Original Article

A comparative dosimetric study of seven radiation techniques for breast cancer after mastectomy and immediate breast reconstruction

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Background: To explore the optimal irradiation technique for breast cancer after mastectomy and immediate breast reconstruction.

Methods: Ten breast cancer patients undergoing immediate breast reconstruction after mastectomy were included. We compared the target volume coverage, doses to breast implant and organs at risks (OARs) using seven techniques, including three-dimensional conformal radiation therapy (3DCRT), field-in-field intensity-modulated radiation therapy (FIF-IMRT), the mixture of 3DCRT and IMRT (HYBRID), IMRT, flattening filter-free (FFF)-IMRT, volumetric-modulated arc therapy (VMAT) and FFF-VMAT.

Results: IMRT, FFF-IMRT, VMAT, and FFF-VMAT had better conformity index compared to 3DCRT, FIF-IMRT, and HYBRID. The IMRT and FFF-IMRT had the improved homogeneity index in comparison with VMAT and FFF-VMAT. IMRT and FFF-IMRT also had significantly lower dose to breast implant compared to 3DCRT, FIF-IMRT, and HYBRID. However, the volume of ipsilateral lung receiving 10 Gy (V10) and mean dose of ipsilateral lung in VMAT and FFF-VMAT were higher than those of other techniques. The dose to ipsilateral lung in IMRT was in the range of traditional radiation techniques and VMAT. The V10 of heart in IMRT, FFF-IMRT, VMAT, and FFF-VMAT were significantly higher than that of other techniques, and the V40 were improved in IMRT, VMAT and FFF-VMAT compared with 3DCRT, FIF-IMRT, and HYBRID. The FFF technique did not affect the dose to target volume coverage, breast implants, and OARs in IMRT and VMAT.

Conclusions: Among the seven radiation techniques, IMRT achieves similar or superior target volume coverage and a better breast implant sparing.

Keywords: Breast cancer; breast reconstruction; implant; intensity-modulated radiation therapy (IMRT); target volume

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Introduction

Postmastectomy radiotherapy (PMRT) can reduce the locoregional recurrence rate and improve overall survival in high risk breast cancer patients (1,2). Breast reconstruction can improve the cosmetic effect and quality of life of patients after mastectomy, and more than 50% of breast cancer patients receive breast reconstruction after mastectomy (3,4). However, the optimal mode of breast reconstruction and PMRT is still controversial.

Breast reconstruction after mastectomy includes autologous breast reconstruction and breast reconstruction with implant. PMRT did not have adverse effects on reconstruction in several studies with autologous breast reconstruction (5,6). However, studies on breast reconstruction with an implant suggested that severe capsular contracture occurred after PMRT, which may cause implant loss (7-11). A previous study has been reported that the exposure dose to breast implant is one important factor for capsular contracture (12), but relevant research to identify the optimal irradiation technique to reduce the exposure dose to breast implant is lacking.

At present, conventional PMRT is still a tangential field technique based on three-dimensional conformal radiation therapy (3DCRT). Modern radiotherapy techniques with better dose homogeneity and conformity, including intensity-modulated radiation therapy (IMRT) and volumetric-modulated arc therapy (VMAT) have been adopted in clinical research of breast cancer (13-17). Additionally, the application of flattening filter-free (FFF) beams in IMRT can achieve a high-dose rate, and reduce the treatment time and dose to surrounding normal tissues (18). In this study, we carried out the dosimetric comparison to breast implant after mastectomy among seven different radiation techniques, including 3DCRT, field-in-field IMRT (FIF-IMRT), the mixture of 3DCRT and IMRT (HYBRID), IMRT, FFF-IMRT, VMAT and FFF-VMAT, and explored the optimal radiation technique for breast cancer patients after mastectomy and immediate breast reconstruction.

Methods

Patients

Ten breast cancer patients between July 2011 and December 2013 were identified from the First Affiliated Hospital of Xiamen University in the current study. Patients were included if they met the following criteria: (I) female, unilateral breast cancer, received mastectomy and axillary lymph node dissection, and immediate permanent implant breast reconstruction; (II) stage of II or III (T1-4N1-3M0) according to the 7th edition (2009) of the American Joint Committee on Cancer/Union for International Cancer Control staging system. The study was approved by the ethics committee of the First Affiliated Hospital of Xiamen University (approval number of institutional review board, 2016J01635). Patient characteristics are showed in *Table 1*.

