Purpose: To show that biological dose based optimization with appropriate beam arrangements is able to achieve the desired proton dose distribution with the correction of relative biological effectiveness (RBE).
Methods and Materials: The RBE calculation was derived from the linear-quadratic model and the relationship between RBE and linear energy transfer (L), and L was calculated using the Bethe-Bloch formula. Scanning proton pencil beams (1x1cm2) were used to generate intensity modulated proton therapy (IMPT) plans and IMPT1 with RBE correction. The pencil beams with RBE correction were employed in optimization to achieve the optimal IMPT2 with RBE correction. The 1-, 2-, 4- and 7-beam plans were investigated to see the effect of beam arrangement on RBE and optimization. A new parameter RBEv (= VRBE(D)/V(D))was introduced as a measure of the volume change caused by the RBE.
Results: The results showed that the RBE values ranged from 1.10 to 1.48, and the RBEv from 1.03 to 2.89 for IMPT1 that was no longer optimal in terms of RBE-corrected dose distribution. All RBE values were equal or greater than 1.10, and ranged from 1.10 to 1.50. For the rectum, the one-beam plan had the highest RBE value of 1.37, while the two-lateral beam plan had the lowest of 1.14. The IMPT2 plans used the same optimization constrains as the IMPT plans without RBE correction and the results were comparable to those of IMPT plans. The degree of agreement between IMPT2 and IMPT was beam geometry dependent and increased with the number of beams.
Conclusions: The variable RBE values changed the optimal intensity modulation of proton therapy. In order to generate optimal IMPT2 plans with RBE correction, the RBE-corrected dose should be employed in optimization. However, this can only be achieved with appropriate multiple beam arrangements.