

Functional diffusion tensor imaging in the evaluation of early response after radiosurgery in patients with acoustic neuroma

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Introduction:

Stereotactic radiosurgery (SRS) of acoustic neuroma have shown to reduce or arrest tumor growth. Outcome evaluation in clinical oncology is conventionally based on the volumetric changes in the tumor size ¹. Unfortunately, these changes require a significant time interval of months to years after radiosurgery before being apparent ². Growing evidence has accrued that functional diffusion map (fDM) might serve as an early imaging biomarker to assess early response to cancer treatment ³. However, fDM studies focus exclusively on changes in water diffusivity and directional information is discarded. In the present study, we used an fDM-based approach to study anisotropic diffusion to investigate the balance between numerous factors including cellularity, vascularity, and integrity of cell membranes. To demonstrate the feasibility of combining fDM with anisotropic diffusion, we prospectively investigated by means of DTI patients with acoustic neuroma. By using the diffusion information, we were able to detect early changes in response to treatment.

Materials and Methods:

Five patients with unilateral acoustic neuroma were planned for the SRS using single dose of 12-13 Gy. Serial DTI studies were scheduled as: (1) 1 day before SRS; (2) 2 weeks; (3) 4 weeks; (4) 8 weeks; (5) 12 weeks and (6) 24 weeks after SRS. DTI studies were performed on a 3T MR scanner with 12 non-collinear directions and b factor of 1000 s/mm². The post-treatment DTI data were spatially co-registered to the pretreatment T2 weighted images. The mean diffusivity (MD), fractional anisotropy (FA), and intervoxel diffusion coherence (IVDC)⁴ were calculated using simple average methods and functional diffusion maps. fDM was performed by segmenting the tumor into three different categories: areas of significantly increased diffusion values were marked as red color, while decreased in blue; the remaining voxels without significant changes were represented as green. Thresholds of significant change were determined to be the 95% confidence intervals (CI) calculated from normal contralateral white matter of patients. The percentage of the tumor within the three categories was then calculated as volume increased (V_R), volume decreased (V_B) and volume unchanged (V_G).

Results:

Figure 1 depicts the longitudinal changes in mean diffusion measures and tumor volumes. Tumors did not change significantly in size until 24 weeks after treatment. Diffusion indices changed significantly during the study period. There was a transient decrease in averaged MD followed by a significant increase. IVDC showed an opposite behavior compared to MD. FA decreased continuously throughout the study period. Figure 2 demonstrates the time course of fDMs from a representative patient with a left side acoustic neuroma. The heterogeneous responses of the tumor to treatment through the investigation period were well depicted. Figure 3 shows the mean V_R and V_B values from 5 patients. As for MD (Fig 3a), V_B was more prominent and showed a transient increase followed by a significant decrease at week 24. In contrast, V_R showed a continuous increase throughout the study period. As for FA (Fig 3b), V_R remained low and unchanged during the study. Notably, V_B was higher than V_R at all time points. V_B remained unchanged until week 12, whereas a significant increase was evident at week 24. As for IVDC (Fig 3c), V_R had the highest value throughout the study, but a significant decrease from 59.9% at week 2 to 42.6% at week 24 was observed. V_B was low at beginning of the study (2.5%) and slowly increased to 10.2% at week 24.

Conclusions:

Functional changes detected by DTI precede changes in tumor volume. By using functional diffusion maps extending to anisotropic diffusion, we were able to reveal the heterogeneity of response to treatment. Our approach might provide complementary information compared to simple averaged values.

References:

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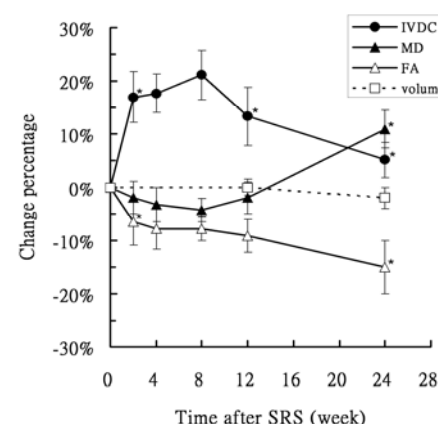


Fig.1 Longitudinal changes of mean MD, FA, IVDC and tumor volumes over time for five patients after SRS treatment. (*p < 0.05, vs. previous time point).

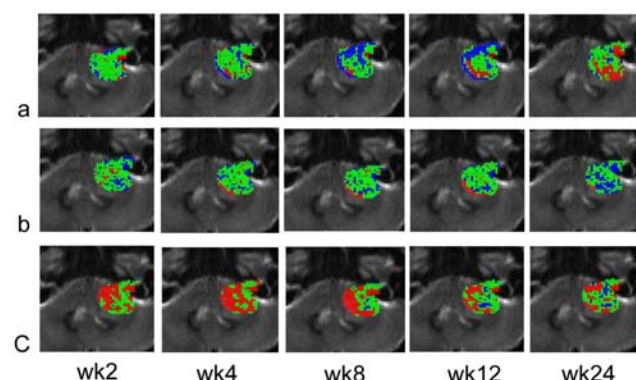


Fig 2. fDMs of MD (a), FA (b) and IVDC (c) from a patient with left side acoustic neuroma after SRS therapy. Areas of significantly increased values were expressed as red, while decreased in blue; The remaining voxels without significant changes were expressed as green.

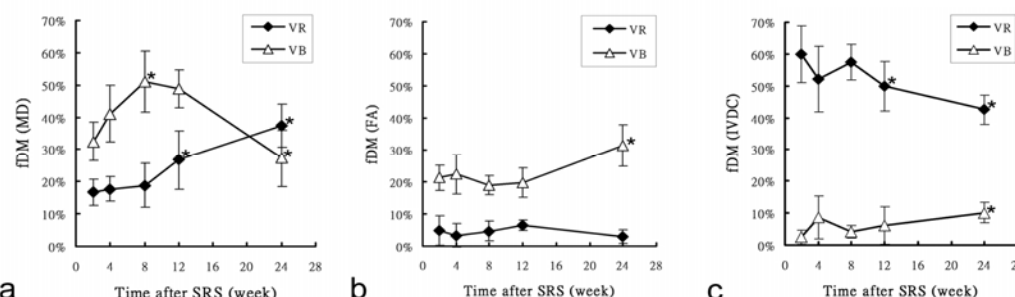


Fig 3. Mean values of fDM in (a)MD, (b)FA and (c)IVDC maps as a function of time post treatment. The fDM volumes were normalized as a percentage of total tumor volume. V_R: the volumes within the tumors that had significantly increased diffusion values; V_B: the results for the tumor volumes that had a significant decrease in diffusion values. (*p < 0.05, vs. previous time point)