Atom Indonesia

Journal homepage: http://aij.batan.go.id

Skin Dosimetric Comparison of 3DCRT and IMRT Planning for Post-Mastectomy Breast Radiotherapy

F. K. Hentihu[1*], A. K. Anto[1], R. S. Nugroho[1,2]

[1]*Radiotherapy Department, Lavalette Hospital, Jl. W. R. Supratman 10, Malang 65111, Indonesia*

[2]*Radiotherapy Department, Saiful Anwar General Hospital, Jl. Jaksa Agung Suprapto 2, Malang 65111, Indonesia*

ARTICLE INFO

Article history:
Received 21 December 2020
Received in revised form 16 December 2021
Accepted 29 December 2021

Keywords:
3DCRT
IMRT
Post-mastectomy radiotherapy
Skin dose
Skin-sparing

ABSTRACT

Breast cancer is the most common cancer for incidence and mortality among females globally and in Indonesia. Mastectomy is still the most common surgery for female breast cancer in Indonesia. After the mastectomy, several patients will receive a whole breast radiotherapy session. About 68.75 % of breast cancer patients in the radiotherapy department at Lavalette Hospital during 2019 had undergone the mastectomy. Radiotherapy treatment for breast cancer can be delivered using Intensity Modulated Radiotherapy (IMRT) or 3D-Conformal Radiotherapy (3DCRT) technique. This study is aimed to compare the skin dosimetric between IMRT and 3DCRT for post-mastectomy breast radiotherapy. Left-sided breast cancer patients who underwent radiotherapy at Lavalette Hospital during 2019 were included in this study, and 15 patients were selected. All patients received 50 Gy in 25 fractions over 5 weeks using 6 MV photons. The planning target volume (PTV) and organ at risk (OAR) were delineated. Skin with 3 mm thickness along PTV was also contoured for evaluating the dose delivered to the skin. The treatment planning was conducted using 3DCRT and 5 fields IMRT planning. The plans were optimized for at least 95 % of the prescribed dose to cover 95 % volume of the PTV. The mean dose and maximum dose were used for evaluating and comparing each plan. The skin's mean dose from 3DCRT planning was 24.65 ± 4.12 Gy and 22.85 ± 3.68 Gy (p = 0.002) for IMRT planning. Meanwhile, skin maximum doses were 54.15 ± 0.68 Gy and 53.89 ± 1.05 Gy (p = 0.001) respectively for 3DCRT and IMRT planning. These results showed that IMRT offered a lower dose to the skin and a better skin-sparing effect than 3DCRT.

INTRODUCTION

Breast cancer is one of the most commonly diagnosed cancers among females. Based on Global Cancer Statistic 2018, breast cancer is the most common cancer for incidence and mortality among females both globally and in Indonesia [1]. The common treatments for female breast cancer are surgery (radical mastectomy or breast-conserving surgery), chemotherapy, and radiotherapy. The treatment could be the adjuvant of several modalities or only one modality, depending on the physician's decision.

Mastectomy is still the most common surgery for female breast cancer in Indonesia. After the mastectomy, several patients will receive a whole breast radiotherapy session. Radiotherapy sessions after mastectomy can reduce the recurrence rate and improve survival rates [2]. About 68.75 % of breast cancer patients in the radiotherapy department at Lavalette Hospital during 2019 had undergone the mastectomy. The thickness of the chest wall will decrease after mastectomy. On the contrary, the skin has an average thickness of about 2-3 mm in healthy adults [3]. Therefore, there will be radiation-related dermatitis effects during whole breast radiotherapy.

Radiotherapy treatment for breast cancer can be delivered using Intensity Modulated Radiotherapy (IMRT) or 3D-Conformal Radiotherapy (3DCRT) technique. IMRT gives an optimal balance between target volume coverage and organ at risk (OAR) sparing for post-mastectomy radiotherapy [2,4]. IMRT also offers a

*Corresponding author.
E-mail address: fatimah.hentihu@gmail.com
DOI: https://doi.org/10.17146/aij.2022.1105

more prominent skin-sparing effect than 3DCRT in post-breast-conserving surgery-radiotherapy [3]. This study is aimed to compare the skin dosimetric between IMRT and 3DCRT for post-mastectomy radiotherapy.

METHODOLOGY

Left-sided breast cancer patients who underwent radiotherapy at Lavalette Hospital during 2019 were included, then 15 patients with chest wall thickness ≥ 1 cm were selected. The radio-opaque wire was used for surgical scar marker during CT Simulation. The simulation was performed using Toshiba Alexion 16 slices CT scanner with 3 mm slice thickness. During the simulation, the patient used an immobilization device with a 5-degree thorax-abdomen wedge (ORFIT - The AIO Solution). Monaco version 5.11.03 was used as a radiotherapy treatment planning system.

