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DOSIMETRIC INVESTIGATION OF RADIOTHERAPY OF SMALL SIZE TUMORS IN RADIOSURGERY DEVICES

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Abstract: *In stereotactic radiotherapy, high radiation doses were delivered to tumors using small fields in 1-5 fractions. It is very important to make sure the accuracy of dose and position of given dose in stereotactic radiotherapy. In this study, dosimetric measurements of small sized brain tumors irradiated in CONE- based linear accelerator (linac) and the volumetric arc therapy (VMAT) linac modalities were performed with EBT3 film. 1,2 and 3 cm diameter tumors were virtually created in Cyberknife head and neck phantom. Gafchromic EBT3 film was placed into the phantom to evaluate the accuracy of the doses given. The phantom was irradiated with Gafchromic EBT3 film according to treatment plans created in the treatment planning system of two separate devices for each tumor size. Conformity Index (CI) and Homogeneity Index (HI) were calculated for the quality of created treatment plans. The dose distributions calculated in the film and the TPS were compared. When the CI and HI values were examined, the CI and HI values of the cone-based linac device were close to 1. The EBT3 measurement results indicate that all SRT treatment modalities achieved accurate doses. According to results, if a critical organ, such as the brainstem, is located near the tumor and the situation requires a steep dose gradient, the cone-based linac should be used for SRT therapy. This study has shown that on CONE-based linac or VMAT-based linac devices can be used instead of each other in small-area irradiations.*

Keywords: *Stereotactic radiosurgery, Cyberknife, Linac, VMAT, Film dosimetry.*

1. Introduction

The main purpose of radiotherapy; to give the least dose to the critical organs around the tumor and to give the maximum dose to the tumor. Many modern radiotherapy techniques have been developed for this purpose. Stereotactic Radio Surgery (SRC) which is preferred in clinics in recent years is one of the modern radiotherapy techniques developed. SRC is (tumor diameter <4 cm) high-dose irradiation with a single fraction of small targets on the brain. If this application is applied in multiple fractions (not in a single fraction), it is called Stereotactic Radiotherapy (SRT). The same procedure is referred to as Stereotactic Body Radiotherapy (SBRT) if it is applied to the tumor placed at a small area in any part of the body as hypofraction. Higher conformity treatment is provided with SRT and SBRT compared to normal radiotherapy applications [1]. SRT and SBRT have very speed dose gradient between the critical organs and tumor. Due to the fact that the treatment area is less than 4 cm, there are a number of problems in small-field irradiation. Because for small fields, the accuracy of Treatment Planning Systems (TPS) is more difficult than large treatment fields. There are problems such as the detector used to measure the dose received by the irradiated target is not small enough for the small area, the area size is not large enough to provide lateral electronic balance, sharp dose change and partial blocking of the source. These problems come as dosimetric effects on the absorbed dose in the central axis, in the dose profile taken in the axial section and in the stored dose at a certain x point [2-3].

SRS or SRT treatments can be performed with many treatment devices. Different treatment devices have different output dose characteristics, which may affect the radiation doses received by normal tissues surrounding the tumor [4].

We aimed to compare the SRT treatment doses of the cone-based linac and VMAT linac treatment modalities and evaluate the differences between doses calculated according to treatment planning systems and measured radiation doses. In this study; 1, 2 and 3 cm diameter virtual tumor volumes were irradiated in two stereotactic radiosurgery devices.

2. Material and Method

Scannings using Philips Big Bore Brilliance 4D CT was applied to obtain images of the Cyberknife head and neck phantom. The images were sent to Multiplan 4.5.3 TPS and Ecplise 8.9. TPS. As a small area in the study, 1, 2 and 3 cm diameter GTV volumes were virtually created in Cyberknife head and neck phantom. Different treatment plans were designed by the treatment planning systems according to the size of the tumors as shown in Figures1 and 2.