Target volume and organ at risks (OARs) delineation

The delineation of the clinical target volume (CTV) and OARs was finally approved by three experienced radiation oncologists. Since this study was a dosimetric comparison, CTV was delineated as the ipsilateral chest wall. The ipsilateral chest wall was delineated according to the recommendations of the International Commission on Radiation Units report 83 (19). The cranial, caudal, medial and lateral borders for CTV were the bottom of the clavicle head, a 1 cm margin from below the contralateral breast, the ipsilateral sternal-rib junction, and the mid-axillary line, respectively. The planning target volume (PTV) was defined as a 5-mm expansion in all directions around the CTV except for the skin surface, including the set-up margin and accounting for patient movement.

Delineation of OARs included the breast implant, contralateral breast, ipsilateral lung, contralateral lung, and heart on the computed tomography image of each slice. *Table 2* lists the volume of the target volume and normal tissue of the 10 patients.

Radiation techniques

The prescription dose to the PTV was 50 Gy with 2.0 Gy per fraction in 25 fractions. The radiation plans used six MV photon beams. Seven radiation techniques were generated and calculated to compare the difference of dosimetry in the PTV, breast implant and OARs, including the ipsilateral lung and heart in left breast cancer. Treatment planning was performed in Eclipse (Varian Medical Systems, PRO 11.0, AAA 11.0) treatment planning system. All plans were normalized in such that at least 95% of the PTV received 95% of the prescribed dose.

3DCRT

A paired, conventional opposed tangential technique with a physical wedge was applied.

Table 1 Clinical characteristics of the 10 patients

Characteristic	Value
Age (years)	
Median	39.5
Range	26–54
Menopausal status (n)	
Premenopausal	7
Postmenopausal	3
Tumor side (n)	
Left	6
Right	4
Tumor stage (n)	
T1	4
T2	6
Nodal stage (n)	
pN1	2
pN2	6
pN3	2
Pathology type (n)	
Invasive ductal carcinoma	9
Mucinous adenocarcinoma	1
ER/PR status (n)	
Negative	2
Positive	8
Her-2 (n)	
Negative	7
Positive	3

ER, estrogen receptor; Her-2, human epidermal growth factor receptor 2; N, node; PR, progesterone receptor; T, tumor.

FIF-IMRT

Briefly, the contribution of two opposed tangential beams and multiple subfields were used to achieve the dose homogeneity of the PTV without wedges. The dose distributions of an open beam configuration were first calculated and evaluated. The lung block was formed by multileaf collimator (MLC) and then used to smooth out the lateral hot spots. Additional 2–3 subfields were generated using by manually fitting the MLC to "hot" areas.

IMRT

Five tangential direction fields were generated for homogeneous dose delivery to the PTV using a dynamic sliding window MLC. An angle of 20° to 30° separated the two beams, which were oriented in the same direction. The maximum number of segments was 50.

HYBRID

In the HYBRID plan, a mixture of 3DCRT and IMRT techniques was used. 3DCRT technique (40 Gy/20f) was used for the first 20 times, and IMRT (10 Gy/5f) for the later five times.

FFF-IMRT

The tangential directions of FFF-IMRT were similar to IMRT using 6MV-X FFF beams.

VMAT

Two arcs were used for the VMAT plan. The first arc started from 300° to 170°. The second arc had exactly opposite starting and ending angles relative to the first arc.

FFF-VMAT

The two arcs of FFF-VMAT were similar to the VMAT plans by using 6MV-X FFF beams.

Table 2 The volume of target and normal tissue of 10 patients

Target volume and normal tissue	Volume		
	Mean (cm^3)	Median (cm^3)	Range (cm^3)
PTV-whole breast	804.48	745.80	596.40–1069.0
PTV-exclude breast reconstruction	568.65	503.15	359.70–878.0
Breast reconstruction	235.83	239.10	191.00–257.40
Ipsilateral lung	1079.41	1.63.80	708.00–1509.00
Heart (left side)	532.48	546.00	442.40–593.20

PTV, planning target volume.

