Improving Dose Homogeneity in Large Breasts by IMRT
Efficacy and Dosimetric Accuracy of Different Techniques

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Purpose: Evaluation of a simplified intensity-modulated irradiation (IMRT), a three-field (MFT), and a conventional two-tangential-field technique regarding dose homogeneity, target coverage, feasibility and, for the first time, dosimetric reliability in patients with large breasts treated postoperatively for breast cancer on a low-energy linac.

Material and Methods: CT datasets of ten patients with relatively large breast volumes treated for breast cancer were selected. For each patient, four treatment plans were created: low-energy conventional (C-LE), high-energy conventional (C-HE), three-field (MFT), and a two-field aperture-based IMRT technique. Apertures for the IMRT and MFT were created with the aid of a three-dimensional dose display. Dosimetric accuracy of each technique was evaluated in an anthropomorphic thorax/breast phantom.

Results: The mean of planning target volumes receiving < 95% or > 105% of the prescribed total dose was reduced from 16.0% to 13.9% to 10.4% to 8.9% in the C-LE, C-HE, MFT, and IMRT plans, respectively. Phantom dose measurements agreed well with the calculated dose within the breast tissue.

Conclusion: Aperture-based IMRT using two tangential incident beam directions, as well as a three-field technique with inverse optimization, provide a better alternative to the standard wedged tangential beams for patients with large breasts treated on low-energy linacs while maintaining the efficiency of the treatment-planning and delivery process.

Key Words: Aperture-based IMRT · Three-field breast treatment · Breast cancer

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Verbesserung der Dosis-Homogenität in großvolumigen Brüsten mit IMRT: Die Wirksamkeit und die dosimetrische Genauigkeit der verschiedenen Techniken


Material und Methodik: CT-Datensätze von zehn Patientinnen mit relativ großem Mammavolumen, bei denen eine postoperative Radiotherapie wegen Mammakarzinoms durchgeführt worden war, wurden für diese Untersuchung verwendet. Für jede Patientin wurden vier Bestrahlungspläne generiert: Niedrigradiation konventionell (C-LE), Hochenergie konventionell (C-HE), Drei-Felder-Plan (MFT) und eine aperturbasierte Zwei-Felder-IMRT-Technik. Aperturen (Segmente) für die IMRT und MFT wurden mit Hilfe eines dreidimensionalen Dosisdisplays generiert. Die dosimetrische Reproduzierbarkeit der generierten Pläne wurde in einem anthropomorphen Thorax/Mamma-Phantom evaluiert.

Ergebnisse: Das mittlere Volumen des Planungszielvolumens, das < 95% oder > 105% der Verschreibungsdosis erhielt, wurde von 16,0% (C-LE) auf 13,9% (C-HE) auf 10,4% (MFT) bzw. 8,9% (IMRT) reduziert. Die gemessene Dosis stimmt für alle Pläne im Bereich der Mamma gut mit der berechneten Dosis überein.

Schlussfolgerung: Die aperturbasierte IMRT mit zwei tangentialen Primärstrahlrichtungen und die Drei-Felder-Technik mit inverser Optimierung verbessern die Planqualität bei der postoperativen Bestrahlung voluminöser Mamm.en an Linacs mit niedriger Energie bei hervorragender Behandlungssituation.

Schlüsselwörter: Aperturbasierte IMRT · Drei-Felder-Mammabestrahlungstechnik · Mammakarzinom

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Introduction
Breast cancer is considered to be one of the frequent targets in radiation oncology; therefore, any improvement in treatment quality would benefit a large number of patients [24].

In the past 2 decades, more women were offered breast-conserving surgery and although partial-breast irradiation is emerging as a possible method of treatment [16–19, 22], the two-tangential-wedged-beam technique is still considered to be the standard treatment. And while simple tangents with beam energy of 6 MV are satisfactory for most clinical situations, inherent drawbacks exist for the treatment of large breast volumes. Among these are the unavoidable hot regions created within the planning target volume (PTV) [4, 7], which may, depending on patient-individual factors [6, 25], cause acute skin reactions and result in poor cosmesis [1, 12, 14]. In addition, a general problem of physical wedges is the increased radiation scatter that leads to unnecessary exposure to the contralateral breast [10, 28].

On dual-energy linacs, the problem of dose inhomogeneity in large breasts is partially overcome by applying part of the dose with an energy > 6 MV. On 4- or 6-MV linacs, however, other solutions have to be found.

In this study, we compared conventional wedged fields using single or dual energies, with optimized wedge angle and wedge orientation to the same setup with an additional anterior field and to a simplified intensity-modulated irradiation (IMRT) technique based on an intuitive visual aid for segment generation with regard to:
• dose homogeneity in the target volume,
• feasibility of routine delivery, and, for the first time,
• dosimetric proof of the theoretical advantages of the suggested techniques in an anthropomorphic phantom.

Material and Methods
The study is based on a comparative analysis of four different techniques used in postoperative radiation therapy of early breast cancer patients. Ten patients with relatively large breast volumes (mean PTV 1,606 cm³, range 1,260–2,216 cm³) were selected. Six patients had left-sided disease. Treatment planning was based on the Elekta Synergy™ 6- and 15-MV linear accelerator using PrecisePLAN® treatment-planning system (TPS).

For each of the ten patients, four treatment plans were created. A reference plan was generated using the conventional two-tangential-wedged-field technique, once with 6-MV photons only (C-LE), and again using mixed 6- and 15-MV photons (C-HE). The third plan was a three-field technique (two tangential wedged fields + one anterior open field) using 6-MV photons (MFT). For these three techniques, the OmniWedge™ provided in the Elekta Synergy linac was used. OmniWedge™ is an extension of the common virtual (dynamic) wedge concept. In a single beam, it combines an open field segment, a motorized wedge segment, and an orthogonal dynamic (delivered as if IMRT step-and-shoot) wedge segment [20]. Hence, the treatment planner has an additional degree of freedom, to first optimize the direction of the multileaf collimator (MLC) aperture (for optimal target coverage and risk-organ shielding) and then to optimize the wedge direction and angle. This provides the potential for improving dose homogeneity in the breast over conventional wedges. The fourth technique was an aperture-based IMRT technique using only two multisection tangential 6-MV beams (IMRT).

For all techniques, two tangential beams were created with the gantry and collimator angles chosen for the best coverage of the PTV with the least exposure of the ipsilateral lung while preventing divergence of the beams into the lungs. 2 cm of flash margin were taken outside the anterior skin outline. This basic beam setup was considered the starting point for all four plans.

For the C-LE and C-HE techniques, a wedge angle was chosen to allow for the best possible dose homogeneity throughout the PTV which was assessed using the 3D-Visual-DVH (dose-volume histogram) display tool in PrecisePLAN®. The Visual-DVH allows for the three-dimensional display of dose in a given volume in the beam’s eye view by calculating a dot matrix of varying colors, representing different dose ranges in different volume depths (Figure 1). Also, through reviewing the Visual-DVH and by using the OmniWedge™, a virtual wedge orientation is chosen to allow for the best possible distri-