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PHYSICS CONTRIBUTION

EVALUATION OF TWO TOMOTHERAPY-BASED TECHNIQUES FOR THE DELIVERY OF WHOLE-BREAST INTENSITY-MODULATED RADIATION THERAPY

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Purpose: To evaluate two different techniques for whole-breast treatments delivered using the Hi-ART II tomotherapy device.
Methods and Materials: Tomotherapy uses the standard rotational helical delivery. Topotherapy uses a stationary gantry while delivering intensity-modulated treatments. CT scans from 5 breast cancer patients were used. The prescription dose was 50.4 Gy.
Results: On average, 99% of the target volume received 95% of prescribed dose with either technique. If treatment times are restricted to less than 9 min, the average percentage ipsilateral lung receiving ≥20 Gy was 22% for tomotherapy vs. 10% for topotherapy. The ipsilateral lung receiving ≥50.4 Gy was 4 cc for tomotherapy vs. 27 cc for topotherapy. The percentage of left ventricle receiving ≥30 Gy was 14% with tomotherapy vs. 4% for topotherapy. The average doses to the contralateral breast and lung were 0.6 and 0.8 Gy, respectively, for tomotherapy vs. 0.4 and 0.3 Gy for topotherapy.
Conclusions: Tomotherapy provides improved target dose homogeneity and conformality over topotherapy. If delivery times are restricted, topotherapy reduces the amount of heart and ipsilateral lung volumes receiving low doses. For whole-breast treatments, topotherapy is an efficient technique that achieves adequate target uniformity while maintaining low doses to sensitive structures.

Breast radiotherapy, Tomotherapy, Treatment planning.

INTRODUCTION

Historically, whole-breast radiotherapy as part of breast conservation therapy has been performed mainly with tangential fields. Because of the simple geometry of tangential fields, the lack of need for dose escalation in breast conservation, and the perceived relatively low complication rates, there has been little impetus for change in the technical delivery of breast radiotherapy. Tangential fields provide adequate coverage of the target tissue (i.e., the breast). However, pulmonary complications, cardiac complications, and fibrotic changes in the irradiated soft tissues are well documented consequences of whole-breast irradiation. It is not clear how modern conformal techniques, including intensity-modulated radiotherapy (IMRT), will impact clinical outcomes. However, IMRT techniques have been investigated for whole-breast irradiation in an effort to increase dose homogeneity and/or decrease normal-structure doses. In addition to compensators and their use, multileaf collimator (MLC) based techniques have been investigated (1–4). A common approach is to modulate the intensity of the two tangential fields; i.e., the gantry angles used for IMRT are identical to those used for standard tangential radiation therapy.

The availability of helical tomotherapy units is increasing, and the evaluation of this device for breast cancer treatments is of interest. In the current study, the use of helical tomotherapy units for the treatment of whole-breast

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patients is tested. Two different irradiation techniques are evaluated. Both techniques use the same hardware, but in one technique the gantry rotates during delivery, whereas in the second technique gantry positions are stationary.

In helical tomotherapy, the gantry continuously rotates around the patient, who is translated through the beam delivery plane (5). This technique allows beam delivery from any gantry angle. In comparison with whole-breast treatments with standard tangential radiation therapy, the use of all gantry angles could result in a delivery of low doses to areas in the body that would normally receive only scatter dose. The organs of particular concern are the contralateral breast and lung. This situation can be mitigated by constraining delivery through certain structures or angles. To prevent dose delivery to a structure of interest, the structure can be designated as a blocked during the tomotherapy planning process. This inhibits the use of any beamlet that passes through this structure, therefore limiting the dose to just scatter dose. It is also possible to directionally block a structure. This allows beamlets only to exit from a structure, but not to enter the structure on its path to the target. By using such methods, the treatment delivery is constrained to a smaller range of directions and a smaller set of beamlets. However, because the gantry speed is constant, as the number of treatment directions decreases, the treatment delivery efficiency decreases. This is not a significant problem for most delivery types, but can be a larger consideration for cases such as breast when the desired treatment is constrained to a very small number of directions. To avoid this inefficiency, an obvious extension of helical tomotherapy delivery is therefore the use of static gantry positions, combined with simultaneous couch translation and MLC modulation. This option, called topotherapy, seems particularly well suited for the treatment of the whole breast. If the static gantry angles are identical to the tangential beam angles, this technique is similar to intensity-modulated tangential fields.

