ORIGINAL ARTICLE

Dosimetric Comparison of Tomotherapy and 3D-Conformal Radiotherapy for Left-Sided Breast Cancer in Patients with Pendulous Breast

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Abstract

Purpose: This study compares helical Tomotherapy in the supine position with three-dimensional Conformal Radiotherapy (3D-CRT) delivered in both prone and supine positions in pendulous left-breast cancer patients, aiming to achieve optimal target coverage while minimizing dose to Organs At Risk (OARs).

Materials and Methods: Twenty non-metastatic patients with large pendulous left breasts received three separate treatment plans (3D-prone, 3D-supine, and Tomo-supine). Dose–Volume Histogram (DVH)-based indices, including D_{mean}, V5Gy, V10Gy, V20Gy, and V30Gy for the heart, ipsilateral lung, contralateral lung, and contralateral breast, as well as CI and HI for the PTV, were evaluated. Plans were generated using TIGRT (3D-CRT) and Accuray Precision® Tomotherapy TPS. Statistical analysis was performed using paired t-tests, and $p < 0.05$ was considered significant.

Results: Tomotherapy achieved superior target conformity and homogeneity (higher CI and lower HI) and slightly increased PTV D_{mean} compared to 3D-CRT. However, it increased low- and intermediate-dose exposure to the ipsilateral lung and contralateral organs while significantly reducing high-dose volumes. The prone 3D-CRT approach demonstrated the lowest ipsilateral lung mean dose among all techniques.

Conclusion: While tomotherapy provides excellent PTV coverage and dose uniformity, it increases low-dose exposure to OARs compared with 3D-CRT. Therefore, the choice of technique should be individualized based on clinical priorities, particularly in younger patients, where secondary cancer risk may be of concern.

Keywords: Tomotherapy; 3Dimentinal Conformal Radiotherapy; Pendulous Breast; Dosimetry; Heart; Lung.

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1. Introduction

Breast cancer is the main cause of cancer-related deaths among women and the most common type of female cancer in the world [1–3]. As reported by the American Cancer Society, breast cancer will develop in one in eight women during their lifetime [4]. In the USA, above 260,000 instances of breast cancer are identified each year, of which 600,000 die [5,6].

In general, the main treatment for breast cancer is surgery. Meanwhile, other methods, such as chemotherapy, radiotherapy, and hormone therapy, have been used as adjuvant treatments to increase the average survival rate in patients [7–9]. Almost half of patients with breast cancer receive whole-breast radiotherapy following surgery and tumor removal [10,11].

Despite the efficacy of radiation therapy for breast cancer, it can have late radiation-related side effects [12–16]. As shown by recent research findings, the possibility of death due to heart complications is higher in patients with breast cancer undergoing left breast (vs. right breast) radiation therapy [17–21]. In the conventional method, when patients are irradiated supine, the tangential fields cover part of the lung and heart volume, increasing the number of deaths from lung cancer and cardiac disorders [22,23].

Breast radiotherapy plays a crucial role in reducing local recurrence and improving survival in patients with left-sided breast cancer; however, irradiation of the heart and lungs remains a major clinical concern. Various modern radiotherapy techniques, including IMRT, VMAT, prone positioning, and helical tomotherapy, have been developed to improve target coverage while reducing dose to organs at risk, particularly the heart and lungs.

A specific and clinically challenging subgroup consists of patients with pendulous breasts, in whom breast geometry, gravitational displacement, and tissue deformation may compromise dose homogeneity and reproducibility. In such patients, treatment planning is often more complex, and the balance between adequate target coverage and organ-at-risk sparing becomes more critical. Despite this, limited data are available focusing specifically on dosimetric optimization in pendulous left breast patients.

Pendulous breasts represent a particularly challenging anatomical subgroup, where gravitational displacement, breast separation, and tissue deformation complicate PTV coverage and reproducibility. Despite the clinical relevance, limited studies have specifically addressed dosimetric optimization in this population. Many available reports focus on standard breast anatomy, thereby underrepresenting patients with large ptotic breasts who may benefit differently from advanced techniques.

