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Comparison of dose distribution 6 MV photon in breast cancer treatment using plasticine and silicone rubber boluses

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ABSTRACT

There are many cases where treatment of breast cancer was performed with thin body contours, especially after the breast mastectomy. This may lead in a larger radiation dose in the lungs, so that a bolus is needed to compensate the thin body for the optimal dose distribution. This study was aimed to compare the dose distribution in the breast cancer treatment between using commonly used of the plasticine bolus and newly developed bolus, i.e. the sillicone rubber. The study was implemented in the chest of an anthropomorphic phantom. The anthropomorphic phantom was scanned using a CT scanner without bolus and with boluses of the plasticine and the silicone rubber. The dose distribution was calculated using the Xio treatment planning system (TPS). The results show that a dose reduction of the sillicone rubber bolus that reaches the breast tissue higher than the plasticine bolus. This is because the silicone rubber bolus has a higher number electron density than the plasticine bolus. The silicone rubber bolus may produce an optimal dose homogeneity within breast cancer and relatively lower dose to the lung.

Keywords: breast cancer, bolus, plasticine, sillicone rubber, dose homogeneity

I. INTRODUCTION

Breast cancer is a malignancy that often occurs in women. Clinically, there are two types of breast cancer, i.e. breast cancer stays in the ductus or in the lobular, and invasive breast cancer. Clinical treatments of breast cancer are surgery, chemotherapy, hormonal therapy, or radiotherapy. The treatment can be accomplished with a combination of both radiotherapy and chemotherapy [1], surgery with radiotherapy, surgery with chemotherapy, or radiotherapy with hormonal therapy. Application of radiotherapy to the breast cancer reduces the recurrence rate and increases the quality life for patients with a palliative stage. In radiotherapy, the tumor area is limited by the primary tumor and the lymph node areas. The primary tumor is at the location of the chest wall, while the surrounding lymph nodes are the supraclavicular and axillary glands [2].

The treatment of the breast cancer depends on the level of malignancy which is determined by the

presence of tumor (T), nodules (N), and defined metastases (M). In the early stages (i.e. stages I and II), combination of surgery and radiotherapy is an effective treatment. Combination of chemotherapy and hormonal therapy can also be chosen. In stages I-II, adjuvant is used, i.e. surgery first and it is followed by radiotherapy for kill the tumor roots [2]. In stage III, neo adjuvant is used, i.e. radiotherapy first and it is followed by surgery. Meanwhile, in the late stage (i.e. stage IV) with spreading cancer to the bone or poor prognosis, chemotherapy combined with palliative radiotherapy is generally chosen [1].

In our hospital (Dr. Sardjito hospital), 6 MV photon beams is usually used for treating a deep seated breast cancer, however the high energy electron beam can also be used for treating superficial tumor.

If breast cancer is treated using 6 MV photon beams, additional boluses are often required due to a very close distance between the lungs and the skin surface for a thin body or post-surgery patients. Bolus is used for tissue compensation, and is put on the skin at proper angles to the beam axis [1,3,4]. Additional boluses make a distance from the lungs to the artificial skin surface (i.e. surface of bolus) farther. Bolus is used for the purpose of increasing the dose within the clinical target volume (CTV). Bolus is made from a tissue-equivalent density material [3, 5-7]. Thus, the entrance dose to the skin increases due to electrons produced by the bolus. Since the bolus is in contact with skin, the depth of maximum dose (d_{max}) gets close to the skin surface. Therefore, bolus is considered as one of the compensators for delivering a homogeneous dose distribution within the CTV. In our hospital, it was recorded that 11% patients (total of 240 patients) with breast cancer from August 2018 to December 2018 were treated by using boluses.

The bolus used in our department is a plasticine (PTN) bolus. The PTN is one type of soft material called the oil-based clay made from aliphatic acid ingredients, and petroleum jelly calcium salt. Clinically, the PTN bolus is generally used as a compensator for breast cancer radiation. The PTN bolus is easy to be found in the market, easy to be formed, and it has a low price. In some cases, the PTN bolus is also suitable for surface radiation with uneven contours using an electron radiation source.

