Swami Rama Himalayan University
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Sub Code: PHDMP110

Subject Name: Advances in Medical Physics **100 Marks**

Unit-I

External beam radiotherapy

- Overview of clinical radiotherapy
- Photons interaction and their effects on tumor biology
- Cell survival curve , Dose-response curve , Early and late effects of radiation
- Modelling, Linear Quadratic Model, α/β Ratio
- Fractionation, EQD2Gy , Dose Rate Effect
- Tumour Control Probability (TCP), Normal Tissue Complication Probability (NTCP) Equivalent Uniform Dose (EUD) , Tolerance Doses and Volumes
- Quantitative Analysis of Normal Tissue Effects in the Clinic (QUANTEC)
- Normal and tumour cell therapeutic ratio.
- Physics of photon and particulate beam therapy
- Beam modifiers wedge filters , MLC ,shielding blocks, tissue compensators
- Components and Configuration of modern Linear Accelerators
- Production of clinical photon and electron beams in Linear Accelerators
- Calibration of megavoltage X-ray and electron beams
- Site specific application of medical accelerators
- Fundamental of 2D dose calculations
- Dose calculation in heterogeneous medium.
- Conventional and conformal radiotherapy.
- Treatment time and Monitor unit calculations
- SSD and SAD/isocentric technique, Co-60 and accelerator calculations.
- Photon beams 3DCRT, Monte Carlo simulation
- Optimization and Inverse Planning, forward planning IMRT
- Image Guidance and Motion Management.
- Skin dose, field matching, integral dose, DVHs
- Treatment planning in teletherepy – target volume definition and dose prescription criteria – Gross tumor volume (GTV), Clinical target volume (CTV), Internal target volume (ITV), Internal margin, Planning target volume (PTV), Organ At Risk (OAR), Treated volume,

Irradiated volume, Maximum target dose, Median target dose, Modal target dose and hot spot.

- ICRU 50, ICRU 62 and ICRU 83- SSD and SAD set ups – two and three dimensational localization techniques, dose specification and normalization
- Clinical electron beams, Basic electron radiation therapy ICRU report 71.
- Beam flatness and symmetry – penumbra – isodose plots – monitor unit calculations – output factor formalisms – effect of air gap on beam dosimetry – effective SSD.
- Relative merits of electrons, neutron, x-ray and gamma ray beams and heavily charged particles
- Neutron capture therapy and Heavy ion (proton and carbon ion) therapy physical principle and equipment.
- Conventional Simulator, CT simulator- use of contrast, markers - patient data acquisition-contours, contouring images from CR, CT, MRI, US, PET, fusion techniques - virtual simulation – digitally reconstructed radiographs(DRR). Cone beam CT simulators, ultrasound, portal imaging, (AAPM TG 179 and 95) .
- Field arrangements – single, parallel opposed and multiple field corrections for tissue inhomogeneity, contour shapes and beam obliquity – integral dose. Arc/rotation therapy and Clarkson technique for irregular fields
- Monte Carlo simulation methods Radiation therapy information systems, International standards § IEC, DICOM, IHE, HIS/RIS/PACS, Radiotherapy R&V systems, Navigation systems, Registration.
- Central axis dosimetry parameters: percentage depth doses (PDD), tissue air ratio (TAR), back scatter factor/Peak scatter factor (BSF/PSF) - tissue phantom ratio (TPR) - tissue maximum ratio (TMR)- collimator scatter factor, phantom scatter factor and total scatter factors - relationship between TAR and PDD and its applications - relationship between TMR and PDD and its applications – scatter air ratio(SAR) – scatter maximum ratio(SMR)-off axis ratio field factors- surface dose and buildup region- Tissue equivalent phantoms-Radiation Field Analyzer (RFA)

<u>Dosimetry, Quality assurance and Commissioning</u>

- Linac (AAPM TG 106 and 142)
- Simulators (AAPM RPT 83)
- EPID
- kV Imager, R&V
- MU calculation (ESTRO)
- QA TPS (AAPM TG43)
- TRS 277, 398 protocol for photon, electron beam dosimetry
- In- vitro patient dosimetry by Film and TLD
- IMRT plan patient specific dosimetry with film and ion chamber
- HDR source dosimetry with film and TLD