Table 3 Comparison of the dose to the PTV between the rival techniques

Technique	V95%	V100%	V105%	Dmin	Dmax	Dmean	CI	HI
3DCRT	95.0±0	73.2±11.2^{A}	29.7±17.9^{A}	3,850.5±393.5	5,662.8±92.8^{A}	5,130.7±77.9^{A}	0.38±0.06^{A}	1.15±0.02^{A}
FIF-IMRT	95.0±0	72.9±8.2^{a}	15.7±12.5^{B,a}	3,830.4±576.4	5,410.6±187.8^{a}	5,093.1±60.7^{a}	0.42±0.06^{a}	1.12±0.03^{B,a}
HYBRID	95.0±0	32.0±14.9^{B,b,c}	0.16±0.16^{B,b}	3,582.3±1,278.7	4,803.3±1,570.8^{B,b,c}	4,455.6±1,548.6^{B,b,c}	0.59±0.10^{B,b,c}	1.08±0.01^{B,b,c}
IMRT	95.0±0	21.9±12.9^{B,b,e}	0±0^{B,b}	3,669.5±297.7	5,299.3±84.6	4,924.3±29.0	0.73±0.05^{B,b,d}	1.07±0.01^{B,b,e}
FFF-IMRT	95.0±0	24.1±17.1^{B,b,g}	0.1±0.4^{B,b}	36,663±341.1	5,338.1±115.2	4,927.2±41.7	0.73±0.06^{B,b,d}	1.07±0.01^{B,b,g}
VMAT	95.0±0	60.7±15.1^{d,f,h}	4.7±8.5^{B,b}	4,077.3±159.9	5,434.5±96.0^{d}	5,029.0±52.2^{d}	0.73±0.06^{B,b,d}	1.10±0.02^{B,b,d,f,h}
FFF-VMAT	95.0±0	56.8±17.2^{B,b,d,f,h}	3.4±6.4^{B,b}	4,049.2±166.2	5,410.8±104.5^{d}	5,012.9±55.8^{d}	0.72±0.08^{B,b,d}	1.09±0.02^{B,b,f,h}

Vx%, percentage of the target volume covered by the x% isodose. Dmin, Dmax and Dmean, the minimal, maximal and mean target volume dose. ^{A} had significant difference with ^{B} (P<0.05), ^{a} had significant difference with ^{b} (P<0.05), ^{c} had significant difference with ^{d} (P<0.05), ^{e} had significant difference with ^{f} (P<0.05), ^{g} had significant difference with ^{h} (P<0.05). Otherwise the differences were not significant between any two (P>0.05). 3DCRT, three-dimensional conformal radiation therapy; CI, conformity index; FFF, flattening filter-free; FIF, field-in-field; HI, homogeneity index; IMRT, intensity-modulated radiation therapy; HYBRID, the mixture of 3DCRT and IMRT; VMAT, volumetric-modulated arc therapy.

Conformity index (CI) and homogeneity index (HI) calculation

The CI and HI were evaluated according to our previous study (20). CI = (VTref/VT) × (VTref/Vref), where VTref represents the target volume covered by isodose, VT is the target volume and Vref is the total volume covered by 95% of isodose. CI range was 0–1, in which the conformity was better when the CI value was larger. HI = D5/D95, where D5 represents the radiation dose received by 5% of PTV, while D95 represents the radiation dose received by 95% of PTV. The closer the HI value is to 1, the better the target uniformity will be.

Statistical analysis

One-way analysis of variance tests was performed to compare dosimetric differences between the rival techniques. All statistical tests were performed using SPSS software (release 17.0, SPSS Inc., Chicago, IL, USA) and the differences were considered statistically significant at a P value of <0.05.

Results

Target volume coverage

Table 3 shows the target volume coverage of 10 patients. On the basis of meeting 95% of the coverage, the V105% of IMRT was minimal, significantly lower than that of 3DCRT and FIF-IMRT, but was not significantly different with FFF-IMRT. The Dmax of 3DCRT was maximal, significantly higher than that of HYBRID, which was the minimum, and significantly lower than that of VMAT and FFF-VMAT, but without differences with IMRT.

The CIs of 3DCRT, FIF-IMRT and HYBRID were significantly worse than those of IMRT, FFF-IMRT, VMAT, and FFF-VMAT. The CIs in IMRT, FFF-IMRT, VMAT, and FFF-VMAT were no significant difference. The HIs of IMRT and FFF-IMRT were superior to those of other techniques.

