

Multisegmented Tangential Breast Fields: a Rational Way to Treat Breast Cancer

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Purpose: Using three-dimensional conformal radiation therapy (3D-CRT) and multisegmented conformal radiation therapy (MS-CRT) for breast cancer treatment, the dose coverage of the planning target volume (PTV) and the radiation burden on the organs at risk (OARs) were evaluated.

Material and Methods: 3D-CRT and MS-CRT were planned for 436 unilateral breasts (217 left). All patients were treated with MS-CRT between 2005 and 2007. For PTV delineation and beam orientation, supportive structures were applied. The mean PTV was 1,130 cm³ (in ten patients > 2,200 cm³). Three-dimensional planning with weight-optimized medial and lateral open fields at a total dose of 50.4/1.8 Gy was followed by multisegmented planning with a reasonably high-dose-level dose cloud to define the medial subfield, and renewed optimization. This was repeated for the lateral subfield with a final optimization. For PTV coverage evaluation, the ICRU 50 was considered: the PTV portions receiving 95–107%, < 95% and > 107% of the prescribed dose (PTV_{D95–107%}, PTV_{<D95%} and PTV_{>D107%}), and the PTV maximal dose (PTV_{Dmax}). To compare the OAR radiation burdens, the mean doses to the ipsi-/contralateral lung, contralateral breast, and whole heart were documented.

Results: The multisegmented plans furnished significantly ($p < 0.0001$) better target coverage (PTV_{D95–107%} 82.8% vs. 90.9%, PTV_{<D95%} 11.4% vs. 8.8%, PTV_{>D107%} 5.9% vs. 0.3% and PTV_{Dmax} 56.6 vs. 54.3 Gy). The mean OAR doses remained almost unchanged: ipsilateral lung 10.5 versus 10.4 Gy, contralateral lung 0.4 versus 0.4 Gy, contralateral breast 0.8 versus 0.8 Gy, and whole heart (for left-sided cancers) 4.8 versus 4.8 Gy. The subfields required a mean of 9.8 MU (monitor units), i.e., a mean total 7.6 MU increment. The planning took 10–20 min, and the delivery 5–10 min.

Conclusion: MS-CRT is a good alternative to breast intensity-modulated radiation therapy (IMRT) and seems adequate for right-sided cancers, whereas left-sided cancers necessitate a longer follow-up of heart-related side effects before a final assessment.

Key Words: Breast cancer · Segmented beams · Plan optimization · IMRT · Dose homogeneity · Dummy structure

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Multisegmentale tangentielle Brustfelder: eine geeignete Bestrahlungsmethode bei Brustkrebs

Ziel: Die Erfassung des Planungszielvolumens (PTV) und die Strahlenbelastung der Risikoorgane (OARs) bei dreidimensionaler konformaler Radiotherapie (3D-CRT) oder multisegmentaler konformaler Radiotherapie (MS-CRT) des Mammakarzinoms wurden ausgewertet.

Material und Methodik: Dreidimensionale und multisegmentale konformale Bestrahlungspläne wurden für 436 unilaterale (217 linksseitige) Brüste erstellt. Zwischen 2005 und 2007 erhielten alle Patientinnen eine MS-CRT. Zur PTV-Konturierung und Feldausrichtung wurden Hilfsstrukturen angebracht. Das durchschnittliche PTV betrug 1 130 cm³ (bei zehn Patientinnen > 2 200 cm³). Im Anschluss an die dreidimensionale Planung mit optimal gewichteten medialen und lateralen Feldern bis zu einer Gesamtdosis 50,4/1,8 Gy erfolgte die multisegmentale Planung mit einer angemessen hohen Dosiswolke für das mediale Teilfeld und erneuter Optimierung. Dies wurde für das laterale Teilfeld wiederholt und abschließend optimiert. Bei der Beurteilung der PTV-Erfassung wurde der ICRU 50 berücksichtigt: die Anteile des PTV, die 95–107%, < 95% und > 107% der verordneten Dosis erhielten (PTV_{D95–107%}, PTV_{<D95%}, PTV_{>D107%}), sowie das Dosismaximum (PTV_{Dmax}). Zum Vergleich der Dosisbelastung der OARs wurden die Durchschnittsdosen der ipsi-/kontralateralen Lungen, der kontralateralen Brust und des Herzens dokumentiert.

Ergebnisse: Die multisegmentale Planung erbrachte eine signifikant ($p < 0,0001$) bessere PTV-Erfassung (PTV_{D95–107%} 82,8% vs. 90,9%, PTV_{<D95%} 11,4% vs. 8,8%, PTV_{>D107%} 5,9% vs. 0,3% und PTV_{Dmax} 56,6 vs. 54,3 Gy). Die durchschnittlichen OAR-Dosen blieben nahezu unverändert: ipsilaterale Lunge 10,5 versus 10,4 Gy, kontralaterale Lunge 0,4 versus 0,4 Gy, und kontralaterale Brust 0,8 versus 0,8 Gy, Herz (bei linksseitigem Brustkrebs) 4,8 versus 4,8 Gy. Für die Teilfelder wurden durchschnittlich 9,8 MU (Moni-

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toreinheiten) benötigt, d.h. eine Gesamterhöhung um im Mittel 7,6 MU. Die Planungsprozedur dauerte 10–20 min und die Bestrahlung 5–10 min.