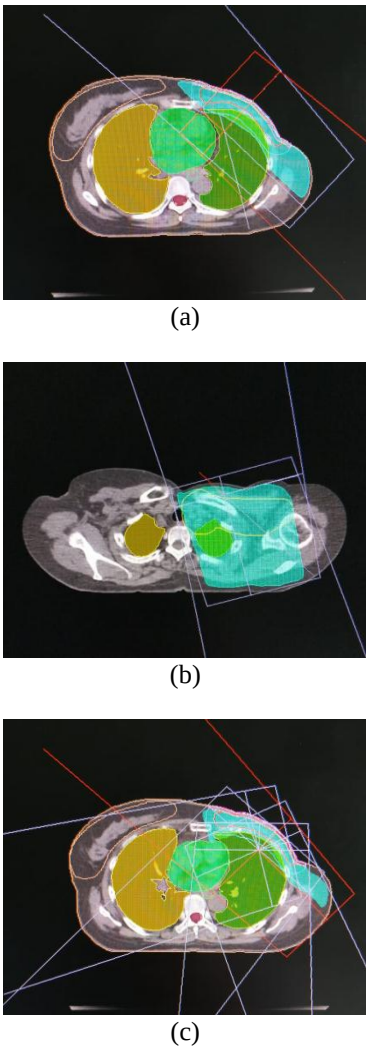
The prescribed dose was 50 Gy in 25 fractions, and a 6 MV photon was used. The planning target volume (PTV) and OAR were delineated. The OARs were heart, ipsilateral lung, contralateral lung, spinal cord, contralateral breast, and esophagus. Skin with 3 mm thickness was contoured for evaluating the dose delivered to the skin. The PTV was trimmed 3 mm from the skin for skin-sparing treatment planning.

The treatment planning was conducted using 3DCRT and 5fields-IMRT (5F-IMRT) planning for all patients. For 3DCRT, the field-in-field (FIF) technique was used for decreasing the hot spot. The calculation grid for both techniques was 3 mm × 3 mm. The collapsed cone algorithm was used for the 3DCRT plan, and the Monte Carlo algorithm was used for IMRT. The 3DCRT planning used 4 fields; two tangential opposed fields (range from 300°-313° for mediolateral field and 120°-133° for lateromedial field) for the chest wall and a pair of 345° and 165° fields for the supraclavicular area. The IMRT planning used 5 fields; 335°, 0°, 40°, 75°, and 135°. The field configuration for both plans can be seen in Fig. 1.

The plans were optimized to deliver a minimum of 95 % of the prescribed dose to 95 % of the PTV. The conformity and homogeneity index of target volume for both plans were evaluated and compared. The conformity index (CI) was calculated using Eq. (1) [5], and the homogeneity index (HI) was calculated using Eq. (2) [6].

$$CI = \frac{TV_{RI}}{TV} \times \frac{TV_{RI}}{V_{RI}} \quad (1)$$

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



(a)

(b)

(c)

Fig. 1. Field configuration for 3DCRT planning in the chest wall (a), supraclavicular area (b), and 5F-IMRT planning (c).

TV_{RI} is the target volume covered by the reference isodose, which is 95 % of the dose prescription (47.5 Gy). TV is the target volume, V_{RI} is the volume of reference isodose, and $D_{x\,\%}$ is the dose covering x % of the target volume. The CI values ranged from 0-1; the higher the value, the more conform the dose coverage to the target. The HI value close to 0 means better dose uniformity in the PTV.

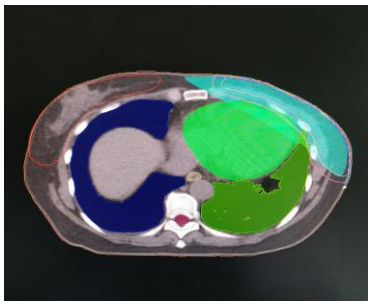
The dose limitations of the OARs were as follows: lung D_{mean} < 20 Gy; heart D_{mean} < 26 Gy; esophagus D_{mean} < 34 Gy; and spinal cord D_{max} < 45 Gy [7]. The skin dosimetric parameters were evaluated using mean dose (D_{mean}), maximum dose (D_{max}), V_{40}, and V_{30} (V_n was the percentage volume of skin surrounded by n Gy dose) for both plans. The statistical analysis to compare for both plans was conducted using SPSS Statistics 17.0 (IBM SPSS Statistics, USA) and Wilcoxon signed-rank test for paired t-test was used to

compare the two plans. A *p-value* < 0.05 was considered statistically significant.