Another available bolus is Natural Rubber which has an electron density similar to the density of human tissue [8]. In a previous study [9], the bolus from silicone rubber (SR) has been proposed. The SR is a type of synthetic polymer that has a function as an easily formed material with good flexibility [8,9]. It was reported that the use of SR at a thickness of 1 cm was able to increase the dose on the surface of the skin at 5 and 7 MeV energies. However, comprehensive study on the use of SR bolus in clinical patients or anthropomorphic phantom has never been carried out. A previous study was only conducted on surface dose. Therefore, the purpose of this study is to evaluate the dose distribution within the CTV and OAR due to implementation of SR bolus in breast cancer treatment for thin or post-surgery patient. The implementation of the SR bolus will also be compared with the PTN and treatment planning (TPS) boluses.

II. METHODS AND MATERIAL

In this study, evaluation dose distribution within the CTV and OAR of using SR, PTN and TPS boluses was performed on 6 MV Elekta Precise Linear Accelerator (Elekta Oncology Systems, Crawley, UK). Contours of the CTV and OAR were created with a MonacoSIM software (Elekta Oncology Systems, Crawley, UK). The MonacoSIM is one of the specialized software to delineate tumor targets and contour the patient's organs and body. Dose distribution within patient was calculated using Xio TPS (Release 5.1Q license Elekta USA). Axial images were obtained using Toshiba Aquilion TSX-201A CT scanner (Toshiba Corporation, Japan). The evaluations were carried out on an anthropomorphic whole-body

phantom PBU-60 (Kyoto Kagaku CO.LTD) which has the same density and anatomy as humans.

A. Boluses development

In this study, boluses of SR and PTN with thickness of 0.5 and 1 cm were developed. The PTN bolus was produced by heating plastic bolus in a plastic bag then it was boiled for 15 minutes at a temperature of 70o C. After that, it was put in a bolus mold with thicknesses of 0.5 and 1 cm. Meanwhile, the SR bolus was made by mixing Silicone Rubber Resin (Indrasari Chemical shop, Semarang) and RTV 52 (Room temperature vulcanizing) (Indrasari Chemical shop Semarang) with 3% catalyst from resin liquid, and mixing 5% thinner of liquid so that the liquid did not freeze too fast and not too hard. The materials were mixed for 15 minutes and then it was poured into a mold bolus with thickness of 0.5 and 1 cm. The photograph of developed boluses is shown in Figure 1.

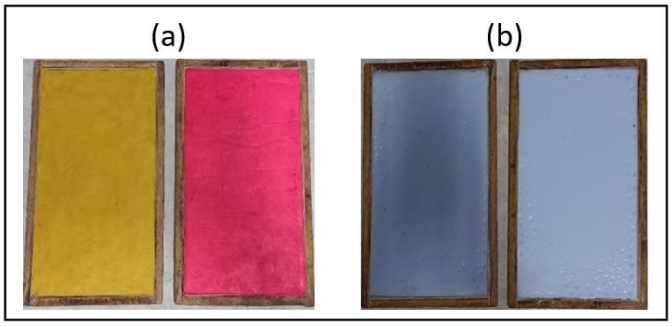

Figure 1. Photograph of developed boluses for thicknesses of 1 cm and 0.5 cm. (a) PTN, and (b) SR boluses.

B. CT images

The images of the anthropomorphic phantom with and without boluses were obtained with CT scanner that is devoted to TPS planning. A slice thickness of CT images was 0.5 cm, and images were acquired with 120 kVp and 150 mAs. An anthropomorphic phantom was scanned 5 times, i.e. without a bolus, with a Plasticine bolus of 0.5 cm, with a Plasticine bolus of 1 cm, with a SR bolus of 0.5 cm, with a SR bolus of 1 cm. The bolus was attached to the phantom as tightly as possible to avoid gab due to air which can reduce the surface dose [10-13]. Setting phantom position on CT scanner with bolus on the chest is depicted in Figure 2. CT images of the phantom with boluses of SR and PTN on right breast are depicted in Figure 3.

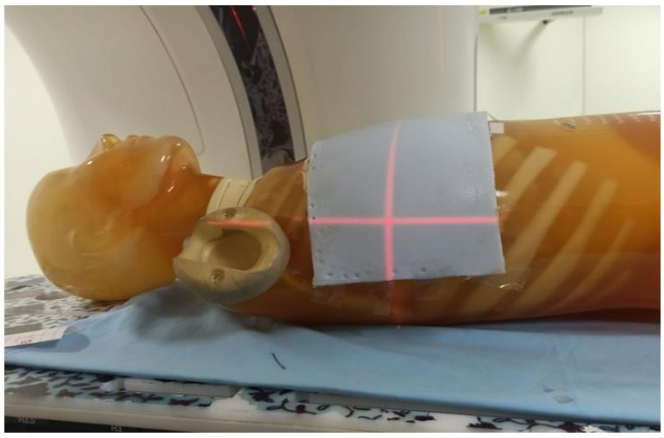

Figure 2. Setting position of anthropomorphic whole-body phantom on CT machine with bolus on its right chest.