The accelerator used for the cone-based linac was a 6 MV Accuray Cyberknife treatment device. Cone diameters of 5-10, 10-20, and 12,5-25 mm were used for 1, 2 and 3 cm target, respectively.

The arc-therapy method was used for 6 MV VMAT linac plans. The beam angles were as follows: counter-clockwise from 179.9^0 -180.1^0 with a collimator angle of 45^0, a couch angle of 0° and clockwise from 180.1^0- 179.9^0 with a collimator angle of 315°, a couch angle of 0°.

In all treatment plans, a dose of 500 cGy was delivered to the tumors, and the conditions were optimized to maintain %100 dose coverage on the tumor.

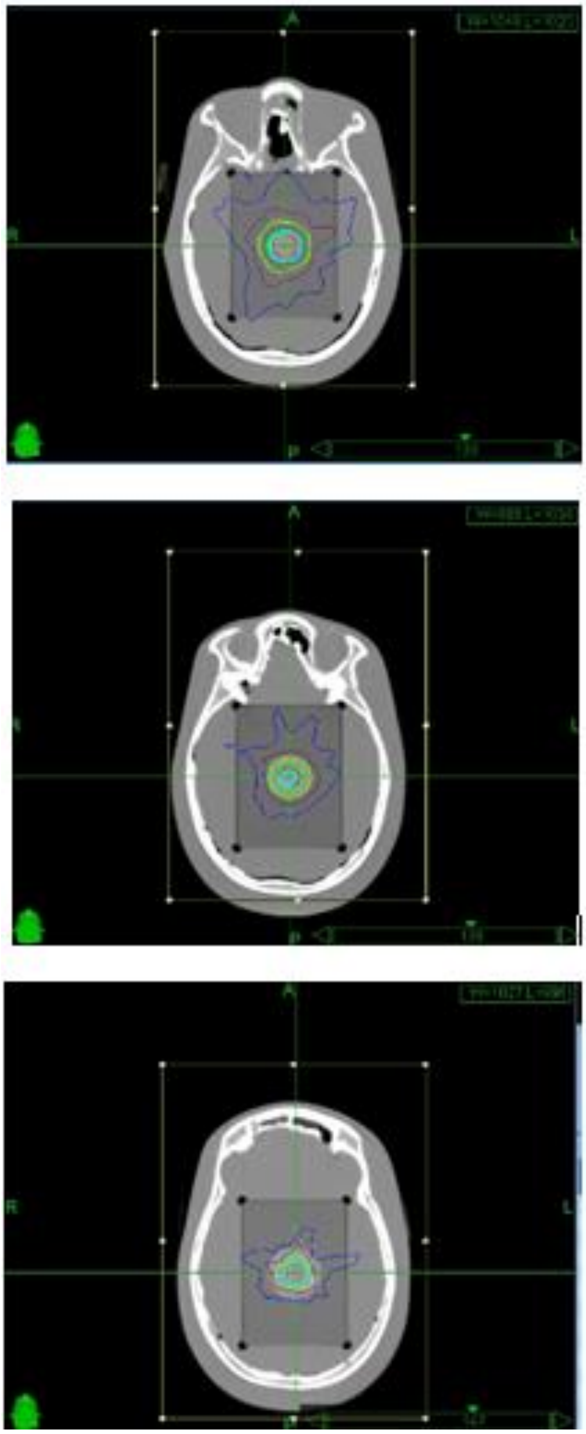

Figure 1. The treatment plan for a 1,2 and 3 cm tumors in Multiplan TPS

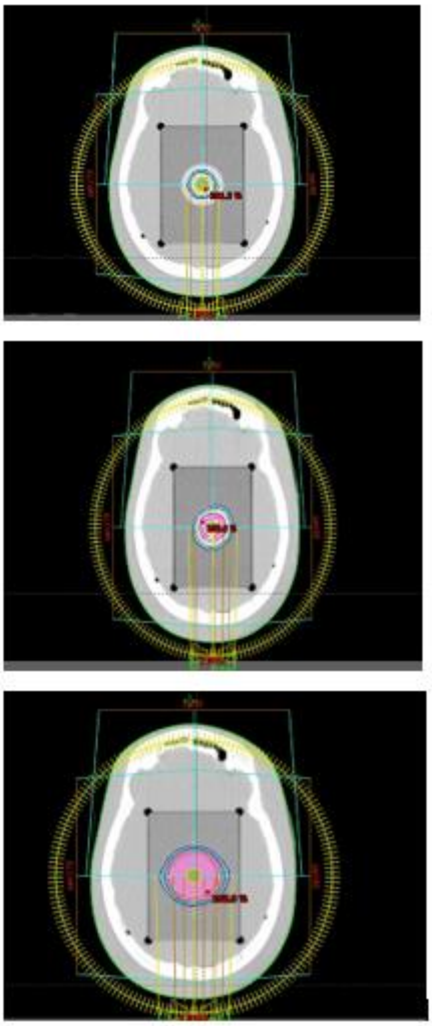

Figure 2. The treatment plan for a 1,2 and 3 cm tumors in Eclipse TPS