It is the purpose of this work to evaluate and compare treatment plans that are based on helical and static treatment modes. To establish a common framework for comparison, the quality of the helical tomotherapy plans was restricted by enforcing delivery times comparable to simple 2 tangential beam directions (on the order of 6 to 9 min, depending on the extension of the target inferior-superior). A longer treatment time would allow a higher degree of beam modulation and would potentially allow the design of better plans.

METHODS AND MATERIALS

Simulation CT scans from 5 early-stage breast cancer patients who received breast conservation therapy with conventional techniques were used for this study. Patients were chosen at random and represented a range of body types. Target breast volumes ranged from 374 to 975 cc (mean = 691 ± 210 cc). Four patients had left-sided tumors, and one had a right-sided lesion. Simulation CT scans were obtained in the supine position with arms extended above the head. Contours were drawn using FocalSim (CMS, St. Louis, MO). The planning target volume (PTV) encompassed all radiographically visible breast tissue. Contralateral breast, ipsilateral and contralateral lung, and left ventricle volumes were defined as organs at risk (OAR). The lung and skin contours were automatically outlined.

Treatment plans were generated using the Hi-Art II System (TomoTherapy Inc., Madison, WI). The first technique that was evaluated is referred to as tomotherapy and is based on the typical helical delivery with the Hi-Art II System. These helical tomotherapy plans were generated using the commercial planning software of the Hi-Art System. A jaw width of 2.6 cm was used for all plans, along with a pitch of 0.3 and a modulation factor of 2. A prescription dose of 50.4 Gy was used for all plans. The projected treatment times were calculated for all plans. Left ventricle, lungs, and contralateral breast were treated as avoidance structures. The contralateral lung and breast were designated as blocked structures so that no beamlets were allowed to enter or exit through these structures. The spinal cord was directionally blocked, hence allowing only exit beams to pass through this structure. A goal of 20 Gy to 20% of ipsilateral lung volume was set based on prior data suggesting 20–30 Gy as the range of radiation doses resulting in pneumonitis (6). The ipsilateral lung was not blocked. A maximum dose of 30 Gy was set for the left ventricle. The optimization was driven with a goal to deliver the prescription dose to 95% of the PTV. Dose–volume histogram points and penalties were adjusted throughout the optimization to best meet OAR dose constraints without compromising PTV coverage. Modulation factors were selected to keep the delivery times in the range of 6 to 9 min.

The second technique that was evaluated is referred to as *topotherapy*. Topotherapy plans were generated using prototype software from TomoTherapy, Inc. Topotherapy uses the Hi-Art unit, but the gantry remains stationary during treatment delivery. During topotherapy, the beam intensity is modulated via the binary collimators in the fan beam path while the patient is advanced through the stationary gantry. After the patient is treated from one gantry angle, the gantry is rotated to an opposite tangential beam direction (typically 180° minus the beam divergence angle), and the patient is again passed through the bore for delivery of the second field. This is fundamentally equivalent to opposed intensity-modulated tangents.

Comparison end points included PTV coverage defined as the percentage volume of the PTV receiving 95% of the prescribed dose (Target $V_{95\%}$), target dose homogeneity, percentage volume of ipsilateral lung receiving ≥20 Gy ($V_{20\ Gy}$), the volume of the ipsilateral lung receiving a dose greater than the prescription dose, percentage volume of left ventricle receiving ≥30 Gy ($V_{30\ Gy}$), contralateral breast and lung doses, and unspecified soft-tissue volumes receiving ≥50.4 Gy. Unspecified soft tissues are defined as tissues within the irradiated volume minus PTV and OARs.

RESULTS

A comparison of the two treatment techniques in terms of PTV coverage and dose homogeneity is shown in Table 1. Both techniques result in similar PTV coverage, whereas tomotherapy plans are slightly more homogeneous than topotherapy plans. Figure 1 shows typical transverse mid-breast coverage of the target with the helical and static techniques, and Fig. 2 shows dose–volume histograms typical of the helical and static techniques for the patient shown in Fig. 1. These figures qualitatively demonstrate that to-