Comparative Dosimetric Evaluation of Intensity-Modulated Radiation Therapy (IMRT) Using a Linear Accelerator and Helical TomoTherapy for Highly Complex Breast Cancer Targets

Jasmeen Kaur Multani[1], Sajad Jamali, CMD[2], Danushka Seneviratne, MD, PhD[2], Salahuddin Ahmad, PhD[1], Erich A. Schnell, PhD, MS[1]

[1]University of Oklahoma Health Sciences Center, Oklahoma City, OK • [2]OU Health, Oklahoma City, OK

2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

INTRODUCTION

BACKGROUND

Radiation dose to the heart raises the risk of major coronary events, and that risk rises roughly linearly with no clear threshold[1], while dose to the ipsilateral lung contributes to pneumonitis and second malignancy[2]. With the MA.20 and MA.39 trials making comprehensive nodal irradiation, including the internal mammary chain (IMN), standard for many patients, there is now less room to keep heart and lung doses low.

On C-arm linacs, inverse-planned Intensity-Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) are the usual choice for breast plans that require nodal coverage. Helical TomoTherapy delivers continuous-rotation modulation through a binary Multi-Leaf Collimator (MLC), yet it is rarely considered for these cases. The available TomoTherapy breast data are limited. Some studies used TomoDirect, the static-gantry mode with reduced modulation[3], and others looked only at chest-wall post-mastectomy plans without IMN coverage[4]. The one dosimetric study that did include the IMN with helical delivery is now more than a decade old and was compared against 3D and field-based plans rather than modern inverse-planned IMRT[5]. How helical TomoTherapy performs on the harder problem, an intact breast with full nodal coverage including the IMN, is still not well established.

PURPOSE

To test whether helical TomoTherapy can match LINAC-IMRT for complex breast plans with comprehensive nodal coverage, including the IMN.

METHODS

PATIENT COHORT

- 19 breast cancer patients (11 left-sided, 8 right-sided), studied retrospectively.
- All needed whole-breast or chest-wall radiotherapy with regional nodal coverage, including the internal mammary chain (IMN) where indicated.
- Prescription: 5000 cGy in 25 fractions (200 cGy per fraction).

TREATMENT PLANNING

- Clinical plans were made in Eclipse (Varian) and delivered on a Varian Edge or TrueBeam C-arm linac; DVH data came from these approved plans.
- Each case was re-planned in Accuray Precision for Radixact using the same CT and structure set, so any differences come from the delivery platform alone.
- The Varian couch was swapped for the Radixact couch model, with its couch-catcher geometry, for correct beam attenuation.

TOMO OPTIMIZATION

- VOLO Ultra engine (helical IMRT with Dynamic Jaw), 2.5 cm field width, pitch 0.300, patient-specific modulation factor (1.7-2.4).
- A Normal Tissue Objective was used on every plan to limit dose spillage and hot spots.
- All cases started from the same institutional Precision templates, so the optimization goals were consistent.

PLAN NORMALIZATION

- LINAC plans followed our standard Eclipse convention of V95% = 95%.
- That rule does not suit Radixact: its sharper peripheral falloff pulls the prescription isodose inward and under-covers the target. Radixact plans were therefore normalized to V100% = 95%, giving full dose across 95% of the target.

EVALUATION METRICS

- Targets: PTV V95%, IM-PTV V90%, and the V107% hot spot.
- Organs at risk (per MA.39 and RTOG 1005): heart (Dmean, V10, V20, V25), LAD (Dmean, Dmax), ipsilateral lung (V5, V20), contralateral lung, and contralateral breast.
- Plan quality: Conformation Number (Van't Riet), Conformity Index (RTOG), Gradient Index (RTOG), and Homogeneity Index (RTOG and ICRU 83).

STATISTICS

- Plans were compared pairwise with the Wilcoxon signed-rank test (two-sided, α = 0.05), used because the sample is small and the paired differences are not assumed to be normal.
- Heart and LAD were assessed only in the 11 left-sided patients, since these structures receive appreciable dose only when the left breast is treated. All other endpoints, including ipsilateral lung, used the full cohort.
- When a structure was not contoured for a patient, that patient was dropped from that endpoint alone, so the sample size varies between endpoints.