Schlussfolgerung: Die MS-CRT stellt eine gute Alternative zur intensitätsmodulierten Radiotherapie (IMRT) der Brust dar und scheint sich vor allem bei rechtsseitigem Brustkrebs anzubieten, während bei Befall der linken Mamma aufgrund der kardialen Nebenwirkungen vor einer abschließenden Bewertung eine längere Nachbeobachtung erforderlich ist.

Schlüsselwörter: Mammakarzinom · Segmentierte Felder · Planungsoptimierung · IMRT · Dosishomogenität · Hilfsstruktur

Introduction

Radiation therapy (RT) is an essential component of breast cancer treatment, the combination of breast-conserving surgery and adjuvant RT [5, 11, 40] leading to appreciable benefits. Despite the documented importance of RT, normal-tissue toxicities [8, 34] (including secondary radiogenic cancer) can disturb the quality of life and limit the survival rate [20], highlighting the importance of treatment planning (TP).

We have elaborated an improved breast TP method, in an attempt to combine the advantages of three-dimensional conformal radiation therapy (3D-CRT) and intensity-modulated radiation therapy (IMRT), with maintenance of the quality assurance: fast TP, short treatment time in 3D-CRT, improved dose homogeneity on the planning target volume (PTV), and reduced doses to the organs at risk (OARs) in IMRT. We describe here the clinical implementation of our multisegmented radiation therapy (MS-CRT) for breast cancer treatment.

Material and Methods

Between January 2005 and February 2007, 436 women with (217 left-sided) breast cancer (without supraclavicular irradiation) were treated with MS-CRT [17]. 10-mm increment CT scans for all patients in supine position with elevated ipsilateral arm were transferred to the TP system (Elekta, PrecisePLAN™ 2.02/2.03).

Contouring

The OARs (whole heart, ipsi-/contralateral lungs, and contralateral breast) were first contoured, “unspecified tissue” (body excluding PTV and OARs) was used as surrounding tissue.

For the PTV contour, a “supporting structure” PTV-Out was first contoured precisely in the mid-axillary and mid-sternal regions, but loosely into the lung and outside the body (Figure 1). For PTV generation, PTV-Out was excluded from lung and all areas outside a 2-mm skin margin with an automatic subroutine, and deleted. PTV borders: mid-sternal lines, mid-axillary plane, bottom of the clavicle’s head, 2 cm below the submam-

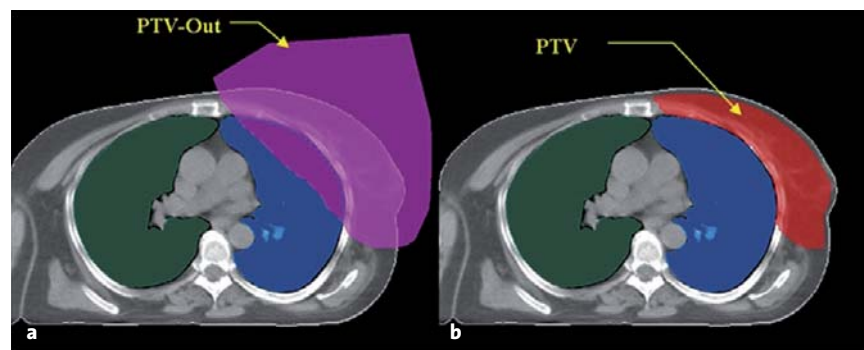
mary fold of the contralateral breast, and from radial direction, 2 mm subdermally, and the soft tissue-lung junction. Mean PTV: 1,130 cm³ (279–3,028 cm³; in ten patients > 2,200 cm³). The prescribed dose (PD) was 50.4/1.8 Gy. For dose calculation, the only photon algorithm of PrecisePLAN™ (i.e., modified 3D-Clarkson with dual-source model) was used.

Three-Dimensional Conformal Radiotherapy Planning

Two quasi-opposite 6-MV open fields were set with minimized PTV projections, using the beam’s eye view (BEV). A “dummy structure” termed the “midline” (Figure 2) was contoured between the sternum and skin to avoid contralateral breast irradiation, and to promote the optimal beam orientation. For generating the multileaf collimator (MLC) field the following shapes were used: 1.5 cm outward from the PTV, 0 cm from the lung side, and 1 cm above and below the PTV. Segment-weight optimization was performed at this setting with the dose-volume-histogram-(DVH)-based IMRT Optimizer of PrecisePLAN™ to achieve a 50.4-Gy mean PTV dose. A dose point receiving the PD (i.e., ICRU [22] reference point) was then chosen for normalization.

Multisegmented Conformal Radiotherapy Planning

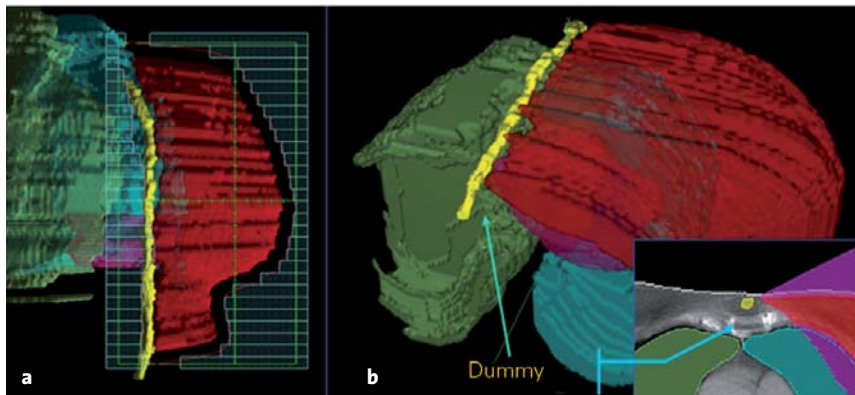
From the optimized dose distribution of the three-dimensional plan, what we term a dose cloud was derived (individually for each patient) at a dose level between 106% and 109%. The



Figures 1a and 1b. An example of the delineation of the “PTV-Out” supporting structure (violet, a) to create the final PTV (red, b) using a 0.2-mm “skin margin”, excluding the left lung.

