

Localization, Reproducibility and Dosimetry for Spinal Radiosurgery

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Purpose. A new method for fractionated stereotactic irradiation of spinal malignancies has been investigated in preparation for clinical trials. Evaluations of the theoretical and practical limitations of localization accuracy and the implementation of the method in swine are presented.

Methods and Materials. In a percutaneous procedure, a minimum of three small (1.7mm diameter) titanium markers are permanently affixed to the bone of the vertebral column. Markers are localized on biplanar radiographs. Isocenter positions are determined on computed tomography (CT) relative to the rigid body defined by the vertebral markers. The markers provide the means for accurate day-to-day reproducibility necessary for fractionated radiation delivery. A special frame defines a coordinate system inside which the patient rests. A three-dimensional reference frame through the patient is established using external fiducial markers in a localization bridge. Radiographs coupled with a rigid body rotation algorithm account for daily differences in patient position relative to the stereotactic frame; therefore, it is not important if a patient moves between treatments. Immobilization is utilized to ensure movement is restricted between the time of the daily radiographs and the completion of radiation delivery. A treatment simulation program was written to estimate the uncertainty inherent in the localization technique. Phantom studies were used to verify theoretical uncertainty calculations. A swine model was used to evaluate the difficulty and duration of the implant technique, the suitability of the vertebral processes as an implant site, vertebral motion due to normal respiration and the ability to target one vertebra with markers in an adjacent vertebra.

Results. Theoretical accuracy studies confirmed that localization accuracy is a function of marker separation. Phantom studies involving 296 measurements showed that individual implants could be localized within ± 0.25 mm. The largest targeting error observed in 3,600 measurements of one hundred clinically relevant implant configurations was 1.17 mm. The implant procedure took 5-10 minutes per site. No significant migration of implants was observed out to thirty-five days post-implantation and respiratory motion had no detectable influence on vertebral position. Adjacent vertebrae may be useful for targeting one another with a small sacrifice in localization accuracy.

Conclusions. The use of implanted markers for localization of spinal malignancies has merit for applications in stereotactic radiotherapy. Phantom measurements suggest localization accuracy similar to intracranial stereotactic radiotherapy techniques is achievable. Swine studies suggest that the implant technique is expedient and feasible for tumor targeting purposes.