Doses to breast implant

There were no significant differences in V20 (Vx indicating the volume of OARs or target volume receiving xGy), V30 and V55 among the seven techniques; the V40 and V50 values of IMRT, FFF-IMRT, VMAT, and FFF-VMAT were significantly lower than those of other techniques, but there

Table 4 Comparison of dose to the breast implant between the rival techniques

Technique	V20	V30	V40	V50	V55	Dmin	Dmax	Dmean
3DCRT	100±0	100±0	100±0^{A}	79.7±26.2^{A}	3.19±3.6	4,904.0±147.3^{A}	5,561.1±170.2^{A}	5,157.0±130.6^{A}
FIF-IMRT	100±0	100±0	100±0^{a}	92.4±13.5^{B,a}	5.7±17.9	4,867.1±132.1^{a}	5,397.6±188.3^{B,a}	5,196.0±129.5^{a}
HYBRID	100±0	100±0	100±0^{c}	19.5±13.6^{B,b,c}	0±0	4,462.1±121.7^{B,b,c}	5,216.3±50.3^{B,b,c}	4,839.6±85.8^{B,b,c}
IMRT	100±0	99.8±0.6	80.1±10.0^{B,b,d}	5.0±3.2^{B,b,d}	0±0	3,192.5±328.1^{B,b,d}	5,225.0±66.8^{B,b,e}	4,395.3±120.8^{B,b,d}
FFF-IMRT	100±0	99.7±0.9	79.0±9.4^{B,b,d}	4.5±2.4^{B,b,d}	0±0	3,121.2±328.5^{B,b,d}	5,197.4±54.8^{B,b,g}	4,383.9±117.0^{B,b,d}
VMAT	100±0	99.2±2.4	83.4±14.3^{B,b,d}	9.7±6.9^{B,b}	0±0	3,222.8±487.6^{B,b,d}	5,378.4±81.5^{B,d,f,h}	4,461.0±208.6^{B,b,d}
FFF-VMAT	100±0	99.1±2.8	83.7±12.1^{B,b,d}	9.9±8.4^{B,b}	0±0	3,178.4±543.3^{B,b,d}	5,390.6±88.7^{B,d,f,h}	4,461.0±204.8^{B,b,d}

Vx, percentage of the target volume covered by xGy. Dmin, Dmax and Dmean, the minimal, maximal and mean dose. ^{A} had significant difference with ^{B} ($P<0.05$), ^{a} had significant difference with ^{b} ($P<0.05$), ^{c} had significant difference with ^{d} ($P<0.05$), ^{e} had significant difference with ^{f} ($P<0.05$), ^{g} had significant difference with ^{h} ($P<0.05$). Otherwise the differences were not significant between any two ($P>0.05$). 3DCRT, three-dimensional conformal radiation therapy; FFF, flattening filter-free; FIF, field-in-field; HYBRID, the mixture of 3DCRT and IMRT; IMRT, intensity-modulated radiation therapy; VMAT, volumetric-modulated arc therapy.

was no significant difference between the four techniques. The IMRT and FFF-IMRT techniques could reduce the exposure dose and volume to breast implant including V40, V50, Dmax, and Dmean; significantly lower than those of 3DCRT and FIF-IMRT. The V40, V50, Dmin, and Dmean in IMRT and FFF-IMRT were also significant difference with HYBRID. IMRT and FFF-IMRT also had significantly lower dose to breast implant compared to VMAT and FFF-VMAT, but there was no significant difference between IMRT and FFF-IMRT (*Table 4*) (*Figures 1,2*).

Dose to ipsilateral lung and heart

The V10 and Dmean of ipsilateral lung in VMAT and FFF-VMAT were higher than those of other techniques. In addition, there was no significant difference in the ipsilateral lung between VMAT and FFF-VMAT. The V10, V20, and Dmean of ipsilateral lung were also no significant difference among the techniques including 3DCRT, FIF-IMRT, HYBRID, and IMRT. FIF-IMRT was better than FFF-IMRT, VMAT, FFF-VMAT in terms of the V10. The dose to ipsilateral lung in IMRT was in the range of traditional radiation techniques and VMAT, but there was no significant difference between IMRT and FFF-IMRT (*Table 5*). The FFF technique did not affect the dose to the ipsilateral lung in IMRT and VMAT

For the exposure dose to the heart in seven patients with left breast cancer, the V10 of IMRT, FFF-IMRT, VMAT, and FFF-VMAT were significantly higher than that of other techniques. However, there were no significant differences among the four techniques including V10, V20, V30, V40, Dmin, Dmax and Dmean. In addition, the V40 of the heart were improved in IMRT, VMAT and FFF-VMAT compared with 3DCRT, FIF-IMRT, and HYBRID. The FFF technique also did not affect the dose to the heart in IMRT and VMAT (*Table 5*).

