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Implementation of Small Field Radiotherapy Dosimetry for Spinal Metastase Case

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Abstract. The main objective of this study was to know dose profile of small field radiotherapy in the spinal metastase case with source axis distance (SAD) techniques. In addition, we evaluated and compared the dose planning of stereotactic body radiation therapy (SBRT) and conventional techniques to measurements with Exradin A16 and Gafchromic EBT3 film dosimeters. The results showed that film EBT3 had a highest precision and accuracy with the average of the standard deviation of ±1.7 and maximum discrepancy of 2.6 %. In addition, the average value of Full Wave Half Maximum (FWHM) and its largest deviation in small field size of 0.8 x 0.8 cm^2 are 0.82 cm and 16.3 % respectively, while it was found around 2.36 cm and 3 % for the field size of 2.4 x 2.4 cm^2. The comparison between penumbra width and the collimation was around of 37.1 % for the field size of 0.8 x 0.8 cm^2, while it was found of 12.4 % for the field size of 2.4 x 2.4 cm^2.

INTRODUCTION

The third most widely location of cancer metastases after lung and liver is bone. Compared with its primary cancer, bone metastases are more common case, especially in adults [1]. The most common site of bone metastases is in the spine, about 50 % of bone metastases. Liang *et al*. [2] describe that 5 % to 10 % of patients with cancer will have spinal metastases. Recently small field radiotherapy is employed to care cancer and it can effectively control the primary and oligometastatic cancers in early stage that located along abdominopelvic, spinal, paraspinal and cavities of thoracic. The recent technology, stereotactic body radiation therapy (SBRT) employed the small dosimetry to treat the patient with cancer. The main thing that distinguishes SBRT from conventional radiotherapy is delivering few fractions in high doses, beside it has a high biological effective dose (BED). High doses that conform to the target and steep dose gradient outside the target is very important to reduce damage in normal tissues. Therefore, the SBRT treatment needs a high accuracy in the whole irradiation process [3].

Previous work has been done to evaluate the dose measurements in the case of spinal metastases with SBRT technique using Exradin A16 ion chamber. The results showed that the measurements on IMT anthropomorphic phantom for Exradin A16 ion chamber gave the deviation between measured and calculated doses in the thoracic region is 3.2 % [4]. Nuruddin [5] had performed the profile measurements on a small field of virtual water phantom using Elekta Synergy S and Gafchromic EBT film dosimeter. In this study, we prepared to evaluate the profile and the dosimetry implementation of SBRT and conventional methods of source surface distance (SSD) and source axis distance (SAD) in the medium spine in the lumbar and thoracic regions using Exradin A16 ionization chamber and Gafchromic EBT3 film dosimeter.

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METHODOLOGY

Radiotherapy Planning

All measurements were performed using CIRS 002LFC thorax phantom and CIRS 002H9K head and torso phantom. Phantom scanning was performed using CT Simulator GE bright speed by entering Exradin A16 into the spine holder. Furthermore, treatment plans were simulated using treatment planning system (TPS) pinnacle[3] for SBRT and 2D conventional techniques with SSD and SAD method. For SBRT technique, the SAD method using thirteen beams with different gantry directions and MU. Conversely, the SAD and SSD method in 2D conventional radiotherapy use only one beam with gantry direction of 180° and field size for each beam about 2.4 x 2.4 cm^2 (Fig. 1).

Calibration of Dosimeters

Gafchromic EBT3 film was calibrated using Elekta Synergy S for both 6 MV and 10 MV photon energies. Calibration was done using the solid water phantom at a field size of 10 x 10 cm^2, depth of 5 cm, and SSD of 100 cm. The film was cut with the size of 2 x 2 cm^2 and irradiated with dose in the range between 0 cGy -500 cGy for low dose measurements and between 500-1800 cGy for high dose measurements. After 72 hours post irradiation, each piece was scanned with Epson V700 flatbed scanner with 48 bit-RGB color depth and spatial resolution of 72 dpi. The image analysis of the film was made using the Image-J software on the red channel. From this calibration, the calibration curve was obtained and used to calculate the dose measurement on film. For Exradin A16, we did the calibration of the detector for the small field constant.

