Fusion of DWI and Structural MRI with Radiation Dose Distributions for Quantitation of Radiation Effects in the Brain and Prediction of Response to Radiosurgery in Temporal Lobe Epilepsy

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Synopsis

We have developed a computer-aided, quantitative image processing and analysis technique to test the following hypothesis: that the quantitative imaging measures of brain parenchymal change following gamma knife stereotactic radiosurgery (GKR) for mesial temporal lobe epilepsy (TLE) correlate with absorbed radiation dose in the mesial temporal lobe, and can serve as an early imaging surrogate marker to predict therapeutic seizure reduction at one and two years. The image processing workflow includes the 3D registration of radiation dosage map with stereotaxic MRI, registration with various % isodose lines, computation of total dose within arbitrarily shaped volumes of interest (VOIs), and finally registration of the stereotactic MRI with diffusion tensor images (DTI), Contrast-enhanced MRI, and other sequences. This system is designed to allow qualitative assessment of water content and leakage of contrast, and quantitative computation of apparent diffusion coefficient (ADC) and anisotropy index (AI) maps within a VOI including the hippocampus and mesial temporal lobe, in both pre-operative and post operative MR scans.

Purpose

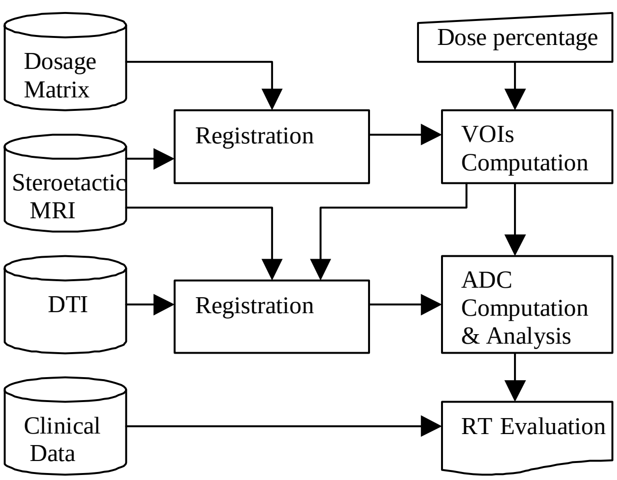
To determine if quantitative and qualitative MR imaging changes can be used as early surrogate markers to predict later response to stereotactic radiosurgery for TLE. Stereotactic RT technique focuses gamma radiation into precisely controlled region of the brain. There is preliminary evidence that radiation therapy reduces seizures at 1-2 years, but no method exists to predict which patients will respond either before or shortly after GKR. Diffusion tensor imaging (DTI) offers new insights into the micro-structural organization of the brain and permeability and perfusion imaging can assess the delivery of blood to the brain. Investigation in animal models of epilepsy report that reduced diffusion is associated with seizure activity. DTI studies in ischaemia also have shown an early decrease in ADC, progressing at a later stage to a high ADC if infarction occurs. Thus ADC analysis in the treatment region before and after radiation therapy is expected to yield a quantitative measure of tissue response to GKR, and may allow early pre or post-operative prediction of therapeutic response. Such an early marker could greatly improve patient care by allowing patients unlikely to respond to be referred for resective conventional surgery.

Methods

The MR image processing workflow as shown in Figure 1 includes the 3D registration of radiation dosage map with stereotactic MRI, computation of VOIs with various % isodose lines, registration of stereotactic MRI with DTI, contrast-enhanced MRI and other sequences to assess water content and leakage of contrast, and the computation and analysis of ADC and AI maps in the pre-operative and post-operative VOIs.

Result

Software and protocol used have been developed for the dosage registration with stereotactic MRI, automatic display of VOI, automatic overlay of isodose lines, ADC analysis and mapping and fusion of the resulting data sets. Figure 2 shows stereotactic MRI data fused with dosage distribution data, and displayed with an overlayed 25% isodose curve.



Figrue 1 Workflow of MRI Image Processing System Developed to Evaluate the Efficacy of Gamma Knife Radiosurgery.

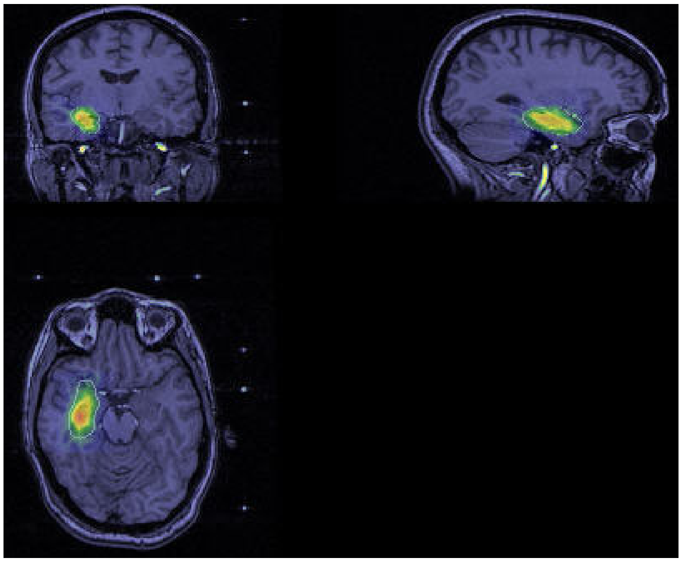


Figure 2 Radiation dosage distribution, volumes of interest (VOIs) with 25 % isodose lines around the temporal lobe region.