The dose delivery effect of the different Beam ON interval in FFF SBRT: TrueBEAM

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Abstract. The purpose of this study is to determine the dose delivery effect of the different Beam ON interval in Flattening Filter Free Stereotactic Body Radiation Therapy (FFF-SBRT). The three 10MV-FFF SBRT plans (2 half rotating Rapid Arc, 9 to10 Gray/Fraction) were selected and irradiated in three different intervals (100%, 50% and 25%) using the RPM gating system. The plan verification was performed by the ArcCHECK for gamma analysis and the ionization chamber for point dose measurement. The dose delivery time of each interval were observed. For gamma analysis (2%&2mm criteria), the average percent pass of all plans for 100%, 50% and 25% intervals were 86.1±3.3%, 86.0±3.0% and 86.1±3.3%, respectively. For point dose measurement, the average ratios of each interval to the treatment planning were 1.012±0.015, 1.011±0.014 and 1.011±0.013 for 100%, 50% and 25% interval, respectively. The average dose delivery time was increasing from 74.3±5.0 second for 100% interval to 154.3±12.6 and 347.9±20.3 second for 50% and 25% interval, respectively. The same quality of the dose delivery from different Beam ON intervals in FFF-SBRT by TrueBEAM was illustrated. While the 100% interval represents the breath-hold treatment technique, the differences for the free-breathing using RPM gating system can be treated confidently.

1. Introduction

The stereotactic body radiation therapy (SBRT) was introduced after the stereotactic radiosurgery (SRS) and the stereotactic radiation therapy (SRT) for the extra-cranial lesion. The delivery treatment time is prolonging for the dose of 6-30 Gray per fraction (Gy/Fx) [1-3]. The using of the Flattening Filter Free (FFF) beam for SBRT (FFF-SBRT) with the Linac-Based SBRT becomes more practicable. The flattening filter was removed out of the beam then the dose rate is increasing from 600 monitor unit per minute (MU/min) for the flattened beam to 1400 and 2400 MU/min for 6MV-FFF and 10MV-FFF beams, respectively. The total dose delivery time is shortening at least 2 times for FFF SBRT [4].

The margin added to the Gross Tumor Volume (GTV) due to the respiratory is essential. The breath hold technique allows the SBRT to be irradiated with the smallest added up margin. The repeatability of the same breath hold level may require using some from many systems used to monitor the patient’s respiratory [5, 6].

The patient specific QA is very important to make sure that the LINAC machine can deliver the dose correctly. The gamma analysis with different criteria was investigated in many studies [7-9]. The accepted percent pass of the gamma analysis is depending on the instruments used. The point dose measurement is also performed. The purpose of this study is to determine the effect of the difference Beam
ON interval in Flattening Filter Free Stereotactic Body Radiation Therapy (FFF-SBRT) according to the phase selection using RPM gating system.

2. Materials and methods

The TrueBEAM LINAC, the Eclipse treatment planning version 11.0.31 and the Real-time Position Management (RPM) respiratory gating system (Varian Medical Systems, Palo Alto, CA) were employed in this study. The dose distribution was measured using the ArcCHECK 2 (Sun Nuclear Corp., FL). The CC13 ionization chamber (IBA dosimetry, Barlett, TN) was inserted into the center of ArcCHECK2 to measure the point dose at the isocenter. The setup of the instruments was illustrated in figure 1.

![Figure 1. (A) The ArcCHECK2 and RPM system, (B) The Reflector box and the Breathing cycle simulator and (C) The ionization chamber inserted into ArcCHECK2](image)

The three 10MV-FFF SBRT plans (2 half rotating Rapid Arc, 9 and 10 Gy/Fx) were selected and irradiated in three different Beam ON interval (100%, 50% and 25%). The RPM Gating System was used as the trigger of the BEAM ON interval in SBRT. The 100% Beam ON interval has represented the treatment of breath hold technique with intentional hold the beam by the therapist. For 50% and 25% intervals, the gating phase was selected as 25%-75% and 37%-62%, respectively. As shown in Figure 2, the yellow strip represents the Beam ON interval.

