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Scientific Article

Wide Tangent Photon Field Versus Electron Field in the Treatment of Internal Mammary Lymph Nodes in Patients With Left Breast Cancer: A Decision-Making Flowchart

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Purpose: This study of internal mammary lymph node chain (IMC) irradiation in patients with left breast cancer aimed at comparing the merits of using, on one hand, a dedicated direct IMC electron field versus a wide tangent photon field covering both breast and IMC on the other. The objective was to produce guidelines allowing clinicians to readily determine the preferred method for each patient.

Methods and Materials: For 19 patients with cancer of the left breast/chest wall, we produced 2 treatment plans each using a different technique: the electron technique using 2 standard opposed photon tangents covering only the breast or chest wall along with a matching adjacent electron field targeting the IMC only or the wide tangent technique using 2 opposed wide tangents covering simultaneously IMC and breast or chest wall. All plans were then optimized for acceptable target coverage.

Results: For patients where the left anterior descending coronary artery (LAD) was located outside of the wide tangent fields (13 patients), the wide tangent technique resulted in lower dose to the LAD, left lung, and heart. When the LAD was inside the wide tangents (6 patients), dose was lower with the electron technique for LAD and heart. In all cases, regardless of LAD location, the wide tangent technique returned strictly superior dose homogeneity but much higher right (contralateral) breast dose.

Conclusions: A flowchart was produced based on LAD location that allows the clinician to readily determine the preferred technique for each patient without having to perform and compare 2 treatment plans, thus saving valuable planning time.

Introduction

Unless there is clinical or pathologic involvement of internal mammary lymph node chain (IMC) in locally advanced breast cancer, the need for adjuvant radiation therapy to the IMC has remained controversial for a long time in the management of breast cancer. In 2015, 2 randomized trials[1,2] demonstrated a benefit in disease-free survival with lymph node irradiation (both axillary and IMC). Similarly, the Danish Breast Cancer Group found an overall survival benefit for IMC irradiation.[3] As a result, the IMC is now often included in the treatment of patients at high risk of locoregional recurrence.

Two techniques are currently widely used in the treatment of IMC lymph nodes along with the supraclavicular (SCV) lymph nodes and the breast or chest wall.[4] The

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first, the electron technique, uses a pair of standard opposed shallow photon tangential beams to cover the breast without the IMC, with a direct dedicated electron field targeting the IMC only and matched with the adjacent photon tangents. The second, the wide tangent technique, uses 2 photon tangent fields widened medially, enough to cover the IMC, thus eliminating the need for a dedicated IMC electron field. Treatment by proton beams or by IMRT photon beams are 2 other techniques currently used much less frequently, the first being promising but still largely unavailable and the second delivering considerable unwanted dose to the contralateral breast and heart.

In this study, we aimed at comparing the 2 techniques: electron versus wide tangent for adjuvant left breast cancer radiation therapy in terms of target coverage and dose to adjacent organs at risk, including mean heart dose, average and maximum ipsilateral left lung dose, average and maximum dose to the left anterior descending coronary artery (LAD), right breast mean and maximum dose, and hot spots anywhere in the patient. The objective was to produce guidelines allowing clinicians to readily recognize the preferred method for each patient without having to perform and compare 2 different treatment plans.

Methods and Materials

Nineteen patients with left breast cancer previously treated in our center for breast and IMC were selected and anonymized. Using the existing patients' computed tomography simulation scans, a radiation oncologist contoured for each patient the IMC clinical target volume (CTV) and planning target volume (CTV + 5 mm), heart, LAD, right breast, lung, and inferior medial breast border (Fig. 1). A physicist then produced 2 3-dimensional