<u>Radiation Protection</u>

- Activity, half-life, exponential attenuation, half-value layer (HVL), inverse square law,
- tenth-value layer (TVL)
- Biological Effects of Radiation
- Radiation Quality factor, Equivalent dose, Effective dose
- Legal framework for radiation protection (BSS)
- As low as reasonably achievable (ALARA) concept
- Occupational, public exposure and annual limits
- Radiation protection detectors (Ionization chambers, Geiger-Mueller, Proportional counters, Scintillators, Thermoluninescent Dosimeters (TLDs), neutron detectors)
- Personal and environmental dosimetry
- Shielding calculation
- Radioactive transport and waste management
- Emergency procedures
- Radiation protection programme design, implementation and management in the medical sector

Unit-II

Brachytherapy

- Principles of brachytherapy
- Radionuclide sources
- Clinical implementation of LDR, MDR and HDR, Pulse Dose Rate Brachytherapy .
- Description of radium and radium substitutes –Cs^{137}, Co^{60}, Ir^{192}, I^{125} and other commonly used brachytherapy sources.
- Brachytherapy treatment planning including intracavitary, intraluminal, interstitial and surface moulds. Balloon catheter and SAVI in carcinoma breast.
- Intraoperative and intravascular brachytherapy
- Permanent and Temporary Implant, Volume implant
- Stepping source loading applicators and templates
- ICRU Report 38, 58, AAPM TG 43, AAPM TG 60 formalism and HDR/LDR, Equipment.
- CT/MR based brachytherapy planning – forward and inverse planning
- DICOM image import/export from OT – Record & verification.
- Paterson Parker and Manchester Dosage systems.
- Specification and calibration of brachytherapy sources – RAKR and AKR – IAEA TECDOC 1274 and ICRU 72 recommendations.
- Point and line sources dosimetry formalisms – Sievert integral AAPM TG-43/43U1 and other dosimetry formalisms with film and TLD.
- Effects of tissue inhomogeneities (present in patient body) on HDR source dose distribution.
- Source position accuracy and treatment plan verification with FILM and TLD dosimeters.
- Electronic brachytherapy, Quality assurance.

Unit-III

Advanced Clinical Radiation therapy Physics:

- **3D CT Simulation**
- **4D CT Simulation** : Four-dimensional CT is an imaging technique that provides information on organ motion during respiration. It provides a more accurate assessment of target shape and trajectory, and similar information on organs at risk. The ability to generate 3D CT maps of anatomy as a function of respiratory phase has important applications in treatment planning and delivery, including optimization in the presence of motion, aperture design, dose calculations to moving targets, and image guided therapy delivery.
- **CBCT imaging during treatment**
- **Portal Imaging Verification**: EPID
- **Monte Carlo** calculation algorithm in Treatment Planning System
- **Radiobiological models**
- **Image Registration and fusion**
- **Image Guided Brachytherapy** : Image–guided brachytherapy (IGBT) is the use of advanced imaging techniques to make brachytherapy more accurate, safe, and effective.
- **Ultrasound guided Brachytherapy**
- **Intraluminal Brachytherapy**
- **Interstitial Brachytherapy**
- Brachytherapy source dosimetry with **Radiochromic films**
- **IMRT** : (Intensity Modulated Radiotherapy) : It is an advanced type of high-precision radiation that is the next generation of 3DCRT. IMRT uses multiple small beams of varying intensities to precisely irradiate a tumor. The radiation intensity of each beam is controlled, and the beam shape changes throughout each treatment. IMRT improves the ability to conform the treatment volume to concave tumor shapes, for example when the tumor is wrapped around a vulnerable structure such as the spinal cord or a major organ or blood vessel. The goal of IMRT is to conform the radiation dose to the target and to avoid or reduce exposure of healthy tissue to limit the side effects of treatment.
- **IGRT** : Image Guided Radiotherapy : Image-guided radiation therapy (IGRT) is the use of imaging during radiation therapy to improve the precision and accuracy of treatment delivery. When undergoing IGRT, high-quality images are taken before each radiation therapy treatment session. IGRT may make it possible to use higher doses of radiation, which increases the probability of tumor control and typically results in shorter treatment schedules. May be done by Portal Imaging, EPID, CBCT's etc.
- **SRS/SRT** : the destruction of precisely selected areas of tissue using ionizing radiation rather than excision with a blade. In stereotactic radio surgery the word "stereotactic" refers to a three-dimensional coordinate system that enables accurate correlation of a virtual target seen in the patient's diagnostic images with the actual target position in the patient. The aim of stereotactic radio surgery is to destroy target tissue while preserving adjacent normal tissue, where fractionated radiotherapy relies on a different sensitivity of the target and the surrounding normal tissue to the total accumulated radiation dose. Both Gamma Knife and Linac Radio surgery can be used. Radiosurgery is indicated primarily for the therapy of brain tumors, vascular lesions and functional disorders.