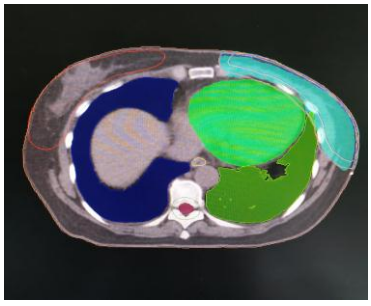
RESULTS AND DISCUSSION

The mean volume of PTV from 15 patients is 826.34 ± 35.72 cc. The volume that received 95 % (47.5 Gy) and 107 % (53.5 Gy) of the prescribed dose are compared. Table 1 shows the dosimetric parameter of PTV used to compare both plans, where $V_{y\ \%}$ is the percentage volume of the target surrounded by y % of dose prescription. Statistically, the $V_{95\ \%}$ for both planning is not significantly different, but IMRT could reduce the high dose in the target volume.

The 5 fields-IMRT (5F-IMRT) planning provides better CI numbers than 3DCRT planning, but the HI number is not significantly different for both planning. It shows that 5F-IMRT planning has better conformity than 3DCRT planning but relatively similar homogeneity. Figure 2 shows the target coverage within 47.5 Gy. The 5F-IMRT gives better coverage and is more conform than 3DCRT planning. Moreover, the 5F-IMRT planning also offers lower hot-spot volume than 3DCRT planning, as shown in the lower volume of the target that received 53.5 Gy. The previous studies conducted for post-mastectomy radiotherapy and comparing 3DCRT and 5F-IMRT have shown that 5F-IMRT has given better CI and HI values [4,8,9]. The better dose homogeneity and conformity in the target, then fewer high doses are received by normal tissue.



(a)



(b)

Fig. 2. The target coverage within 47.5 Gy for 3DCRT (a) and 5F-IMRT planning (b).

The comparison of OARs dosimetric shows in Table 2. The 3DCRT planning provides significantly lower mean doses for the heart, contralateral lung, esophagus, and contralateral breast than 5F-IMRT planning. The ipsilateral lung and spinal cord receive similar doses from the 3DCRT and 5F-IMRT planning. These results are consistent with the previous studies [3,4,8-11]. Those studies have shown that the mean dose received by OARs is lower for 3DCRT than 5F-IMRT planning. Other studies have shown that IMRT planning has offered better OARs sparing [12-14]. The 3DCRT planning has given better results for mean dose and reduced V_5, V_{10}, and $V_{20,}$ but IMRT could reduce high-dose irradiation (V_{30}) received by ipsilateral lung and heart [9]. The tangential beam configuration helps to reduce the dose received by the ipsilateral lung and heart.

Table 1. The PTV dosimetric parameter comparison for 3DCRT and 5F-IMRT planning.

Parameter	3DCRT	5F-IMRT	*p-value*
$V_{95\ \%}$ (%)	95.14 ± 0.43	95.01 ± 0.02	0.721
$V_{107\ \%}$ (%)	8.24 ± 5.71	0.32 ± 0.30	0.001
HI	0.18 ± 0.03	0.14 ± 0.03	0.001
CI	0.47 ± 0.04	0.65 ± 0.04	0.001

Table 2. The OARs dosimetric comparison for 3DCRT and 5F-IMRT planning.

Structure	Parameter	3DCRT	5F-IMRT	*p-value*
Heart	D_{mean} (Gy)	8.84 ± 2.82	18.52 ± 1.68	0.001
Ipsilateral lung	D_{mean} (Gy)	19.52 ± 2.77	20.32 ± 2.22	0.156
Contralateral lung	D_{mean} (Gy)	0.83 ± 0.10	7.09 ± 1.06	0.001
Esophagus	D_{mean} (Gy)	10.09 ± 3.68	20.01 ± 3.46	0.001
Contralateral breast	D_{mean} (Gy)	0.91 ± 0.17	3.56 ± 1.61	0.001
Spinal cord	D_{max} (Gy)	29.92 ± 9.96	30.57 ± 4.44	0.733

The 5F-IMRT planning offers a higher monitor unit than 3DCRT planning. In this study, the monitor unit values are 494.30 ± 25.61 MU and 700.42 ± 47.75 MU for 3DCRT and 5F-IMRT planning. The higher the MU value, the longer the treatment time needed. The number of beams used and the high MU in IMRT have caused a larger volume of normal tissue to be irradiated with a lower dose [11,14,15]. The cumulative DVH of the heart, ipsilateral lung, and contralateral breast can be seen in Fig. 3. The cumulative DVH shows that 5F-IMRT planning provides a larger volume of lower doses in each organ.

