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Original Article

Radiotherapy dosimetry and complications in modified radical mastectomy with first-stage breast reconstruction: target coverage and lung protection

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Abstract: Objectives: To compare the radiotherapy dosimetry and complications in patients undergoing modified radical mastectomy (MRM) with first-stage breast reconstruction (FSBR) versus MRM alone. The study aimed to investigate the effect of radiotherapy on breast reconstruction aesthetics and provide evidence for personalized treatment plans. Methods: A total of 82 female patients who underwent MRM between 2016 and 2019 were included. They were first divided into two groups: 51 patients received FSBR (FSBR group) and 31 did not (MRM group). Among the 59 patients who subsequently underwent radiotherapy, 28 were from the FSBR group and 31 were from the MRM group; the remaining 23 FSBR patients received no radiotherapy. Both groups received intensity modulated radiation therapy (IMRT) with the parameters that Planning target volume 1 (PTV1, regional lymph nodes) and planning target volume 2 (PTV2, chest wall) were both prescribed as 50 Gy in 25 fractions over 5 weeks. The homogeneity index (HI), conformity index (CI), target coverage, and dose/volume of organs at risk (OARs) were compared between these two groups. Radiotherapy-related complications were also analyzed. Additionally, the FSBR group was further subdivided into a radiotherapy subgroup (n = 28) and a non-radiotherapy subgroup (n = 23) to evaluate the effect of radiotherapy on breast aesthetics. Results: For OARs, the FSBR group showed better lung protection compared to the MRM group in terms of Dmean, Dmax, V5, V20, V30, and V40 (all $P < 0.05$). There were no significant differences in target coverage, HI, or CI between the groups (both $P > 0.05$). The incidence of radiodermatitis was similar ($P > 0.05$). The aesthetic outcomes of reconstructed breasts were significantly lower in the radiotherapy group compared to the non-radiotherapy group ($P < 0.05$). Despite reduced aesthetic outcomes, FSBR did not compromise radiotherapy dosimetry and provided better lung protection compared to MRM alone. Conclusion: FSBR may be a viable option for patients requiring postoperative radiotherapy, as it offers comparable dosimetry and enhanced lung protection.

Keywords: Breast reconstruction, modified radical mastectomy for breast cancer, intensity-modulated radiotherapy, dosimetric analysis, aesthetics

Introduction

Breast cancer ranks first in incidence and second in mortality among women worldwide [1]. Although the mortality rate has declined significantly in recent years due to advances in diagnosis and treatment, it remains one of the leading causes of cancer-related death in women [2]. Modified radical mastectomy (MRM) continues to be one of the most commonly used surgical approaches [3], but the resulting breast loss often leads to considerable psychological and emotional distress [4]. To address this, breast reconstruction has

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become an important part of comprehensive breast cancer management, offering improvements in patients' quality of life, mental well-being, and body image.

In recent years, the demand for breast reconstruction after mastectomy has increased significantly. Studies in the United States and the United Kingdom have reported reconstruction rates exceeding 40-50% [5, 6]. According to the timing of surgery, reconstruction is classified as immediate (first-stage) or delayed (second-stage) [7]; in terms of materials, reconstruction may involve implants or autologous flaps [8].

Since breast reconstruction often coincides with adjuvant therapies such as radiotherapy, clinical decision-making has become more complex. Although previous studies suggest that neoadjuvant or adjuvant therapy does not necessarily increase reconstruction complication rates [9], there is ongoing debate about the interaction between radiotherapy and immediate reconstruction. Radiotherapy may compromise the aesthetic outcomes of reconstruction or increase complication rates, while reconstruction itself may influence radiation planning and dosimetry.

Despite these concerns, few studies have directly compared dosimetry between patients undergoing MRM with immediate reconstruction and those undergoing MRM alone in the context of modern intensity-modulated radiation therapy (IMRT). Furthermore, there is limited research evaluating both radiation-related complications and cosmetic outcomes simultaneously.

This study aims to address this gap by examining whether first-stage breast reconstruction (FSBR) compromises radiotherapy quality in terms of target coverage, sparing of organs at risk (OARs), and cosmetic outcomes. The findings aim to inform individualized decision-making for patients considering reconstruction in situations where postoperative radiotherapy is necessary.

Materials and methods

Case selection

This retrospective study included 82 female patients who underwent MRM at The Affiliated Hospital of Soochow University between January 2016 and November 2019.