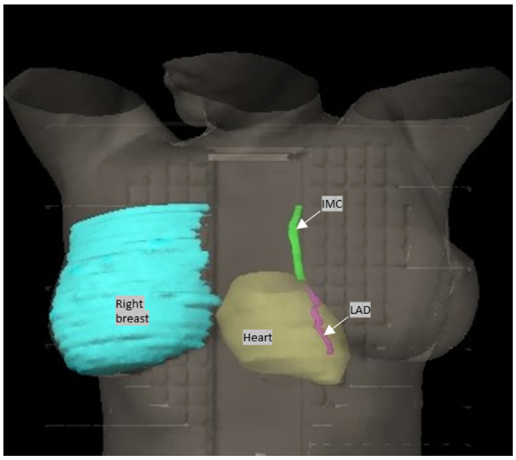

Figure 1 Three-dimensional display of the contoured internal mammary lymph node chain lymph nodes, heart, left anterior descending coronary artery, and right breast.

conformal plans for each patient: 1 electron plan and 1 wide tangent plan to compare the 2 techniques (both plans including SCV irradiation to 50 Gy). The treatment planning system was the Eclipse V.15.1 (Varian Medical Systems, Inc, Palo Alto, CA) commissioned for a Siemens Artiste linear accelerator with a 160 multileaf collimator (MLC), each leaf projecting a 5-mm width at isocenter. The tangent fields were drawn in the planning system on a beam's eye view, encompassing all breast tissues (plus IMC for the wide tangent technique) and limiting the irradiated lung to 2 to 2.5 cm.

For all plans, the prescribed dose was 50 Gy to the breast or chest wall with IMC node coverage set at 40 Gy to 99% of the volume (V40 ≥ 99%), in keeping with the guidelines of the MA.20 group work.[5] All plans were approved by the attending physician before analysis.

In what follows, the term "breast" will be used to equally denote breast or chest wall.

The electron technique

In the electron technique, a pair of standard tangents were drawn to cover the left breast, and an adjacent medial IMC electron field was used, matched on skin with the tangents. The purpose of the latter field was to cover the IMC nodes but also the inferior part of the medial breast target (below the IMC) excluded from the tangents for lung/heart sparing reasons. The angulation of the electron field was 5° to 15° diverging from the photon tangents to reduce under coverage at the junction line with the tangents. Electron dose calculations were done using the Eclipse Monte Carlo algorithm for improved accuracy in the presence of bone and lung inhomogeneity. The electron beam's energy was optimized to provide adequate IMC coverage (V40 ≥ 99% to the CTV), yet minimize dose to the underlying heart and lung. When the initially selected electron energy did not provide deep enough dose coverage to the IMC, it was combined with the next available higher electron energy with gradual increase of the latter's relative dose weight to reach satisfactory coverage. In addition, when a small segment of the IMC was still not adequately covered by the electron field alone, a small direct photon field patch was added within the electron field to improve coverage at the specific IMC cold spot. This was sometimes needed at the superior-most part of the IMC where the chest wall overlying the IMC was thick and when the IMC happened to be running very close to the sternum, thus shaded by it from the angled electron field over a short section of its length. The field typically carried a low dose and was planned to be delivered along with the main tangents (using same isocenter) but with the same gantry angle as the IMC electron field (Fig. 2A).

Then, dose coverage was checked for the inferior part of the medial breast located anterior to the heart, inferior