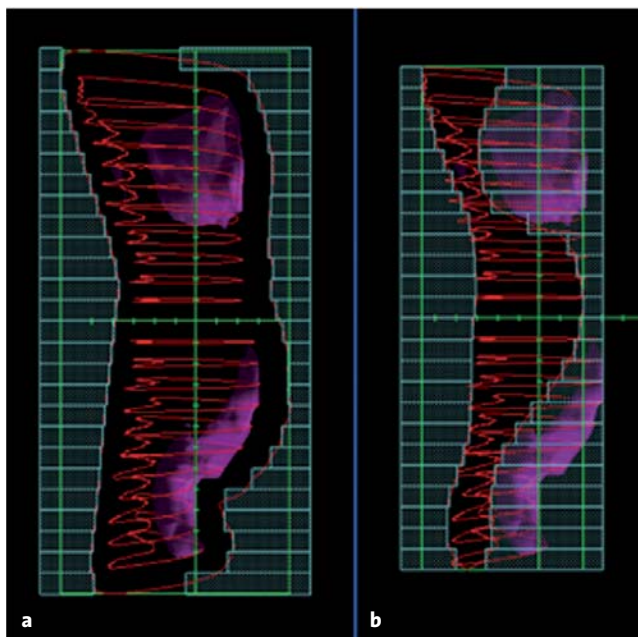
Abbildungen 1a und 1b. Beispiel einer „PTV-Out“-Hilfsstruktur (a, lila) zur Generierung des PTV (rot, b) mit 0,2 mm „Hautabstand“. Dieses Vorgehen schließt die linke Lunge aus.

relatively large chosen dose cloud did not cover > 50% of the BEV. A medial subfield was next set by matching its shape to that of the dose cloud (Figure 3), and optimization was repeated with three segments. The fourth, i.e., lateral subfield was fitted to the newly optimized and chosen dose cloud. Finally, four segments(-weight) were optimized to achieve the optimal dose distribution.



Figures 2a and 2b. An example of the “midline” structure (yellow) represented in the BEV (a), in three-dimensional view (b), and in a slice (insert), used to avoid contralateral breast irradiation.

Abbildungen 2a und 2b. Beispiel einer „Mittellinien“-Struktur (gelb) in BEV (a), in dreidimensionaler Ansicht (b) und in einem Schnittbild (Insert) zur Aussparung der kontralateralen Brust bei der Bestrahlung.



Figures 3a and 3b. An example of the circumscribed (violet) dose cloud (in this case 107% of the PD) in the open (b) and the matched subsegment BEV (a).

Abbildungen 3a und 3b. Beispiel einer umschriebenen (lila) Dosiswolke (in diesem Fall 107% der verordneten Dosis) im BEV des offenen Felds (b) und des angepassten Teilsegments (a).

When the optimization was unsatisfactory, the subfields were deleted, the lateral beam was modified to higher energy, because of the greater risk of an outside-PTV overdose, and the whole procedure was repeated to achieve a suitable solution. In some cases (large breast), both fields were changed to higher energy. Figure 4 illustrates the quasi-linear planning scheme of the outlined procedure. Planning time was ~10–20 min. To avoid delivery dose-MU fluctuations [28, 31], all segments were > 2 MU and were treated after the open segments, during the 5–10 min of delivery.

Multisegmented or Intensity-Modulated

The basic idea of MS-CRT is to add subfields to the open beams with identical gantry angles. It may be stated, that MS-CRT is not true IMRT because only two intensity levels per beam are used.

Evaluation of Three-Dimensional and Multisegmented Plans

DVHs of all structures and the dose distributions were analyzed to assess the quality of the final plan, which was approved by the radiation oncology team. The following PTV items were analyzed as in ICRU 50 [22]: the PTV portions receiving 95–107% ($PTV_{D95-107\%}$), < 95% of the PD ($PTV_{<D95\%}$), hot spots ($PTV_{>D107\%}$), and the PTV maximal dose (PTV_{Dmax}). OAR analysis involved mainly the breast IMRT criteria [24] (Table 1).

The 3D-CRT and MS-CRT plans were compared with two-tailed t-tests (significant at $p < 0.05$).

Results

Our aims were PTV irradiation with a homogeneous 50.4-Gy dose, without coherent underdosage and overdose, and reduction of the dose to the OARs (Table 1).

The multisegmented plans resulted in a more uniform PTV coverage (Figures 5a to 5c, Table 2), and PTV_{Dmax} (Figure 5d) was significantly lower ($p < 0.0001$).

The mean OAR doses did not differ relevantly; meanwhile “unspecified tissue” maximal dose was lower for the multisegmented plans (Table 2).