The ArcCHECK2 was designed for higher rep rate detectable which compatible with FFF mode. At the center of the phantom, the ionization chambers and inhomogeneity materials can be inserted as the option [8].

The measured dose distribution from ArcCHECK2 was compared with the calculated dose from the TPS. The 2% dose different and 2 mm distance-to-agreement threshold was used for gamma analysis. The integral point dose was calculated from the charge which corrected for pressure and temperature. The dose delivery time of each interval were observed.
3. Results and discussion

3.1 Gamma analysis
For the 2% dose different and 2 mm distance-to-agreement threshold, the average percent pass of all plans for 100%, 50% and 25% interval were 86.1±3.3%, 86.0±3.0% and 86.1±3.3%, respectively. The demonstrated percent pass was representing the similarity of the different Beam ON interval. The results were shown in Table 1.

In the real clinical situation, we still observed for the accepted percent pass and the suitable criteria. The percent pass was 94.3±0.5%, 94.4±0.6% and 94.7±0.8% in the same order as above when using the 3% dose different and 3 mm distance-to-agreement threshold.

Table 1. The results of the 3 Rapid arc cases from the different Beam ON interval

| Case No | Percent pass (2%, 2mm) | Point dose ratio (Measured/TPS) | Delivery time (sec) |
|---------|------------------------|---------------------------------|--------------------|
|         | 100% | 50% | 25% | 100% | 50% | 25% | 100% | 50% | 25% |
| 1       | 88.3 | 87.1 | 86.2 | 1.0065 | 1.0062 | 1.0059 | 69 | 141 | 325 |
| 2       | 87.6 | 88.3 | 89.4 | 1.0283 | 1.0265 | 1.0252 | 75 | 156 | 351 |
| 3       | 82.3 | 82.6 | 82.8 | 1.0007 | 1.0007 | 1.0007 | 79 | 166 | 365 |
| Average | 86.1 | 86.0 | 86.1 | 1.012 | 1.011 | 1.011 | 74.3 | 154.3 | 347 |
| SD      | 3.3  | 3.0  | 3.3  | 0.015 | 0.014 | 0.013 | 5.0 | 12.6 | 20.3 |

3% dose different and 3 mm distance-to-agreement threshold.

3.2 Point dose
For point dose measurement, the mean dose for assumed ionization chamber volume at the isocenter of the ArcCHECK2 from the TPS was used to compare with the measurement. The average ratios of each interval to the TPS were 1.012±0.015, 1.011±0.014 and 1.011±0.013 for 100%, 50% and 25% interval, respectively. The deviation of the integral dose at the isocenter was about 1% from interval to interval.

3.3 Delivery time
The average dose delivery time was increasing from 74.3±5.0 second for 100% interval to 154.3±12.6 and 347.9±20.3 second for 50% and 25% interval, respectively. The delivery time was depending on the dose per fraction and the size of the target. The relative ratio was 2 and 4 times for 50% and 25% compared to 100% interval, respectively.

Even though the percent gamma passed result of our study was lower than the other studies [7, 8], the maximum ratios of point dose were within 2-3%. The higher dose rate of 2400 MU/min and the higher dose gradient in delivering the dose of 9-10 Gy in two half rotating arcs may be the major factors
which affected on the gamma analysis outcome. The more number of the SBRT patient specific QA have to be investigated to establish the optimal percent pass acceptable and the suitable gamma criteria.

4. Conclusion
The performance of gating SBRT in TrueBEAM was investigated. The same quality of the dose delivery from different Beam ON interval in FFF-SBRT was illustrated. The increasing number of the patients can be confidently treated by free breathing and using the RPM gating system. The Breath hold technique is the best selection to minimize the side effect from the treatment. While not all patients can hold their breath for a long period, free breathing plus the RPM Gating System may be used to increase the opportunity for these people. The increasing treatment time may be negotiated by the benefit of receiving SBRT with the optimal margin.

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