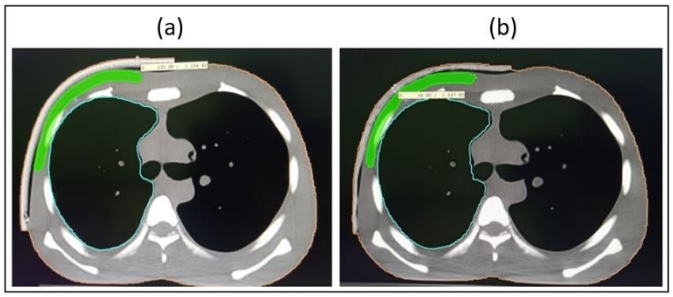

Figure 3. CT images of the phantom with boluses on right breast. (a) SR, and (b) PTN boluses. Images show contouring of right lung as organ at risk (OAR) and clinical target volume (CVT) (green color).

C. Calculation of dose distribution with TPS

Each data set was exported to the pre-planning workstation (MonacoSIM). Dose calculation was carried out using mono-isocenter technique as depicted in Figure 4. The mono-isocenter is a planning technique with half beam which has only one central point of treatment. The radiation field was made tangentially for the local region, and the radiation filed was given posteriorly in 2D for regional, i.e. supraclavicular lymph and the posterior axilla. For local region, the radiation dose was 6000 cGy and regional was 5000 cGy. This setting was used for planning with and without boluses. The TPS bolus

used an electron density of 1 as standard. The implementation the SR and PTN boluses were compared to the TPS bolus.

In each treatment planning, the CTV and OAR have been delineated. In this study, all parameters were kept constant. Position of iso-center was at coordinates x, y, z of (-2.75, -120.4, 5.99). The axis field was set to a length of 12.5 cm, a width of 9 cm, a gantry angle of 180°, a collimator angle of 30°, and a depth of 10 cm. The depth point was at the x, y, z coordinates of (-11.53, -11.95, -4.21). Supra-clavicula field was set with a length of 11.5 cm, a width of 14 cm, a gantry angle of 10°, a collimator angle of 90 °, with the manufacture of MLC blocks for the trachea, humeral head and pulmo. The depth point was at the x, y, z coordinates of (-6.73, -114.95, 1.07). The local tumor target field uses a 3D Conformal Radiotherapy (CRT) technique, which is a planning technique with a delineated target so that the MLC can follow or conform to the shape as planned. The local target uses 2 lighting fields with a gantry angle of 55° and 237° with a collimator angle of 0° and the depth point is at coordinates x, y, z of (-11.53, -118.95, -4.21).

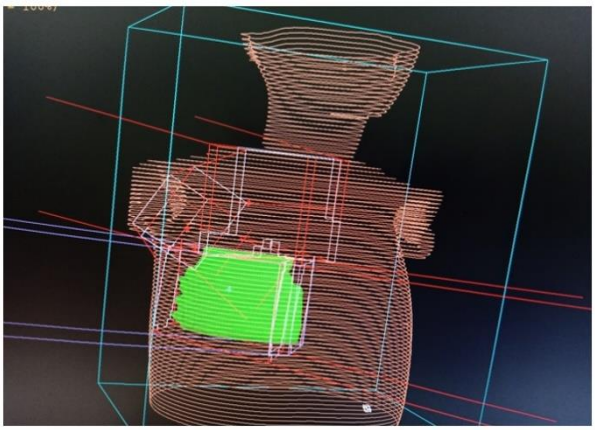

Figure 4. Treatment planning system with the mono-isocenter technique.

III.RESULTS AND DISCUSSION

Dose distribution in the anthropomorphic phantom without bolus is shown in Figure 5. It shows a hot spot with 100% dose (orange color) is outside the CTV (green color). Dose distributions with the TPS bolus for thicknesses of 0.5 cm and 1 cm are shown in Figure 6. The TPS bolus has a standard electron density of 1 which is equal to the density of body tissue. It shows a hot spot outside the CTV decreases compared to those without bolus. An implementation of bolus with thickness of 1 cm provides slightly lower dose to the right lungs compared to that of 0.5 cm.