The subfields required a mean 9.8 MU (monitor units), i.e., a 7.6 MU (4.2%, range: 3.2–9.9%) increment in the mean total MU (Table 2).

Discussion

The recent advances in RT techniques [16] have influenced two aspects of our breast RT: the contouring techniques and the TP.

Supportive Contouring Techniques

PTV contours for a given status can differ considerably [21, 23, 42]. In our practice, human-based errors for the mid-sternal and mid-axillary regions were reduced with “PTV-Out” and automatic PTV contour generation. Because of the shortness of manually indicated contour parts the PTV differences might decrease. A comparable method was developed by van Vaerenbergh et al. [39], with “plan optimization volume” simulation, breast tissue being overlapped by two tangents and an orthogonal field.

Dummy structures have been used in TP to reduce radiation [10] or block regions [1, 7, 30]. We applied “midline” for similar reasons.

The frequent use of automatic contouring and inverse planning [15] may extend the importance of such structures.

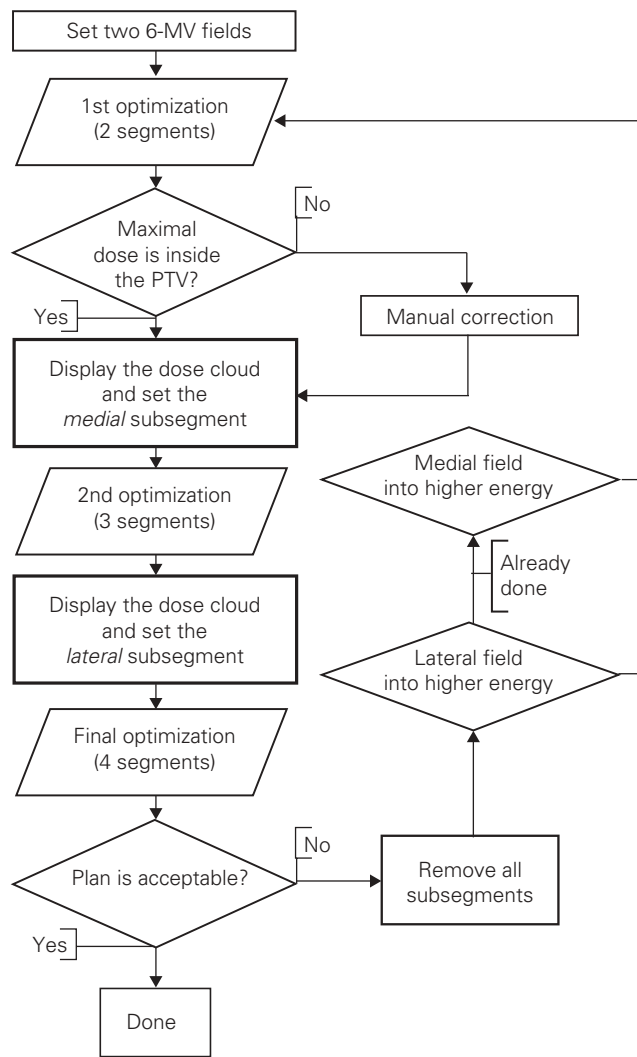


Figure 4. The rational and well-traceable workflow of the MS-CRT planning.

Abbildung 4. Ablaufschema der MS-CRT-Planung.

Table 1. Summarized goals. PTV: planning target volume.

Tabelle 1. Zusammenfassung der Zielsetzungen. PTV: Planungszielvolumen.

Primary goals		Documented
PTV mean dose	50.4 Gy	No
PTV _{D95-107%}	(Maximize)	Yes
PTV _{<D95%}	(Minimize)	Yes
PTV _{>D107%}	(Minimize)	Yes
PTV _{Dmax}	< 55 Gy	Yes
Maximum unspecified tissue dose	< PTV _{Dmax}	Yes

Secondary (optional) goals	Mean dose	
Ipsilateral lung	≤ 10 Gy [23]	Yes
Contralateral lung	≤ 1 Gy [23]	Yes
Contralateral breast	≤ 1 Gy [23]	Yes
Whole heart	≤ 3 Gy	Yes

