

Complete dose study of double orbit cone-beam computed tomography (CBCT)

Introduction: A relatively new improvement of cancer radiation treatment involves the method of image-guided radiotherapy (IGRT). It allows the physician to take detailed volumetric images of the treatment area before and during radiation treatment to ensure an accurate delivery of planned treatment. The nature of radiotherapy is that the process itself is spread out over a period of time whether it is weeks or months, so the changes in the patient's anatomy over time must be taken into consideration before each treatment (2). To this end we implement computed tomography (CT) which is an x-ray imaging modality that reconstructs a 3D volumetric image of the anatomy of the patient. It is used broadly in diagnostics as well as radiotherapy treatment planning and readjustment (4). While conventional diagnostic CT uses fan beam geometry, cone beam CT uses a different geometry, detector system, and hence new reconstructions and is found useful in a treatment setting. Because commercial systems of cone beam CT-integrated treatment machines and cone beam CT-based simulators just became available in the past several years, research groups as well as manufacturers are carrying out studies to improve different aspects of the new modality.

At VCU's department of radiation oncology, methodologies have been devised to acquire double orbit cone beam CT's and create a fused image set from the two rotations. By deviating from the conventional single orbit method and acquiring a double orbit, we increase the field of view of the CT image, making it easier to plan out treatments and make adjustments throughout the treatment course. One problem that needs to be investigated is the radiation exposure or absorbed dose to the patient of this new imaging technique. There are two main reasons the absorbed dose to the patient must be studied: (i) the double orbit method was locally developed and has not been broadly researched and applied anywhere in the field and (ii) the fusing of the images results in an overlap that, however slight, must be accounted for in terms of the absorbed radiation dose to the patient. The overlap means that the absorbed dose to the patient will not be uniform throughout the entire scan area. Also, while one imaging procedure produces a minimal amount of radiation exposure to the patient, in terms of IGRT, several procedures over the radiotherapy period will significantly increase the radiation dose to the patient's normal tissues. The question we want to answer is exactly how much is the dosage increase and can we produce an image of better quality with minimal increase of the exposure?

Method: The double orbit technique refers to the number of times the imaging arm will rotate around the phantoms we will use. As the phantom lays on the table, we will commence one rotation and stop. Then the table will be advanced to the next position and a second rotation will commence in series with the first. This is called “step and shoot.” The resulting image has a small overlap but a larger field of view.

Our method of testing dosimetry involves:

A) Use special x-ray film to measure dosage and make the dose more precise in terms of optimal image quality with minimal exposure (calibrate: measure dose to precision); the darker the film, the greater the exposure. What we need is a film that is sensitive enough to give an accurate reading of the dose, and we have yet to find one suitable. We are currently looking into mammography film to adapt to our purposes.

We will be implementing two types of phantoms to stand in for patients: a solid water phantom and a rando phantom. The use of water is derived from the fact that the human body is 70% water, so a solid water phantom would be analogous to a real patient. Rando phantoms are designed to closely mimic the anatomy of the human body, with the use of real bone in their skeletons. They come in slices that can be assembled or disassembled in order to model whatever part of the anatomy is under test.

The film procedure goes as follows: we will sandwich the film in between the slices of the rando phantom on the table on the CT machine. For the water phantom, we will place the film between two slabs of solid water. The film and phantom will be scanned using the previously mentioned process and the film developed. The optical density of the film, the lightness and darkness, will illustrate the film exposure during the scan and from the exposure we can derive the absorbed radiation dose to the different areas of the film (6).

B) Use thermoluminescent dosimeters (TLD) dispersed throughout a rando phantom, which comes pre-adapted for the implantation of the tubes which contain the TLD's. The TLD's are crystals that have special properties that allow them to react when exposed to radiation. Incoming radiation excites an electron in the crystal atoms, sending it to a higher energy level. From there the electron will drop down and be trapped in the energy band gap between the valence band and the conduction band. Upon removing the tubes, we expose them to heat, and the crystals inside will give off visible light. The intensity of the light emitted is proportional

to the radiation absorbed during the scan, so we can calibrate a dosage and measure the relative absorption (5).

The random phantoms prove valuable in this regard in that they come equipped with small holes throughout each slice where the TLD tubes fit nicely. In this manner we can place the tubes in a specific area and get an approximation of the absorbed radiation dose to certain organs or areas of the anatomy.

Possible Results/Implications: The method developed at the Department of Radiation Oncology is relatively new and has not been extensively studied by research groups and manufacturers. We know from previous research on single orbit conventional scanning that our double orbit method will result in a minimal amount of radiation exposure to normal tissues in comparison with the actual treatment dosage (1,2,3). The abnormality of the overlap resulting in non-uniform absorption is the aspect of double orbit cone beam computed tomography that is still to be determined. Although we expect the dose to be small, we feel this information is still valuable to the general public given the novelty of such a procedure.

References

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