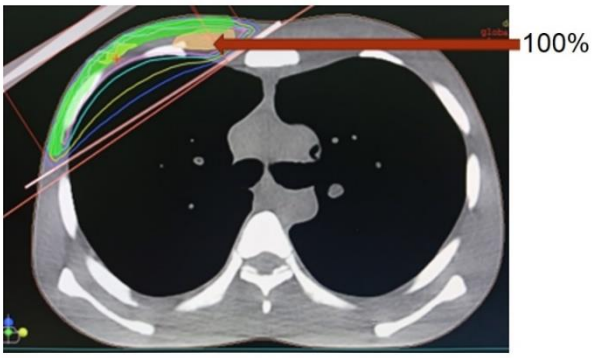

Figure 5. Dose distribution without bolus. It shows 100% dose (orange color) is outside the CTV (green color).

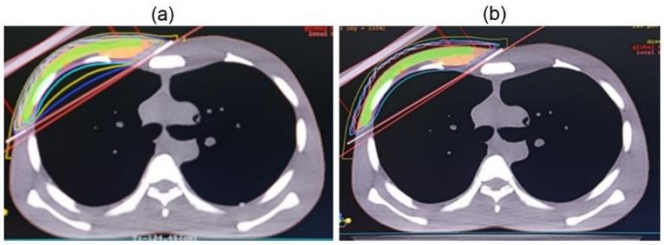

Figure 6. Dose distribution with the TPS bolus for 2 thicknesses. (a) 0.5 cm, and (b) 1 cm.

Dose distributions with the PTN bolus for thicknesses of 0.5 cm and 1 cm are shown in Figure 7, and dose distributions with the SR bolus for thicknesses of 0.5 cm and 1 cm are shown in Figure 8. It also shows a hot spot outside the CTV decreases compared to those without bolus. Visually, the dose distributions provide similar results to those of TPS bolus.

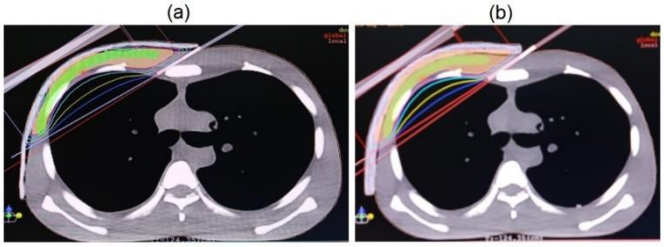

Figure 7. Dose distribution with the PTN bolus for 2 thicknesses. (a) 0.5 cm, and (b) 1 cm.

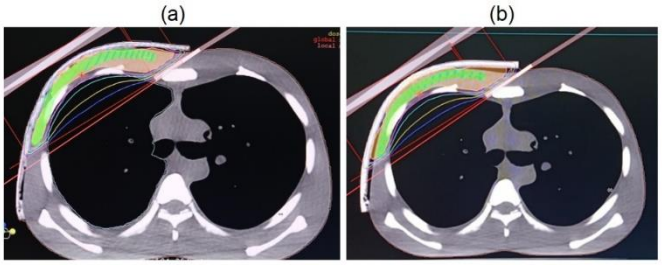

Figure 8. Dose distribution with the SR bolus for 2 thicknesses. (a) 0.5 cm, and (b) 1 cm.

The DVHs of CTV without and with various boluses are shown in the Figure 9. It shows a significant difference of CTVs. Planning without bolus, the CTV is covered by 41% dose. It is clear that implementation of boluses increases the doses in the CTV. 90% dose to the CTV is achieved using boluses. The implementation of the SR bolus is slightly higher dose to the CTV compared to the TPS and PTN boluses, both at thicknesses of 0.5 cm and 1 cm. It also shows that implementation of the 1 cm boluses is slightly higher dose to the CTV compared to 0.5 cm boluses. The DVHs of OAR without and with various boluses are shown in the Figure 10.

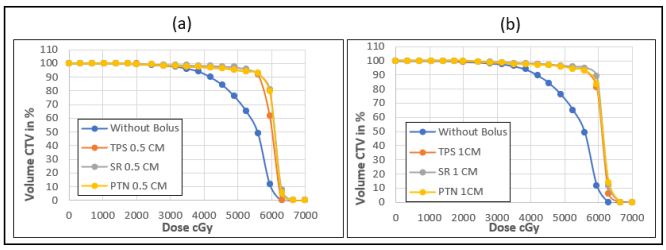

Figure 9. DVH comparison of CTV with and without boluses. (a) Bolus thickness is 0.5 cm, and (b) Bolus thickness is 1.0 cm.