Therefore, this study aimed to perform a dosimetric comparison between helical Tomotherapy (supine) and conventional 3D-CRT delivered in both supine and prone positions in pendulous left-breast cancer patients, focusing on target coverage and organ-at-risk sparing.

Although VMAT and DIBH techniques are increasingly used in many centers, they are not universally available or applicable to all patients, especially those with challenging anatomy or limited compliance. Therefore, evaluating Tomotherapy against widely practiced 3D-CRT approaches remains clinically meaningful and relevant for many radiotherapy departments.

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2. Materials and Methods

In this study, 3D-CRT (prone and supine) and Tomotherapy (supine) techniques were examined and compared using dosimetry data from the Dose Volume Histogram (DVH). DVH was calculated using the treatment planning system in the treatment plan of pendulous breast cancer cases.

2.1. Sample Selection

The current work was conducted according to the Declaration of Helsinki and was approved by the Research Ethics Committees of Isfahan University of Medical Sciences. The study's adult participants provided written informed consent for participating in the research.

The research population included 20 patients randomly selected among patients with non-metastatic pendulous breast cancer whose intrathoracic lymph nodes were not involved. These patients were referred

to Seyed Al Shohada Hospital in Isfahan, Iran, from April 2021 to December 2022 for whole breast radiation therapy. The average age of the participants was 45 years, which ranged from 35 to 62 years, with a primary lesion in the left breast. Table 1 presents the demographic information of the research participants. In the present study, "pendulous breast" refers to patients with large ptotic breasts characterized by downward displacement of breast tissue in the supine position. Operationally, this included patients with clinically evident ptosis (Regnault grade II–III) and/or large breast volume associated with Body Mass Index (BMI) above 30 kg/m², resulting in gravitational deformation and increased breast separation during simulation. These anatomical conditions make dose homogeneity and OAR sparing particularly challenging. Only patients fulfilling these criteria were included in the study.

Table 1. Patient and demographic characteristics (mean ± SD)

Parameter	Value
Number of patients	20
Age (years)	48.3 ± 8.9
Height (cm)	159.7 ± 3.31
Weight (kg)	86.3 ± 16.83
BMI (kg/m²)	33.85 ± 6.54

2.2. Treatment Simulation

The treatment was simulated by fixing the candidate patients on the breast board in the position of radiation therapy (prone or supine) and performing a Computed Tomography (CT) scan on them in the same position. The images were taken using a Siemens CT machine with a slice thickness of 5 mm in the range from the mandible to the end of the chest. Accordingly, it covered all critical organs near the target, such as the contralateral breast, heart, and lung. Finally, the CT scan images of the patients were sent to the TPS. Twenty consecutive non-metastatic left-sided breast cancer patients fulfilling the above pendulous breast criteria and referred for whole-breast irradiation were included. Patients were not randomly assigned; instead, each patient underwent three separate plans (3D-prone, 3D-supine, and Tomo-supine), allowing intra-patient dosimetric comparison.

2.3. Contouring

Target and OAR delineation wereperformed according to the RTOG and ESTRO consensus guidelines. The Clinical Target Volume (CTV) included the whole ipsilateral breast tissue. A uniform 5-mm margin was added to generate the Planning Target Volume (PTV), accounting for setup uncertainties and respiratory motion, while excluding the superficial 5-mm skin. OARs included the ipsilateral lung, contralateral lung, heart, contralateral breast, and spinal cord.

2.4. Treatment Plan

After contouring and determining the critical and target organs, each of the 20 patients underwent three treatment plans for whole breast radiation therapy. Two treatment plans for the 3D-CRT method in two prone and supine positions were designed according to the conditions of the device and the energy required for pendulous patients. Then, the treatment plan for the Tomotherapy method was also performed in the supine position.

2.4.1. 3D-CRT

3D-CRT plans were generated using TIGRT TPS with collapsed-cone convolution algorithm, 2.5–3 mm dose grid, and heterogeneity correction enabled. Opposing tangential fields using 6 MV photons were applied, with wedges/field-in-field modulation used when required to improve dose uniformity. The prescription dose was 50 Gy in 25 fractions, normalized to ensure ≥95% of PTV received ≥95% of the prescribed dose.

