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COMPARISON OF COMPUTED TOMOGRAPHY SCOUT BASED REFERENCE POINT LOCALIZATION TO CONVENTIONAL FILM AND AXIAL COMPUTED TOMOGRAPHY

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Abstract—Identification of source positions after implantation is an important step in brachytherapy planning. Reconstruction is traditionally performed from films taken by conventional simulators, but these are gradually being replaced in the clinic by computed tomography (CT) simulators. The present study explored the use of a scout image–based reconstruction algorithm that replaces the use of traditional film, while exhibiting low sensitivity to metal-induced artifacts that can appear in 3D CT methods. In addition, the accuracy of an in-house graphical software implementation of scout-based reconstruction was compared with seed location reconstructions for 2 phantoms by conventional simulator and CT measurements. One phantom was constructed using a planar fixed grid of 1.5-mm diameter ball bearings (BBs) with 40-mm spacing. The second was a Fletcher-Suit applicator embedded in Styrofoam (Dow Chemical Co., Midland, MI) with one 3.2-mm-diameter BB inserted into each of 6 surrounding holes. Conventional simulator, kilovoltage CT (kVCT), megavoltage CT, and scout-based methods were evaluated by their ability to calculate the distance between seeds (40 mm for the fixed grid, 30–120 mm in Fletcher-Suit). All methods were able to reconstruct the fixed grid distances with an average deviation of <1%. The worst single deviations (approximately 6%) were exhibited in the 2 volumetric CT methods. In the Fletcher-Suit phantom, the intermodality agreement was within approximately 3%, with the conventional sim measuring marginally larger distances, with kVCT the smallest. All of the established reconstruction methods exhibited similar abilities to detect the distances between BBs. The 3D CT-based methods, with lower axial resolution, showed more variation, particularly with the smaller BBs. With a software implementation, scout-based reconstruction is an appealing approach because it simplifies data acquisition over film-based reconstruction without requiring any specialized equipment and does not carry risk of misreads caused by artifacts. © 2011 American Association of Medical Dosimetrists.

Key Words: **Fletcher-suit applicator, Brachytherapy treatment planning, CT scout view.**

INTRODUCTION

Cervical cancer is one of the most common radiation-treated gynecologic malignancies in the United States, with approximately 12,000 cases diagnosed each year between 1999 and 2006.[1] Radiotherapy of these patients typically consists of whole-pelvic external beam irradiation combined with intracavitary brachytherapy. The brachytherapy is commonly performed at a low dose rate with a Fletcher-Suit applicator loaded with ^{137}Cs sources. Once the applicator has been inserted into the body cavity, the position of the sources must be determined for dose distribution calculations. The conventional approach to localization requires several steps: mark the relevant features on orthogonal x-ray films (colpostat, reference points, seed positions), digitize their positions, and reconstruct the locations for dose calculation.

Many clinics are replacing their conventional simulators with CT simulators, allowing more options for seed location. Some efforts toward CT-based seed location for brachytherapy planning have been made,[2–7] but metal-induced artifacts and less-than-ideal slice thicknesses make localization inconsistent. This can be reduced or overcome with specialized applicators,[8,9] artifact-reduction algorithms,[10–12] or high-energy megavoltage CT (MVCT) images[13,14] and magnetic resonance imaging,[15,16] but these are not widely available and could incur additional equipment costs.

CT scout images, however, can readily replace the films used in the conventional approach and are always taken during CT setup to decide the field of view. They have better resolution in the axial direction than reconstructed CT images, do not have significant metal-induced artifacts, and are inherently digital and convenient for data transfer and calculations. Meli and Son originally proposed their application to seed reconstruction in 1990 by considering the orthotropic magnification of the scout images.[6] The result was a practical method that produced a similar isodose distribution when used for planning.[17] In the present study, we develop a user interface and implement an algorithm based on Meli and Son's scout view method; we also assess its accuracy in measuring

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distances between metal BBs attached to a phantom. These results are compared with those from both kilo-voltage CT (kVCT) and MVCT images and conventional simulator films. The performance of each reconstruction modality is quantitatively assessed using 2 phantoms, one with known BB intervals and another incorporating a metal Fletcher-Suit apparatus.