Discussion

3DCRT is generally recommended for radiation in breast cancer, but study has found that use of IMRT significantly reduce the radiation dose to OARs, with a better target dose coverage when compared to 3DCRT (17). In this study, we compared the target volume coverage, doses to breast implant and OARs using seven techniques for breast cancer after mastectomy and immediate breast reconstruction. Our results show that the IMRT technique minimizes the dose to breast implant, with acceptable doses to ipsilateral lung

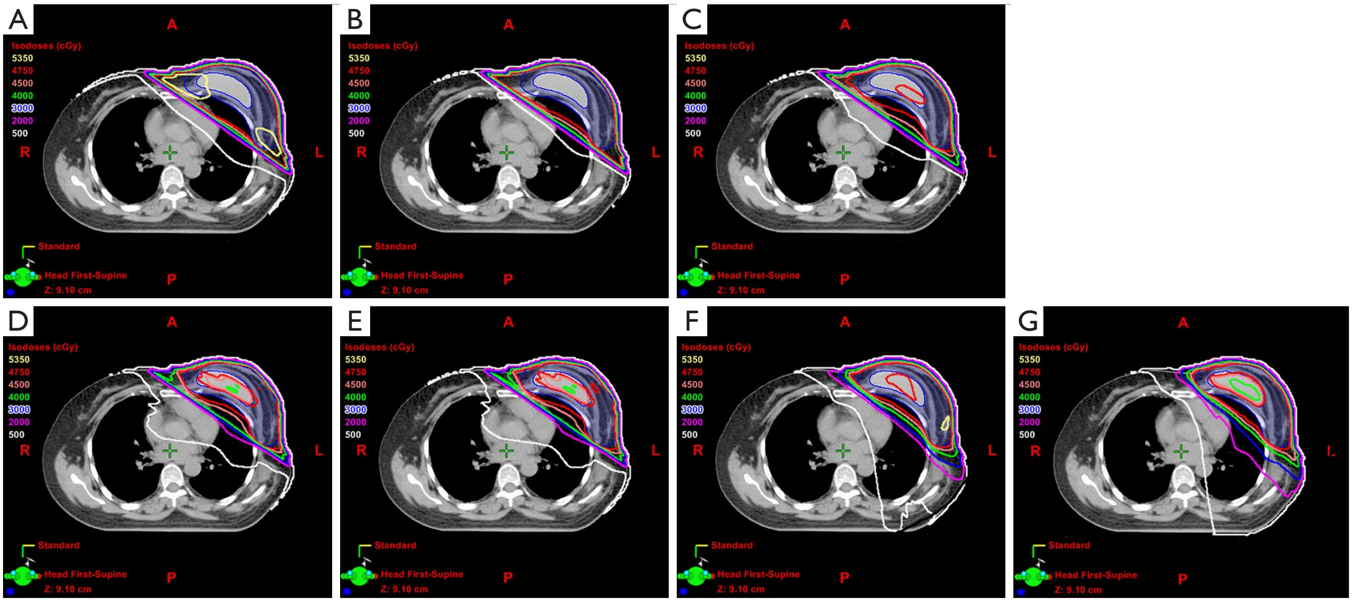

Figure 1 Axial dose distributions of breast reconstruction volume coverage and organs at risks according to (A) 3DCRT; (B) FIF-IMRT; (C) HYBRID; (D) IMRT; (E) FFF-IMRT; (F) VMAT; (G) FFF-VMAT. 3DCRT, three-dimensional conformal radiation therapy; FIF-IMRT, field-in-field intensity-modulated radiation therapy; HYBRID, the mixture of 3DCRT and IMRT; IMRT, intensity-modulated radiation therapy; FFF, flattening filter-free; VMAT, volumetric-modulated arc therapy.