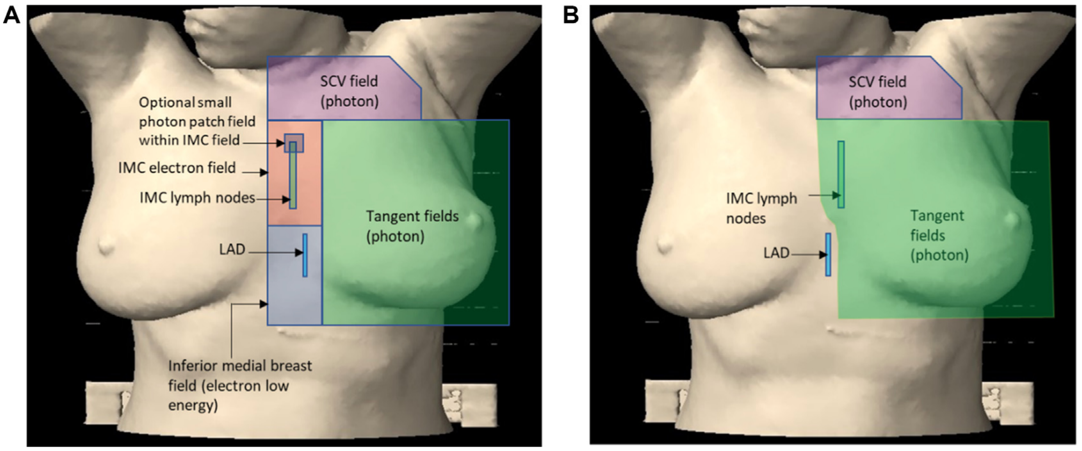

Figure 2 Schematic drawing of (A) the electron technique and (B) the wide tangent technique.

to the IMC (breast tissues located under the blue patch in Fig. 2A). If over coverage of the tissues was observed in this location (dose reaching too deep beyond the breast tissues into heart and lung), the previously described electron field was split into 2 smaller adjacent matched electron fields with different energies: a superior field targeting the IMC and an inferior field with a lower energy intended to cover the inferior medial breast tissues with minimal dose transmitted to the underlying heart and lung. These 2 latter fields were individually shaped to adequately cover medial breast tissues and match with the medial border of the photon tangents (Fig. 2A).

The wide tangent technique

In the wide tangent technique (Fig. 2B), no electron field is used, and the previously described tangent pair is instead widened in the medial direction to include the IMC and the inferior medial target breast tissues, while keeping the LAD outside the wide tangents' field border by closing the MLC over the LAD by a certain margin (Fig. 3).

Results and Discussion

While designing the wide tangent, we were able to block the LAD by a margin of at least 5 mm without under-coverage of the medial breast tissue for 13 out of 19 patients only (Fig. 3A). We will refer to this group of 13 patients as the "LAD outside" group. For the remaining 6 patients, the LAD could not be shielded by the MLC without under-coverage of the medial breast tissue; thus it had to be included inside the wide tangents (Fig. 4). We will refer to this group of 6 patients as the "LAD inside" group.

The dosimetric parameters used in comparing the merits of the 2 techniques were mean heart dose, maximum LAD dose, mean LAD dose, mean lung dose, V20 lung (left lung volume receiving 20 Gy or more), mean right breast dose, right breast maximum dose, and D0.2

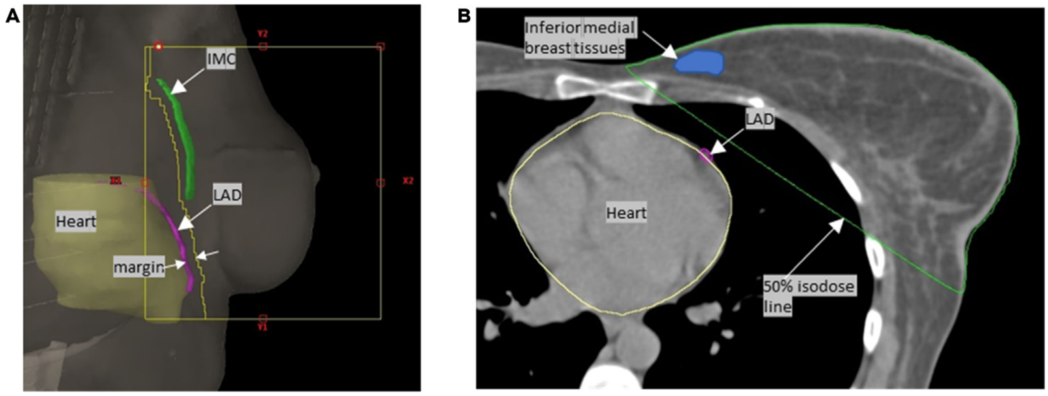

Figure 3 Wide tangent technique. (A) Beam's eye view for medial tangent field showing the inclusion of the internal mammary lymph node chain in the field and exclusion of heart and left anterior descending coronary artery by a certain margin. (B) Axial slice showing the coverage of the inferior medial breast tissues within the field's medial border represented by the 50% isodose line.