Dose and Dose Profile Measurement

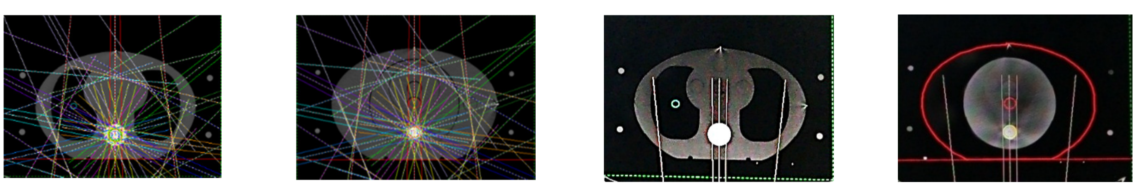
The dose measurements have been performed in thoracic and lumbar region with SBRT 6 MV photon energy and 2D conventional techniques (Fig. 2) for both 6 MV and 10 MV photon energies using Exradin A16 ion chamber and Gafchromic EBT3 film. Point dose measurement using Exradin A16 were performed using original holder from the thorax phantom, while measurement using film were performed using holder which made from the teflon material. For point dose measurements using film, the size of the film used is 2 x 2 cm^2.

Dose profile measurements performed with SAD method with gantry 0° and were done using EBT3 Gafchromic film with the size of 2.4 x 2.4 cm^2 for 0.8 x 0.8 cm^2 irradiation field size and 2.4 x 4 cm^2 for 2.4 x 2.4 cm^2 irradiation field size. For 0.8 x 0.8 cm^2 field size, dose profile measured along *X*-axis and *Y*-axis, but for 2.4 x 2.4 cm^2 field size, dose profile measured only along *Y*-axis.

RESULTS AND DISCUSSION

Dose Measurement

All measurement results using film EBT3 have the positive discrepancy, it is mean that the dose measurements are larger than the dose planning. This results because measurement using film is not affected by volume averaging effect.



(a) (b) (c) (d)

FIGURE 1. Illustration of SBRT technique for (a) thoracic (b) lumbar region and 2D conventional radiotherapy for (c) thoracic (d) lumbar region

FIGURE 2. Measurements using film (a) SBRT and (b) 2D conventional radiotherapy

In addition, holder used was made from teflon material that has a density more dense than the spine. According to Gallo *et al*. [4], measurements in high dose irradiation cause some noisy from the flatbed scanner while scanning the films. However, according Borca *et al*. [6] there are no problems in dose measurements using high dose irradiation up to 40 Gy.

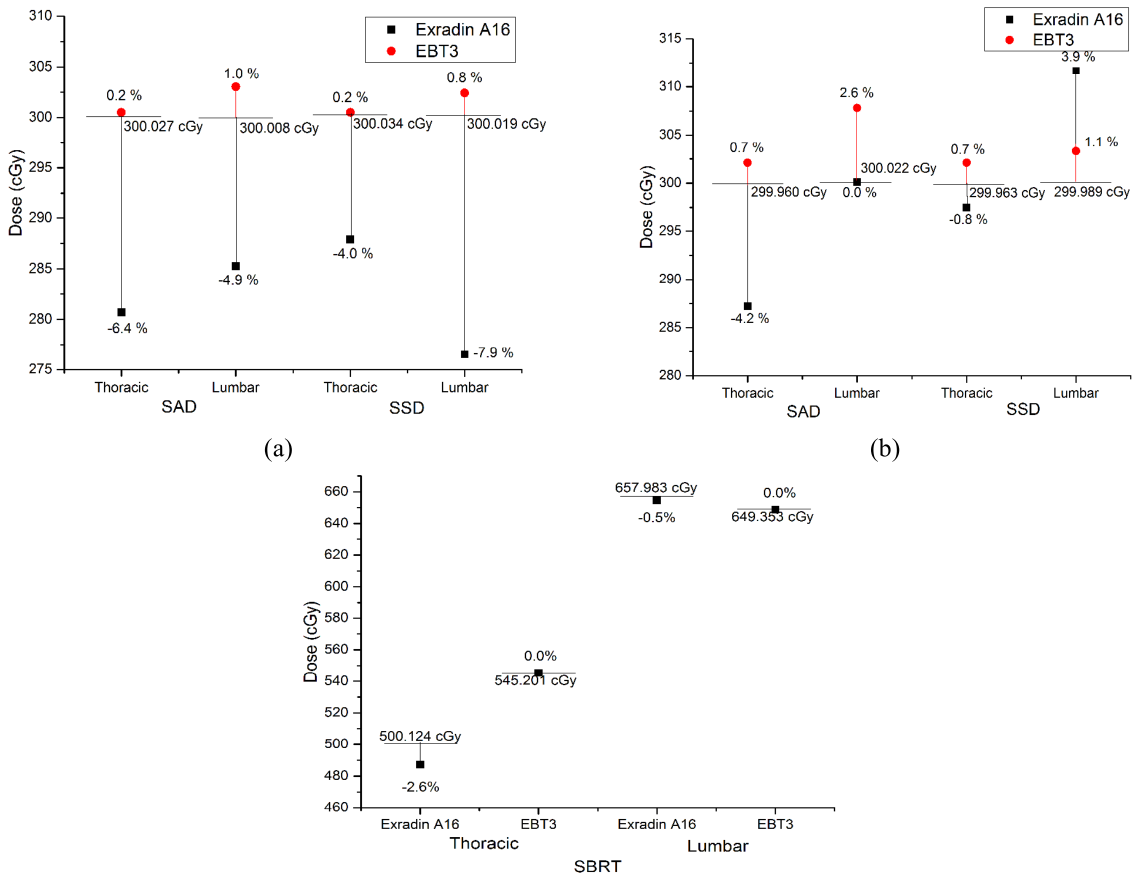
Figure 3 shows that measurement using Exradin A16 for SBRT technique has smaller results compared to the calculated dose by TPS. This value is likely due to the volume averaging effect on Exradin A16 active volume and with lack of the lateral electron disequilibrium. The results of measurement in conventional techniques using Exradin A16 also mostly had negative discrepancies. According to research by Fitriandini [7], the small active volume of Exradin A16 causes it unfavorable for low dose measurements, because signal measured is not much bigger than the existing noise.