Gafchromic EBT3 films were used to measure the radiation dose. The measurements were repeated for three times for each tumor location and each treatment device. The films for the irradiations were cut in accordance with the phantom dimensions (6.3 x 9 cm) and placed in the 3. part of the RW4 solid water phantom in 1 cm thickness as shown in Figure 3.

Figure 3. The positioning of the films to be irradiated in the Cyberknife phantom

Phantom was positioned as in routine patient irradiation position according to the treatment plan. PTW Verisoft was used to evaluate the profile changes in superior-inferior (S–I) directions on the films as shown in Figures 4, 5 and 6. Moreover, isodose curves generated from irradiated films were plotted in S-I rotation for each tumor dimension.

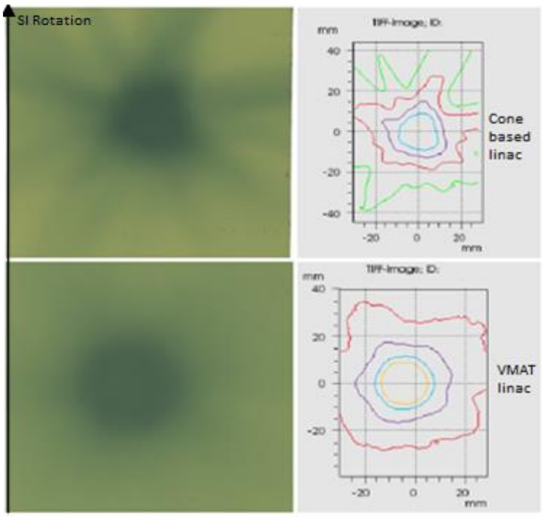

Figure 4. Films irradiated by Cone based linac and VMAT linac devices of the one-cm tumor and their isodose curves.

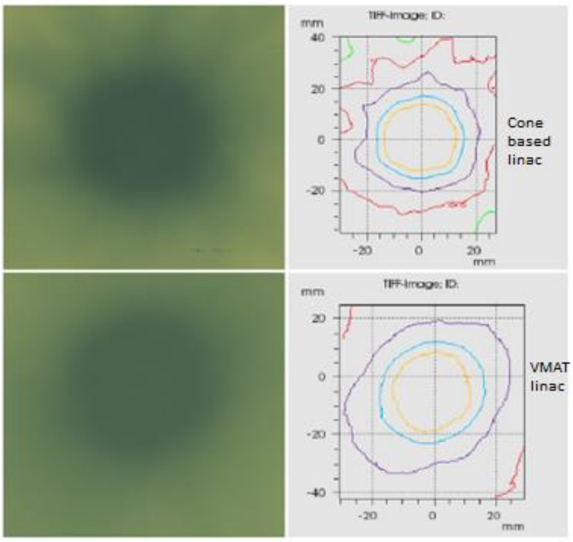

Figure 5. Films irradiated by Cone based linac and VMAT linac devices of the two-cm tumor and their isodose curves