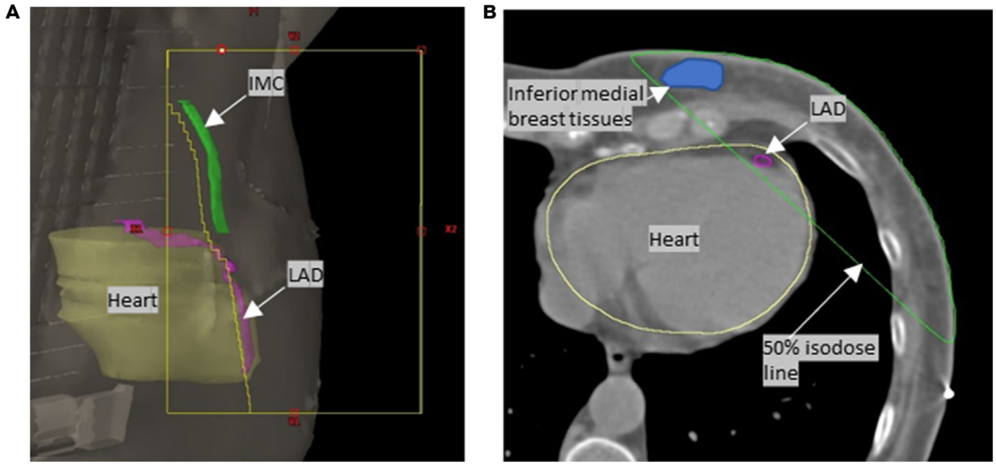

Figure 4 Wide tangent technique for the left anterior descending coronary artery inside group. (A) Beam's eye view for medial tangent field showing the inclusion of heart and left anterior descending coronary artery within the field to cover the medial breast tissues. (B) Axial slice showing the coverage of the inferior medial breast tissues within the field's medial border represented by the 50% isodose line.

cc (minimum global dose to the hottest 0.2 cc of tissue, representing the plan's hot spot). LAD dose and mean heart dose are both correlated with cardiac morbidity,[5-7] whereas mean lung dose and V20 are correlated with lung pneumonitis.[8,9] Parameter values used in the comparison included the contribution from all the fields shown in Fig. 2, including SCV.

For the LAD outside group (where it was possible to place the LAD outside the field edge by a margin of at least 5 mm), Tables 1 and 2 give values for the above parameters, respectively, for the electron technique and the wide tangent technique.

In this group, based on the mean column in Tables 1, 2, and 3, we can conclude: the LAD dose (mean LAD and max LAD) using the wide tangent technique was about half of the dose using the electron technique. Also, the wide tangent technique gave a 20% reduction in hot spot over the electron technique, as given by the D0.2 cc parameter, along with a lower left lung dose (V20 and mean) and a lower mean heart dose. Another advantage of the wide tangent technique was an expected shorter treatment time and fewer potential errors in treatment delivery due to the more complex nature of the electron technique where more fields have to be critically matched and delivered. The high values recorded for D0.2 cc with the electron technique are because of the electron-electron or electron-photon field match and are caused by the typical bowing out of the fields below the surface. These hot spots were considered clinically acceptable by the radiation oncologist approving the plan because they concerned a very small volume of tissue located within the chest wall muscle.