2.4.2. Tomotherapy

Tomotherapy plans were generated using the Accuray Precision® treatment planning system. A field width of 5 cm, pitch of 0.430–0.437, and modulation factor of approximately 4 were applied. These parameters were selected to achieve a balance between treatment efficiency, adequate modulation, and dose homogeneity, consistent with institutional practice and previous literature. Dose calculation was performed using a convolution–superposition algorithm with a 2–3 mm grid size and heterogeneity correction enabled. Directional blocking and virtual

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structures were implemented as needed to reduce unnecessary irradiation of the contralateral breast and lung while maintaining adequate PTV coverage [24,25].

2.5. QA and Approval Statement

All generated plans underwent review and approval by a senior radiation oncologist and a certified medical physicist. Only clinically acceptable plans that fulfilled institutional and guideline-based dose constraints were included in the analysis.

Table 2 shows the dose limits for organs at risk.

Table 2. Dose limits for organs at risk (Mean ± SD)

Organ	Limitation(mean ± sd)
Heart	$V_{25(mean \pm sd)}$<25%±1.6 $d_{mean(mean \pm sd)}$<20 gy±1.6
Ipsilatera Lung	$V_{20(mean \pm sd)}$<30%±1.6 $d_{mean(mean \pm sd)}$<22 gy±1.6
Spinal Cord	$d_{max(mean \pm sd)}$<40 cgy±1.6
Contralateral Lung	$V_{20(mean \pm sd)}$<8%±1.6
Breast Contralateral	$d_{mean(mean \pm sd)}$<5 gy±1.6

2.6. Comparison of Radiotherapy Methods Based on Dosimetric Indicators

Certain dosimetric indices were used to compare the plans designed for pendulous left breast cancer cases (Tomo-supine + 3D-prone + 3D-supine = three plans). The dosimetry indices related to the target volumes (CTV and PTV) include D_{mean}, Conformity Index, and Homogeneity Index (HI and CI), which were obtained using Equations 1 and 2 [26]. In addition, the indices related to sensitive volumes, including D_{mean}, V_{5Gy}, V_{10Gy}, V_{20Gy}, and V_{30Gy} (V_{xGy}; the volume of tissue taking a dose of X Gy), were extracted from the DVH curves (Table 3).

$$CI=\frac{V_{47,5\,Gy}}{V_{PTV}} \quad (1)$$

$$HI=\frac{(D_{2\%}-D_{98\%})}{D_{50\%}} \quad (2)$$

In the above equations, V_{PTV} is the volume including PTV, $V_{47.5\,Gy}$ is the volume containing a dose of 47.5 Gy in the target, $D_{2\%}$ is the amount of the received dose in 2% of the target volume, $D_{50\%}$ denotes the received dose in 50% of the target volume, and $D_{98\%}$ represents the received dose in 98% of the target volume.

2.7. Immobilization /Positioning

Patients were simulated in both prone and supine positions using a dedicated breast board. For the prone setup, the affected breast was positioned through an opening allowing gravitational displacement while maintaining reproducibility. Arm elevation, head support, and positioning markers were standardized in all cases.

2.8. QA and Clinical Approval Statement

All plans were reviewed and approved by a senior radiation oncologist and a certified medical physicist. Only clinically acceptable plans fulfilling institutional dose constraints were included in the analysis.