CONTACT

Jasmeen Kaur Multani
Jasmeen-Multani@ou.edu | (405)370-4431
University of Oklahoma HSC, Oklahoma City, OK

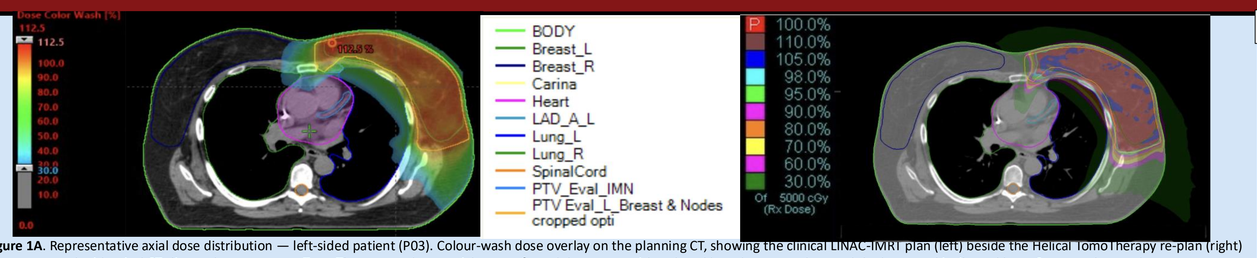

Figure 1A. Representative axial dose distribution — left-sided patient (P03). Colour-wash dose overlay on the planning CT, showing the clinical LINAC-IMRT plan (left) beside the Helical TomoTherapy re-plan (right) on the identical CT slice and structure set. TomoTherapy produces a tighter conformal dose wrap with reduced low-dose spread toward the heart and ipsilateral lung. Structure key as shown.

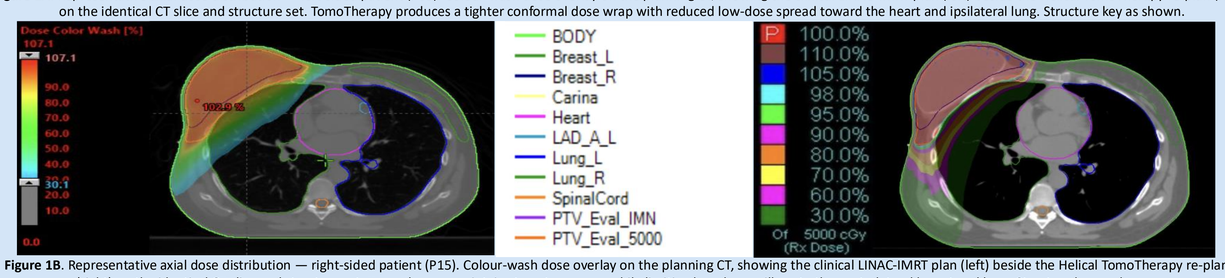

Figure 1B. Representative axial dose distribution — right-sided patient (P15). Colour-wash dose overlay on the planning CT, showing the clinical LINAC-IMRT plan (left) beside the Helical TomoTherapy re-plan (right) on the identical CT slice and structure set. TomoTherapy maintains target coverage while limiting low-dose spillage to the contralateral breast and lung. Structure key as shown.

