron and photons were measured separately for an integrated time of 1 minute each.

Results: Out of 198 positions, only locations with maximum measured H*(10) for each zones are presented here. The maximum total (neutron and photon) H*(10) measured at

various locations in μSv/hr around CV are 1.33 (Cyclotron control room), 1.84 (outside CV wall), 2.21 (common wall between CV and treatment room) and 1.23 above CV. Total H*(10) of 4.57 μSv/hr was observed in BTS outer wall which increased to 62 μSv/hr in BTS corridor access wall. Above BTS area, total H*(10) was 0.82 μSv/hr. Ambient total H*(10) measurement around GTR1 at different gantry angles showed maximum value of 21 μSv/hr in treatment control console, 23.4 μSv/hr behind the common wall between GTR1 and GTR2, 4.01 μSv/hr on first floor and 25.7 μSv/hr in the second floor above the isocenter. The time average dose equivalent rate (TADR) calculated for all locations were within the permissible limit of public and occupational workers stipulated by AERB.

Conclusion: The contribution of neutron in total ambient dose equivalent was observed to be larger than that of photon in majority of the measurement locations. The shielding thickness of our proton facility is adequate to limit the dose to occupational worker and public within the permissible limit stipulated by AERB. The data reported here can be used as a reference for any new and existing proton facility for inter-comparison and validation.

PP-142

PYTHON SCRIPTING FOR ROBUTNESS EVALUATION IN HYBRID ROBUSTLY OPTIMISED INTENSITY MODULATED PROTON THERAPY TREATMENT PLAN

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Introduction: The major challenge of intensity modulated proton therapy (IMPT) is its higher susceptibility to uncertainties. The two most important sources of errors in IMPT are the beam range and patient setup uncertainties. Recently, a new approach called robust optimization was introduced to consider the uncertainties during the optimization process itself. However, this approach leads to increase in computation time even with GPUbased latest hardware configuration. The increase in planning time is significantly large in a complex clinical case like cranio spinal irradiation (CSI) where multiple isocenter, large field length and field abutment are used. Moreover, the present version of treatment planning system (TPS) can evaluate only one perturbed scenario at a time. The aim of this study is to a create hybrid, robustly optimized IMPT plan using different beam geometries and to evaluate the robustness of the competing plans using in-house developed python scripting.

Materials and Methods: CT datasets of five mock CSI patients were chosen for this study. For each patient, five different plans (P1 to P5) were generated on RayStation (v7) TPS modelled for proteus plus proton therapy system. Proteus plus can deliver proton pencil beam size of minimum 3 mm sigma in air for 230 MeV proton in scanning mode. It can modulate the energy from 4.1 to 32 g/cm^2 without any range shifter. The five plans differ in number and geometry of cranial fields while the spine was always treated using two posterior fields. Dose gradient was created in the field abutment region using numerous optimization structures and spot assignment technique. Using our new hybrid optimisation approach, the plans were optimized for the PTV to cover the target and the CTV was robustly optimized with a 3 mm uncertainty in superior-inferior (S-I) direction without range uncertainty to create the dose gradient. In order to evaluate the robustness of these plans towards the set up and range uncertainties, an in house script was written in Iron python 2.7 and implemented through the scripting module available in the ray station TPS. Using this script, all the possible perturbed scenarios in set up with a magnitude of $\pm$3 mm in A-P, S-I and R-L, and range uncertainty of $\pm$3.5% were simulated. For each patient and plan, 16 perturbed dose distribution were created. From the resulting DVHs, worst case decrease in CTV coverage and worst case increase in dosimetric parameters of OARs were evaluated and compared.

Result and Discussion: In every plan, dose values of CTVs and OARs are presented as mean (SD) of five patients. All plans were able to meet our pre-set planning goal of D98% of both CTVs receiving above 99% and 97% of dose in nominal and worst case scenario respectively except in plan P1 & P3 where worst case D98% of brain is 96% and 95% respectively. In all nominal plans, D1% to both lenses are within 3.5 Gy which increases up to 12.4 Gy in worst case scenario. The maximum Dmean (SD) values in Gy to thyroid, heart, oesophagus, lung and kidneys from nominal plans were 5.11 $\pm$ 0.27, 0.34 $\pm$ 0.29, 3.49 $\pm$ 0.21, 1.86 $\pm$ 0.37, 0.34 $\pm$ 0.31 respectively. These values increased greatly to 7.67 $\pm$ 0.40, 0.737 $\pm$ 0.64, 6.01 $\pm$ 3.45, 4.32 $\pm$ 1.99, 0.77 $\pm$ 0.76.

Conclusion: The proposed hybrid robust optimization technique results in significant reduction in treatment planning time. We have developed, tested and successfully implemented in house python script for plan robustness evaluations. All the five tested beam arrangement pass the robust evaluation criteria for target coverage with increase in OAR doses. However, due to physical characteristics of the proton beam and IMPT planning technique dose to all OARs were very less and well within the clinical tolerance limit. Besides robustness, ease to implement a treatment plan need to be considered while finalizing a plan.

