Breast Boost: Are We Missing the Target?
A Dosimetric Comparison of Two Boost Techniques

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BACKGROUND. Randomized trials have shown improved local control with the use of a breast boost for patients given breast-conserving treatment for breast carcinoma. Although the use of a breast boost is routine practice, no standard technique has been established. The authors compared the commonly used clinical technique with a technique based on computed tomography (CT) imaging of surgical clips in the tumor bed.

METHODS. Thirty patients underwent CT simulation for postoperative radiation treatment planning as part of breast conservation therapy. During simulation, a CT-compatible wire was placed on the patient’s skin, outlining the intended electron boost field; an electron boost volume (EBV) was generated by contouring the tissue underlying the wire. Also contoured was a CT-based clinical target volume (CTV) using surgical clips and postsurgical changes in the tumor bed as a guide. A planning target volume (PTV) was generated using a 1 cm margin around the CTV. An electron beam treatment plan was generated for each technique using the FOCUS three-dimensional treatment planning system. Dose–volume histograms (DVH) were generated to determine the fraction of the PTV receiving 90% of the prescribed dose if treatment was delivered using the EBV. In addition, DVH analysis was done to determine the volume of normal tissue unnecessarily irradiated when using the EBV.

RESULTS. Although the electron cone size remained unchanged in most patients for both EBV and PTV, the isocenter differed more than 1 cm in the medial-lateral direction in 5 patients and in the cephalocaudal direction in 12 patients. The en face gantry angle differed for most patients. On average, only 51% (range, 27–79%) of the PTV received 90% or more of the prescribed dose when the electron plan was generated using the EBV ($P < 0.0001$). Ten patients received the prescription dose to less than 50% of the PTV. Mean volume of normal tissue receiving more than 50% of prescribed dose was 64.5 cm$^3$ (range, 24–119 cm$^3$).

CONCLUSIONS. Clinical delineation of the tumor bed not only carries a significant risk of missing the target, but unnecessarily treats breast tissue that may otherwise be spared. Better delineation of the tumor bed, which optimizes coverage of the target volume and spares normal breast tissue, has the potential to improve both local control and cosmetic outcome. The authors recommend the use of surgical clips to delineate the target volume, followed by CT-based treatment planning, accounting for not only microscopic disease, but also organ motion and daily setup error. Cancer 2003;97:905–9. © 2003 American Cancer Society. DOI 10.1002/cncr.11142

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Six randomized trials have established the equivalence of breast conservation to mastectomy. Although five of the six trials delivered a boost as part of the radiation therapy, the usefulness of a breast boost...
boost remains controversial. A French randomized trial showed statistically significant improved local control using a 10 Gy boost in addition to whole breast irradiation to 50 Gy. A multi-institutional randomized European Organisation for Research and Treatment of Cancer (EORTC) study recently confirmed a decreased rate of local recurrence with the addition of a boost despite histologically negative margins, especially in younger patients. This confirms the concept of dose-response for a specific tumor volume in breast carcinoma. Several studies also confirmed the impact of local control on survival. Although a breast boost as part of breast conservation is routinely done, no standard technique has been established. Most centers use a 10–20 Gy boost to the tumor bed after delivering a dose of 45–50 Gy to the entire breast. Most commonly, the boost is delivered using electrons with an en face technique. Reduced tangential photons or interstitial brachytherapy are also used in certain settings.

The current study was designed to evaluate, by means of three-dimensional (3D) computer treatment planning tools, the accuracy of two techniques for volume definition and dose coverage: the commonly used clinical technique and a technique based on computed tomography (CT) imaging of surgical clips in the tumor bed.

MATERIALS AND METHODS
Thirty patients with early stage breast carcinoma underwent CT simulation for radiation treatment planning as part of breast conservation. All patients were CT scanned in the treatment position using the Marconi PQ2000s AcQSim CT scanner (Marconi Medical Systems, Highland Heights, OH). A CT scan with 3 mm-thick slices was acquired throughout the entire breast volume for each patient. The entire breast volume was treated to a dose of 50 Gy with tangential 6 MV/10 MV photon beams followed by a 10 Gy boost with an en face electron beam to the tumor bed. Two treatment planning techniques were considered for the boost target.

In the first technique, the treatment area was outlined on the patient’s skin by placing a wire around the clinically palpable tumor bed with at least a 1 cm margin, including the surgical scar. If the tumor bed was not easily palpated, a 3-4 cm margin was placed parallel to the surgical scar, with a 1 cm margin at the ends of the scar. In addition, all available clinical information, such as presurgical physical findings and mammogram, were used to help determine the electron boost volume (EBV). The energy of the electron beam was chosen so as to provide 90% dose coverage to the deepest portion of the target on an axial CT image at the isocenter of the EBV. A maximum electron energy of 16 MeV was used to minimize skin and lung dose. An en face gantry angle was selected to place the beam perpendicular to the planning target volume (PTV) plane of greatest dimension.