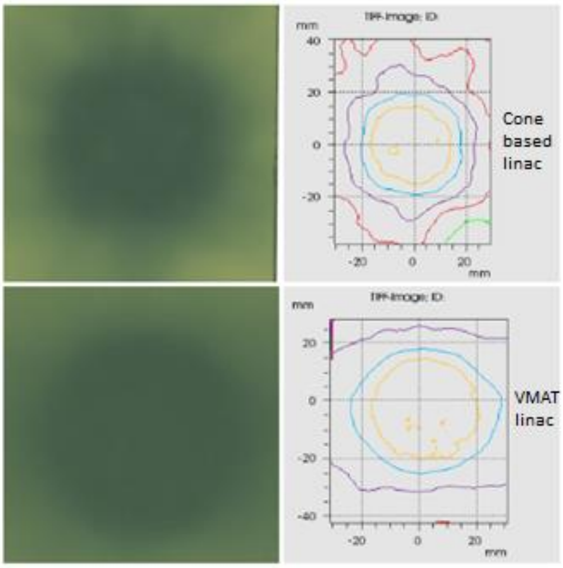

Figure 6. Films irradiated by Cone based linac and VMAT linac devices of the three-cm tumor and their isodose curves

Besides, the homogeneity index (HI) and conformity index (CI) were used to compare the quality of the treatment plans in this study. The HI was used to describe the homogeneity of the dose within the tumor [5].

HI = MD/PD

where MD is the maximum dose within the tumor and PD is the 100% prescription dose. The HI of a perfect treatment plan should be 1.

The CI is defined as

$CI= (TV_{PIV})^2 /TV \times PIV$

where PIV refers to the volume covered by the 100% prescription dose curve, TV is the tumor volume, and TV_{PIV} is the tumor volume covered by PIV. The CI of a perfect treatment plan should be 1 [6].

3. Results

3.1 CI and HI values calculated in treatment planning systems

CI and HI values calculated by Ecplise TPS and Multiplan TPS for each tumor dimension are shown in Table 1.

Table 1. CI and HI values calculated by Ecplise TPS and Multiplan TPS for each tumor dimension

	Multiplan TPS	**Ecplise TPS**
1 cm tumor		
CI	0,98	0,5
HI	1,18	1,01
2 cm tumor		

CI	0,998	0,53
HI	1,12	1,04
3 cm tumor		
CI	0,999	1,21
HI	1,10	1,06

3.2 Dose profiles for tumor irradiation in all three dimensions from treatment planning systems and scanned films

Dose profiles for 1 cm tumor from treatment planning systems and scanned films are shown in Figure 7.

3.2.1. 1 cm tumor

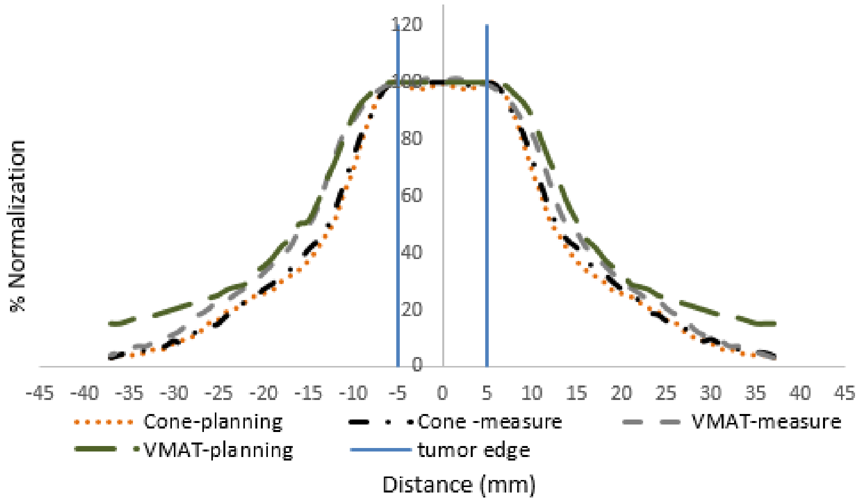

Figure 7. Dose profiles for 1 cm tumor from treatment planning systems and scanned films. All doses were normalized to the dose of the center of the fields.