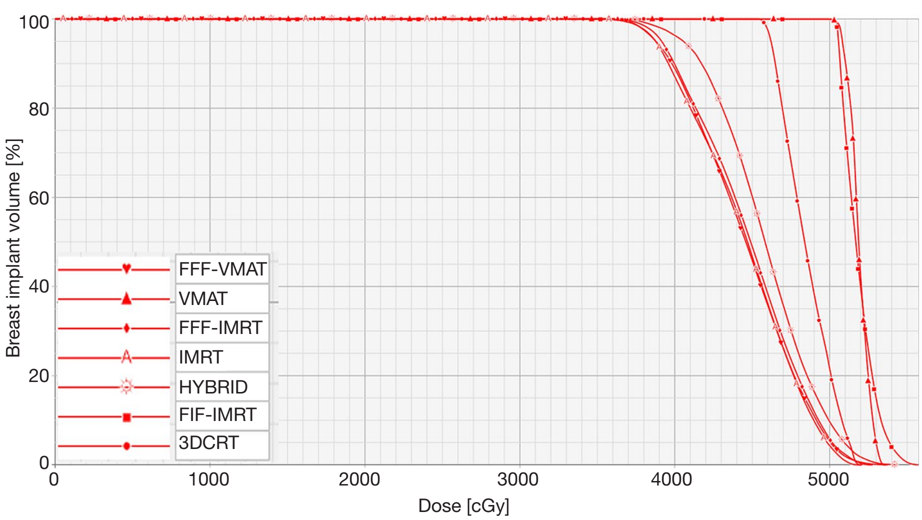

Figure 2 Dose volume histogram of the breast implant with seven irradiation techniques.

and heart, while ensuring a better target volume coverage.

The potential effect of PMRT on breast implant could lead to capsular contracture, which might even require removal of the breast implant (7-11). The exact correlation between PMRT and capsular contracture is still unclear. However, a previous study has found that PMRT can induce modifications of silicone (12), and radiotherapy is an important factor leading to breast implant removal (21,22). Nevertheless, unified criteria on the radiotherapy mode and technique after implant-based breast reconstruction are lacking. The use of PMRT for patients with positive axillary lymph nodes has increased over time, but the

Table 5 Comparison of dose to the ipsilateral lung and heart between the rival techniques

Organ at risks	Technique	V10	V20	V30	V40	Dmin	Dmax	Dmean
Ipsilateral lung	3DCRT	24.5±6.9^{A}	23.9±5.8	21.4±5.4^{A}	18.5±5.2^{A}	111.0±43.8^{A}	5,402.2±151.0^{A}	1,376.0±294.2^{A}
	FIF-IMRT	27.1±6.2^{a}	23.1±5.6	20.7±5.2^{a}	16.6±4.4^{a}	39.7±20.9^{B,a}	5,133.1±157.3^{B,a}	1,189.4±252.4^{a}
	HYBRID	29.9±5.4^{c}	23.5±5.3	20.6±4.8^{c}	15.4±3.0^{B,c}	47.1±17.2^{B,c}	4,978.0±86.5^{B,b,c}	1,248.3±213.6^{c}
	IMRT	36.7±5.4^{e}	24.0±4.5	17.5±3.7^{B}	11.7±2.4^{B,b,d}	56.9±17.3^{B,e}	5,078.3±89.5^{B,e}	1,295.5±177.8^{e}
	FFF-IMRT	37.3±6.9^{b,g}	23.8±4.6	17.5±3.8^{B}	11.8±2.5^{B,b,d}	63.3±17.9^{B,b,g}	5,111.7±73.1^{B,d,g}	1,302.7±191.3^{g}
	VMAT	56.3±19.6^{B,b,d,f,h}	26.1±6.3	16.7±3.3^{B,b,d}	10.0±2.2^{B,b,d}	110.2±25.3^{b,d,f,h}	5,222.1±83.6^{B,d,f,h}	1,587.8±191.3^{b,d,f,h}
	FFF-VMAT	60.1±17.3^{B,b,d,f,h}	26.3±4.6	16.6±2.8^{B,b,d}	10.0±2.2^{B,b,d}	116.6±24.3^{b,d,f,h}	5,214.2±119.5^{B,d,f,h}	1,635.6±237.5^{B,b,d,f,h}
Heart (left breast)	3DCRT	16.4±7.4^{A}	13.5±6.5	12.1±6.0	10.5±5.3^{A}	146.4±21.4^{A}	5,319.0±98.8^{A}	942.2±321.4
	FIF-IMRT	15.2±7.1^{a}	13.1±6.4	11.6±5.8	9.7±5.0^{a}	38.8±10.4^{B,a}	5,115.8±124.6	751.2±304.3^{A}
	HYBRID	22.1±10.5^{c}	13.7±6.6	11.9±5.9	9.7±4.9^{c}	54.7±13.9^{B,c}	4,933.5±117.4^{B}	961.3±317.1
	IMRT	42.2±8.1^{B,b,d}	17.9±8.8	9.4±5.0	4.8±3.4^{B,b,d}	82.0±17.4^{B,b,d,e}	5,083.5±311.6	1,221.3±247.6^{B}
	FFF-IMRT	42.0±8.4^{B,b,d}	18.6±10.1	9.5±5.2	5.2±3.5^{B}	87.9±19.0^{B,b,d,g}	5,079.2±251.1	1,228.7±265.4^{B}
	VMAT	37.1±15.3^{B,b,d}	12.5±6.3	6.5±3.8	2.3±1.6^{B,b,d}	158.3±24.2^{b,d,f,h}	4,991.5±307.2^{B}	1,062.0±254.6
	FFF-VMAT	37.8±13.7^{B,b,d}	14.2±8.0	6.8±4.3	2.9±2.3^{B,b,d}	175.6±26.6^{B,b,d,f,h}	5,042.7±3,330.2	1,126.5±256.6^{B}