2.9. Statistical Analysis

Statistical analysis was performed using SPSS software version 26 (IBM Corp., Armonk, NY, USA). Since each patient had three corresponding plans, intra-patient paired comparisons were conducted. Data normality was first assessed using the Shapiro–Wilk test. For normally distributed data, paired t-tests were applied, whereas the Wilcoxon signed-rank test was used for non-normal data. Results are presented as mean ± standard deviation. A significance threshold of $p < 0.05$ was considered. Where multiple comparisons were evaluated across several dosimetric

Table 3. Dosimetry indicators used for evaluating the dose distribution in risky and target organs

Volumes		Dosimetry Indicators						
		D_{mean}	V_{5Gy}	V_{10Gy}	V_{20Gy}	V_{30Gy}	HI	CI
Target(PTV & CTV)		*					*	*
OARs	**Ipsilateral lung**	*	*	*	*			
	Heart	*		*		*		
	Contralateral lung	*	*	*				
	Contralateral breast	*	*					

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parameters, Bonferroni correction was considered to reduce the risk of type I error. In addition, confidence intervals improved the robustness of interpretation. Although the sample size was moderate, it was considered reasonable for a dosimetric comparison study, consistent with previous similar investigations.

3. Results

This research comprehensively discusses the dosimetric investigation and comparison of the three-dimensional conformal technique (prone and supine) and tomotherapy (supine) in whole breast radiotherapy in 20 patients with pendulous breasts suffering from left breast cancer. For this purpose, dosimetry indices derived from DVH curves calculated by the treatment planning system were used for organs at risk, such as the heart, ipsilateral lung, contralateral lung, contralateral breast, and PTV, and the results are shown in Tables 4, 5, 6, 7, and 8, respectively. Unless otherwise stated, reported differences refer to paired intra-patient comparisons, and confidence intervals are provided to support the strength of the observed effects.

Tables 4, 5, 6, and 7 show the dosimetric indices obtained from the DVH curves of the organs at risk in radiotherapy of the left breast using 3D prone, 3D supine, and tamo-supine methods.

Overall, tomotherapy demonstrated superior target conformity and homogeneity indices compared with both prone and supine 3D-CRT plans. However, tomotherapy generally resulted in higher low- and intermediate-dose exposure to the ipsilateral lung and contralateral structures, while prone 3D-CRT

Table 4. Dosimetry indices derived from the DVH curves of the heart organ in radiation therapy of the left breast using 3D-prone, 3D-supine, and Tomo-supine methods. (Mean ± SD)

Heart	Tomo-supine(Mean ± SD)	3D-CRT		P-value
		Supine(Mean ± SD)	Prone(Mean ± SD)	
D_{mean}(Gy)	4.27 ± 0.30	4.18 ± 1.13	4.87 ± 0.30	<0.001
V_{10} (%)	1.95 ± 0.60	12.70 ± 4.70	10.48 ± 1.24	<0.001
V_{30} (%)	0.00 ± 0.00	4.10 ± 1.00	3.53 ± 1.31	<0.001

*All data are per 50 Gy prescription dose

Table 5. Dosimetry indices derived from DVH curves of the ipsilateral lung in radiation therapy of the left breast using 3D-prone, 3D-supine, and Tomo-supine methods. (Mean ± SD)

Ipsilateral Lung	Tomo-Supine(Mean ± SD)	3D-CRT		P-Value
		Supine(Mean ± SD)	Prone(Mean ± SD)	
D_{mean} (Gy)	9.55 ± 0.42	6.64 ± 1.71	4.02 ± 1.71	<0.001
V_5 (%)	74.50 ± 2.30	22.50 ± 7.40	12.36 ± 3.10	<0.001
V_{10} (%)	43.00 ± 6.86	18.60 ± 4.70	9.64 ±2.21	<0.001
V_{20} (%)	4.40 ± 0.90	17.00 ± 5.80	6.70 ± 2.73	<0.001

* All data are per 50 Gy prescription dose

Table 6. Dosimetry indices derived from the DVH curves of the opposite lung (contralateral) radiation therapy of the left breast using the 3D-prone, 3D-supine, and Tomo-supine methods. (Mean ± SD)

Contralateral Lung	Tomo-Supine(Mean ± SD)	3D-CRT		P-Value
		Supine(Mean ± SD)	Prone(Mean ± SD)	
D_{mean}(Gy)	3.00 ± 0.90	0.45±0.11	0.18 ± 0.12	<0.001
V_5 (%)	45.70 ± 8.50	0.00 ± 0.00	0.00 ± 0.00	<0.001
V_{10} (%)	6.90 ± 2.31	0.00 ± 0.00	0.00 ± 0.00	<0.001