In the second technique, the clinical target volume (CTV) was contoured with the surgical clips as a guide but also incorporated any surgical defect or seromas seen on the CT scans. An attempt was also made to add 1 cm for microscopic extension, as long as the extension remained within the breast tissue (Fig. 1). Six clips were placed at the time of surgery to mark the edge of the resection cavity in all patients. The clips were placed in a circumferential fashion about 2 cm apart at a depth estimated to be the depth of the tumor bed. The planning target volume (PTV) consisted of the CTV plus a 1 cm margin allowing for organ motion and daily setup error. In the plane of the beam, the PTV did not extend beyond the skin edge anteriorly and the rib cage posteriorly. CT scans with target contours were transferred to the FOCUS 3D treatment planning system (CMS Corporation, St. Louis, MO). The electron blocks were designed using the beam’s eye view with a 1 cm margin around the PTV. The electron beam energy was chosen so as to provide at least 90% isodose coverage to the PTV. The maximum electron energy used was 16 MeV to minimize skin and lung dose. The gantry angle was determined on CT using an en face technique for both plans and was selected to place the beam perpendicular to the PTV plane of the greatest dimension.

A dose–volume histogram (DVH) was generated...
for each patient to determine the fraction of the PTV that would receive 90% of the prescription dose if the EBV were treated. In addition, DVH analysis was performed to determine the volume of normal tissue that would be unnecessarily irradiated by treatment of the EBV. Normal tissue volume was the difference between the EBV and the PTV.

RESULTS

Differences in treatment parameters for the treatment plans generated by the two treatment techniques are reported in Table 1. Electron energy was different in seven patients (two-sample t test, \( P = .08 \)). Although the electron cone size remained unchanged in most patients, the isocenter for the PTV was shifted more than 1 cm in the medial-lateral direction in five patients and in the cephalocaudal direction in 12 patients (Fig. 2). The planned en face gantry angle differed in most patients.

Mean volumes of the EBV and PTV were 68.4 cm\(^3\) (14 cm\(^3\) to 147 cm\(^3\)) and 53.5 cm\(^3\) (14 cm\(^3\) to 126 cm\(^3\)), respectively. The EBV was larger than the PTV in 23 patients, unchanged in two patients, and smaller in five patients. This difference in volumes was statistically significant (\( t = 3.77, P = .0007 \)) on a two-sample t test. On average, only 51% of the PTVs received 90% or more of the prescribed dose from the EBV plan (range, 27% to 79%). This was significant on a two-sample t test (\( t = 7.46, P < .0001 \)). In 10 patients, the EBV provided the prescribed dose to less than 50% of the PTV. One hundred percent of the PTV was covered by 90% dose in the CT plan. Compared with a maximum electron energy of 16 MeV, a photon boost would achieve better coverage of the tumor bed in six patients.

The mean volume of normal tissue unnecessarily irradiated by the EBV plan was 143 cm\(^3\) (range, 48 cm\(^3\) to 252 cm\(^3\)). The mean volume of normal tissue receiving more than 50% of prescribed dose by the EBV plan was 64.5 cm\(^3\) (24 cm\(^3\) to 119 cm\(^3\)).

DISCUSSION

Negative surgical margins were required for treatment with lumpectomy either with or without postoperative radiation in National Surgical Adjuvant Breast and Bowel Project (NSABP)-06.\(^7\) After 12 years of observation, local recurrence developed in only 40% of patients treated with lumpectomy alone in this study. It is therefore reasonable to infer that only approximately 40% of patients actually had residual disease after lumpectomies that achieved negative surgical margins. In NSABP-06 and in other studies of breast-conserving therapy with surgery and radiation therapy, local recurrence rates approach 10% after 10 years of observation.\(^7\)–\(^9\) Given that only 40% actually had residual disease, the true recurrence rate is actually 25% for microscopic residual breast carcinoma. Given disease control rates with radiation therapy in other carcinomas with both microscopic and gross disease, it would appear significant opportunity exists for increased disease control with radiation therapy in the setting of breast-conserving therapy.

