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Master Lecture

Importance of imaging in simulation and treatment planning in radiation therapy

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The main imaging modalities for simulation and treatment planning in Radiation Therapy today are CT, MRI an PET/CT. Ultrasound either transabdominal or endocavitary (transrectal or transvaginal) plays a key role in Brachytherapy for uterine, prostate and rectal cancer.

CT provides cross sectional images which are ideal for RT treatment planning. In addition digitally reconstructed radiographs (DRRs) can be reconstructed from the cross sectional data. In recent years, CT simulation has become the accepted standard for pretreatment simulation in a wide variety of disease sites. CT images allow the delineation of the target volume, delineation of critical adjacent structures, calculation of dose distribution, treatment verification and follow up evaluation. The incorporation of CT based treatment planning has improved the quality and delivery of radiation therapy through the use of multiple field arrangements resulting in a more conformal dose distribution around the target volumes and a reduction of radiation dose to surrounding normal tissues.

Although CT shows exquisite cross sectional anatomy, in some areas it does not allow differentiation of diseased from normal tissue even after IV contrast administration. This may need the addition of MRI which has inherent superior soft tissue contrast resolution (classical examples: tumors of the brain, prostate and uterine cervix) or PET/CT which has added functional information. Dedicated CT scanners for XRT planning have a flat table to simulate the treatment position instead of the standard imaging couch which has a concave surface in the transverse plane. It is highly recommended that these dedicated CT units come with a gantry opening of more than the 70 mm diameter typical of commercially available CT scanners which can be restrictive in accommodating markedly obese patients as well as immobilization devices commonly used in XRT planning. Care must be taken with streak artifacts resulting from highly attenuating objects such as metallic implants like hip prostheses and dental metallic implants. These can have a significant effect on the accuracy of CT numbers used for dose calculations. Partial volume effects resulting from the boundary of an object occupying only a portion of a voxel not accurately represented in the CT image should be also recognized. More recently this has become less of a problem with the newer multislice CT scanners capable of acquiring larger data sets in a few seconds in an isotropic fashion improving the quality of sagittal and coronal images. Digital projection images or Scout Views obtained at the beginning of the study are used to determine the location and spacing of the axial scans and the position of the axial images can be annotated in relation to different reference points for the patient set up.

MRI has the advantage over CT of improved discrimination between tumor and normal tissues even in plain MRI. Sometimes the addition of MR contrast enhancement will be essential for example to demonstrate perineural tumor spread in head and neck cancer or to evaluate presence, number and extent of brain metastases. Functional MRI of the brain can identify speech, visual and sensory areas to spare when treating intracranial lesions. Newer MR techniques such as MR Spectroscopy (MRS), diffusion weighted MRI and dynamic contrast enhanced contrast sequences for multiparametric evaluation and treatment planning for example in prostate cancer XRT are coming into clinical use albeit mostly still in a research setting. Drawbacks of MRI for XRT treatment planning include the lack of signal from cortical bone and the fact that pixel intensities do not correlate with electron density as they do in CT so that they cannot be used directly to calculate dose.

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Whole body FDG PET CT has functional information (SUV of increased levels of glucose metabolic by the cancer cells) in addition to anatomic information. It is increasingly being used to improve target definition and to find additional lesions unsuspected in even good contrast enhanced CT scans. Usually the addition of PET CT leads to improved XRT planning for example by decreasing the gross tumor volume (GTV) and the clinical tumor volume (CTV) in patients with central lung cancers and post-obstructive atelectasis by identifying tumor margins more accurately. Integrating MRI or PET/CT with the planning CT requires image registration or fusion. Since PET images are acquired over many breathing cycles, if respiratory sorting is not performed, care must be taken when using this image for tumor definition. The complexity of the image registration required can be reduced by taking measures to reproduce the patient geometry between each imaging session.