Point dose measurement on center and peripheral target for stereotactic treatment using Helical Tomotherapy Hi-Art

Laras Ati Nur Fatimah[1], Nuruddin Nasution[2], Wahyu Edy Wibowo[2], and Supriyanto Ardjo Pawiro[1]

[1] *Department of Physic, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok, Indonesia*
[2]*Department of Radiotherapy, National General Hospital Dr. Cipto Mangunkusumo, Jakarta, Indonesia*

E-mail: fatimalarasati06@gmail.com

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Abstract: Stereotactic radiosurgery (SRS) and stereotactic radiotherapy (SRT) using tomotherapy were advanced radiotherapy technique with prescribing high dose on the peripheral target to get as steep as possible fall-off dose criteria on the target. These technique need an accurate and high precision treatment delivery also passing the criteria for patient specific quality assurance. Point dose measurement was a simple verification to ensure these goals. However, there are many issues for point dose measurement with ionisation chamber related to the problem of high dose gradient area on the peripheral target. Therefore, the purpose of this study was to verify the assessment criteria of ±3% discrepancies for center and peripheral target measurement. The work has been done by point dose verification for 11 patient with brain cancer using Helical Tomotherapy Hi-Art. Point dose measurement were done on the center and peripheral PTV, also brainstem for organ parameter in the off-axis area, using Exradin A1SL. The measurement results show that highest discrepancy compared to the dose plan for center and peripheral target reach 1.95% and 2.81%, respectively. The Higher discrepancies shows for peripheral target compared to the center target measurement. The measurement on the brainstem show a highest discrepancies reach 5.29%. This result occur because of the off-axis area of the brainstem location. In conclusion, the center and peripheral target measurement are meet the criteria ±3% by the dose plan with peripheral target measurement shows higher discrepancies influences by volume averaging effect and lack of particle equilibrium of the condition related to the chamber size.

Keywords*: patient spesific QA, volume averaging*

1. Introduction

Stereotactic radiosurgery (SRS) and stereotactic radiation therapy (SRT) were radiation therapy modality with prescribing dose on the peripheral planning target volume (PTV). The goal of SRS and SRT was achieving highly conformal dose distribution on the target, and getting as steep as possible fall-off dose on the extra-target normal tissue.[1,2] In stereotactic treatment, it possible to get heterogeneous dose distribution on the target tumor. By the study of Lax, 1993[3] the results show heterogeneous target coverage was allowed to reduce target extra dose. Helical Tomotherapy was a treatment modality with a high conformality on the target. This modality was chosen to optimised stereotactic treatment with lower off-axis dose compared to conventional LINAC based radiotherapy.[4] This condition occurred because of less scatter on helical Tomotherapy treatment compared to linac based treatment. The off-axis dose was potentially influenced by leakage and scatter.[4] Therefore, it was important to use less scatter modality to get low dose on the off-axis location.

Patient specific quality assurance (QA) was a mandatory step to ensure the quality of patient treatment. Patient specific dosimetric verification gives information of dose difference between planned and delivered dose on the target volume. Point dose measurement was a simple patient specific QA to ensure the delivered dose was accurate and persistence. By the recommendation of the Netherlands Commission on Radiation Dosimetry, for the homogeneous dose regions an acceptance criterion of 3% for TomoHelical deliveries.[5] Therefore, ±3% dose difference could accept for dosimetric QA goal for high and low dose gradient regions.[6] The AAPM Task Group Report 119 on "IMRT commissioning: Multiple institution planning and dosimetry comparisons" also provide benchmark data for commissioning IMRT with gamma criteria 3%/3 mm \for evaluation of planar dose distribution.[7] Although, patient specific QA by point dose measurement have some issue related to the small field condition of stereotactic treatment. High dose discrepancy was produced when the small field was combined with the irregular shape of the target.[8] The other reasons were steep dose gradient of the target, volume averaging effect and lack of particle equilibrium related to the size of the volume detector.[9,10,11] By this condition, the issues were getting more significant for measurement on the peripheral target. By the study of Hidayanti, 2016[12], the discrepancy form peripheral target measurement was reached 9.14% compared to the planned dose. The peripheral target covered by highly steep dose gradient compared to the center target volume. This condition can influence for the peripheral target dose measurement, so it can produce a higher error for point dose measurement compared to the center target volume measurement. Therefore, peripheral target point dose measurement was a critical issue for stereotactic treatment to ensure delivered dose was meet the criteria of patient specific QA. For those reasons, this study has been done to verify the assessment criteria of dose verification ±3% for center and peripheral target.

2. Materials and methods

This work has used helical Tomotherapy Hi-Art (TomoTherapy, Inc., Madison, WI) and TomoHD™ treatment planning system (version 2.1.0) with a convolution based algorithm. The point dose measurement was performed by using 6 MV photon on the cheese phantom called "TomoPhant" for the center and peripheral target of 11 patients with brain cancer case treated with stereotactic treatment. The position of the ion chamber was in the central of the phantom. All of measurement area was sets on the effective volume of the chamber Figure 1 shows the location of the chamber position. The dose at the point of the chamber then compared to the measured dose. With this methode, effective volume of the chamber were set on the center and peripheral target volume and also the brainstem area.

DQA plan was made using patient individual plane and change the phantom with cheese phantom CT, then recalculated to get phantom calculation dose. The dose on the brainstem also being assessed to get the information of the off-axis organ at risk.The measurement was done by using ionisation chamber Exradin A1SL (Standard Imaging Inc., of Middleton, WI) with 0.056 cc collecting volume. The slice thickness 1 mm was used to do delivery QA plan for each patient. Analysis of the measurement was done by comparing measured dose with the average of calculated dose on the TPS. The measurement discrepancies follow the equation from AAPM TG-119:

$$discrepancy(\%) = \frac{D_{measured} - D_{plan}}{D_{plan}} 100$$

The $D_{measured}$ was measured dose and D_{plan} was planned dose calculated by the treatment planning system.