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ANALYSIS OF MOTION OF THE BLADDER DURING VOLUMETRIC MODULATED ARC THERAPY FOR CERVICAL CANCER AND ENDOMETRIAL CANCER USING CONE BEAM COMPUTED TOMOGRAPHY AS POILOT STUDY

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Purpose: Volumetric Modulated Arc therapy (VMRT) is an advanced radiotherapy technique, allows higher conformity of radiation dose to the tumor and minimizes the dose to the organs at risks (OARs). However, the effectiveness of the treatment plans is limited by the variation of shape and size of OARs (e.g., Rectum and bladder in case of pelvic malignancies) lying near to the target volumes. Changes in the daily bladder

filling affect the position of target volumes. Therefore, bladder volume must be kept consistent while simulation, planning and throughout treatment in pelvic malignancies to reduce positional uncertainties. In this study we are studying the daily volumes and dose variations for bladder to analyse the volumetric changes of bladder filling using CBCT scans taken during radiation therapy (RT) for cervical & endometrial cancer patients.

Materials and Methods: In this study a total 5 patients who underwent treatment with volumetric modulated arc therapy(VMAT) technique for cervical cancer were retrospectively analysed. All the patients were instructed to follow the bladder protocol as per our department. CBCT scans are obtained daily during treatment. Bladder volumes were contoured on each CBCT scan following with image fusion with planning CT. The change in bladder position and volumes were evaluated for daily CBCT. The percentage of variation in bladder volumes are compared with the planning CT and mean doses to bladder volumes were noted and evaluated.

Results and Discussions: Planning CT and series of CBCTs for individual patient were analyzed in this study. The mean bladder volumes are calculated for each patient and compared with planning CT. The variation between daily bladder volumes ranged between 2.5 % to 25% which is always lower than planning CT volume. The change in position of the bladder was calculated for each patient which are ranged from -0.09 cm to 0.33 cm in lateral, -2.87 cm to 0.63 cm in longitudinal and -1.07 cm to 0.67 cm in vertical directions and the median values are 0.08 cm (lat), -0.13 cm (long), -0.09 cm (ver). The difference in mean dose of bladder in daily and planned CT ranged from 0.97% to 13.7% with median value of 4.5%.

Conclusion: In this pilot study we found that by maintaining strict bladder protocol variation in bladder volume and positional shift was not significant and hence the mean dose in bladder shows very less variation from planning CT. This study will help us to assess the daily bladder filling and gives us the confidence to treat the patients. This study will continue further for larger number of cases to give more feasible outcomes.

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DEVELOPMENTS IN MATHEMATICAL EXPRESSIONS TO MAP 3D IONIZATION CLUSTER SIZE DISTRIBUTION IN THE NANODOSIMETER

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Introduction: Nanodosimetry strives to link phenomenological dosimetric concepts like radiation quality and relative biological effectiveness to measurable physical quantities related to the track structure of ionizing radiation. The ultimate goal of nanodosimetry is to determine novel dosimetric quantities such as ionization cluster size distribution. The ionization cluster size is defined as the number of ionizations generated in a target volume of nanometer scaling (DNA dimension) by a primary particle and its secondary electrons. The indigenously fabricated nanodosimeter consists of a positive ion detector made up of 576 holes in 52 arrays where each hole represents a detector. At present, the nanodosimeter gives the cumulative signal which is collected from all the 576 detectors. In order to get ionization cluster size distribution three dimensionally, it is necessary to isolate the signal produced by the individual detector. As the detector structure has a common detector between two array of detectors, it is possible to isolate the signal by measuring the signal corresponds to each array of detectors and solving a series of linear equations.

Purpose: To disclose the developments in a series of mathematical expressions to map the ionization cluster size distribution of 0.8 μCi activity Co-60 source in the indigenously fabricated nanodosimeter.

Materials and Methods: The present detector consists of three layers namely top, X, and Y layer. These layers are made up of thin gold strips separated by an epoxy resin fiber glass substrate FR4. It has an active area of 2 x 5 cm2, which contains 576 holes of 1 mm diameter with a pitch of 2 mm and thickness of 3.483 mm. The upper (top layer) electrode is formed by gold plated strips common to each row of holes which is kept at ground potential. The second (X) layer of an orthogonal array of strips (26 arrays), kept below the top strip layer, provides a 2D readout of individual cells. The third layer (Y) of readout strips (52 arrays). Each array are separated, connected with the DSO and the signal was captured under methane medium at 1 Torr pressure optimized cathode using the Co-60 source. The spatial ionization distribution (3D) in the path of the beam can be reconstructed by knowing the 2D position of the cell firing and the ion drift time.

Results and Discussion: To isolate the signal, 52 linear equations were written to represent the 52 array of detectors. These equations consist of 52 known variables and 576 unknown variables. After solving all these equations in 3 months, the solution was transferred to MathLab software to get the number of ionization corresponds to each detector. The same software was used to get the ion drift time at individual detector. By knowing the number of ionization in 2D positions and the ion drift time in its location, the ionization cluster size distribution of Co-60 source was mapped three dimensionally.

Conclusion: The indigenously fabricated nanodosimeter would be used to measure the ionization cluster size distribution of any particle track three dimensionally in nanometer resolution.

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