- **SBRT** : Stereotactic body radiation therapy is a cancer treatment method in which concepts and techniques previously developed for brain tumor radiosurgery are adapted to eradicate tumors elsewhere in the body where there is significant organ motion with the help of 4D CT Scan. The major feature that separates SBRT from conventional radiation treatment is the delivery of large doses in a few fractions, which results in a high biological effective dose. Used for lung tumors, pancreatic and heptic tumors, prostate cancer and metastasis.
- **Rapid Arc**
- **VMAT** : Volumetric Arc Therapy (VMAT) Technology is an advanced form of IMRT that delivers a precisely-sculpted 3D dose distribution with a 360-degree rotation of the gantry in a single or multi-arc treatment. Unlike conventional IMRT treatments, during which the machine must rotate several times around the patient or make repeated stops and starts to treat the tumor from a number of different angles, can deliver the dose to the entire tumor in a 360-degree rotation, typically in less than two minutes making it for a very rapid treatment.
- **Cyber knife**
- **Gamma Knife**
- **Tomotherapy IMRT**
- **Helical Tomotherapy** : is a type of radiation therapy in which the radiation is delivered slice-by-slice. HT is a form of computed tomography (CT) guided intensity modulated radiation therapy (IMRT). HT machines are purpose built for IMRT and differ from IMRT delivered by conventional medical linear accelerators (LINACs) in a number of ways. The main difference is that in HT a narrow intensity modulated pencil beam is delivered from a rotating gantry while the patient is simultaneously moved through the bore, compared to the much wider intensity modulated beam and static patient in conventional IMRT. HT units are therefore better able to target treatment sites throughout the body without a pause for the patient to be moved and set-up differently.
- **Nuclear Particles in cancer treatment** [Protons, Carbon ion and Heavy (“Light”) Ions]
- **PET/CT** application in Radiotherapy treatment planning
- **IORT** : The application of therapeutic levels of radiation to the tumor bed while the area is exposed during surgery. It delivers a high dose of radiation precisely to the targeted area with minimal exposure of surrounding tissues which are displaced or shielded. It may be given using electrons, X rays, HDR brachytherapy or Low Energy IORT. Mobile Linear Accelerators or Dedicated Operating Rooms are used for this.

Unit-IV

Diagnostic Medical Physics:

Bremsstralung, Characteristic line spectrum, Factors affecting the X-ray spectrum, Attenuation of heterogeneous and homogenous X-rays, Attenuation coefficients, Radiographic image quality, Factors affecting image quality, Focal spot, Heel Effect, Filters, Grids, Intensifying Screens, X-ray film, Mobile and Dental X-ray machine, Mammography, Computed and Digital radiography systems, Interventional radiology and fluoroscopy guided procedures, Principle of computed tomography, Generations of CT scanners, Spiral and multi-detector CT, Image reconstruction and CT artifacts, Radiation dosimetry and quality assurance in diagnostic radiology, Principle and instrumentation in magnetic resonance imaging, Physics of ultrasound imaging and Doppler techniques,

Unit-V

Physics Of Nuclear Medicine:

- Radiation Physics and Applied Mathematics
- Radiation Biology and Chemistry
- Radiation Detection and Measurements
- Medical Applications of Radioisotopes
- Nuclear Medicine Instrumentation: Scintillation counters, Radioisotope generators
- Gamma Camera, SPECT
- Radiological Protection & Dosimetry
- Principles and Practice of Radiopharmacy
- Nuclear Medicine Imaging & Non-imaging Procedures
- Medical Cyclotron, PET/CT & Allied Instrumentation
- Nuclear Medicine Imaging & Radionuclide Therapy
- Recent advances in Nuclear Medicine

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