Vx, percentage of the target volume covered by xGy. Dmin, Dmax and Dmean, the minimal, maximal and mean dose. ^{A} had significant difference with ^{B} ($P<0.05$), ^{a} had significant difference with ^{b} ($P<0.05$), ^{c} had significant difference with ^{d} ($P<0.05$), ^{e} had significant difference with ^{f} ($P<0.05$), ^{g} had significant difference with ^{h} ($P<0.05$). Otherwise the differences were not significant between any two ($P>0.05$). 3DCRT, three-dimensional conformal radiation therapy; FFF, flattening filter-free; FIF, field-in-field; HYBRID, the mixture of 3DCRT and IMRT; IMRT, intensity-modulated radiation therapy; VMAT, volumetric-modulated arc therapy.

breast reconstruction rates did not decrease (23). Breast reconstructions are located in the conventional tangential field during PMRT. Therefore, it is difficult to avoid an irradiation dose to the breast reconstruction (24).

In a study with flap reconstruction, Lee *et al.* found that HYBRID could reduce over 10% of the mean dose to the flapped area compared with 3DCRT and FIF-IMRT, and the mean dose of HYBRID was 12.8% and 3.9% higher than that of IMRT and VMAT (25). Our results suggest that IMRT and FFF-IMRT techniques could reduce the exposure dose and volume to breast implant than those of other techniques. However, it is still unclear whether dose improvement can enhance the reconstruction effect. Ribuffo *et al.* found that radiation-induced modifications of silicone may be one of the co-factors underlying capsular contracture (12). Therefore, the exposure dose to breast implant should be reduced as much as possible, which may decrease the risk of capsular contracture. IMRT technique is suitable for use in breast cancer after mastectomy and immediate breast reconstruction.

FFF beams offer the potential benefit for a higher dose rate, shorter treatment time, and lower peripheral dose (18). In this study, we did not find that the application of FFF technique in IMRT and VMAT could improve the dose to the target volume, breast implant and OARs. Other studies have also failed to find the advantages of FFF technique in breast cancer radiation therapy (18,26), although FFF mode may be suitable for use with hypofractionated dose schemes (27). IMRT exhibited acceptable acute toxicities and better clinical outcomes in patients after breast-conserving surgery (13,14,16). In our study, VMAT had advantages such as a better CI and significantly reduced high-dose range of OARs; however, the low-dose volume of VMAT was significantly higher than that of other techniques, especially in the ipsilateral lungs. In a dosimetric study of left sided breast cancer after breast-conserving surgery, the IMRT technique has demonstrated the combined advantages in target volume coverage and dose to most OARs, besides for the heart and coronary artery compared to VMAT (28). Therefore, the potential risk of radiation-induced secondary lung cancer should be considered before using VMAT (29), especially in young women with breast cancer.

Several limitations should be acknowledged in this study. First, it was a dosimetric study and unable to represent final clinical results. Second, movement caused by breathing could have affected the actual dose to the target volume and OARs during breast radiation, whereas an active breathing control (ABC) technique may have improved the relevant conditions (30,31). However, studies with breast IMRT after breast-conserving surgery in which the ABC technique was not applied have exhibited acceptable acute toxicities and clinical outcomes (13,14).

Conclusions

In conclusion, according to our dosimetric study, IMRT achieves similar or superior target volume coverage and a better breast implant sparing for patients with breast implant after immediate breast reconstruction.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/tcr.2017.06.38). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of the First Affiliated Hospital of Xiamen University (No.2016J01635) and written informed consent was obtained from all patients.

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