METHODS AND MATERIALS

Phantoms

Because the identification of source positions is essentially a geometry problem, metal BBs were used as image reference points to test and compare reconstructions. Two phantoms were built: A fixed-interval planar phantom and a Fletcher-Suit phantom. The fixed-interval phantom was constructed by attaching a sheet of 1-mm graph paper to the face of a Styrofoam (Dow Chemical Co., Midland, MI) block. Thirty BBs were taped to the graph paper in a fixed grid with 40-mm intervals, alternating between 1-mm diameter BBs and 3.2-mm diameter (15 of each size). Two additional BBs were affixed outside of the grid as landmarks to help orient the user, made necessary by the symmetry of the phantom. The Fletcher-Suit phantom was assembled by embedding an applicator in Styrofoam and placing six 3.2-mm BBs in nearby recesses of varying depth (Fig. 1).

Conventional simulator

A Ximatron conventional simulator (Varian Medical Systems, Inc., Palo Alto, CA) was used to produce anterior-posterior (AP) and lateral images of the 2 phantoms. The grid phantom had a wedge placed underneath to offset the roll by approximately 20 degrees so the BBs would be distinguishable in the lateral projection. The images were captured and imported into a computer system *via* a Kodak (Eastman Kodak Co., Rochester, NY) ACR-2000i computed radiography system with high resolution (2048 pixels/line) and subsequently transferred to a Pinnacle (Philips Healthcare, Andover, MA) treatment planning system. The BB positions in the AP and lateral images were manually determined using the brachytherapy module of Pinnacle, whereby the physical locations were calculated using the known pixel size, and number of pixels between the manually identified BBs. This process was additionally verified in a preliminary study by sending an identical binary DICOM image with 4 "on" pixels to Pinnacle and eFilm (Merge Healthcare, Milwaukee, WI), whose distance measurements proved to be identical.

kVCT imaging

A Philips Brilliance CT scanner was used to obtain the digital scout images and reconstructed CT images of the phantoms at 120 kV (Fig. 2). The approximate center of each phantom was placed at the machine isocenter. The grid phantom used the wedge as noted in the conventional simulator setup, to offset the roll for viewability in the lateral scout images. The reconstructed CT images were 512 × 512 pixels, 3-mm thick slices, field of view (FOV) = 34 cm × 34 cm based on the phantom size and typical clinical settings for pelvic scans. The BBs' locations were determined by visual analysis within eFilm. Monthly quality assurance (QA) of the scanner include tests of geometrical resolution on the single-pixel scale.

MVCT imaging

A helical TomoTherapy Hi-Art treatment unit (Tomotherapy, Inc., Madison, WI) was used to image the phantoms with a nominal 3.5-MV X-ray beam. Each phantom was set up such that the center of the phantom lay on the approximate axial isocenter of the TomoTherapy unit. This produced 512 × 512 pixel slices with 2-mm thickness, typical of MVCT scans for patient setup. Images were acquired with high-resolution mode with FOV of 38.6 cm × 38.6 cm (Fig. 2). The positions of the BBs

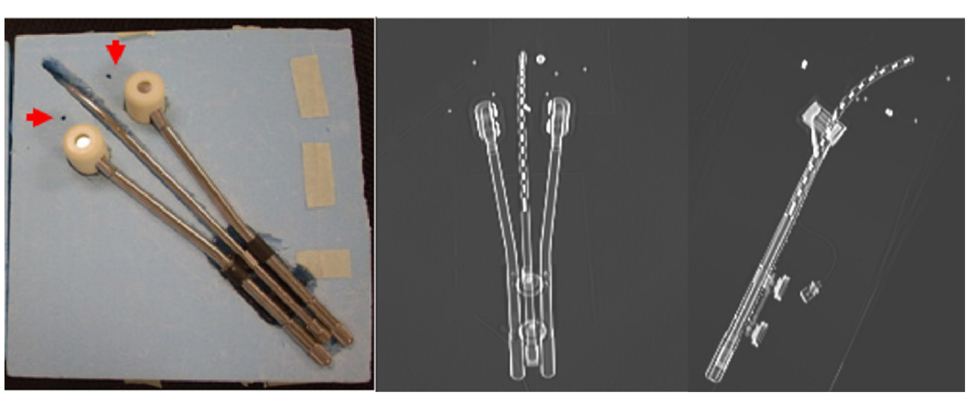

Fig. 1. Fletcher-Suit phantom, with applicator embedded in Styrofoam. Six 3.2-mm diameter BBs were inserted into holes near the applicator to simulate the reference positions. Each BB resides in its own hole; 4 were on the other side of the Styrofoam block, and the 2 on the near side are indicated by red arrows on the photograph (*left*). Also depicted are A-P (*middle*) and lateral (*right*) scout images.