Gradient Moment Nulling in MR Elastography of the Liver

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Introduction: Recently, MR Elastography (MRE) in the liver has been shown to be a promising and quantitative method for noninvasive assessment of liver fibrosis [1]. However, bulk motion can induce signal loss, ghosting and unwanted phase accumulation. In MRE, we want spins to accrue phase from applied sinusoidal motion. To separate these two sources of phase accumulation, Gradient Moment Nulling (GMN) can be applied to both a standard Spin Echo EPI (SE EPI) pulse sequence [2-3] and to the Motion Sensitizing Gradient (MSG) waveform [4]. In this paper we investigate the application of a GMN pulse sequence in MRE of the Liver.

Methods: It is well known that so called 1-2-1 (pulse widths of the first and last lobe are half of the central lobe) gradient pulses inherently have their 0^{th} and 1^{st} moments nulled. By their definition, moments are a linear operation. Therefore, multiple 1-2-1 can be superimposed on each other to yield longer trains of GMN pulses. **Figure 1a** displays a SE EPI pulse sequence showing a MSG with two bipolar gradients. A GMN version with the same sensitivity to sinusoidal motion can also be played out. The resulting 1^{st} moments are seen in **Figure 2b**.

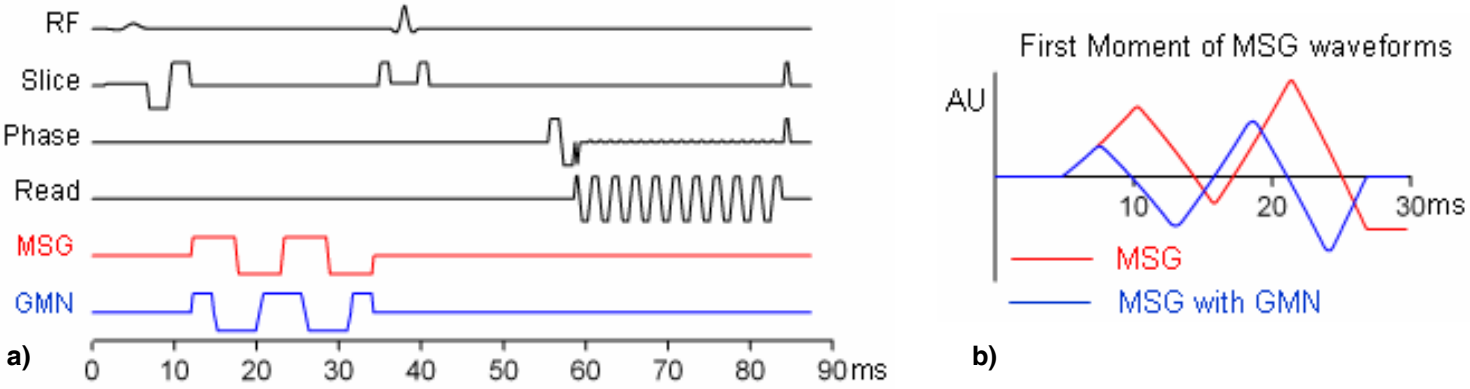

Figure 1: a) SE EPI pulse sequence with flow compensation gradients shown on the imaging axes, The MSG waveform can be played on any of the imaging axes. While the MSG pulse and its GMN version play out in the same time, the non-nulled form results in a large 1^{st} moment as seen in b).

Results: Shown in **Figure 2** is a representative magnitude image from a healthy volunteer. The reduced ghosting is clearly seen in **Figure 2b**. Also noted is the recovered signal in the bile ducts, aorta and IVC.

Discussion: A reshaping of the MSG waveforms to null the 1^{st} moment reduces its susceptibly to bulk motion with out increasing the echo time or reducing sensitivity to cyclic motion. Application of GMN for the rest of the imaging gradients will increase the TE time modestly. Nulling the 1^{st} moment of the MSG waveform does not require the entire sequence to have its 1^{st} moment nulled. Much of the improved image quality seen in **Figure 2b** can be obtained with out an increase in echo time.

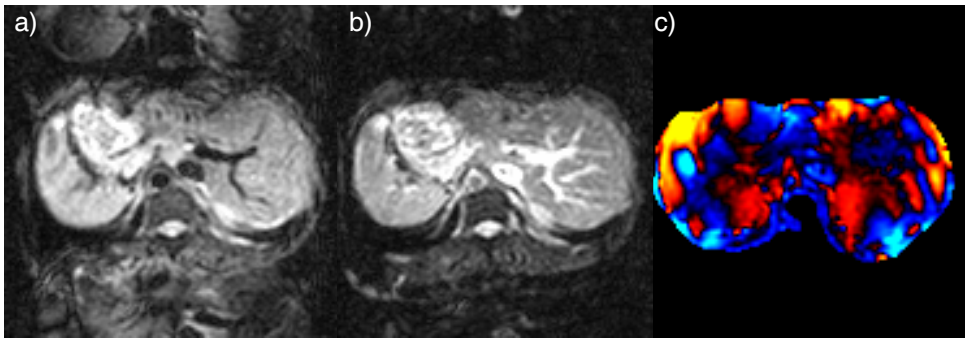

Figure 2: Magnitude images obtained using a 2 shot SE EPI sequence with 80x80 sampled resolutions. A single 60Hz pulse was used to encode motion in the phase direction. A non-nulled MSG waveform was used to acquire the image in a). A GMN version of the MSG waveform was used to acquire the image in b) along with the resulting wave image in c).

References: 1) Rouviere, Yin, et al. Radiology 2006; 240(2):440-8. 2) Weisskoff, Crawley, Wadeen. SMRM proceedings 1990; 398. 3) Haacke, Lenz. Am J Roentgenol 1987; 148:1251-1258. 4) Muthupillai, Rossman, et al. ISMRM proceedings 1996; 1515.