Inclusion criteria: (1) Pathologically confirmed breast cancer; (2) No evidence of distant metastasis on imaging; (3) Age between 18 and 70 years; (4) Karnofsky Performance Status (KPS) ≥ 70; (5) Received IMRT with a prescribed dose of 50 Gy in 25 fractions over 5 weeks to the chest wall (planning target volume 2, PTV2) and regional lymph nodes (planning target volume 1, PTV1); (6) Complete clinical and follow-up data available.

Exclusion criteria: (1) History of prior chest wall radiotherapy; (2) Presence of other malignancies; (3) Severe cardiopulmonary dysfunction or connective tissue disorders; (4) Incomplete radiotherapy or loss to follow-up; (5) Reconstruction involving both implant and autologous tissue.

Among the included patients, 51 underwent MRM with FSBR, and 31 underwent MRM alone.

Among the included patients, 51 underwent MRM with FSBR (FSBR group) and 31 underwent MRM alone (MRM group). All 31 patients in the MRM group received postoperative radiotherapy; within the FSBR group, 28 patients received radiotherapy (FSBR-RT subgroup) and 23 did not (FSBR-no-RT subgroup).

Ethical considerations

This study was approved by the Ethics Committee of The Affiliated Hospital of Soochow University. Informed consent was waived for the retrospective analysis of anonymized data, as per the ethics approval. However, written informed consent was obtained from patients with available follow-up and aesthetic evaluations during their clinical visits.

Treatment methods

Patients were positioned using a vacuum pad or breast bracket, with alignment facilitated by a laser positioning system. Lead markers were placed for reference. CT simulation scans were performed from the mandible to L2 with a 3 mm slice thickness and imported into the Eclipse treatment planning system.

Table 1. Comparison of general clinical information between the two groups

Item	FSBR group (n = 51)	MRM group (n = 31)	X^2	*P* value
Tumor location			2.02	0.155
Right	28	12		
Left	23	19		
T stage			0.63	0.73
T1	14	7		
T2	32	22		
T3	5	2		
Lymph node metastasis			6.64	0.084
N0	25	7		
N1	18	14		
N2	3	5		
N3	5	5		
TNM stage			2.21	0.33
I	8	2		
II	32	19		
III	11	10		

MRM = modified radical mastectomy; FSBR = first-stage breast reconstruction.

Target delineation was performed by a senior radiation oncologist. Clinical target volume 1 (CTV1) included regional lymphatic drainage areas (supraclavicular and axillary nodes), and CTV2 covered the chest wall. In patients with implant reconstruction, the expander was excluded from CTV2, whereas in autologous reconstruction, the flap was included. Each CTV was expanded by 0.5 cm to form the corresponding planning target volumes (PTV1 and PTV2).

OARs included the ipsilateral lung, heart, humeral head, esophagus, trachea, and thyroid. OARs were also contoured and expanded into planning risk volumes (PRVs). All patients received IMRT with uniform planning parameters and dose constraints.

Data collection and outcome definitions

Radiotherapy dosimetric indices included Dmax, Dmean, D2, D98, V95, V105, homogeneity index (HI), and conformity index (CI) for both PTV1 and PTV2. Dose-volume data were also recorded for OARs, including the ipsilateral lung and heart (e.g., V5, V20, Dmean).

Primary outcomes: Dosimetric comparison between the FSBR and MRM groups regarding target volume coverage and OAR sparing.

Secondary outcomes: Radiotherapy-related skin toxicity was evaluated using the Radiation Therapy Oncology Group criteria [10], graded from 0 to IV. Aesthetic outcomes in FSBR patients were assessed at least 6 months after radiotherapy using the Harris scale: excellent, good, fair, or poor, based on symmetry and shape of the reconstructed versus contralateral breast.

Statistical analysis

Statistical analysis was performed using SPSS version 22.0. Measured data were expressed as mean ± standard deviation (SD), and comparisons were conducted using paired t-tests. Categorical variables were expressed as frequencies or percentages and analyzed using the Chi-square test or Fisher's exact test, depending on expected cell counts. A p-value < 0.05 was considered significant.

Results

Comparison of baseline clinical characteristics

There were no significant differences in baseline characteristics, including tumor location, T stage, lymph node involvement, or TNM stage, between the FSBR and MRM groups (all P > 0.05) (**Tables 1** and **2**).