This confirms the superiority of the wide tangent technique for patients where the LAD is outside of the field by a margin of at least 5 mm. The only weakness of this technique was a higher contralateral maximum right breast dose caused by the proximity to the medial right breast of

Table 1 Dosimetric values for the electron technique in the LAD outside group

Patient no.	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean	Sigma
V40 IMC (%)	99.6	99.7	99.3	99.9	100.0	99.3	99.2	99.6	100.0	99.7	99.8	99.9	100.0	99.7	0.3
Mean heart dose (Gy)	2.9	1.7	2.5	1.8	2.1	2.3	1.7	2.0	1.6	3.0	2.6	1.5	1.9	2.1	0.5
Max LAD dose (Gy)	18.2	9.9	37.0	11.3	15.0	28.6	18.0	32.9	17.7	20.2	20.8	20.7	13.3	20.3	7.8
Mean LAD dose (Gy)	9.9	5.0	17.1	5.6	7.5	17.4	6.3	24.0	8.7	7.2	10.8	9.6	6.3	10.4	5.5
V20 left lung (%)	20.7	17.9	23.6	19.5	22.3	21.3	24.4	19.6	24.2	21.7	28.7	23.7	18.7	22.0	2.8
Mean left lung dose (Gy)	11.2	10.1	12.0	11.2	11.5	11.5	12.1	10.3	12.2	11.6	13.6	11.9	10.5	11.5	0.9
Max right breast dose (Gy)	20.2	3.1	7.5	3.4	3.8	3.0	2.4	1.8	11.6	17.0	8.1	4.6	67.6	11.9	17.0
Mean right breast dose (Gy)	1.0	0.5	1.2	0.5	0.6	0.7	0.5	0.2	0.7	0.8	0.5	0.8	0.9	0.7	0.3
Global max dose D0.2 cc (Gy)	67.0	63.0	74.7	68.4	71.3	67.0	70.2	71.9	77.2	70.9	77.3	69.7	72.9	70.9	3.9

Abbreviations: IMC = internal mammary lymph node chain; LAD = left anterior descending coronary artery.

Table 2 Dosimetric values for the wide tangent technique in the LAD outside group

Patient no.	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean	Sigma
V40 IMC (%)	99.0	100.0	99.3	100.0	99.7	99.2	100.0	99.9	99.8	98.5	99.5	97.5	99.2	99.4	0.7
Mean heart dose (Gy)	1.7	1.4	1.3	1.3	1.4	1.5	1.3	2.0	1.4	1.6	1.4	1.0	1.6	1.5	0.2
Max LAD dose (Gy)	15.6	11.7	12.2	10.6	11.1	12.0	8.3	12.0	12.7	11.9	7.8	11.9	13.1	11.6	1.9
Mean LAD dose (Gy)	6.0	5.3	5.9	4.3	4.1	6.4	3.4	6.3	6.6	3.8	3.5	5.4	5.2	5.1	1.1
V20 left lung (%)	22.0	18.4	23.3	17.3	23.3	21.8	22.0	15.8	22.0	20.2	27.1	17.7	15.7	20.5	3.2
Mean left lung dose (Gy)	11.3	10.0	11.4	9.7	11.7	11.8	11.6	8.9	11.5	10.2	13.7	9.0	8.8	10.7	1.4
Max right breast dose (Gy)	5.1	13.6	48.5	10.0	43.5	10.2	3.5	2.8	8.9	52.2	15.8	3.8	48.7	20.5	18.9
Mean right breast dose (Gy)	0.2	0.5	2.6	0.3	0.5	0.5	0.4	0.2	0.4	1.7	0.3	0.4	1.3	0.7	0.7
Global max dose D0.2 cc (Gy)	54.7	55.3	55.5	55.9	58.9	57.8	57.1	59.1	59.9	54.2	59.9	53.1	56.4	56.8	2.1

Abbreviations: IMC = internal mammary lymph node chain; LAD = left anterior descending coronary artery.