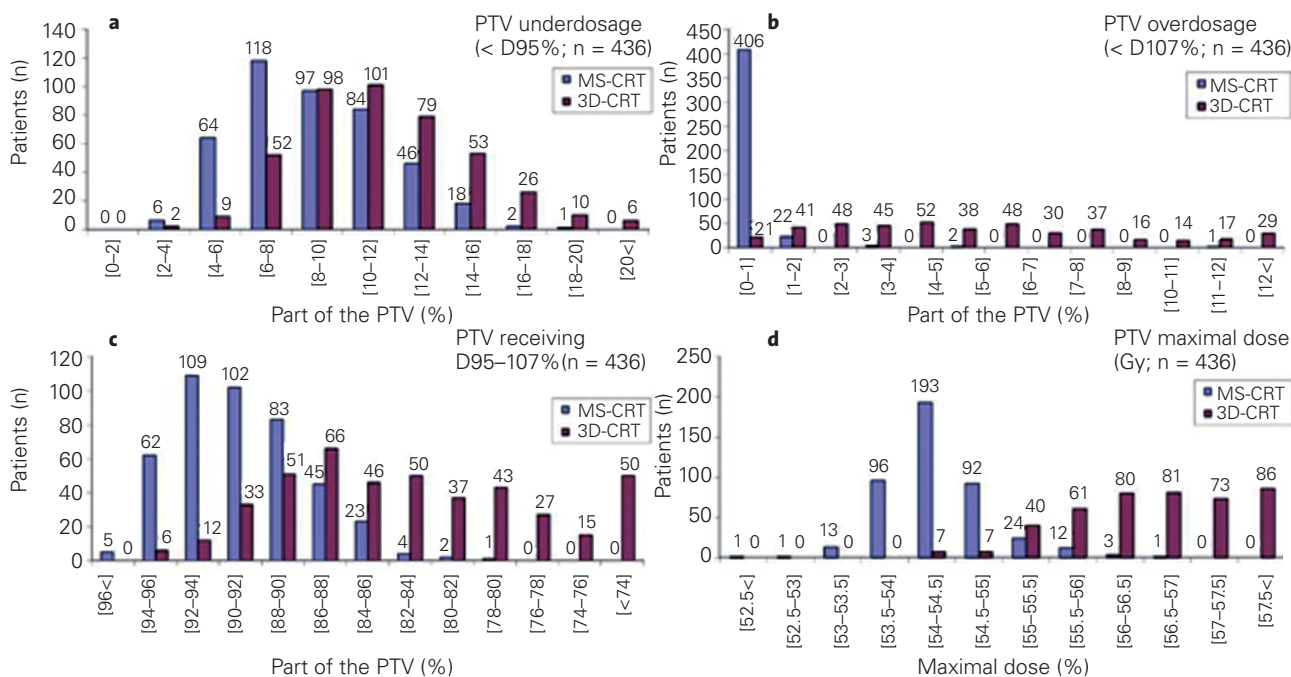
Planning Procedure

For anatomic reasons, breast TP remains a challenge. There have been recent changes in the direction of 3D-CRT with wedges, MLCs, compensators [13, 43] or field-in-field techniques [26]. Breast IMRT is a further step toward an ideal solution [24]. These techniques partially overlap, without an exact border.

For breast RT, IMRT/3D-CRT combinations have been used to increase the plan quality and reduce the treatment time (see Table 3). In a field-in-field method, based on two equally weighted open fields [41], BEV isodose surfaces were contoured from 80% of the PD at increments of 5% to define further fields. Four to six segments per beam were set to fit the shape to different isodose surfaces. These eight to twelve segments were optimized (the remaining three to twelve segments were > 2 MU). 18 MV was sometimes used. 40–45 min of planning and < 10 min of treatment time yielded better PTV coverage and decreased acute skin toxicity, but MU increments and OAR doses were not documented. About 83% of the MU were treated with open tangents. Clinical implementation was based on a treated (281)/analyzed (95) patient population. An even better plan might have been achieved with an optimized starting point (not equally weighted tangents), not mirror-pair subsegments, and a higher number of optimizations during TP.

A combined, conventional-dynamic wedged-field technique (with a ratio ~92/8%) devised to reduce PTV inhomogeneity [44] furnished a better dose distribution than the conventional wedged-field technique, though the low number (n = 12) of planned patients, the small PTVs (340–1,350 cm³) and the comparison only with conventional technique could limit the validity of the conclusions.

In a retrospective planning study on 15 patients [32], the technique of Zackrisson et al. [44] was improved: wedge



Figures 5a to 5d. Volume-based analysis of PTV parts: distribution of underdosage (a), prescribed dose portion (b), and overdosage (c) comparing 3D-CRT and MS-CRT, while representing the PTV maximum doses (d).

Abbildungen 5a bis 5d. Volumenbasierter Vergleich der 3D-CRT und MS-CRT: Verteilung der PTV-Anteile, die eine zu niedrige (a), die verordnete (b) und eine zu hohe Dosis (c) erhalten, mit Darstellung des PTV-Dosismaximums (d).

fields were used with MLC-modified fields. The 107% isodose surface was blocked out, mirrorwise from both directions, and PTV_{D95-107%} increased up to ~93%, i.e., somewhat better than our result (91%). Use of the 107% dose cloud proved less effective for small/large PTVs. The population

was planning-favorable (PTV: 223–1,659 cm³), but the planning time increased. OAR doses and total MU were not documented, but the physical wedge might increase lung and heart doses and increase MU/head leakage through longer beam-on time [12, 13, 43].

Table 2. Summarized results. Statistical analysis with two-tailed t-tests with 870 degrees of freedom. 3D-CRT: three-dimensional conformal radiation therapy; MS-CRT: multisegmented conformal radiation therapy; MU: monitor units; OARs: organs at risk; PTV: planning target volume.

Tabelle 2. Zusammenfassung der Ergebnisse mit statistischer Analyse unter Verwendung zweiseitiger t-Tests mit einem Freiheitsgrad von 870. 3D-CRT: dreidimensionale konformale Radiotherapie; MS-CRT: multisegmentale konformale Radiotherapie; MU: Monitoreinheiten; OARs: Risikorgane; PTV: Planungszielvolumen.