Comparison of target area dose, CI and HI

The dosimetric comparison of radiation plans used in the FSBR and MRM groups is shown in **Table 3**. Indices such as Dmean, D2, D98, V95, V105, and HI for PTV1 (regional lymph nodes) and PTV2 (chest wall) did not differ significantly between the two groups (all P > 0.05). The target area CI also showed no significant difference (P > 0.05).

Comparison of irradiation dose and volume of OARs

Comparison of the irradiation dose and volume of the ipsilateral lung between the two groups

Table 2. Radiotherapy in the two groups

Group	Method	Patients with radiotherapy	Patients without radiotherapy	p	χ^2
FSBR (n = 51)	Implant reconstruction	20	20	< 0.001	17.26
	Autologous tissue reconstruction	8	3		
MRM (n = 31)		31	0		

*FSBR = first-stage breast reconstruction; MRM = modified radical mastectomy.

Table 3. Comparison of HI (Homogeneity Index), CI (Conformity Index) and other indices between the two groups

Index	FSBR-RT group (n = 28)	MRM-RT group (n = 31)	t value	*P* value
PTV1				
Dmean (cGy)	5092 ± 11.21	5065 ± 8.64	10.28	< 0.0001
D2 (cGy)	5254 ± 17.72	5302 ± 16.42	-10.76	< 0.0001
D98 (cGy)	4752 ± 20.37	4705 ± 28.55	7.33	< 0.0001
V95 (%)	97.78 ± 0.24	97.45 ± 0.25	5.17	< 0.0001
V105 (%)	9.70 ± 2.48	8.838 ± 1.54	1.58	0.12
HI	0.139 ± 0.01	0.1551 ± 0.01	-7.71	< 0.0001
PTV2				
Dmean (cGy)	5140 ± 12.11	5143 ± 12.46	-0.94	0.35
D2 (cGy)	5359 ± 17.24	5397 ± 15.69	-8.82	< 0.0001
D98 (cGy)	4741 ± 23.13	4671 ± 42.55	7.95	< 0.0001
V95 (%)	96.34 ± 1.48	96.02 ± 0.98	0.97	0.34
V105 (%)	19.00 ± 3.88	27.27 ± 3.50	-8.56	< 0.0001
HI	0.161 ± 0.01	0.175 ± 0.01	-6.59	< 0.0001
PTV (PTV1+PTV2)				
CI	0.853 ± 0.02	0.826 ± 0.02	5.18	< 0.0001

*Dmean = mean dose; Dmax = maximum dose; D2 = dose to 2% of the volume; D98 = dose to 98% of the volume; Vx = volume receiving ≥ x% of the prescribed dose; HI = homogeneity index; CI = conformity index; FSBR = first-stage breast reconstruction; MRM = modified radical mastectomy.

Table 4. Comparison of irradiation dose and volume of the ipsilateral lung (mean ± SD)

Index	FSBR-RT group (n = 28)	MRM-RT group (n = 31)	t value	*P* value
Dmean (cGy)	1429 ± 34.72	1529 ± 28.03	-12.09	0.03
Dmax (cGy)	5232 ± 21.57	5309 ± 23.85	-13.02	0.02
V5 (%)	52.64 ± 0.95	57.48 ± 1.71	-13.61	0.02
V10 (%)	38.96 ± 1.47	41.01 ± 1.46	-5.37	0.33
V20 (%)	24.90 ± 1.01	27.85 ± 0.70	-12.89	0.02
V30 (%)	19.31 ± 0.64	21.51 ± 0.63	-13.28	0.02
V40 (%)	13.28 ± 0.62	15.96 ± 0.67	-15.96	< 0.01

*Dmean = mean dose; Dmax = maximum dose; Vx = volume receiving ≥ x% of the prescribed dose; FSBR = first-stage breast reconstruction; MRM = modified radical mastectomy.

showed that the FSBR group had better indices, including Dmean, Dmax, V5, V20, V30, and V40, than the MRM group (all P < 0.05, **Table 4**). The dose and volume of the heart did not significantly differ between the two groups for both left and right breast cancer (P > 0.05, **Tables 5** and **6**).