*All data are per 50 Gy prescription dose

Table 7. Dosimetry indices derived from the DVH curves of the contralateral breast in radiation therapy of the left breast using 3D-prone, 3D-supine, and Tomo-supine methods. (Mean ± SD)

Contralateral Breast	Tomo-Supine(Mean ± SD)	3D-CRT		P-Value
		Supine(Mean ± SD)	Prone(Mean ± SD)	
D_{mean}(Gy)	4.17 ± 0.80	0.17 ±0.05	1.23 ± 0.15	<0.001
V_5 (%)	45.70 ± 8.50	0.00 ± 0.00	3.11 ± 1.62	<0.001

*All data are per 50 Gy prescription dose

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Table 8. Dosimetry indices showing the dose distribution in PTV in left breast radiation therapy using 3D-prone, 3D-supine, and Tomo-supine methods. (Mean ± SD)

PTV	Tomo-Supine(Mean ± SD)	3D-CRT		P-Value
		Supine(Mean ± SD)	Prone(Mean ± SD)	
D_{mean}(Gy)	51.00 ± 0.10	50.45 ± 0.75	49.89 ± 0.15	<0.001
CI	0.96 ± 0.02	0.94 ± 0.03	0.96 ± 0.04	<0.001
HI	0.17 ± 0.01	0.19 ± 0.02	0.18 ± 0.02	<0.001

achieved the lowest mean lung dose. These findings indicate a trade-off between target quality and low-dose bath among the evaluated techniques.

4. Discussion

This study compared the dosimetric parameters between three techniques, namely, tomotherapy in the supine position and 3D-CRT in the supine and prone positions, to obtain the best radiation therapy method to achieve the optimal target dose distribution (pendulum left breast) and reduce the dose to the lungs and heart as much as possible. The data presented in Tables 4, 5, 6, 7, and 8 were used to elaborate the dose distribution in critical organs like the lungs and heart in these mentioned radiotherapy methods.

3D-supine showed the lowest average heart dose and increased by 2.2 and 16.5% in the tomo-supine and 3D-prone, respectively. V10Gy and V30Gy for the 3D-prone method had a decrease of 14% and 17.5%, respectively, compared to the 3D-supine. The Tomo-supine method reduced V10Gy by about 80% and reduced V30Gy (high dose receiver volume) to almost zero. Therefore, this new method brings high radiation protection to the heart organ compared to 3D-CRT.

The average dose (D_{mean}) received by the ipsilateral lung (left side) in 3D radiation therapy in the prone position decreased by 40% compared to the supine position. Besides, the Tomo-supine method caused a more than twofold increase in D_{mean} compared to 3D-prone. In addition, this method increased the volume of the low-dose recipient by a ratio of 3–6 times. However, the tomo-supine decreased the V20 parameter by 1.5 and 4 times compared to 3D in the prone and supine positions, respectively. Therefore, although the new Tomo-supine method increases the average dose and the volume receiving the low dose in the ipsilateral lung, it lowers the volume of the organ that receives the high dose. The average dose received in the contralateral lung (right side) in the prone and supine positions in the 3D method was negligible compared with the prescribed dose. In comparison, in the tomosupine position, it increased up to 3 Gy. In addition to the average dose amount, the volume taking the low dose was proportionally increased in the tomosupine position. As a general conclusion, in the spiral tomosupine method, due to different radiation angles, the average dose of the opposite lung and breast was 3 Gy and 4.17 Gy, respectively. Meanwhile, the average dose of the contralateral breast and lung in the 3D conformal method was almost zero due to choosing two suitable angles for the target and removing the contralateral breast and lung from the radiation field. In addition, V5Gy and V10Gy of the contralateral breast and lung in the Tomo-supine method were significantly increased compared with the 3D conformal method.