3.2.2. 2 cm tumor

Dose profiles for 2 cm tumor from treatment planning systems and scanned films are shown in Figure 8.

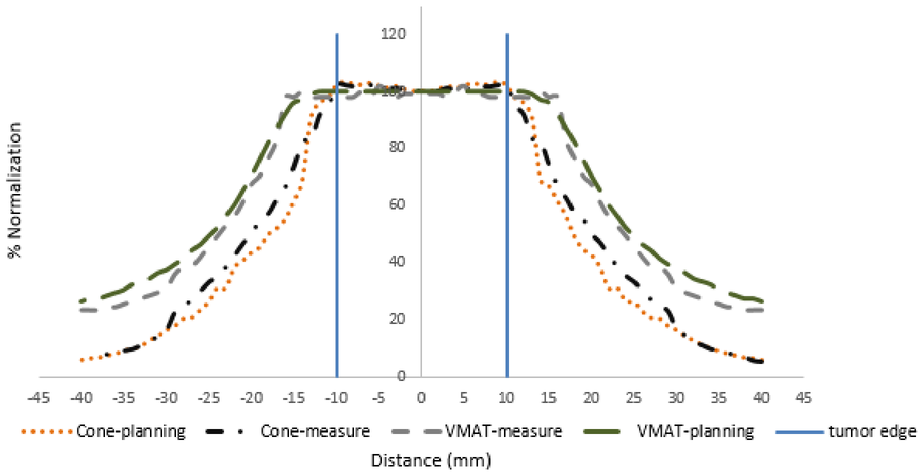

Figure 8. Dose profiles for 2 cm tumor from treatment planning systems and scanned films. All doses were normalized to the dose of the center of the fields.

3.2.3. 3 cm tumor

Dose profiles for 3 cm tumor from treatment planning systems and scanned films are shown in Figure 9.

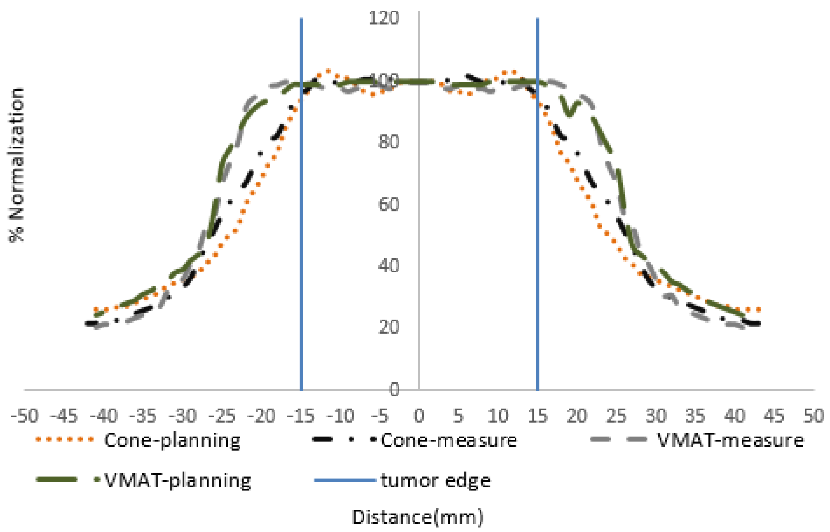

Figure 9. Dose profiles for 3 cm tumor from treatment planning systems and scanned films. All doses were normalized to the dose of the center of the fields.

