Dynamic MRI of the temporomandibular joint at 3 Tesla using a gradient echo sequence

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Introduction Temporomandibular joint (TMJ) dysfunction is a cause of headache, facial pain and referred otalgia, which can be quite debilitating to patients. MRI has been applied in limited circumstances to define contours of the articular disc, and to evaluate disc motion during translation of the condyle with opening and closing of the mouth. Broad implementation of an effective protocol has been limited by lack of an effective dynamic imaging sequence having sufficient temporal resolution to evaluate joint space mechanics. Additionally, current protocols are very time intensive, which is limiting for both the patient and busy clinical practices. We seek to introduce a dynamic sequence able to capture both disc motion and contour. Implementing such a protocol may lead to earlier diagnosis and treatment of TMJ dysfunction, ultimately improving patient care. Recent dynamic TMJ studies demonstrated the feasibility of a single-shot spin echo sequence at 1.5 Tesla [1]. In this work, we report our preliminary studies on the feasibility of a real-time gradient echo (GRE) imaging at 3 Tesla.

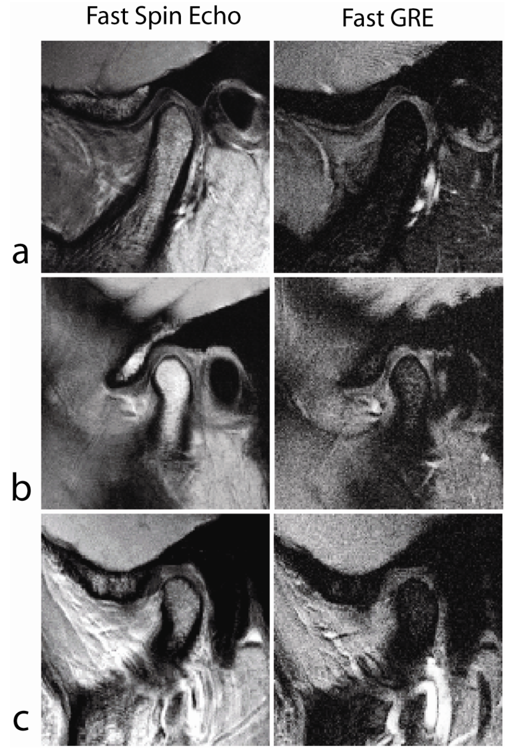

Figure 1. Fast spin echo (left) and fast gradient echo (right) images from three subjects: (a) Subject 1, (b) Subject 2, and (c) Subject 3. These are meant to illustrate typical image quality for current static imaging sequences.

