Combining fMRI, diffusion tensor tractography and time-resolved MRA in pre-operative surgical planning for brain tumors

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Materials & Methods: A non-vocal paradigm for activation of the language areas was developed and validated on 10 right-handed volunteers. BOLD-fMRI images were acquired by BrainWave RealTime (RT) at 3T (GE Signa Excite^{TM} HDx). Activation maps were analyzed using AFNI software to discriminate areas of consistent activation from background activation and to superimpose activation maps onto higher resolution T1 weighted anatomic images. Functional language laterality index (LI) was calculated taking out the inferior frontal gyrus, inferior parietal lobe and superior and middle temporal gyrus. Three dimensional architecture of frontal lobe white matter fibers were visualized using diffusion tensor tractography (DTT) on Volume-one software. After validation, this protocol was applied to 11 left frontal lobe tumor patients. Before scanning all the patients were tested language function by aphasia quotient (AQ) based on Western Aphasia Battery (WAB). MRA (3D-TRICKS) was obtained during injection of 0.1mMol/kg Gd at 3 ml/s. Temporal resolution was 3 to 4s per phase depending upon the number of slices needed to cover the circle of Willis and the entire lesion. All these images demonstrating relationship between tumor and language activation area, white matter fibers and surrounding vessels were reviewed by neurosurgeons as part of pre-operative planning.

Results: Before the operation 3 out of 11 patients had aphasia (AQ<93.8). Language areas were visible on fMRI activation maps in 8 patients all of whom had a left language dominant hemisphere (LI≥0.10). In the other three patients fMRI was corrupted by motion. Diffusion tensor imaging was successful in 10 patients and corrupted by motion in 1 confused patient who could not cooperate with instructions. DTT showed disruption of the left arcuate fasciculus in 2 patients, deviation/deformation in 6 cases and unaffected in the remaining 2 cases. Time-resolved MRA showed normal vasculature with no distortion of the vessels in 4 patients, in 2 patients with Grade III anaplastic oligodendrogliomas a halo of tumor vascularity was visible around the tumors, shift of the ACA was visible in 3 patients and encasement of the MCA was visible in one patient. Although vascular effects were apparent in 6 patients, the underlying tumor was directly visible on time-resolved MRA in only 4 patients. Pre-operative review of language mapping, DTT and MRA influenced the surgical approach in all 10 patients (see table 1). Post-operatively, one patient died and one was lost to follow-up. The remaining 9 patients showed no tumor recurrence at one year follow-up. No patient language function deteriorated, though two patients with mild aphasia pre-op did not improve: one with partial disruption of the anterior left arcuate fasciculus (Fig. 1) and the other with obliteration of the entire arcuate fasciculus by glioma. This compares favorably with the historical 30% incidence of aphasia post resection of left frontal lobe tumors.

Discussion and Conclusion: Optimum planning for resection of brain tumors with sufficient margin for cure while avoiding excessive disruption of functioning brain has been challenging with routine brain MRI. Addition of fMRI, DTT and time-resolved MRA to routine brain MRI is helpful for identifying the relationship of brain tumors to vasculature, language cortex and white matter fibers for improved residual language function.

References:

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Table 1. Combining fMRI, DTT and MRA on left frontal lobe tumor patients

Patient	Pre-operative AQ	Distance (tumor to Broca) (cm)	Arcuate fasciculus	Time-resolved MRA	Post-operative AQ
1	98	1.7	Distortion	Tumor stain, no distortion of vessels	98
2	98	2.6	Shifted inferiorly	Tumor stain & supplying vessels	100
3	100	4.8	Normal	No distortion of vessels	100
4	100	1.4	Motion corrupted	No distortion of vessels	100
5	100	4	Shifted laterally	Encasement of LMCA	100
6	85	1.6	Distortion	Halo of tumor vascularity	94.5
7	97.4	*	Normal	No distortion of vessels	100
8	91.6	*	Shifted posterioly medially	Halo of tumor vascularity	100
9	89.2	5.7	Shifted superiorly medially	Shift of the LACA	100
10	100	0	Shifted posteriorly laterally	Shift of the LACA	100
11	96.2	*	Shifted inferiorly	Shift of the LACA	100

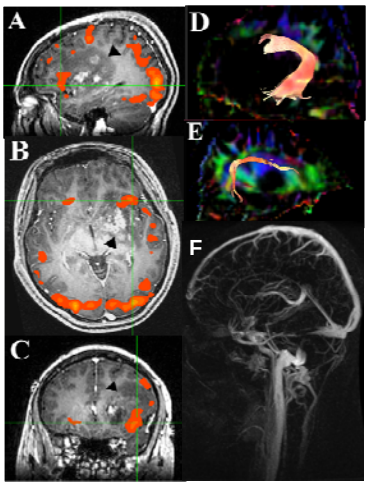

Fig. 1. A 14-year-old girl with right lower extremity numbness and slightly deteriorated language function (patient 1). Tumor (A-C, arrowheads) in the left frontal lobe, basal ganglion and insular lobe showed inhomogeneous enhancement on T1WI. Superimposed activation map shows Brocca area (the center of two green cross lines) is just beneath the tumor. Tractography in sagittal plane, D, shows the anterior part of left arcuate fasciculus has been disrupted by the tumor. Figure E shows the normal right arcuate fasciculus. Figure F shows the normal vasculature of the patient.