Investigation of 3D dosimetry for an anthropomorphic spine phantom

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Abstract. A new dosimetry insert for the Radiological Physics Center’s spine phantom was designed to hold a specially molded dosimeter. The phantom was irradiated with the traditional insert loaded with radiochromic film and TLD, and then with the new 3D dosimetry insert. A comparison with the calculated dose distribution showed that PRESAGE® dosimeter, as well as the film and TLD system, agreed to within ±2mm. Further analysis of the 3D dosimeter, including a measured dose volume histogram, demonstrated the advantages of 3D dosimetry in a clinical environment.

1. Background

The ability of 3D dosimetry to obtain a large amount of dose information in a single irradiation can be advantageous in the clinic [1]. For areas in which dose margins must be closely monitored, such as spinal metastases, the availability of 3D dose information can allow the physicist to investigate high dose gradients and other regions of interest rather than be limited to measurements in selected planes which are most often restricted to the target center.

The Radiological Physics Center (RPC) has designed and implemented an anthropomorphic spine phantom that currently uses radiochromic film and thermoluminescent dosimeters (TLD) to evaluate treatments of spinal metastases [2]. The phantom contains a target located anterior to the vertebrae and avoidance structures simulating the spinal cord and esophagus. Two TLDs are located in the target. A piece of radiochromic film bisects the center of the target in the sagittal plane and a second film is located at the matching edge of the vertebra and the target in the coronal plane. These dosimeters allow for evaluation of the dose distribution along only these two planes. A 3D dosimeter encompassing the entire section of the spinal column allows for complete visual evaluation of the dose volume delivered and the ability to choose 2D planes for further analysis. For this study, we are using PRESAGE® [3], a solid tissue-equivalent [4, 5] radiochromic plastic and an optical-CT system for readout.

2. Methods

A second dosimetry insert for the phantom was created to hold a specially molded PRESAGE® dosimeter. The dosimeter matches the location of the TLD and film in the original insert and is shown in figure 1.
Figure 1. (A) Spine phantom with the original TLD and film insert. (B) Spine phantom with new PRESAGE® insert.

The phantom was CT imaged with each insert and the images were imported to the treatment planning system (TPS, “Pinnacle”, Philips Radiation Oncology Systems, Fitchburg, WI). The target and the organs at risk were contoured. An intensity-modulated radiation therapy (IMRT) plan was created with a prescription of 6 Gy to 90% of the target with appropriate constraints to the normal structures.

The plan was delivered to the phantom twice; once with the TLD and film insert and once with the 3D dosimetry insert. The film was scanned with a CCD microdensitometer and while the PRESAGE® was analyzed with an optical-CT system, reconstructed to a 2 mm slice width.

The measured dose distributions were compared to the treatment plan calculated dose distribution using RPC in-house developed software or the Computational Environment for Radiotherapy Research (CERR) [6]. Film and PRESAGE® dose profiles were taken across several planes and compared for agreement. The distance to agreement (DTA) between the measured data and treatment plan, within the high dose gradient region, was quantified. The dose line profile through other areas of interest was also quantified. Dose volume histograms of structures within the PRESAGE® volume were calculated.

3. Results

Figure 2. Dose Profiles comparing the treatment plan with PRESAGE® measurements and film measurements respectively.
The dose profiles show agreement within 2 mm in the anterior-posterior direction and within 1 mm in the superior-inferior direction using the PRESAGE®. The film agreed within 2 mm across all profiles. Representative dose profiles are shown above in figure 2.

Line profiles can also be taken across any area of interest as seen in figure 3 where a profile through the spinal cord shows agreement within 2 mm. Figure 4 is an isodose plot in the sagittal plane showing agreement with the treatment plan in a plane not covered by the film measurement. Figure 5 shows a dose volume histogram (DVH) comparing the calculated dose plan to a fully measured dose volume.

4. Discussion and Conclusions

The PRESAGE® dosimetry system shows great promise in phantom studies producing a measured volumetric dose set. Comparisons with film measurements confirm the 3D dosimeter is recording the expected dose values. Areas away from the traditional film planes were analyzed to demonstrate the comparatively large amount of measured data from a single irradiation. The major difference in dose coverage for the PTV from the DVH is attributed to the dosimeter not fully covering the PTV calculated dose. This measured DVH is only attainable with a volumetric dosimeter and can be advantageous in a clinical environment.
5. References

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