MR Elastography of Skull Base Tumors

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Target audience: Neuroradiologists, neurosurgeons and researchers interested in the clinical application of MR elastography and novel pre-operative planning tools for skull base tumors.

Purpose: Several groups have investigated the use of MR elastography (MRE) for neurological diseases including brain tumors[1], normal pressure hydrocephalus[2] and Alzheimer's disease[3]. Correlation with the preoperative stiffness of meningiomas and findings at surgery has been reported[4]. Tumors of the skull base vary in stiffness; however, stiffness cannot reliably be predicted with conventional MRI sequences. Stiff tumors can result in a difficult surgical resection with extended operative time and increased risk to the patient. In addition, with the increasing role of endoscopy, knowing tumor stiffness prior to surgery could be critical to decide between an open or endoscopic approach. The goal of this study was to determine the potential of MR Elastography to preoperatively assess the stiffness of skull base meningiomas, pituitary adenomas, and vestibular schwannomas.

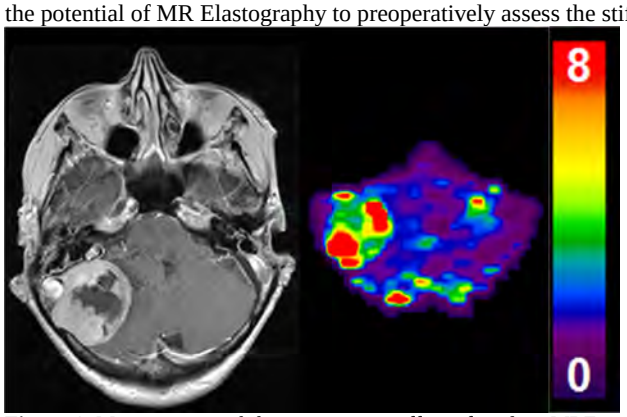

Figure 1. Meningioma with heterogeneous stiffness found on MRE and confirmed at surgery.

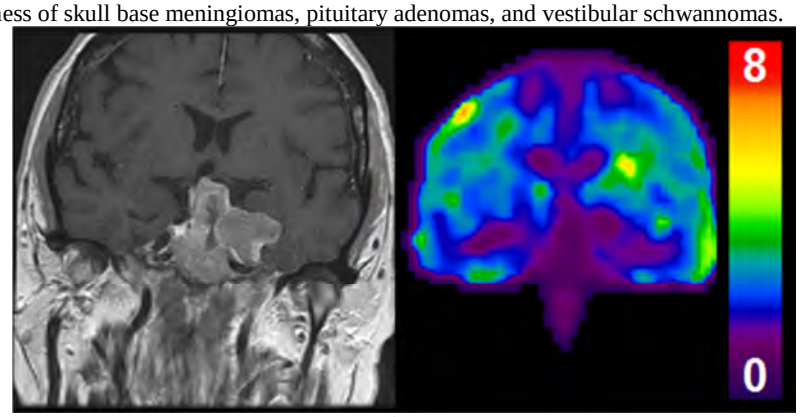

Figure 2. Pituitary adenoma shown to be soft with MRE and surgery.

Methods: We conducted an IRB approved study of 5 pituitary adenomas (range 31-49 mm), 7 posterior fossa meningiomas (range 23-37 mm) and 8 vestibular schwannomas (range 20-38 mm). A modified spin-echo echo planar imaging sequence was used to acquire MRE data with the following imaging parameters: 60 Hz vibration; TR/TE = 3600/62 ms; FOV = 24cm; 72x72 image matrix reconstructed to 80x80; 48 contiguous 3 mm thick axial slices; one 18.2 ms motion encoding gradient on each side of the refocusing RF pulse; x, y, and z motion encoding directions; and 8 phase offsets spaced evenly over one period of 60 Hz motion. The MRE postprocessing has been previously described[3] and can be summarized in 3 steps: 1) calculating the curl of the displacement images; 2) smoothing the data with a quartic smoothing kernel; and 3) calculating the stiffness using a direct inversion of the Helmholtz wave equation. Regions of interest were manually segmented from the resolution-matched T1-weighted images and applied to the elastograms to determine tumor stiffness. When the lesions were heterogeneous on the T1-weighted images, multiple sub-volumes within the tumors were created and regional stiffness values were calculated within these volumes.

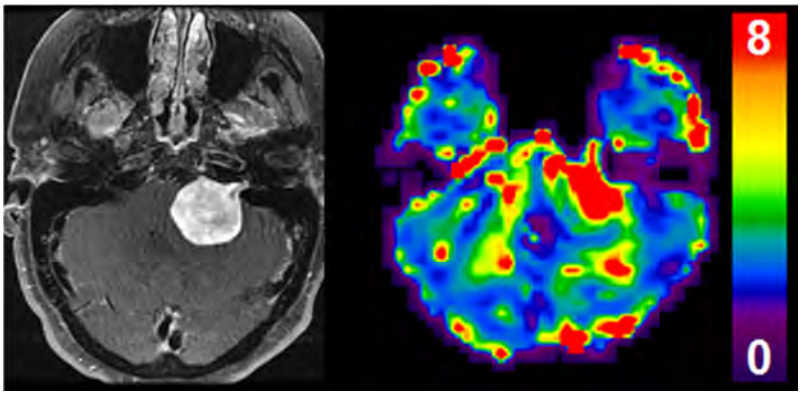

Figure 3. Figure 3. Vestibular schwanoma that was very stiff on MRE and difficult to resect due to the hard components of the tumor.

Results and Discussion: Four of the meningiomas were homogenous in stiffness and 3 had heterogenous stiffness on MRE while at surgery 3 were homogenous and 4 were heterogenous (Fig. 1). Pituitary adenomas (Fig. 2) and vestibular schwannomas (Fig. 3) were of uniform signal on MRI and stiffness on MRE. Concordance of stiffness findings was demonstrated with the pituitary adenomas including 4 tumors characterized as soft with MRE and at surgery. One adenoma was characterized as intermediate stiffness with MRE and at surgery. For the vestibular schwannomas, 3 were found to be soft with MRE and at surgery, 1 of intermediate stiffness with both MRE and at surgery and 1 characterized as hard with MRE and at surgery. Two tumors were calculated to be intermediate stiffness with MRE but found to be soft at surgery. One of these schwannomas was associated with a high degree of vascularity and the other with probable increased intracranial pressure. MRE was excellent at determining if a tumor was heterogenous with stiff regions but was less effective in ruling-out heterogeneity. If MRE demonstrated a tumor would be stiff or contain a stiff portion then this was always encountered at surgery.

Conclusion: These preliminary results demonstrate a good correlation between MRE measurements and the findings at surgery for the evaluation of skull base meningiomas, pituitary adenomas and vestibular schwannomas. Further investigation of the role of tumor vascularity and increased intracranial pressure is needed. However, MRE shows substantial promise as a tool for the preoperative assessment of skull base tumor stiffness.

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References: [1] Xu et al. Acta Rad 2007. 48:327. [2] Streitberger et al. NMR in Biomed 2010. [3] Murphy et al. JMRI 2011. 34(3):494. [4] Murphy et al. J Neurosurg 118**:**643–648, 2013.