In SBRT technique, the measurement results on thoracic region show a larger discrepancy than the lumbar, because of its inhomogeneity. In the 2D conventional technique, measurement using Exradin A16 or Gafchromic EBT3 on the thoracic has a smaller discrepancy compared to the lumbar. It looks like in 2D conventional technique, inhomogeneous medium on the thoracic does not affect the absorbed dose measurement results. This is caused by the irradiation was performed using a gantry of 180^{O} (from the back) so it did not pass through the material of the lungs.

From the dose measurement results, it is seen that at each target, the SSD method has a smaller discrepancy than the SAD method. In addition, the average value of discrepancies using Exradin A16 is larger than the EBT3 film. The average value of discrepancies for EBT3 in lumbar and thoracic are 1.37 % and 0.42 %, respectively. According to IAEA-TECDOC-1540, acceptable tolerance value for measurement in homogeneous and inhomogeneous medium are 2 % and 3 %, respectively [8]. Beside according to IAEA-TECDOC-1583, agreement criterion for measurement using CIRS 002LFC thorax phantom in bone site is 3-5 %, based on its gantry direction, field size, collimator angle, and MLC [9]. The smaller discrepancy indicates that the measurement results more accurate. The average standard deviation in measurement using EBT3 is smaller than Exradin A16, this shows that EBT3 more precision than the Exradin A16. Therefore, the better detector for the measurement of the spine is the EBT3 film for good precision and high accuracy.

Dose Profile Measurement

Table 1 shows that measurements using 10 MV photon energy for both the target area and the thoracic 6 MV photon beam have FWHM values along the *X*-axis was larger than the width of the collimated field and FWHM values along the *Y*-axis were less than the width of the collimated field. In the lumbar 6 MV photon beam, FWHM values along the *X*-axis is smaller than the width of the collimated field and FWHM values along the *Y*-axis were larger than the width of the collimated field. Previous research, Wong *et al*. [10], shows that the FWHM values for measurements along the *X*-axis was smaller than the width of the collimated field and for measurements along the *Y*-axis was larger than the width of the collimated field.



(a) (b)

(c)

FIGURE 3. Discrepancies of (a) 2D conventional 6 MV, (b) 2D conventional 10 MV and (c) SBRT

TABLE 1. FWHM and penumbra width for 0.8 x 0.8 cm^2 collimation field

Energy	Target	Orientation	FWHM (cm)	FWHM evaluation (%)	80 %-20 % negative (cm)	Negative penumbra evaluation (%)	80 %-20 % positive (cm)	Positive penumbra evaluation (%)
6 MV	Thoracic	*Y*-axis	0.72	-9.6	0.19	23.6	0.26	33.0
		X-axis	0.93	16.3	0.27	34.1	0.27	33.6
	Lumbar	*Y*-axis	0.86	7.3	0.24	29.5	0.27	33.6
		X-axis	0.75	-6.1	0.22	27.2	0.22	27.6
10 MV	Thoracic	*Y*-axis	0.76	-4.6	0.25	30.7	0.23	29.0
		X-axis	0.90	13.0	0.32	39.5	0.29	36.7
	Lumbar	*Y*-axis	0.73	-9.0	0.23	28.5	0.23	28.9
		X-axis	0.93	16.2	0.30	37.1	0.28	35.6

*Penumbra evaluation obtained by dividing the penumbra width with collimation field size and multiplied by 100%

From all measurements at 2.4 x 2.4 cm^2 field size as shown in Table 2, the FWHM less than the width of the collimated field. However, the difference is very small, it can be seen from the maximum value of FWHM evaluation about 3 %. The biggest difference between the FWHM and collimated field is 0.07 cm in the lumbar region with 6 MV photon energy. The maximum value of FWHM evaluation for 0.8 x 0.8 cm^2 field size is 16.3 %, this value much larger than 2.4 x 2.4 cm^2 field size.