Table 3 Mean dosimetric values side by side for electron plans versus wide tangent plans

	LAD outside, mean dosimetric values		LAD inside, mean dosimetric values	
	Electron	Wide tangent	Electron	Wide tangent
V40 IMC (%)	99.7	99.4	99.5	99.7
Mean heart dose (Gy)	2.1	1.5	2.7	2.6
Max LAD dose (Gy)	20.3	11.6	19.6	39.9
Mean LAD dose (Gy)	10.4	5.1	8.1	19.5
V20 left lung (%)	22.0	20.5	23.5	23.8
Mean left lung dose (Gy)	11.5	10.7	12.2	12.1
Max right breast dose (Gy)	11.9	20.5	6.4	15.3
Mean right breast dose (Gy)	0.7	0.7	0.6	0.5
Global max dose D0.2 cc (Gy)	70.9	56.8	71.6	58.2

Abbreviations: IMC = internal mammary lymph node chain; LAD = left anterior descending coronary artery.

the wide tangent's medial border. This result was expected because the wide tangent technique pushes the tangent's border medially toward the right breast to fully capture the IMC within the field. Nevertheless, only a small part of the medial-most part of the right breast is affected by the maximum dose reported, thus the associated difference in secondary cancer risk is expected to be negligible, especially because the mean right breast dose was the

Table 4 Dosimetric values for the electron technique in the LAD inside group

Patient no.	14	15	16	17	18	19	Mean	Sigma
V40 IMC (%)	99.4	99.2	99.1	99.3	100.0	100.0	99.5	0.4
Mean heart dose (Gy)	3.3	2.9	2.4	2.1	1.9	3.8	2.7	0.7
Max LAD dose (Gy)	23.0	13.9	19.8	18.6	17.3	25.0	19.6	3.6
Mean LAD dose (Gy)	9.9	6.4	6.7	6.8	7.3	11.3	8.1	1.9
V20 left lung (%)	20.7	23.4	23.8	22.6	26.5	24.0	23.5	1.7
Mean left lung dose (Gy)	11.2	12.0	13.0	11.8	13.0	12.1	12.2	0.6
Max right breast dose (Gy)	20.2	4.2	3.6	2.4	3.2	4.7	6.4	6.2
Mean right breast dose (Gy)	1.0	0.7	0.3	0.2	0.5	0.6	0.6	0.3
Global max dose D0.2 cc (Gy)	72.1	68.1	83.2	71.1	68.5	66.4	71.6	5.5

Abbreviations: IMC = internal mammary lymph node chain; LAD = left anterior descending coronary artery.

Table 5 Dosimetric values for the wide tangent technique in the LAD inside group

Patient no.	14	15	16	17	18	19	Mean	Sigma
V40 IMC (%)	100	99.3	99.3	99.7	99.6	100	99.7	0.3
Mean heart dose (Gy)	3.3	3.2	3.1	1.9	1.6	2.5	2.6	0.7
Max LAD dose (Gy)	24.7	45.8	48.8	44.6	42	33.4	39.9	8.3
Mean LAD dose (Gy)	44.9	17.8	22.7	14.8	9.2	7.4	19.5	12.5
V20 left lung (%)	21.5	22.3	25.3	26.7	24.6	22.3	23.8	1.9
Mean left lung dose (Gy)	10.9	11.7	13.3	13.2	12.3	11.4	12.1	0.9
Max right breast dose (Gy)	5.6	39.4	3.6	3.8	5.3	34.2	15.3	15.3
Mean right breast dose (Gy)	1.7	0.4	0.2	0.2	0.4	0.3	0.5	0.5
Global max dose D0.2 cc (Gy)	58.5	59.2	57	57.7	55.6	60.9	58.2	1.7

Abbreviations: IMC = internal mammary lymph node chain; LAD = left anterior descending coronary artery.