	3D-CRT	MS-CRT	t	p-value	Significant
PTV					
PTV _{D95-107%}	82.8 (6.7)	90.9 (3.0)	23.03	< 0.0001	Yes
PTV _{<D95%}	11.4 (3.4)	8.8 (2.8)	12.33	< 0.0001	Yes
PTV _{>D107%}	5.9 (3.2)	0.3 (0.8)	30.11	< 0.0001	Yes
PTV _{Dmax}	56.6 (1.1)	54.3 (0.5)	39.75	< 0.0001	Yes
OARs					
Ipsilateral lung	10.5 (2.6)	10.4 (2.5)	0.58	0.57	No
Contralateral lung	0.4 (0.4)	0.4 (0.2)	0	1	No
Contralateral breast	0.8 (0.4)	0.8 (0.3)	0	1	No
Heart (left-sided cancer)	4.8 (1.7)	4.8 (1.7)	0	1	No
Heart (right-sided cancer)	1.4 (0.3)	1.4 (0.3)	0	1	No
Normal-tissue maximum	54.9 (1.5)	53.3 (0.8)	19.7	< 0.0001	Yes
Total MU	191.1 (6.2)	198.7 (7.7)			

For ten just-planned patients four- and six-field hybrid IMRT, conventional, dynamic IMRT and field-in-field method were compared [27]. In the favored four-field hybrid IMRT technique, ~83% of the dose was delivered from conventional beams, affording a low (~10% of 270) MU increment. Although the mean OAR doses were reduced, a 110% overdosage might occur outside the PTV and the method has IMRT requirements.

In nine left-sided breast cancer patients planned with 3D-CRT, IMRT and predefined segmented IMRT with clinical (quasi-opposed) and optimal (heart-sparing) orientations [4], three predefined segments were set for both fields: PTV, PTV heart and PTV lung. Good PTV coverage was observed for the clinical-oriented beam setting; heart sparing was possible only at the cost of

Table 3. Comparison of published techniques that are similar to MS-CRT, focusing on the complexity and efficiency. MU no.: number of monitor units; OARs: radiation burden on organs at risk; PTV: homogeneity/coverage of planning target volume. ↑ : increase; ↓ : decrease; ↓ ↑ : some OAR dose is increased, some decreased; ↔ : no significant difference.

Tabelle 3. Vergleich MS-CRT-ähnlicher Techniken in der Literatur hinsichtlich Komplexität und Effizienz. IMRT: intensitätsmodulierte Strahlentherapie; MLC: Multileafkollimator; MU no.: Anzahl der Monitoreinheiten; OARs: Strahlenbelastung der Risikoorgane; PTV: Homogenität/Erfassung des Planungszielvolumens. ↑ : Zunahme; ↓ : Abnahme; ↓ ↑ : Einige OAR-Dosen nehmen zu, andere ab; ↔ : kein signifikanter Unterschied.

Institution	Patients (n)	Idea of favored technique	Complexity, planning time	Dosimetric findings
William Beaumont Hospital [41]	281 ^a	Isodose-based mirror-paired subsegments for equal-weight open tangents	3–12 segments, 40–45 min	PTV ↑ Skin dose ↓
Umeå University [44]	12	Conventional and dynamic wedged-field combination to reduce dose outside the PTV	Hard + dynamic wedge, time ↓	PTV ↑
Newcastle General Hospital [31]	15	Wedged fields combined with (mirrorwise) reduced MLC to block higher-dose region	Wedge + reduced MLC, time ↓	PTV ↑
University of Massachusetts [27]	10	Open field combined with IMRT fields (four-field hybrid plans)	Open + dynamic segments, 15–20 min	PTV ↑ OARs ↓ ↑ MU no. ↑
The Netherlands Cancer Institute [4]	9	Optimization of predefined open segments (PTV, PTV heart, PTV lung)	6 segments, time ↓	PTV ↑ OARs ↓
University Medical Center Utrecht [38]	5	Equivalent pathlength-based predefined segmentation	4 segments, time ↑	PTV ↑
University of Pécs (current analysis)	436 ^a	Optimized high-dose-level dose cloud for separately set subsegment	4 segments, 10–20 min	PTV ↑ OARs ↔ MU no. ↑

^atreated patients

a PTV underdosage. $PTV_{D95-107\%}$ did not exceed 82.5%, which is similar to our three-dimensional (not multisegmented) plans. The skin surface near the PTV could alter the dose distribution, but cannot be compensated with this technique.

In an algorithm-based method for tissue thickness-related segmentation [38], the equivalent tissue pathlength defined from both BEV-DRRs (digitally reconstructed radiographs) was divided into four discrete levels according to the darkness. For the five planned patients, ~88% of the dose was delivered from the first segment. In this time-consuming procedure, the discrete darkness levels of the largest PTV were not evident. Moreover, the PTV is not always equivalent to the whole pathlength of the (large) breast BEV-DRRs.

We implemented MS-CRT into clinical practice for 436 patients. With one exception [41], the relevant publications [4, 27, 32, 38, 44] involve TP procedures. For these techniques, large breasts (> 1,600 cm³) pose a challenge. PTV in our patients varied significantly (279–3,028 cm³), similarly as in [41].

The PTV coverage was improved in our own and all published studies [4, 27, 32, 38, 41, 44]. OAR radiation burdens were documented in only four studies: two indicated a decrease [4, 41], one was inconclusive [27], and we found an unchanged OAR radiation burden.

With a planning time of 10–20 min, our method is short. Moreover, it is more readily applicable than those with wedges, IMRT or multiple segmentation [4, 27, 32, 38, 44]. Only one

patient group from the literature has been treated within about the same time (< 10 min) [41].

Almost all teams mentioned that open/wedged tangents are responsible for ~80–90% of the doses; thus, ~10–20% reduces the PTV inhomogeneity and OAR/surrounding tissue doses.

