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Development and validation of a CT-3D rotational angiography registration method for AVM radiosurgery.

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In this paper a novel technique is proposed and validated for radiosurgery treatment planning of arteriovenous malformations (AVMs). The technique was developed for frameless radiosurgery by means of the CyberKnife, a nonisocentric, linac-based system which allows highly conformed isodose surfaces to be obtained, while also being valid for other treatment strategies. The technique is based on registration between computed tomography (CT) and three-dimensional rotational angiography (3DRA). Tests were initially performed on the effectiveness of the correction method for distortion offered by the angiographic system. These results determined the registration technique that was ultimately chosen. For CT-3DRA registration, a twelve-parameter affine transformation was selected, based on a mutual information maximization algorithm. The robustness of the algorithm was tested by attempting to register data sets increasingly distant from each other, both in translation and rotation. Registration accuracy was estimated by means of the "full circle consistency test." A registration quality index (expressed in millimeters) based on these results was also defined. A hybrid subtraction between CT and 3DRA is proposed in order to improve 3D reconstruction. Preprocessing improved the ability of the algorithm to find an acceptable solution to the registration process. The robustness tests showed that data sets must be manually prealigned within approximately 15 mm and 20 degrees with respect to all three directions simultaneously. Results of the consistency test showed agreement between the quality index and registration accuracy stated by visual inspection in 20 good and 10 artificially worsened registration processes. The quality index showed values smaller than the maximum voxel size (mean 0.8 mm compared to 2 mm) for all successful registrations, while it resulted in much greater values (mean 20 mm) for unsuccessful registrations. Once registered, the two data sets can be used for CyberKnife treatment planning. Target delineation is performed on 3DRA while dose calculation and DRR generation are performed on CT. In conclusion, a method was developed for using 3DRA images for AVM frameless radiosurgery treatment planning. The method proved to be feasible, robust, and accurate for clinical use. 3DRA can be performed at different times or locations compared to standard, frame based stereotactic angiography. Unlike two-dimensional angiography, 3DRA allows examination of the shape of the AVM and of the surrounding target from any arbitrary point of view during treatment planning. The method can be applied to any case of intermodality registration, is operator-independent, and allows estimation of registration quality. Further research is desirable to improve time resolution in order to distinguish between feeding and draining vessels.

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