TABLE 2. FWHM and penumbra width for 2.4 x 2.4 cm^2 collimation field along *Y*-axis

Energy	Target	FWHM (cm)	FWHM evaluation (%)	80 %-20 % negative (cm)	Negative penumbra evaluation (%)	80 %-20 % positive (cm)	Positive penumbra evaluation (%)
6 MV	Thoracic	2.36	-1.7	0.25	10.3	0.24	10.0
	Lumbar	2.33	-3.0	0.26	10.6	0.24	10.2
10 MV	Thoracic	2.38	-1.0	0.30	12.4	0.28	11.5
	Lumbar	2.37	-1.2	0.28	11.8	0.25	10.5

* Penumbra evaluation obtained by dividing the penumbra width with collimation field size and multiplied by 100%

TABLE 3. Comparison of dose profile analyzes

Energy	Field size (cm)	Orientation	*CIRS head and torso phantom*		*Solid water phantom* (Nuruddin, 2012) [5]	
			FWHM (cm)	Penumbra* (cm)	FWHM (cm)	Penumbra* (cm)
6 MV	0.8	*X*-axis	0.75	0.22 - 0.22	0.75	0.24 - 0.24
		Y-axis	0.86	0.24 - 0.27	0.83	0.39 - 0.34
	2.4	*Y*-axis	2.33	0.26 - 0.24	2.36	0.30 - 0.30
10 MV	0.8	*X*-axis	0.93	0.30 - 0.28	0.86	0.37 - 0.47
		Y-axis	0.73	0.23 - 0.23	0.77	0.38 - 0.42
	2.4	*Y*-axis	2.37	0.28 - 0.25	2.37	0.28 - 0.24

* Penumbra (20 % - 80 %) measured on the left (negative) – right (positive) side

Comparison of profile analyzes results with previous study [5] for 6 MV and 10 MV photon energies can be seen in Table 3. The study was conducted with same linear accelerator but using a solid water phantom and EBT films [5], in this study we are using a homogeneous phantom CIRS head and torso and EBT3 film. Measurements using a solid water phantom had FWHM value better (closer to the width of the collimated field) compared to measurements using CIRS phantom head and torso. However, measurements using CIRS phantom head and torso have a penumbra width smaller than the measurements using a solid water phantom because in this study dose measurements performed on a medium (bone) that has a density more dense than water. More dense density allowing a greater attenuation, so the range of electrons become shorter.

CONCLUSIONS

Most of the measurement results using Exradin A16 have a lower value than the dose calculation by TPS with an average discrepancy of all measurements amounted to -2.7 %. Gafchromic EBT3 film is a dosimeter with good precision and high accuracy, indicated by the average value of standard deviation is ±1.7 and the maximum discrepancy is 2.6 % of all radiation. The average value of FWHM and its largest deviation for 0.8 x 0.8 cm^2 field collimation are 0.82 cm and 16.32 %, while for 2.4 x 2.4 cm^2 field collimation are 2.36 cm and -3.0 %. The penumbra deviation for 0.8 x 0.8 cm^2 field collimation is 37.1 %, while it was 12.4 % for the field size of 2.4 x 2.4 cm^2.

REFERENCES

1. See supplementary material at http://www.cancer.org/acs/groups/cid/documents/webcontent/003087-pdf.pdf for Bone metastasis.
2. T. Liang, Y. Wan, X. Zou, X. Peng, and S. Liu, Clin. Orthop. Relat. Res. **471**, 628-639 (2013).
3. S. Benedict *et al.*, Med. Phys. **37**, 4078-4101 (2010).
4. J. J. Gallo *et al.*, J. Appl. Clin. Med. Phys. **16**, 170-182 (2015).
5. Nuruddin, *Perbandingan Pengukuran PDD dan Beam Profile antara Detektor Pin Point Microchamber dan Gafchromic Film pada Lapangan Kecil*, B.Sc Project, Universitas Indonesia, Depok, 2012.
6. V. C. Borca *et al.,* J. Appl. Clin. Med. Phys. 14, 158-171 (2013).
7. A. Fitriandini, W. E. Wibowo, and S. A. Pawiro, Journal of Physics: Conference Series 694, 012006 (2016).

8. See supplementary material at http://www-pub.iaea.org/MTCD/publications/PDF/te_1540_web.pdf for Specification and acceptance testing of radiotherapy treatment planning systems.
9. See supplementary material at http://www-pub.iaea.org/MTCD/Publications/PDF/te_1583_web.pdf for Commissioning of radiotherapy treatment planning systems: Testing for typical external beam treatment techniques.
10. C. J. Wong *et al*., Radiat. Meas. **44**, 249–256 (2009).