Similarly to others [4, 27, 38, 41], we applied open fields to counter the disadvantages of wedges (increased scattering, OAR dose, etc.). MS-CRT is a good alternative to IMRT, while the quality control of IMRT is difficult [2, 6, 14]. Moreover, IMRT increases MU for large irradiated volumes relative to 3D-CRT. Our technique (open fields, few segments) causes only a mean 4.2% MU increment, while our MU/dose rate remained low [12].

Since the incidence of chemotherapy-/RT-induced leukemia may be even 7% [3, 36], while that of solid tumors is ~2% [25, 33], secondary cancer incidence (SCI) must be taken into consideration [37]. Clinical examinations demonstrated an SCI increase in the region receiving < 6 Gy [9]. Although the SCI process is unknown, the 10-year SCI for IMRT has been estimated to be 1.75% [18, 19] as compared with 1% for 3D-CRT. Others have reached similar conclusions [12, 25, 35].

Our estimate of SCI for MS-CRT was ~1.016–1.032%. Although this value is low, ALARA (as low as reasonable achievable) [29] should be implemented in RT as well, especially for long-term survival. Thus, MS-CRT can be a rational alternative to breast IMRT, because of small MU increment.

Conclusion

MS-CRT is a good alternative to breast IMRT. The fast planning and short treatment seem adequate for right-sided cancers, whereas left-sided cancers necessitate a longer follow-up of heart-related side effects before a final assessment. This method can be implemented without additional clinical resources, and can be recommended to institutions which do not wish to utilize breast IMRT.

