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Development of an imaging QA phantom for Tomotherapy

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Introduction

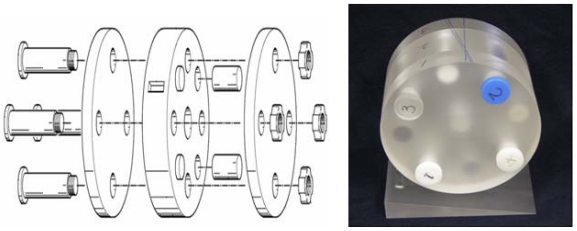
The TomoTherapy Hi*Art II unit (TomoTherapy Inc., Madison, WI, USA), an image-guided intensity-modulated radiation therapy system, is becoming more commonly used for image-guided radiation therapy (IGRT) [1-2]. In contrast to a traditional linac system, various factors have to be considered to achieve correct patient setup: the virtual isocenter, machine isocenter, and couch translation. Thus, the MVCT image quality assurance (QA) program should include not only an imaging test portion, but also a patient setup accuracy portion. The cylindrical phantom supplied by the manufacturer can be used to achieve laser alignment accuracy, image registration, and image quality. However, since the phantom is constructed for the general purpose in TomoTherapy QA protocol, including the treatment beam, it is inadequate for efficient daily imaging QA for both imaging quality and setup accuracy.

We have developed a new phantom for TomoTherapy MVCT imaging QA. The phantom includes several specific structures for image registration accuracy. Here, we describe the design and preliminary evaluation of our new phantom prototype for daily imaging QA.

Materials and Methods

A. Imaging Quality

The 120 mm long and 200 mm wide phantom was constructed mostly of acrylic material and consists of eight density bars for the CT number linearity test. These density bars were made of commercial plastics: polyethylene (0.94 g/cm^3), polypropylene (0.95 g/cm^3), nylon scrap (1.14 g/cm^3), PMMA (1.16 g/cm^3), polycarbonate (1.21 g/cm^3), polyvinylchloride (1.38 g/cm^3), and teflon (2.16 g/cm^3). The resolution plug was inserted into the center of the phantom for spatial resolution measurement. The diameters of the holes in the resolution plug range from 0.4 mm to 1.9 mm with 0.1 mm increments. Figure 1 shows a diagram and a photograph of the QA phantom.



(a) (b)

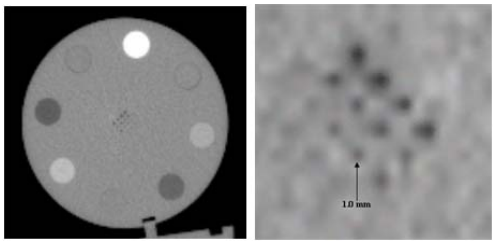
Fig. 1. (a) Diagram and (b) photograph of the QA phantom.

B. Setup Accuracy

TomoTherapy is a MVCT image-guided radiotherapy system. We obtained the MVCT images of the phantom placed at patient setup position. An automatic or a manual fusion system then evaluated the patient setup accuracy by comparing MVCT image with the one obtained from the planning CT. In this phantom, we added specific structures for image registration: a phantom supporter and a fixing piece to evaluate the registration accuracy. The phantom can be firmly fixed on the supporter using the fixing piece placed between the grooves of the phantom and the supporter.

Results and Discussion

The MVCT image and a magnified resolution plug of the phantom are shown in Figure 2. Fenwick *et al.* has recommended the use of 5 holes of 9.5 mm diameter for evaluation of MVCT resolution [3]. The 1.0 mm hole was clearly visualized in the MVCT image set.



(a) (b)

Fig. 2. The MVCT image and magnified resolution plug of the phantom.

Registration accuracy was verified in the combined translation-rotation setting of the phantom using the TomoTherapy automatic calculation option. The accuracy within 1.0 mm for translation and 0.2 degrees for rotation was consistently obtained for the registration results, which attributes to the combined effect of the setup, mechanical, and registration errors.

Conclusion

Image-based radiation treatment systems have been rapidly implemented since their introduction. Due to the complexity of their treatment systems, the QA program should absolutely follow the manufacturer-supplied QA guidelines. However, it is important to establish a QA protocol customized to each clinical environment. We suggest the phantom be used as a daily QA tool for image quality and setup accuracy portions. We hope that our development could provide background knowledge to develop various other QA tools. More advanced study will be followed to further verify the accuracy and consistency of the phantom performance.

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