3. Discussion

In stereotactic radiotherapy, it is important that the dose reaches the target correctly. This is achieved by delivering the dose in the TPS as planned. Therefore, it is necessary to check the accuracy of the given dose of the treatment plan. In this study, three virtual intracranial tumors with 1, 2 and 3 cm diameters were examined [7-8].

In our study, HI values for VMAT were calculated as 1.01, 1.04 and 1.06 for tumors with 1, 2 and 3 cm diameters, respectively. Similarly, HI values for cone-based linac were calculated as 1.18, 1.12 and 1.10 for tumors 1, 2 and 3 cm, respectively. Both treatment modalities are compatible with each other compared to HI values. CI values in VMAT were calculated as 0.5, 0.53 and 1.21 for tumors with 1, 2 and 3 cm diameters, respectively. CI values for cone-based linac were calculated as 0.98, 0.998 and 0.999 for tumors of 1, 2 and 3 cm, respectively. Regardless of the tumor diameter, the cone-based linac device has more conformal irradiation for all tumors than VMAT because the radiation field of the cone-based linac device is similarly compatible with tumor sizes [9].

In research of Shih- Ming Hsu et. al study, the cone-based linac, FFF-VMAT linac, and tomotherapy modalities were evaluated by measuring the differences between the doses delivered during brain SRT and experimentally assessing the accuracy of the output radiation doses through clinical measurements. The average HI values of the cone -based linac, the FFF-VMAT linac, and tomotherapy were 1.20, 1.21, and 1.23, respectively. The average CI for the cone-based linac, the FFF-VMAT linac, and tomotherapy were 0.90, 0.73, and 0.65, respectively. In this study, among the three treatment modalities studied, the cone-based linac had the best conformity and the best dose gradient for all tumors sizes and locations [9].

Q.-R. Jackie Wu et al. in his conformity measurement study for the Gamma knife stereotactic radiosurgery technique, conformity index evaluation was performed for tumors of different sizes of 0.3, 1.0, 3.0, 10.0 and 30.0 cm^3. They developed a different parameter called conformity distance index (CDI) for conformity calculations of treatment. According to the study, CI was 0.61 for 1 cm^3 tumor, while CDI value was 0.93; CI was 0.71 for 3 cm^3, while CDI was found 0.95. Q.-R. Jackie Wu et al. indicated that the low conformity index value would be related to the complex geometry of the target and target volume. The CDI recommended by Q.-R. Jackie Wu et. al is defined as the average distance between the target and the prescribed isodose line. The proposed CDI has provided more consistent and accurate measurement for all target sizes and shapes. They emphasize that CDI is a more useful index for stereotactic radiosurgery [10].

The results measured with EBT3 film for tumors 1, 2 and 3 cm are consistent with the planned values in TPS as shown in Figures 7, 8 and 9 because the difference between the profiles obtained from the planned and measured values is less than 4%. Film measurement results show that both treatment modalities have reached the correct doses. SBRT is the irradiation of small tumor in several fractions using high doses. For this reason, the dose given to the tumor should be compatible with the prescribed dose.

When Figures 7, 8 and 9 are examined, it is shown that the dose gradient of CONE based LINAC device is higher than VMAT. This is a positive finding for critical organs that will take place near the target volume. The faster the dose gradient outside the volume, the very important it is for the protection of critical organs. For example, in the presence of a critical organ such as the brainstem, a cone-based treatment device may be preferred in the surroundings of their irradiated area such as Shih-Ming Hsu et al.

According to results from this study; Stereotactic radiotherapy can be performed with a cone-based linac device and VMAT-based linac devices. However, the cone-based linac had the best conformity and dose gradient for tumors of all sizes and locations. If a critical organ, such as the brainstem, is located near the tumor and the situation requires a steep dose gradient, the cone-based linac should be used for SRT therapy.

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