Clinical implementation of efficient synchrotron operation for respiratory gated beam irradiation

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Purpose:
The most efficient synchrotron operation cycle was investigated for respiratory-gated beam irradiation. The optimal cycle has been implemented for respiratory-gated carbon beam irradiation at our facility. The clinical experience for 6 months of use will be reported.

Method:
Respiratory-gated beam irradiation for carbon beam therapy with a synchrotron (Mitsubishi Electric Corporation) has been used at our facility since March 2014. Based on conventional synchrotron operation, the duration time of the flattop phase was approximately 1.4 seconds for every synchrotron operation cycle of 3 seconds. Since this is not efficient enough for respiratory-gated beam delivery, the optimal synchrotron operation pattern for respiratory gated beam irradiation was determined by simulation. The simulation was performed using synchrotron operation patterns with different flattop duration times of 1.4~4.4 s and real patient breathing data. Respiratory gated beam delivery with conventional synchrotron operation was used to treat 45 patients, and 100 more patients have been treated with the optimal synchrotron cycle. The actual delivery time for respiratory gated beam delivery was compared for conventional and the optimal synchrotron operation.

Results:
The results showed that a 2.4 s flattop duration time with conventional acceleration and deceleration times, a 4 s synchrotron operation cycle in total, provided the optimal pattern for respiratory gated beam delivery. The beam irradiation time with the optimal synchrotron operation was 1.2 times faster on average compared to the conventional synchrotron operation. The deviation in beam irradiation time depending on patient breathing was also smaller using the optimal synchrotron pattern.

Conclusion:
A simulation study showed that the optimal synchrotron operation for respiratory gating has a flattop duration time about 1~2 s longer than the one with conventional synchrotron operation. This was validated in clinical use as well.