Regarding the therapeutic target, i.e., PTV (Table 8), the average dose in the tomo-supine, 3D in the prone mode, and the supine mode was 2% more, 0.2% less, and 0.9% more than the prescribed dose, respectively. When comparing the three radiotherapy methods from this viewpoint, the D_{mean} factor for PTV in the Tomo-supine method was about 2% higher than the other two methods. The conformity index was similar in both the tomo-supine and 3D-prone methods and had a relatively higher value (2.1%) than the 3D-supine method (the closer the conformity index to one, the better the dose conformity in the target). The homogeneity index in the Tomo-supine method was relatively improved. In this respect, the closer the dose homogeneity index value is to zero, the more homogeneous the dose is achieved in the target. Therefore, it is concluded that the Tomo-supine method causes conformity and homogeneity of the appropriate dose in the target. One explanation for this result is the radiation from several different angles in this method.

In summary, this work indicated that the Tomo-Supine method increases the average dose and the

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percentage of volume receiving low and medium doses in vulnerable organs compared with 3D-CRT. However, it lowers the volume of the high doses and provides very good tumor control. In other words, it brings dose conformity and homogeneity to the target, thereby increasing the mean dose in the PTV. Notably, although some differences reached statistical significance, not all statistically significant findings necessarily translate into clinically meaningful superiority; therefore, interpretation should always consider both the magnitude of change and the patient-specific clinical context.

In this regard, several relevant studies were conducted on other areas of the body. For instance, Monadi *et al.* [27] compared two methods, namely, 3D-CRT and Tomotherapy, in treating neck and head tumors, in terms of dosimetric indications. Target quality was improved in Tomotherapy compared to 3D-CRT, such as improvements in dosimetric coverage of target volumes, conformity index, homogeneity, and volume reduction in hot spots. In another study, Jhaveri *et al.* compared the V45, V40, V30, V20, V10, and average dose to the OAR between 3D-CRT and Tomotherapy for locally advanced rectal cancer [28]. The findings revealed a statistically significant difference in OAR doses. Besides, tomotherapy reduced the volumes of normal tissues that received high-dose RT compared with 3D-CRT therapy. Tomita *et al.* [29] observed that in nasal lymphoma patients, better PTV coverage was provided by Tomotherapy, where above 99% of the PTV received 90% and 95% of the recommended dose. In contrast, 3D-CRT did not present sufficient PTV coverage, where 89.1% and 84.5% of the PTV received 90% and 95% of the recommended dose, respectively [30]. Concluded that the 3-D conformal method should not be the primary choice for CSI selection due to its poor conformity. Therefore, they recommended tomotherapy for clinical practice. From a clinical perspective, the present findings are particularly relevant for centers managing patients with large or pendulous breasts. Our results suggest that although Tomotherapy may improve dose conformity, prone 3D-CRT may still be preferable when minimizing lung dose is the primary concern. Thus, treatment selection should be individualized rather than technique-driven, reinforcing the importance of patient-specific planning and evaluation.

The dosimetric results of the present study demonstrate that tomotherapy provides superior target conformity and dose homogeneity compared with conventional 3D-CRT, which is consistent with several recently published studies reporting improved PTV quality in advanced rotational techniques [31,32]. However, similar to previous findings, our study also confirms that this improvement is accompanied by an increase in the volume of low- and intermediate-dose irradiation to surrounding normal tissues, particularly the ipsilateral lung and contralateral organs. This observation reflects the intrinsic nature of helical delivery, where a broader beam spread results in a wider low-dose bath despite excellent high-dose conformality (Table 9).

An important aspect of our work is the focus on pendulous left breast patients, a subgroup in which breast geometry, gravitational displacement, and large breast volume make treatment planning particularly challenging. Our results show that while Tomotherapy may help in achieving more uniform target coverage in such patients, prone 3D-CRT still provides the lowest ipsilateral lung mean dose, supporting the concept that the optimal technique should be individualized. In clinical terms, this implies that Tomotherapy may be preferred when target conformity and homogeneity are the main priorities, whereas prone 3D-CRT may be advantageous in patients where minimizing lung dose is of greater concern. These findings reinforce the need for patient-specific planning evaluation rather than a “one-size-fits-all” approach. Although tomotherapy provides superior conformity and homogeneity, the wider low-dose distribution observed in our study raises potential concerns, particularly regarding lung exposure and theoretical secondary cancer risk. However, it should be emphasized that this study was purely dosimetric and no NTCP/TCP modeling was performed; therefore, our results cannot directly predict clinical outcomes. Existing evidence in the literature also suggests that the actual clinical relevance of low-dose bath remains debated, and interpretation should be made cautiously. For this reason, technique selection should always consider patient age, comorbidities, and long-term risk profile.