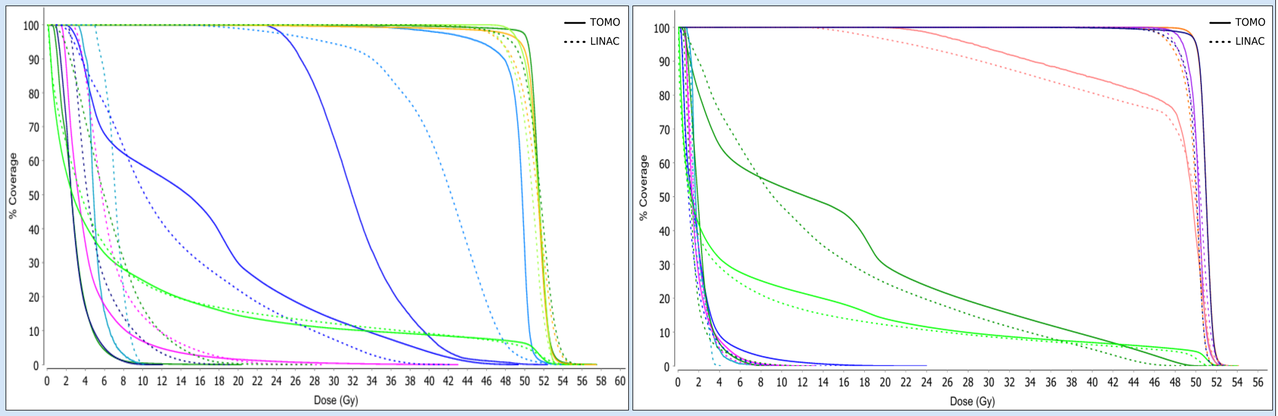

Figure 2 – Dose-volume histograms (DVH) for the same two patients: a left-sided case (A, P03) and a right-sided case (B, P15). TomoTherapy (solid) versus LINAC-IMRT (dashed).

RESULTS

- TomoTherapy was more conformal and had a sharper dose falloff than LINAC-IMRT (CN +0.21, GI −1.22, CI +0.35; all p < 0.001), and it was at least as homogeneous.
- It also covered the targets better. PTV V95% rose by 3.5 points and IMN V90% by 9.2 points (p = 0.015), and it did this under a stricter normalization.
- In left-sided patients, heart and LAD dose dropped: heart mean −0.82 Gy and LAD mean −7.2 Gy (both p ≤ 0.005).
- Across all 19 patients, ipsilateral lung V5 fell by 6.3 points (p = 0.001), while V20 was unchanged.
- Heart volume metrics, LAD max, and contralateral organ doses did not differ. The improvements were targeted, not across the board.

Key findings

Helical TomoTherapy vs LINAC-IMRT

−7.2 Gy LAD mean dose
−0.82 Gy Heart mean dose
−6 pp Ipsilateral lung V5
+9.2 pp IMN V90% coverage

All p ≤ 0.015 (paired Wilcoxon signed-rank).
Cardiac: left-sided, n = 11; lung n = 19; IMN n = 15.

Endpoint		n	LINAC (mean ± SD)	TOMO (mean ± SD)	Δ (TOMO − LINAC)	p (Wilcoxon)
Plan quality	Conformation number (Van't Riet)	19	0.60 ± 0.13	0.81 ± 0.08	0.21	**<0.001**
	Conformity index (RTOG)	19	0.69 ± 0.14	1.04 ± 0.16	0.35	**<0.001**
	Gradient index (RTOG)	19	4.01 ± 1.26	2.79 ± 0.52	-1.22	**<0.001**
	Homogeneity index (ICRU 83)	19	0.14 ± 0.04	0.10 ± 0.07	-0.03	**0.016**
	Homogeneity index (RTOG)	19	1.11 ± 0.03	1.10 ± 0.03	-0.01	0.352
Target coverage	PTV V95%	19	94.8 ± 0.7	98.3 ± 1.3	3.5	**<0.001**
	IMN PTV V90%	15	87.0 ± 19.8	96.3 ± 7.7	9.2	**0.015**
Cardiac (left-sided)	Heart Dmean (Gy)	11	4.51 ± 1.16	3.68 ± 0.70	-0.82	**0.003**
	Heart V10 (%)	11	5.56 ± 5.69	3.82 ± 2.27	-1.74	0.375
	Heart V20 (%)	11	0.55 ± 1.23	0.36 ± 0.51	-0.19	0.634
	Heart V25 (%)	11	0.16 ± 0.45	0.15 ± 0.27	-0.01	1
	LAD Dmean (Gy)	11	16.63 ± 8.91	9.44 ± 1.24	-7.19	**<0.001**
	LAD Dmax (Gy)	11	32.21 ± 12.26	23.13 ± 7.94	-9.09	0.147
Pulmonary	Ipsilateral lung V5 (%)	19	76.1 ± 8.2	69.8 ± 6.2	-6.3	**0.001**
	Ipsilateral lung V20 (%)	19	30.1 ± 4.3	31.4 ± 2.0	1.4	0.073
Other OAR	Contralateral lung Dmean (Gy)	11	0.07 ± 0.02	0.48 ± 1.42	0.41	0.142
	Contralateral breast Dmean (Gy)	10	0.05 ± 0.02	0.52 ± 1.50	0.47	0.322

Paired Wilcoxon signed-rank, two-sided. Bold values significant at α = 0.05. n varies by endpoint due to non-contoured structures.

