



Geometric and Dosimetric Accuracy Analysis of Kilovoltage Cone-Beam Computed Tomography (kV CBCT) Guided Spinal Stereotactic Intensity-Modulated Radiosurgery

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Purpose: Image-guided stereotactic intensity-modulated radiosurgery (IMRS) has been shown to possess great potentials for the treatment of spinal lesions. However, because the target is usually located adjacent to the spinal cord and the dose falloff at the target edge is extremely steep, a small target localization error or intrafraction displacement may result in large dosimetric deviations. The purpose of this work is to investigate target localization accuracy and dosimetric influences arising from the setup errors and patient motion for an on-board kV CBCT-guided spinal stereotactic IMRS.

Methods and Materials: A kV CBCT-guided stereotactic IMRS program was recently implemented in our department to treat spinal lesions. In this technique, the patient is immobilized using BodyFIX® immobilization system (Medical Intelligence) and is initially set up with the aid of the Varian SRS optical positioning system (OPS). Further target localization is accomplished with the guidance of a kV CBCT acquired using an OBI system integrated in a Varian Trilogy linear accelerator. In order to evaluate patient's intrafraction motion, four sets of images are acquired for each patient: CBCT and radiographic kV images acquired before treatment, radiographic kV images acquired in the middle of treatment and another CBCT acquired at the end of treatment. All IMRS plans were generated using Varian Eclipse inverse planning system and delivered with a Varian Trilogy SRS 6 MV X-ray beam. Target localization accuracy and intrafraction motion were evaluated by offline analysis of the 3D/3D registrations between planning CT and CBCTs as well as the 2D/2D registrations between the DRRs and OBI kV images. For each case, CBCT images were also imported into Eclipse to perform CBCT-based dose calculations, in which the patient's real treatment positions and isocenters were used. Therefore, the obtained calculation results can be regarded as a representative of the delivered dose distributions under the real treatment situations and used to assess the dosimetric changes arising from setup errors and intrafraction motion.

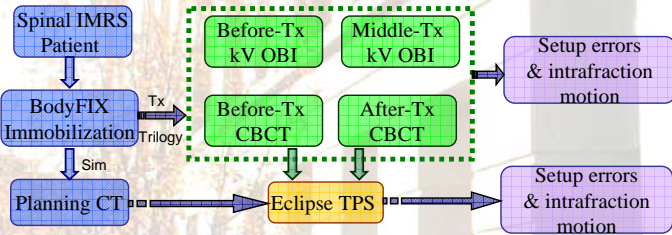


Figure 1: Illustration of the process to the geometric and dosimetric accuracy

Results: Three cases were analyzed for this study. The target volumes for these cases were 3.6 cc, 35.2 cc and 22.7 cc. Offline analysis showed that the target localization accuracy was 1.4 mm for the first case, 0.5 mm for the second and 1.0 mm for the third case. The overall intrafraction displacement was 1.4 mm, 1.0 mm and 1.8 mm, respectively, determined using the registrations of the before-treatment CBCT and after-treatment CBCT as well as the before- and the middle-treatment kV OBI images. The averaged target coverage reduction was ~7 % due to the target localization error and ~12 % due to both the localization error and the intrafraction motion. The largest increase of the maximum spinal cord dose for the three cases was 4.8 Gy due to the target localization error and 7 Gy due to the localization error and the intrafraction motion. The contributions to the dose discrepancies from the localization error and the intrafraction motion were determined using the dose distributions/DVHs calculated based on the before-treatment CBCT and after-treatment CBCT. Comparisons of dose distributions and DVHs for the case 1 and 2 are shown in figure 2-4.

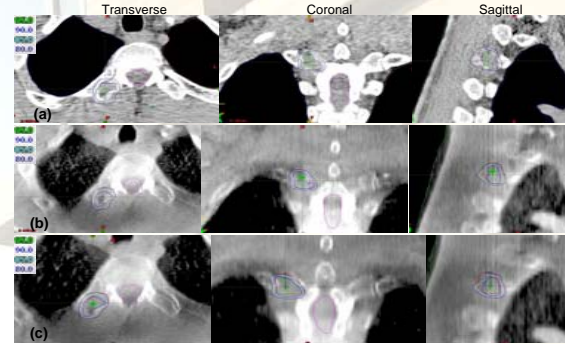


Figure 2: Comparison of the dose distributions of the target and spinal cord for case 1: (a) planned isodoses; (b) calculated isodoses based the CBCT acquired before treatment; (c) calculated isodoses based the CBCT acquired after treatment.

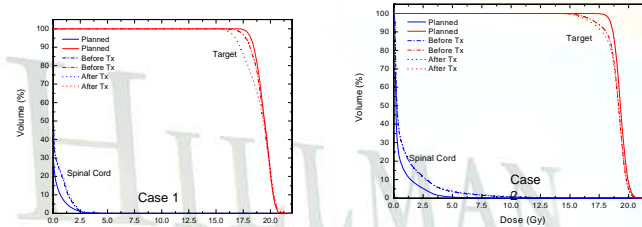


Figure 3: The following DVHs compare DVHs of the target and spinal cord for two cases: the left one is for case 1 and right for case 2.

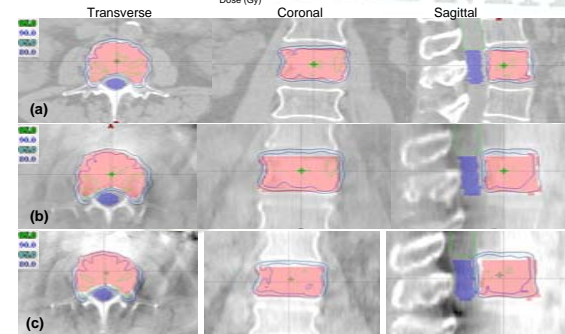


Figure 4: Comparison of the dose distributions of the target and spinal cord for case 2: (a) planned isodoses; (b) calculated isodoses based the CBCT acquired before treatment; (c) calculated isodoses based the CBCT acquired after treatment.

Conclusions: CBCT-guided spinal stereotactic IMRS can provide a target localization accuracy of less than 1.5 mm. For spinal treatment, use of the BodyFIX® immobilization system can effectively reduce the intrafraction displacement to 1–2 mm. Our dosimetric study indicated that the intrafraction motion at this scale may still have some potential influence on the target coverage and the spinal cord dose due to the extreme dose conformity of IMRS. Therefore, it is suggested that a small margin of 1–2 mm be given to the target and the spinal cord to ensure the target coverage and the spinal cord dose within its tolerance range.