Comparison of radiotherapy complications

We retrospectively compared radiodermatitis in patients with and without breast reconstruction. Most patients experienced Grade 2 acute skin toxicity, with only two cases of Grade 3 acute toxicity or dermatitis. The incidence of radiodermatitis was not significantly different between the two groups (P = 0.2, **Table 7**).

Effect of radiotherapy on the aesthetics of reconstructed breast

Aesthetic evaluation of the reconstructed breast was significantly lower in the breast reconstruction plus radiotherapy group compared to those who underwent breast reconstruction without radiotherapy (P = 0.048, **Table 8**; **Figure 1**).

Discussion

This study investigated the dosimetric outcomes and clinical feasibility of postmastectomy radiotherapy (PMRT) in patients undergoing FSBR compared to those receiving MRM alone. Our findings suggest that FSBR does not compromise target volume coverage and may

Table 5. Comparison of Irradiation dose and volume of the ipsilateral lung

Index	FSBR-RT group (n = 28)	MRM-RT group (n = 31)	t value	*P* value
Dmean (cGy)	1004 ± 95.15	1017 ± 64.27	-0.43	0.67
Dmax (cGy)	5145 ± 106.6	5158 ± 76.13	-0.38	0.71
V5 (%)	32.44 ± 2.19	32.59 ± 2.57	-0.18	0.86
V10 (%)	22.36 ± 1.45	22.45 ± 1.94	-0.15	0.88
V20 (%)	14.23 ± 1.12	14.38 ± 1.71	-0.3	0.77
V30 (%)	9.03 ± 0.93	9.10 ± 1.39	-0.17	0.87
V40 (%)	5.43 ± 0.98	5.58 ± 1.31	-0.37	0.71

*Dmean = mean dose; Dmax = maximum dose; Vx = volume receiving ≥ x% of the prescribed dose; FSBR = first-stage breast reconstruction; MRM = modified radical mastectomy.

Table 6. Irradiation dose and volume of the heart (right breast cancer)

Index	FSBR-RT group (n = 28)	MRM-RT group (n = 31)	t value	*P* value
Dmean (cGy)	245.4 ± 17.12	257.3 ± 29.06	-1.25	0.23
Dmax (cGy)	1446 ± 10.00	1716 ± 130.7	-7.14	< 0.05
V5 (%)	11.34 ± 1.23	11.52 ± 2.45	-0.23	0.82
V10 (%)	1.74 ± 0.29	1.76 ± 0.58	-0.11	0.92
V20 (%)	0.07 ± 0.06	0.11 ± 0.11	-1.13	0.27
V30 (%)	0	0	-	-
V40 (%)	0	0	-	-

*Dmean = mean dose; Dmax = maximum dose; Vx = volume receiving ≥ x% of the prescribed dose; FSBR = first-stage breast reconstruction; MRM = modified radical mastectomy.

Table 7. Comparison of radiotherapy complications in the two groups

Radiodermatitis	FSBR-RT group (n = 28)	MRM-RT group (n = 31)	*P* value	χ^2
Grade 0	0	0	< 0.05	3.22
Grade I	2 (7.1%)	5 (16.1%)		
Grade II	24 (85.8%)	26 (83.9%)		
Grade III	2 (7.1%)	0		
Grade IV	0	0		

*FSBR = First-Stage Breast Reconstruction; MRM = Modified Radical Mastectomy.

Table 8. Aesthetic evaluation of reconstructed breasts with or without radiotherapy

Aesthetic Grade	FSBR-RT subgroup (n = 28)	FSBR-no-RT subgroup (n = 23)	*P* value	χ^2
Excellent	0 (0%)	4 (17.4%)	< 0.05	9.51
Good	20 (71.4%)	18 (78.3%)		
Fair	4 (14.3%)	1 (4.3%)		
Poor	4 (14.3%)	0 (0%)		

*FSBR = First-Stage Breast Reconstruction; MRM = Modified Radical Mastectomy.

offer better protection for the ipsilateral lung, although some decrease in aesthetic outcomes was observed among patients receiving postoperative radiotherapy.