Table 1. Dosimetric comparison of LINAC-IMRT and Helical TomoTherapy (mean ± SD; Δ = TomoTherapy − LINAC; paired Wilcoxon p). Plan-quality/coverage: n = 19 (IMN n = 15); cardiac: left-sided only, n = 11.

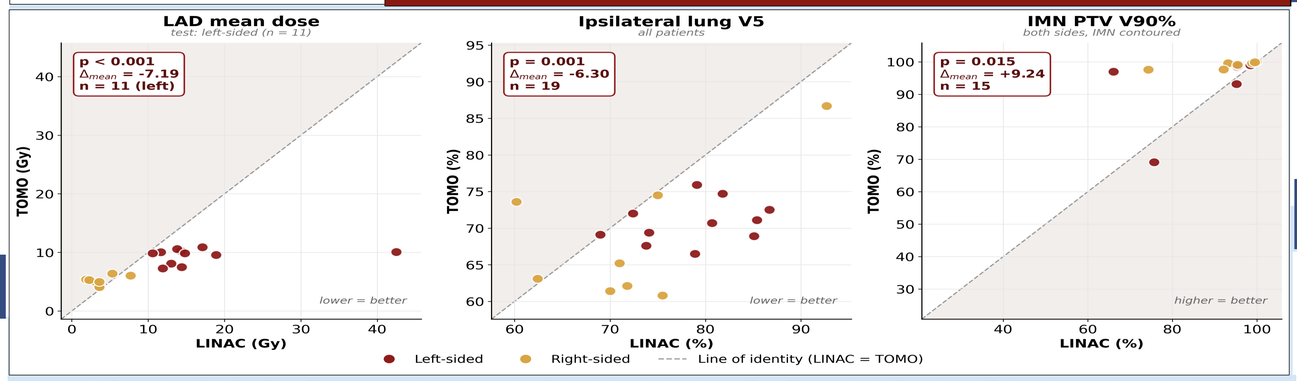

Figure 3. Per-patient LINAC vs TomoTherapy (red = left, gold = right). Points below the line favour TomoTherapy for LAD and lung V5 (lower better), above it for IMN V90% (higher better). LAD tested left-sided only (n = 11); lung V5 and IMN use all patients (n = 19, 15). Paired Wilcoxon; Δmean = TomoTherapy − LINAC.