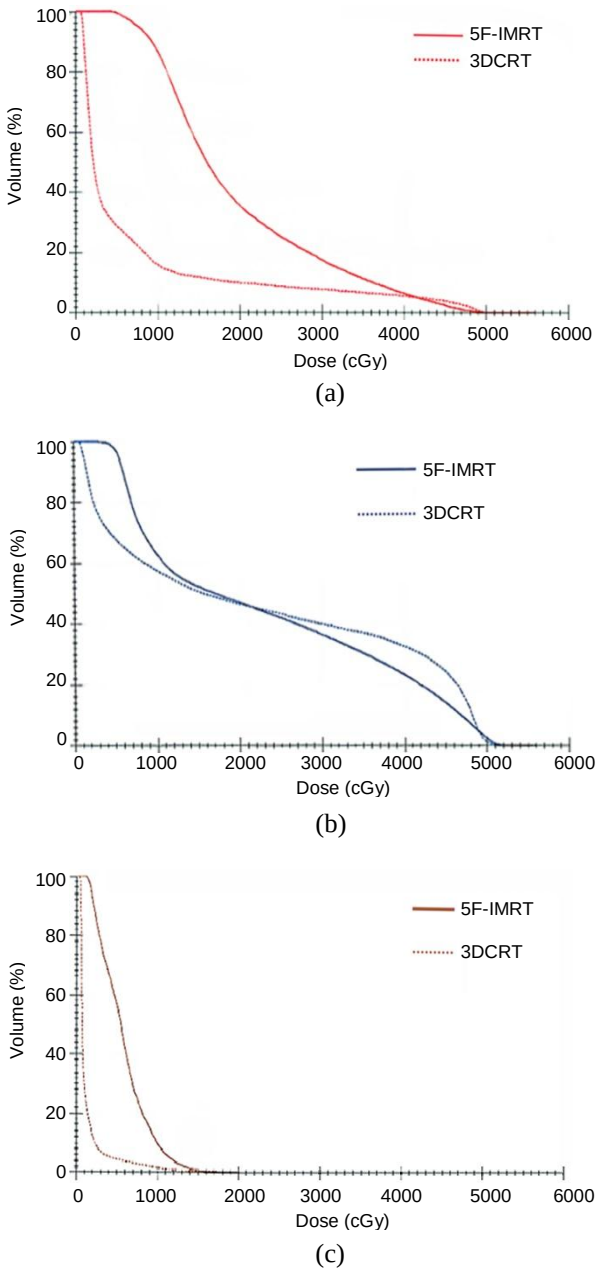


Fig. 3. The cumulative DVH for the heart (a), ipsilateral lung (b), and contralateral breast (c).

Table 3. The skin dosimetric parameters comparison for 3DCRT and 5F-IMRT planning.

Parameter	3DCRT	5F-IMRT	*p-value*
V_{30} (%)	48.69 ± 9.67	39.75 ± 9.88	0.001
V_{40} (%)	31.47 ± 6.97	21.40 ±6.31	0.001
D_{mean} (Gy)	24.65 ± 4.12	22.85 ± 3.68	0.002
D_{max} (Gy)	54.15 ± 0.68	53.89 ± 1.05	0.001

The skin is defined as a structure with 3 mm thickness for the area exposed by radiation. The skin dosimetric parameters are evaluated using: the mean dose, maximum dose, V_{40}, and V_{30} for both plans. The skin dosimetric parameters can be seen in Table 3, and the cumulative DVH is presented in Fig. 4. The 5F-IMRT planning presents a lower skin dose than 3DCRT. It means that IMRT planning offers a better skin-sparing effect. These results are in line with the previous studies [3,13].

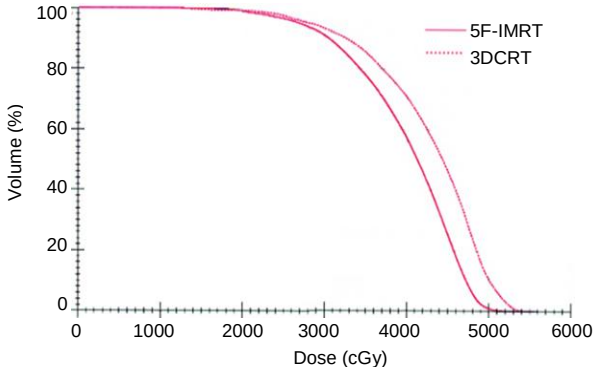


Fig. 4. The cumulative DVH of 3 mm skin structure.