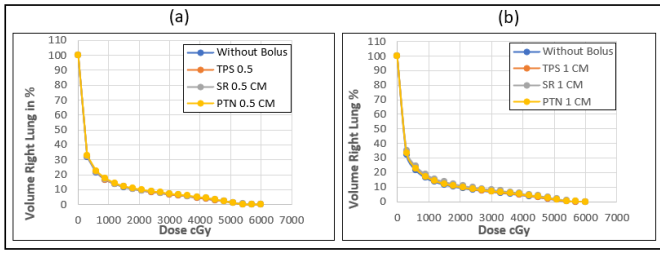

Figure 10. Comparison of DVH of OAR (right lung) with and without boluses. (a) Boluses with thickness of 0.5 cm, and (b) Boluses with thickness of 1.0 cm.

The DVH of CTV and OAR (i.e. right lung) without and with boluses of SR, PTN and TPS with thicknesses of 0.5 cm and 1.0 cm can be summarized in Table 1. The DVH statistics shows that the resulting trend of implementation of boluses is an increase dose in the CTV and a decrease dose in OAR. The highest CTV dose is obtained on implementation of the SR bolus of 1 cm with 95.15% in the CTV. However, the OAR dose is slightly higher than without bolus. Compared to the PTN bolus, the SR bolus provide higher dose to CTV and lower dose to OAR.

Table 1. DVH Statistics of CTV and OAR for radiotherapy with and without boluses of SR, PTN and TPS.

Bolus	Dose volume histogram (DVH) (%)	
	CTV	OAR (Right lung)
Without	41.57	9.57
TPS 0.5 cm	90.05	9.70
TPS 1.0 cm	92.42	10.06
PTN 0.5 cm	92.15	11.91
PTN 1.0 cm	92.34	12.35
SR 0.5 cm	94.62	11.75
SR 1.0 cm	95.15	11.98

Based on the finding of the current study that without bolus, the OAR is covered by 9.57 % doses. Based on the perception of radiotherapy practice, a planning without boluses is still good, because the dose of OAR is within 30%, based on standard OAR of the quantitative analysis of normal tissue effects in the clinic (QUANTEC) dose distribution. However, an implementation of the bolus will provide better result compared to those without bolus.

In clinical setting, the PTN bolus is generally used. Although, the PTN bolus is quite easy, quite elastic, and cheap to be produced, it still has many limitations. It was found a crack within PTN bolus after it had reached two weeks of use and it became hard [5].

Hence, an vailability of new bolus has characteristics of more elasticity than PTN bolus and does not break easily would be very useful in clinical practice. The SR bolus has had such characteristics [5,8,9]. However, careful study on its coverage dose to the CTV and OAR should be performed.

The current study is to evaluate the dose distribution within the CTV and OAR due to implementation of SR bolus in breast cancer treatment, and to compare the SR bolus to previous boluses of PTN and TPS boluses. It is found that the SR bolus provided higher dose coverage to the CTV and lower dose coverage to the OAR compared to two other boluses (Table 1). The electron density of SR, PTN and TPS boluses are 1.2 to 1.4, 1.1 to 1.2, and 1, respectively.

However, it should be noted that the process of producing an SR bolus is a slightly more complicated and requires a longer time than producing of the PTN bolus. The resulted SR bolus has denser than the PTN bolus. This is in accordance with previous studies [9] reported that the SR bolus has a density approach 1with similar soft tissue density so that it is able to increase the skin surface dose.

The current study showed that the material from the SR as bolus is better than the PTN material. However, careful further studies must be carried out because the current study is still limited to breast cancer in the anthropomorphic phantom. Careful study on sufficient cohort of patients will be very interesting. In addition, the current study only investigated two thicknesses of 0.5 cm and 1.0 cm. Evaluations of the SR bolus for different thicknesses will be helpful. Implementation of the SR bolus on other cases (other than breast cancer) will enlarge horizon on implementation of new bolus of SR.

IV. CONCLUSION

From this study, it can be concluded that the use of boluses will increase covered target tumor volume and reduce the dose in pulmonary OAR. It was found that the covered volume target tumor in the SR bolus was higher than the Plasticine bolus, and the covered dose in OAR pulmonary was lower than the Plasticine bolus. The SR bolus has better elasticity because it is not easy to dry and break like Plasticine bolus so the SR bolus may be useful for clinical use on patients

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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