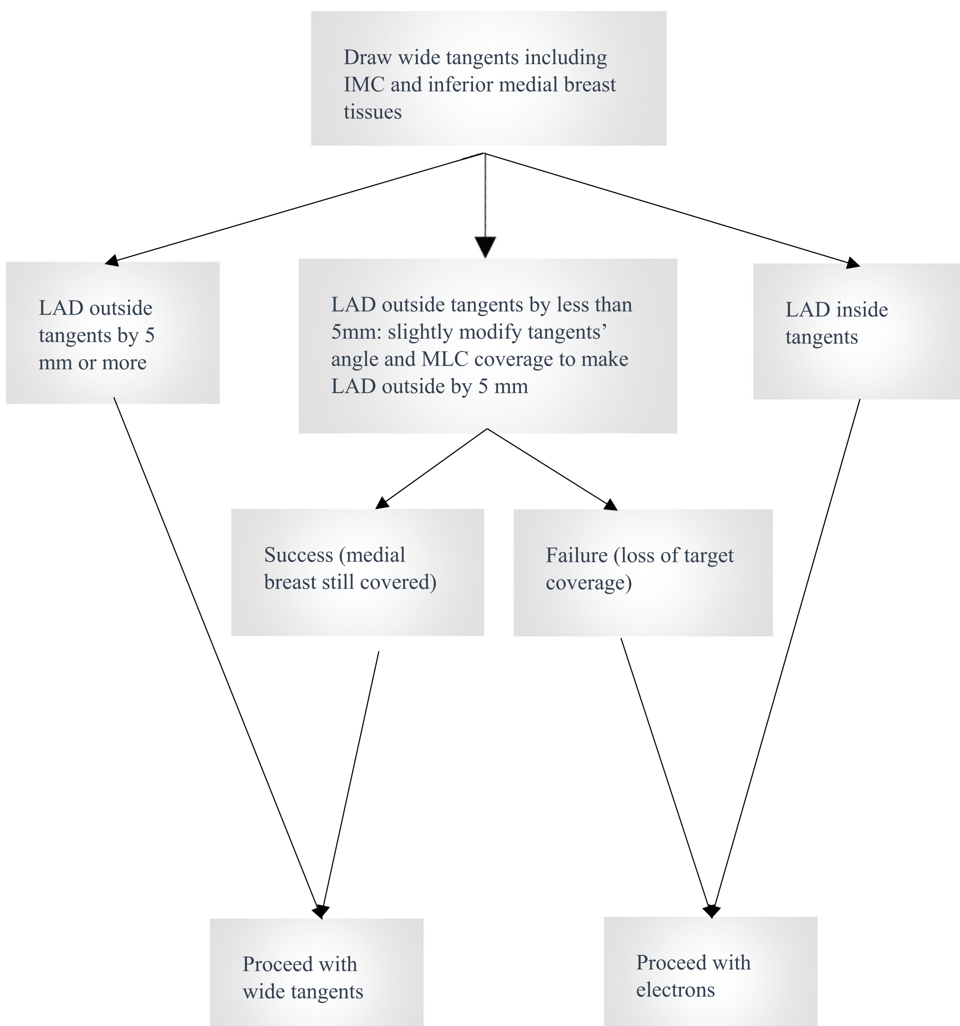

Figure 5 Recommended decision-making flowchart for left breast cancer radiation therapy.
The 5-mm critical margin reported here depends on the linear accelerator, the energy at hand, and the geometric characteristics of the multileaf collimator used, thus this critical value may be different for other machines and can be determined easily by trial and error in any center using the treatment planning system.

same for both techniques, and secondary cancer prediction is usually based on mean, rather than maximum, organ dose.

For the LAD inside group (where the LAD was located inside the field), Tables 3, 4, and 5 give values for these parameters for the electron technique and the wide tangent technique.