The primary goal of breast conservation is disease control in the tumor bed, as that is where the majority of local recurrences occur. The EORTC has shown a benefit in local disease control with the addition of a tumor bed boost in a prospective randomized multi-institutional trial.\(^2\) A significant reduction in the haz-

### TABLE 1

<table>
<thead>
<tr>
<th>Change in Treatment Parameters Comparing PTV with EBV Plan</th>
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<tr>
<td><strong>Parameters</strong></td>
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<tr>
<td>Electron cone size</td>
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<tr>
<td>Changed</td>
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<td>Gantry angle</td>
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<tr>
<td>Changed 5-10 degrees</td>
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<tr>
<td>No change</td>
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<tr>
<td>Isocenter shifted</td>
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<tr>
<td>In medial-lateral direction ≥ 1 cm</td>
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<tr>
<td>In cephalocaudal direction ≥ 1 cm</td>
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<tr>
<td>Shift smaller than 1 cm or no change</td>
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<tr>
<td>Electron energy</td>
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<tr>
<td>Changed</td>
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<tr>
<td>No change</td>
</tr>
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PTV: planning target volume; EBV: electron boost volume.
ard ratio (0.59, confidence interval 0.43–0.81) for local recurrence was observed in the 5318 patients randomized to a 16 Gy boost versus no boost. This finding provides evidence of a radiation dose response for microscopic residual breast carcinoma. It is critically important that the optimal dose be delivered to the tumor bed to achieve the highest local disease control.

There are several factors affecting the actual dose delivered to microscopic residual disease in the tumor bed. The first is accurate definition of the tumor bed. Data from many series\textsuperscript{10,11} show that the tumor bed may be altogether missed or partially covered by both the tumor bed boost and the tangential whole-breast photon fields when the tumor bed is not identified by the surgeon with surgical clips. Other data\textsuperscript{12} show the necessity of CT planning when tangential fields are employed, as surface anatomy does not clearly predict internal anatomy, and medial and lateral breast tissue in particular is susceptible to inadequate coverage.

The second factor is accurate dose prescription. Intuitively, residual disease would likeliest reside in tissue immediately peripheral to the clips demarcating the tumor bed and in any tissue showing postsurgical changes related to hemorrhage or edema. It seems rational to define the CTV as the volume of tissue within the surgical clips and/or showing any postsurgical disturbance plus a margin to include the microscopic extension (in the current study arbitrarily set as 1 cm). Because of organ motion primarily related to respiration, daily setup error and patient motion require an additional margin (arbitrarily set at 1 cm in the current study) to make up the PTV. This PTV is the three-dimensional volume that must be included in the tumor bed boost.

The third factor is the method of dose prescription. To ensure that the intended dose is given to the periphery or highest risk area, it is important that the dose is prescribed to include the entire target volume. In the case of the current study, the dose was prescribed so that the entire target volume received at least 90% of the maximum dose. The final factor affecting the dose delivered is the dose prescribed. The EORTC focused on a prescribed dose of 50 Gy versus a prescribed dose of 66 Gy to the tumor bed.\textsuperscript{2} This study focused on the method of dose prescription to the target volume.

In the current study, a number of observations were made that impact significantly on the actual dose delivered to the target volume. First, determination of the tumor bed depth in a single plane or point, based on a single CT slice, is suboptimal. The depth of the tumor bed from the skin surface may vary from slice to slice, so three-dimensional definition of the tumor bed is critical, particularly since residual disease is likely to be at the periphery rather than the center of the target volume. Clips are a guide to the location of the tumor bed. We must not solely rely on clips. In addition to clips, any area with postoperative changes is at risk and should be included in the target volume. This can only be accomplished using multiple CT slices through the tumor bed. Second, the dose specification to a three-dimensional target volume rather than the simple en face electron beam volume provides more comprehensive coverage of the target volume as well as less normal tissue exposure. Finally, higher energy electrons produce a higher skin dose as well as a slower dose fall-off at depth. Deep-seated tumors may best be treated with tangential photon boosts to avoid both excess skin dose and excess lung dose.

It is probable that with precise target definition based on surgical clips and CT changes and precise dose prescription to the three-dimensional tumor bed target volume, local control could be increased without necessarily increasing the prescribed dose to the tumor bed. This may be important, as the EORTC reported a worse cosmetic outcome in the boost group.\textsuperscript{2} The cosmetic result was assessed by a panel as excellent or good in 86% of the no-boost group at three years compared with 71% of the boost group. Clearly, in the current study, the normal tissue DVH of the CTV showed less normal tissue exposure with the CTV than with the EBV, potentially resulting in a better cosmetic result.

In conclusion, given the evidence for increasing tumor control in breast-conserving therapy (BCT) with the addition of a tumor bed boost, complicated by a decreasing cosmetic result, accurate targeting of the dose delivered to the tumor bed target volume is essential for improvement of the therapeutic ratio. The current data show a significant improvement in the dose distribution associated with CT treatment planning, in contrast to simple en face electron beam applications.

Despite previous convincing data on CT-based breast-boost treatment planning using surgical clips as a guide, this has not become standard practice.\textsuperscript{13–15} We hope the current data in light of the current EORTC boost data will encourage the use of clips and CT-simulation for treatment planning in breast carcinoma.

REFERENCES