3. Results and discussion

The results of the measurement are shown in Table 1. The results shows higher discrepancy of peripheral target measurement, compared to the center target. The highest discrepancy on the center target measurement reach 1.95% and the lowest value is -0.03%. The minus value showed that the measurement was underestimated by the calculated dose. The highest discrepancy reaches 2.81% and the lowest discrepancy is -0.37% for peripheral target measurement. This condition occurs because of volume averaging effect by the size of the detector and lack of particle equilibrium in the peripheral area.

From the Figure 2, measurement on the brainstem area shows high discrepancy. By the pattern of the discrepancy, it value reach 5.29%. This results occur because of brainstem area that contains of heterogeneous isodose. Figure 1 shows the heterogeneity of brainstem area that located on the off-axis location. This discrepancy can be higher by the lack of particle equilibrium and volume averaging effect by the size of ionisation chamber.[9-11]

Table 1. The dose discrepancy by measurement and calculation dose.

Patient	Discrepancy (%)		
	center	peripheral	brainstem
A	1.95	2.81	5.06
B	0.49	1.16	-0.96
C	0.07	-1.08	-5.29
D	0.09	-0.17	0,0
E	-0.09	-2.55	0.69
F	-0.03	0.95	1.50
G	0.38	1.98	-2.39
H	-0.74	-1.03	-1.29
I	0.33	-0.72	2.09
J	-0.49	-1.08	1.52
K	-0.25	-2.37	-3.81

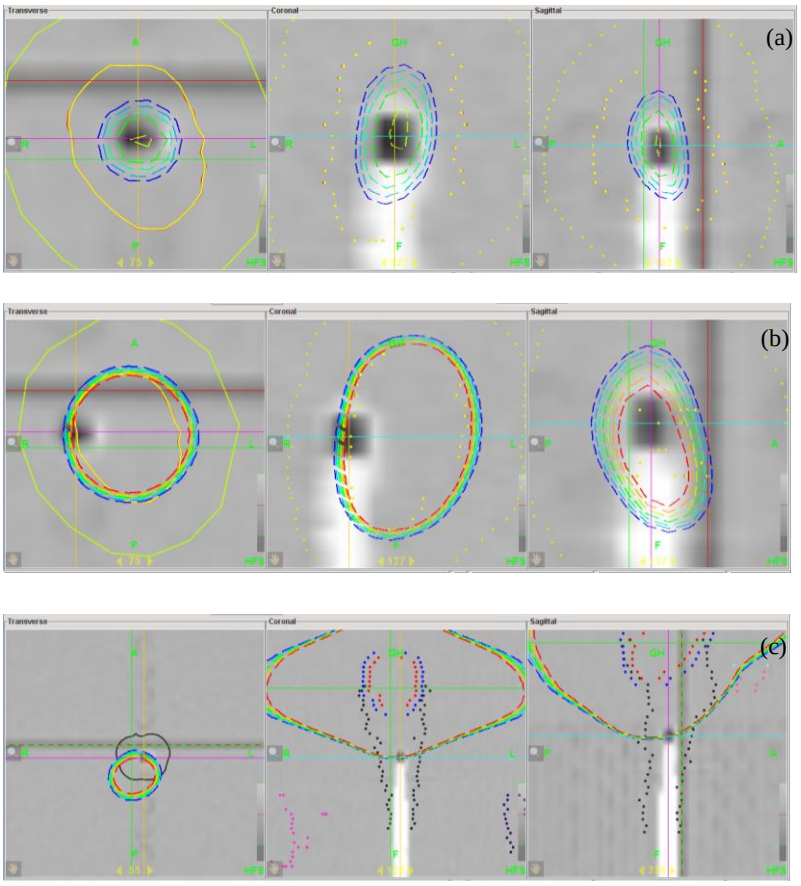

Figure 1. The DQA plan for (a) center PTV; (b) peripheral PTV; (c) brainstem.

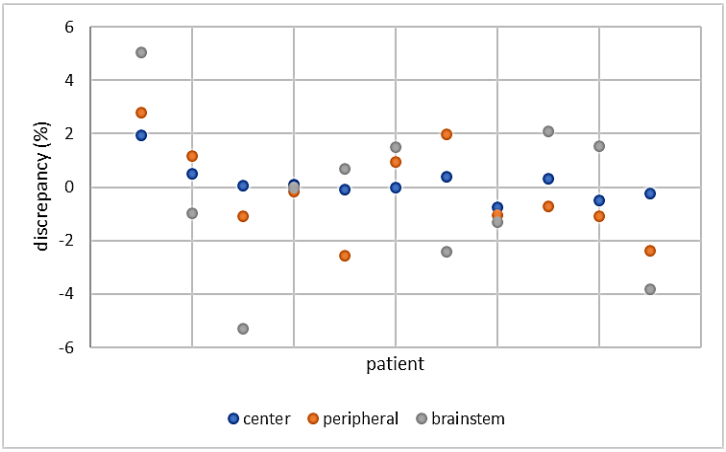

Figure 2. Discrepancies of the point dose measurement on the center target, peripheral target, and brainstem.

4. Conclusion

In conclusion, the center and peripheral target measurement are meet the criteria ±3% by the dose plan with peripheral target measurement shows higher discrepancies influences by volume averaging effect and lack of particle equilibrium of the condition related to the chamber size. For next study, the measurement can compared to smaller size detector and also can be explored with planar dose measurement to get the proven comparation with the gamma index result.

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