Methods and Results Experiments were performed on a GE Signa Excite 3T scanner using a 6-channel Carotid receive coil (NeoCoil) where three coil elements were each placed near the left and right ears. Static and dynamic TMJ imaging studies were performed on eight asymptomatic volunteers. (***Static Fast Spin Echo Imaging***) The disc and its surrounding tissue were first identified using spin echo sequence with a static closed-mouth posture (see the left column in Fig. 1). Imaging parameters were: fast spin echo with echo-train-length = 3, TE = 25 ms, TR = 1500 ms, readout bandwidth = 31.25 kHz, slice thickness = 3 mm, 320 × 320 image matrix, FOV = 12×12 cm^2, scan time = 2:45 sec. (***Static Fast Gradient Echo Imaging***) GRE imaging was also performed with several echo times in order to measure T_2*. Imaging parameters were: TEs = [5, 7, 9, 11, 13, 15, 17] ms, TR = 40 ms, readout bandwidth = 31.25 kHz, slice thickness = 3 mm, 320 × 320 image matrix, FOV = 12×12 cm^2, flip angle = 20°, 26 sec scan time for each TE, NEX = 2. The right column in Figure 1 contains the GRE images obtained with TE = 9 ms using the imaging protocol described above. Tissue regions of interest were drawn manually, and T_2* was estimated by curve fitting [3]. ***(CNR Optimization)*** A simulation study was performed to find the GRE imaging parameters (flip angle, TE, and TR) that maximize the CNR efficiency between the disc and surrounding tissue [2]. We used T_1 = 901 ms for the disc and T_1 = 812 ms for the anterior soft tissue based on the literature [2]. Mean T_2* values for the disc, anterior and posterior soft tissues were calculated to be 12 ms, 17 ms, 18 ms for Subject 1, 12 ms, 15 ms, 12 ms for Subject 2, and 12 ms, 18 ms, 13 ms for Subject 3, respectively. For a given short TR of 16 ms, the parameters of TE = 10 ms and flip angle = 15° produced the optimum CNR efficiency from the simulation. (***Dynamic Imaging***) Dynamic TMJ scans were performed with a 2DFT GRE sequence using custom real-time imaging software [4]. Imaging parameters were: TE = 8 ms, TR = 16 ms, flip angle = 20°, slice thickness = 5 mm, in-plane spatial resolution = 0.5 × 0.5 mm^2, NEX = 1. Partial k-space data (200 out of 300 phase encodes) were acquired at each frame. The temporal resolution was 3.2 sec. Each subject was instructed to open their jaw incrementally and sustain each posture for about 6 seconds without any interruptions from the operator (i.e. self-paced). Final images were obtained by performing sum-of-squares of all three coil images after Homodyne reconstruction. In Figure 2, the motion of the disc relative to the translation of the condyle is well delineated in the frames from the open-mouth postures.

Discussion In three out of eight volunteers, static GRE imaging did not provide sufficient contrast between the disc and surrounding tissue in closed-mouth position, likely due to variations in tissue relaxation properties (e.g. T_1, T_2*) between subjects. Dynamic GRE TMJ imaging was performed without the need for a device controlling position. Several frames had motion artifacts thus leading to poor visualization of the disc. The condyle and disc was often out of the scan plane when imaging open-mouth position. Improvements in real-time GRE TMJ imaging may be possible by 1) implementing real-time adjustment of TE, 2) developing higher temporal resolution sequences, and 3) having better knowledge of the trajectory of the condyle and disc in three dimensions for adaptation of the scan plane. Real-time fast spin echo imaging may be needed, in order to image the disc reliably.

References [1] Wang *et al*., Am J Neuroradiol 28:1126-1132 (2007); [2] Carl *et al*., ISMRM p291 (2009); [3] Sanal *et al*., ISMRM p3993 (2009); [4] Santos *et al.*, IEEE EMBS (2004).

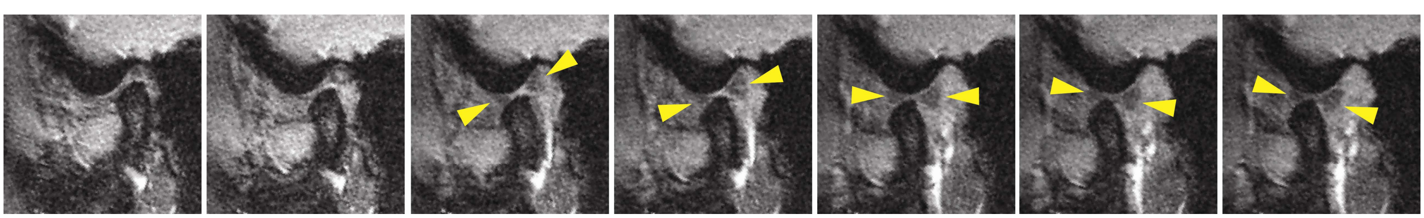

Figure 2. TMJ dynamics obtained by real-time imaging of Subject 2 in Figure 1. Images are shown from closed- (left) to open- (right) mouth positions. The disc motion (see the arrowheads) is clearly seen in the open-mouth positions at the 3rd, 4th, 5th, 6th, and 7th frames (the frame order starts from the left).