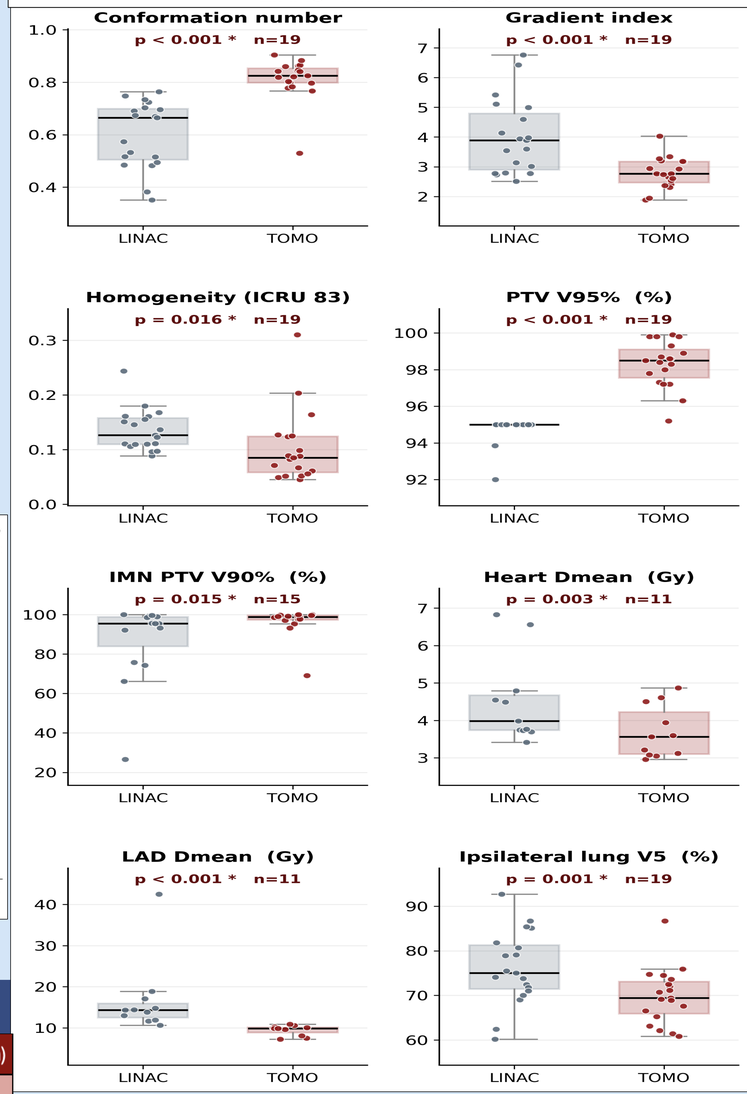

Figure 4. Distribution of key dosimetric endpoints for LINAC-IMRT versus Helical TomoTherapy. Each panel compares the two plans for one endpoint; boxes show the median and interquartile range, whiskers extend to 1.5×IQR, and dots are individual patients. p-values are from paired Wilcoxon signed-rank tests (* p < 0.05). Plan-quality and target-coverage endpoints include all patients (n = 19; IMN PTV n = 15, where the chain was contoured); cardiac endpoints are restricted to left-sided patients (n = 11).

DISCUSSION

- TomoTherapy improved coverage and plan quality while cutting heart, LAD, and lung dose. The gains came together, not at each other's expense.
- The reason is likely the delivery method: continuous-rotation modulation with the dynamic jaw wraps a concave breast-and-nodal target more tightly than fixed C-arm beams.
- That coverage gain is conservative, since TomoTherapy reached it under a stricter normalization than the LINAC plans.
- The heart and LAD reductions sit in the dose range tied to late coronary events, so the Darby model predicts lower long-term risk. That is a projection, not an observed outcome.
- The feared low-dose lung bath never showed up; lung V5 was lower with TomoTherapy across all patients.
- This matters now that MA.20 and MA.39 have made IMN coverage routine, leaving little room to spare heart and lung.
- Limitations: retrospective, single institution, 19 patients, limited right-sided cardiac data, and one planning system and template per platform.

CONCLUSIONS

- Helical TomoTherapy matched or exceeded LINAC-IMRT for complex breast plans with comprehensive nodal coverage, including the IMN.
- It improved target coverage and plan quality while lowering dose to the heart, LAD, and ipsilateral lung, without the low-dose penalty often assumed for helical delivery.
- For these complex cases, helical TomoTherapy is a viable primary option, not just a fallback.

REFERENCES

1) S. C. Darby, M. Ewertz, P. McGale, et al., "Risk of ischemic heart disease in women after radiotherapy for breast cancer," N. Engl. J. Med. 368, 987-998 (2013).
2) C. Taylor, C. Correa, F. K. Duane, et al., "Estimating the risks of breast cancer radiotherapy: evidence from modern radiation doses to the lungs and heart and from previous randomized trials," J. Clin. Oncol. 35, 1641-1649 (2017).
3) T. Reynders, K. Tournel, P. De Coninck, et al., "Dosimetric assessment of static and helical TomoTherapy in the clinical implementation of breast cancer treatments," Radiother. Oncol. 93, 71-79 (2009).
4) W. Nobnop, P. Phakoetsuk, I. Chitapanarux, D. Tippanya, and D. Khamchompoo, "Dosimetric comparison of TomoDirect, helical tomotherapy, and volumetric modulated arc therapy for postmastectomy treatment," J. Appl. Clin. Med. Phys. 21, 155-162 (2020).
5) J. M. Caudrelier, S. C. Morgan, L. Montgomery, M. Lacelle, B. Nyiri, and M. Macpherson, "Helical tomotherapy for locoregional irradiation including the internal mammary chain in left-sided breast cancer: dosimetric evaluation," Radiother. Oncol. 90, 99-105 (2009).