The IMRT planning reduces the high dose received by the skin because it has better dose conformity covering the target. The dose homogeneity in the target affects the chance of skin toxicity. The better dose homogeneity in IMRT could reduce skin toxicity [3,16,17]. V_{40} has provided a significant impact on moist desquamation [17]. In this study, V_{40} also provides a high difference between both plans.

Another study based on NTCP modelling found that V_{35} for skin dosimetric parameters used to predict the risk of grade 2^{+} dermatitis in breast radiotherapy and dose constraint V_{35} < 85.7ml used to keep the incident of grade 2^{+} of toxicity less than 50 % [18]. Besides the dosimetric parameter and planning technique, patient characteristics should be considered for the incident of skin toxicity as well. Previous studies have shown that breast size also was one of the parameters which affected skin toxicity [16,19]. The dosimetric parameter from each plan is different for every patient because each patient has different anatomy and target volume.

CONCLUSION

The IMRT planning offers better skin-sparing which is good for cosmetic purposes without compromising the target coverage. The better skin-sparing, the lower probability of skin toxicity occurrence. However, the IMRT planning gave a higher dose in OARs, and the heart requires a high consideration during left-sided breast radiotherapy. The 3DCRT planning provides a better sparing for the OARs so that a lower volume of the normal tissue received a low dose and a lower MU which gave a shorter treatment time. The patient characteristics and skin-sparing can be considered in

planning selection as well, aside from the OARs sparing and target coverage.

AUTHOR CONTRIBUTION

F.K. Hentihu and A.K. Anto selected patients, conducted the planning, and collected the data. R.S. Nugroho delineated the target and organ at risk. F.K. Hentihu wrote the manuscript with the help and input from A.K. Anto and R.S. Nugroho. All authors read and approved the manuscript.

REFERENCES

1. F. Bray, J. Ferlay, I. Soerjomataram *et al.*, CA. Cancer J. Clin. **68** (2018) 394.
2. J. Hu, G. Han, Y. Lei *et al.*, Biomed. Res. Int. **2020** (2020) 1.
3. I. Y. Jo, S. -W. Kim and S. H. Son, Oncotarget **8** (2017) 3059.
4. C. Ma, W. Zhang, J. Lu *et al.*, Sci. Rep. **5** (2015) 12274.
5. L. Feuvret, G. Noël, J. -J. Mazeron *et al.*, Int. J. Radiat. Oncol. **64** (2006) 333.
6. H. G. Menzel, A. Wambersie, D. T. L. Jones *et al.*, ICRU REPORT 83: Prescribing, Recording, and Reporting Photon-Beam Intensity-Modulated Radiation Therapy (IMRT) 2010.
7. L. B. Marks, E. D. Yorke, A. Jackson *et al.*, Int. J. Radiat. Oncol. Biol. Phys. **76** (2010) S10.
8. B. S. Ozdemir and O. Kirecci, UHOD - Uluslar. Hematol. Onkol. Derg. **29** (2019) 191.
9. S. Wei, N. Tao, S. Ouyang *et al*., Precis. Radiat. Oncol. **3** (2019) 80.
10. M. Kausar, O. P. Gurjar, P. Bagdare *et al.*, J. Radiother. Pract. **15** (2016) 30.
11. Z. S. Al-Rahbi, Z. Al Mandhari, R. Ravichandran *et al*., J. Med. Phys. **38** (2013) 22.
12. W. Wang, Y. Zhang, M. Xu *et al.*, Cancer Manag. Res. **11** (2019) 1097.
13. K. Rastogi, S. Sharma, S. Gupta *et al*., Radiat. Oncol. J. **36** (2018) 71.
14. V. Rudat, A. A. Alaradi, A. Mohamed *et al*., J. Clin. Oncol. **28** (2010) e11087.
15. E. Haciislamoglu, F. Colak, E. Canyilmaz *et al*., SpringerPlus **5** (2016) 688.
16. G. M. Freedman, P. R. Anderson, J. Li *et al*., Am. J. Clin. Oncol. **29** (2006) 66.
17. K. J. Borm, M. Loos, M. Oechsner *et al*., Radiat. Oncol. **13** (2018) 218.
18. T. -F. Lee, K. -C. Sung, P. -J. Chao *et al.*, PLoS One **13** (2018) e0200192.
19. J. B. Schnur, S. C. Ouellette, T. A. DiLorenzo *et al.*, Psycho-Oncology. **20** (2011) 260.