Again, based on the mean columns of Tables 3, 4, and 5, we can conclude the following for the LAD inside group: the LAD dose (mean LAD and max LAD) using the electron technique was about half of the dose using the wide tangent technique, and the contralateral maximum right breast dose is lower for the electron technique because of the proximity to the medial right breast of the wide tangent's medial border, as previously mentioned. Other parameters, like left lung V20, mean dose, mean heart dose, and mean right breast dose, are all very similar between the 2 techniques. This confers a superiority to the electron technique in this group, despite a higher mean value of D0.2 cc over all plans (Table 3, column 3; higher hot spots in the plan) and a higher complexity and delivery time, as explained earlier, but these disadvantages are compensated for by the benefit of reduced cardiac toxicity to the patient.

In this work, whenever the LAD was not outside the tangents by a margin of at least 5 mm, the dosimetric advantages of the wide tangent technique were quickly lost. On the other hand, we also found that when the LAD was outside the tangent field by a margin less than 5 mm, we were always able to redraw the tangent's border by closing the MLC leaves further and pushing the margin to 5 mm without compromising medial breast tissue coverage.

Conclusion

We therefore recommend the following approach for a left breast treatment plan including IMC irradiation (Fig. 5 flowchart):

Start by drawing wide tangents that include both IMC and inferior medial breast tissues.

- If this yields a LAD outside the tangents with a margin of 5 mm or more in beam's eye view, proceed with using the wide tangent technique.
- If instead this yields a LAD outside the tangents with a margin lower than 5 mm, slightly modify the tangents' angle and MLC coverage to increase the exclusion margin to 5 mm. This modification usually does not compromise medial breast tissue coverage, and one can proceed with using the wide tangent technique.
- If, on the other hand, the LAD is found to be inside the tangents, then modifying the tangents to exclude the LAD by a 5-mm margin may or may not succeed. It is therefore recommended in this case to attempt creating a 5-mm exclusion margin as described in the section on the wide tangent technique, and check the resulting medial breast tissue coverage; if the coverage is acceptable, proceed with the wide tangent technique. If not, proceed with the electron technique.

Disclosures

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.adro.2023.101282.

References

1. Poortmans PM, Collette S, Kirkove C, et al. Internal mammary and medial supraclavicular irradiation in breast cancer. *N Engl J Med*. 2015;373:317-327.
2. Whelan TJ, Olivotto IA, Parulekar WR, et al. Regional nodal irradiation in early-stage breast cancer. *N Engl J Med*. 2015;373:307-316.
3. Thorsen LBJ, Offersen BV, Danø H, et al. DBCG-IMN: A population-based cohort study on the effect of internal mammary node irradiation in early node-positive breast cancer. *J Clin Oncol*. 2016;34:314-320.
4. Bellon JR, Wong JS, MacDonald SM, Ho AY. Radiation therapy techniques and treatment planning for breast cancer. *Practical Guides in Radiation Oncology*. New York, NY: Springer International Publishing; 2016.
5. Atkins KM, Chaunzwa TL, Lamba N, et al. Left coronary artery dose exposure predicts major adverse cardiac events in coronary heart disease negative lung cancer patients. *Int J Radiat Oncol Biol Phys*. 2019;105:S44-S45.
6. Darby SC, Ewertz M, McGale P, et al. Risk of ischemic heart disease in women after radiotherapy for breast cancer. *N Engl J Med*. 2013; 368:987-998.
7. Wennstig AK, Garmo H, Isacsson U, et al. The relationship between radiation doses to coronary arteries and location of coronary stenosis requiring intervention in breast cancer survivors. *Radiat Oncol*. 2019;14:40.
8. Werner EM, Eggert MC, Bohnet S, Rades D. Prevalence and characteristics of pneumonitis following irradiation of breast cancer. *Anticancer Res*. 2019;39:6355-6358.
9. Trofimova OP, Tkachev SI, Kostina NP, et al. Radiation pneumonitis in the treatment of early-stage breast cancer. *Vopr Onkol*. 2015; 61:116-120.