Previous studies have raised concerns regarding the compatibility of breast reconstruction with radiotherapy planning [11], particularly with regard to potential compromise in target coverage. However, our results demonstrated that the FSBR group achieved comparable homogeneity index (HI), conformity index (CI), and coverage of planning target volumes (PTV1 and PTV2) compared to the MRM group. This aligns with findings from Koutcher et al. [12], who reported satisfactory PTV coverage in 95% of patients undergoing IMRT after expander-implant reconstruction. Similarly, a prospective study involving 93 patients with breast reconstruction showed excellent target coverage even when internal mammary lymph nodes were included (V90% = 98.5%, V95% = 99.7%) [13]. Advances in radiotherapy technologies such as IMRT and VMAT may help overcome the limitations seen in earlier studies using conventional techniques, which reported compromised plans in reconstructed patients [14].

Regarding sparing of OARs, our study found that FSBR patients had significantly lower doses to the ipsilateral lung across multiple indices (Dmean, Dmax, V5-V40) compared to MRM patients. This may be due to changes in chest wall contouring and target delineation strategies that exclude prosthetic components, as recommended by up-

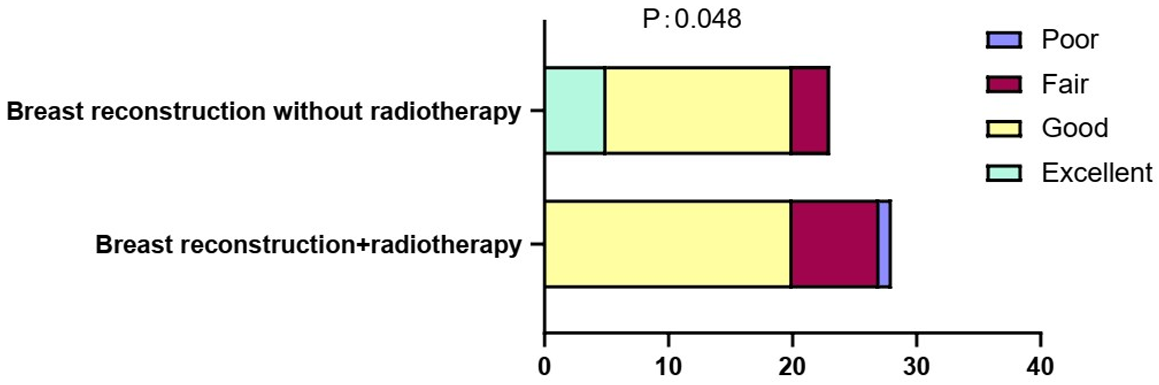

Figure 1. Effect of radiotherapy on the Aesthetic evaluation of reconstructed breast.

dated guidelines for PMRT in reconstructed patients [15]. Ohri et al. [16] similarly reported better lung dose profiles in reconstructed patients, including lower Dmean and V20 values. Koutcher et al. [12] and Ben-David et al. [17] also found that appropriate planning could maintain low heart and lung exposures, even when internal mammary nodes were included.

Despite the dosimetric advantages, we observed a significantly lower aesthetic score in the FSBR group that received radiotherapy compared to those who did not. Radiotherapy may affect the quality of reconstructed breasts by inducing tissue fibrosis, volume loss, or capsular contracture. This trend has been confirmed by prior studies, such as Cordeiro et al. [18], who reported lower aesthetic scores and satisfaction in patients receiving post-reconstruction radiotherapy. Another retrospective study from Tianjin Medical University involving 370 reconstructed breasts also noted increased late complications and fat necrosis in the radiotherapy group [19]. However, long-term satisfaction with autologous reconstruction remains high, even exceeding that of breast-conserving surgery in large surveys [20].

From a clinical perspective, our study supports the feasibility of FSBR in patients who require postoperative radiotherapy. With proper planning and modern radiotherapy techniques, adequate target coverage and acceptable toxicity profiles can be achieved. The potential trade-off in cosmetic outcomes should be openly discussed with patients during multidisciplinary decision-making.

This study has several limitations. It is a single-center retrospective analysis with a relatively small sample size, which may limit the generalizability of the findings. Additionally, aesthetic assessment was based on subjective scoring, and long-term complication data were not fully included. Further prospective studies with larger cohorts and long-term follow-up are warranted to validate our results and refine patient selection criteria.

In conclusion, FSBR may be a viable option for selected breast cancer patients undergoing PMRT. It appears to provide non-inferior target coverage and better lung protection compared to MRM alone, though some compromise in aesthetic outcomes may occur. Careful patient selection and individualized planning remain essential to optimizing outcomes.

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Patients who participated in this research, signed the informed consent and had complete clinical data.

Disclosure of conflict of interest

None.

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