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4.1. Limitations

This study has some limitations. First, the sample size was moderate, although comparable to several dosimetric investigations. Second, the analysis was purely dosimetric, and no clinical toxicity or outcome data were included. Third, NTCP/TCP modeling was not performed; therefore, biological interpretation should be made cautiously. In addition, DIBH and VMAT techniques were not evaluated and may provide different dose distributions. Future studies with larger cohorts, the incorporation of clinical follow-up, and the inclusion of additional modern techniques are recommended to validate and extend our results. Future research with larger cohorts, incorporation of clinical follow-up data, and inclusion of additional modern techniques are warranted to further validate and expand these findings.

Table 9. Dosimetric comparison of left breast radiation therapy methods (3D-prone, 3D-supine, and Tomotherapy). (Mean ± SD)

Cammarota *et al.* [33]			
Organ		Tomo-supine (Mean ± SD)	3D-prone (Mean ± SD)
PTV	D^*_{mean}	43.74 ± 0.60	43.01 ± 0.41
Heart	D_{mean}	5.57 ± 1.06	0.93 ± 0.22
Contralateral breast	V_5**	21.28 ± 8.81	0.00 ± 0.00
	D_{mean}	3.18 ± 0.84	0.59 ± 0.11
Griem *et al.* [28]			
Organ		3D-supine (Mean ± SD)	3D-prone (Mean ± SD)
PTV	D_{mean}	40.19 ± 0.06	40.23 ± 0.09
Ipsilateral lung	V_5	34.28 ± 4.05	28.44 ± 1.16
	V_{10}	18.60 ± 4.70	9.64 ± 2.21
	V_{20}	17.00 ± 5.80	6.70 ± 2.73
	D_{mean}	7.51 ± 1.03	5.52 ± 0.73
Heart	V_{10}	3.51 ± 2.35	3.47 ± 0.92
	V_{30}	0.06 ± 0.05	0.10 ± 0.18
	D_{mean}	2.52 ± 0.59	2.38 ± 0.28
Contralateral breast	V_5	0.20 ± 0.23	0.02 ± 0.05
	D_{mean}	0.83 ± 0.30	0.33 ± 0.07
Contralateral lung	V_5	0.60 ± 0.09	0.35 ± 0.04
	D_{mean}	0.04 ± 0.07	0.00 ± 0.00

* The unit of the average dose quantity is Gy.
**All relative volumes are expressed in %.
*** All data are per about 50 Gy prescription dose.

5. Conclusion

In summary, our results indicate that helical Tomotherapy provides superior target conformity and dose homogeneity compared with conventional 3D-CRT techniques in pendulous left-breast cancer patients. However, this advantage is accompanied by an increase in low- and intermediate-dose exposure to the ipsilateral lung and contralateral organs, whereas prone 3D-CRT generally achieved the lowest lung mean dose. These findings suggest that treatment selection should be individualized, balancing target coverage priorities against potential low-dose irradiation risks, particularly in younger patients or those with lung sensitivity. From a clinical perspective, the present results may assist clinicians in selecting the most appropriate technique for challenging pendulous left-breast patients by balancing target conformity against potential low-dose exposure risks. While tomotherapy may be advantageous in challenging anatomical conditions, the observed low-dose spread warrants careful consideration, and further studies incorporating NTCP/TCP modeling and clinical follow-up are needed to confirm the biological relevance of these dosimetric findings. Overall, tomotherapy may represent a valuable option in challenging anatomical situations, such as pendulous breasts, provided that its dosimetric trade-offs are carefully considered.

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