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# Simulation Study of Range-Adaptive Spot-Scanning Proton Therapy Using a Variable Range Shifter

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## Background / Aims

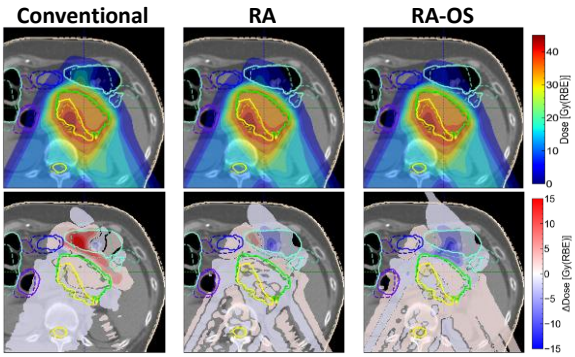
Proton therapy provides a conformal dose distribution to the tumor; however, this distribution is highly sensitive to range variations. Range variations caused by interfractional anatomical changes can disrupt the dose distribution, potentially resulting in reduced tumor dose and increased exposure to surrounding organs at risk (OARs). This study aims to develop and evaluate the effectiveness of a range-adaptive (RA) method that compensates for range variations by adjusting the thickness of a range shifter to mitigate their impact on dose distribution.

## Methods

In the RA method, the thickness of the range shifter is adjusted based on the difference in water equivalent thickness (WET) between the planning CT and the daily CT (ΔWET). ΔWET was calculated for each spot and used to determine the amount of adjustment in range shifter thickness. A default 10 mm range shifter was uniformly inserted during treatment planning, and its thickness was varied by ±10 mm according to the calculated ΔWET. Furthermore, to suppress dose increases caused by positional and morphological changes in OARs adjacent to the target, we also evaluated an extended approach, called RA with OAR sparing (RA-OS), which further adjusts the range shifter based on WET changes between the target and the OARs. The proposed methods were applied to three pancreatic cancer patients treated with proton therapy, and their clinical impact was assessed.

## Results and Discussion

The figure below illustrates, for each irradiation method, an example of the daily dose distribution and the corresponding dose difference from the treatment plan, based on a treatment planning simulation with two oblique posterior fields. In the conventional patient setup, the dose to the OAR located distal to the target tends to increase, whereas in the RA and RA-OS methods, this increase can be suppressed. Compared to conventional patient setup, the D99 of the clinical target volume (CTV) increased by up to 9.1 Gy(RBE) and 8.3 Gy(RBE) in the RA and RA-OS methods, respectively, with corresponding average increases of 1.5 Gy(RBE) and 1.1 Gy(RBE). These results demonstrate the effectiveness of range adaptation by adjusting the thickness of the range shifter in mitigating target dose reduction. Although the RA-OS method more effectively suppressed the spread of low to intermediate doses to the OARs located distal to the target than the RA method, no significant reduction in the maximum dose to the OARs was observed. These findings indicate the need for a more detailed evaluation of OAR doses and further refinement of range shifter thickness.




Daily dose distributions and dose differences in conventional, range-adaptive (RA), and RA with OAR sparing (RA-OS) methods

## Conclusions

Preliminary evaluation demonstrated the potential clinical effectiveness of a range-adaptive method that adjusts range shifter based on ΔWET between the planning and daily CTs to compensate for interfractional range variations and preserve dose distribution.