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References

- Abdulkarim BS, Saibishkumar E, Severin D, et al. Skin sparing radiation approach using helical tomotherapy without compromising target coverage in early breast cancer after lumpectomy. Presented at the ASTRO 48th Annual Meeting, Philadelphia, Nov 5–9, 2006.abstract 2031.
- Bogner L, Scherer J, Treutwein M, et al. Verification of IMRT: techniques and problems. *Strahlenther Onkol* 2004;180:340–50.
- Carli PM, Sgro C, Parchin-Geneste N, et al. Increase therapy-related leukemia secondary to breast cancer. *Leukemia* 2000;14:1014–7.
- Cho BC, Schwarz M, Mijnheer BJ, et al. Simplified intensity-modulated radiotherapy using pre-defined segments to reduce cardiac complications in left-sided breast cancer. *Radiother Oncol* 2004;70:231–41.
- Cuzick J, Stewart H, Peto R, et al. Overview of randomized trials of postoperative adjuvant radiotherapy in breast cancer. *Cancer Treat Rep* 1987;71:15–29.
- Dobler B, Lorenz F, Wertz H, et al. Intensity-modulated radiation therapy (IMRT) with different combinations of treatment-planning systems and linacs. Issues and how to detect them. *Strahlenther Onkol* 2006;182:481–8.
- Dogan N, Leybovich LB, King S, et al. Improvement of treatment plans developed with intensity-modulated radiation therapy for concave-shaped head and neck tumors. *Radiology* 2002;223:57–64.
- Dorr W, Bertmann S, Herrmann T. Radiation induced lung reactions in breast cancer therapy. Modulating factors and consequential effects. *Strahlenther Onkol* 2005;181:567–73.
- Dorr W, Herrmann T. Second primary tumors after radiotherapy for malignancies. Treatment-related parameters. *Strahlenther Onkol* 2002;178:357–62.
- Esik O, Bortfeld T, Bendl R, et al. Inverse radiotherapy planning for a concave-convex PTV in cervical and upper mediastinal regions. Simulation of radiotherapy using an Alderson-RANDO phantom. *Planning target volume. Strahlenther Onkol* 1997;173:193–200.
- Fisher B, Anderson S, Bryani J, et al. Twenty-year follow-up of a randomized trial comparing total mastectomy, lumpectomy, and lumpectomy plus irradiation for the treatment of invasive breast cancer. *N Engl J Med* 2002;347:1233–41.
- Followill D, Geis P, Boyer A. Estimates of whole-body dose equivalent produced by intensity modulated conformal therapy. *Int J Radiat Oncol Biol Phys* 1997;38:667–72.
- Fontenla DP, Napoli JJ, Hunt M, et al. Effects of beam modifiers and immobilization devices on the dose in the build-up region. *Int J Radiat Oncol Biol Phys* 1994;30:211–9.
- Galvin JM, Ezzell G, Eisbrauch A, et al. Implementing IMRT in clinical practice: a joint document of the American Society for Therapeutic Radiology and Oncology and the American Association of Physicists in Medicine. *Int J Radiat Oncol Biol Phys* 2004;58:1616–34.
- Georg D, Kroupa B, Georg P, et al. Inverse planning – a comparative intersystem and interpatient constraint study. *Strahlenther Onkol* 2006;182:473–80.
- Guckenberger M, Flentje M. Intensity-modulated radiotherapy (IMRT) of localized prostate cancer. A review and future perspectives. *Strahlenther Onkol* 2007;183:57–62.
- Gulyban A, Kovacs P, Farkas R, et al. Multisegmented radiation therapy as an alternative to 3D conformal radiation therapy, with special reference to breast cancer tangential fields. *Nowotwory J Oncol* 2007;57:125e–7e.
- Hall EJ. Intensity-modulated radiation therapy, protons, and the risk of second cancers. *Int J Radiat Oncol Biol Phys* 2006;65:1–7.
- Hall EJ, Wu CS. Radiation-induced second cancers: the impact of 3D-CRT and IMRT. *Int J Radiat Oncol Biol Phys* 2003;56:83–8.
- Hurkmans CW, Borger JH, Bos LJ, et al. Cardiac and lung complication probabilities after breast cancer irradiation. *Radiother Oncol* 2000;55:145–51.
- Hurkmans CW, Borger JH, Pieters BR. Variability in target volume delineation on CT scans of the breast. *Int J Radiat Oncol Biol Phys* 2001;50:1366–72.
- International Commission on Radiation Units and Measurements. Prescribing, recording and reporting photon beam therapy. ICRU report 50. Bethesda: ICRU, 1993.
- Jeanneret-Sozzi W, Moeckli R, Valley JF, et al. The reasons for discrepancies in target volume delineation. A SASRO study on head-and-neck and prostate cancers. *Strahlenther Onkol* 2006;182:450–7.
- Krueger EA, Fraass BA, McShan DL, et al. Potential gains for irradiation of chest wall and regional nodes with intensity modulated radiotherapy. *Int J Radiat Oncol Biol Phys* 2003;56:1023–37.
- Kry SF, Salehpour M, Followill DS, et al. The calculated risk of fatal secondary malignancies from intensity-modulated radiation therapy. *Int J Radiat Oncol Biol Phys* 2005;62:1195–203.
- Lo YC, Yasuda G, Fitzgerald TJ, et al. Intensity modulation for breast treatment using static multi-leaf collimators. *Int J Radiat Oncol Biol Phys* 2000;46:187–94.
- Mayo CS, Urie MM, Fitzgerald TJ. Hybrid IMRT plans – concurrently treating conventional and IMRT beams for improved breast irradiation and reduced planning time. *Int J Radiat Oncol Biol Phys* 2005;61:922–32.
- Mohr P, Brieger S, Stahl J, et al. Linearity of the dose monitor system at low monitor units. *Strahlenther Onkol* 2007;183:327–31.
- Prasad KN, Cole WC, Haase GM. Radiation protection in humans: extending the concept of as low as reasonably achievable (ALARA) from dose to biological damage. *Br J Radiol* 2004;77:97–9.
- Price RA, Murphy S, McNeeley SW, et al. A method for increased dose conformity and segment reduction for SMLC delivered IMRT treatment of the prostate. *Int J Radiat Oncol Biol Phys* 2003;57:843–52.
- Ravikumar M, Al Asmary MA, Alla A Sultan R, et al. Dose delivery accuracy of therapeutic photon and electron beams at low monitor unit settings. *Strahlenther Onkol* 2005;181:796–9.
- Richmond ND, Turner RN, Dawes PJ, et al. Evaluation of the dosimetric consequences of adding a single asymmetric or MLC shaped field to a tangential breast radiotherapy technique. *Radiother Oncol* 2003;67:165–70.
- Rubino C, de Vathaire F, Diallo I. Radiation dose, chemotherapy and risk of lung cancer after breast cancer treatment. *Breast Cancer Res Treat* 2002;75:15–24.
- Sanguineti G, Cavey ML, Endres EJ, et al. Does treatment of the pelvic nodes with IMRT increase late rectal toxicity over conformal prostate-only radiotherapy to 76 Gy? *Strahlenther Onkol* 2006;182:543–9.
- Schneider U, Lomax A, Pemler P, et al. The impact of IMRT and proton radiotherapy on secondary cancer incidence. *Strahlenther Onkol* 2006;182:647–52.
- Shuryak I, Sachs RK, Hlatky L, et al. Radiation-induced leukemia at doses relevant to radiation therapy: modeling mechanisms and estimating risks. *J Natl Cancer Inst* 2006;98:1794–806.
- Trott KR, Kamprad F. Estimation of cancer risks from radiotherapy of benign diseases. *Strahlenther Onkol* 2006;182:431–6.
- Van Asselen B, Raaijmakers CP, Hofman P, et al. An improved breast irradiation technique using three-dimensional geometrical information and intensity modulation. *Radiother Oncol* 2001;58:341–7.
- Van Vaerenbergh K, De Gersem W, Vakaet L, et al. Automatic generation of a plan optimization volume for tangential field breast cancer radiation therapy. *Strahlenther Onkol* 2005;181:82–8.
- Veronesi U, Cascinelli N, Martani L, et al. Twenty-year follow-up of a randomized study comparing breast-conserving surgery with radical mastectomy for early breast cancer. *N Engl J Med* 2002;347:1227–32.

41. Vicini FA, Sharpe M, Kestin L, et al. Optimizing breast cancer treatment efficacy with intensity-modulated radiotherapy. *Int J Radiat Oncol Biol Phys* 2002;54:1336-44.
42. Weiss E, Hess CF. The impact of gross tumor volume (GTV) and clinical target volume (CTV) definition on the total accuracy in radiotherapy. *Strahlenther Onkol* 2003;179:21-30.
43. Woo TC, Pignol JP, Rakovitch E, et al: Body radiation exposure in breast cancer radiotherapy: impact of breast IMRT and virtual wedge compensation techniques. *Int J Radiat Oncol Biol Phys* 2006;65:52-8.
44. Zackrisson B, Arevarn M, Karlsson M. Optimized MLC-beam arrangements for tangential breast irradiation. *Radiother Oncol* 2000;54:209-12.

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