MR Elastography of Human Kidney In Vivo: A Feasibility Study

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Introduction: Palpation is an important tool used by physicians to diagnose disease by assessing the mechanical or elastic properties of tissue. Magnetic Resonance Elastography (MRE) is a noninvasive imaging technique that measures and quantifies mechanical tissue properties [1-2]. It is hypothesized that MRE can be used to study diffuse diseases which are not well characterized by other imaging techniques. Recently, MRE was used to investigate nephrocalcinosis in an in vivo rat model [3]. In vivo imaging of kidneys poses new challenges such as adequately illuminating a retroperitoneal structure with shear waves and more familiar challenges such as respiratory motion. The purpose of this study was to obtain pilot data using the technique and to identify experimental factors that might influence the use of MRE to study renal parenchymal disease.

Methods: The methods for imaging propagating mechanical waves in tissue were implemented on a 1.5T whole-body imager and have been previously described in detail [1-2]. MRE experiments were performed in 3 healthy volunteers after obtaining informed consent. The volunteer lies supine on a "drum" driver. This consisted of a flexible membrane on the top of a rigid chamber. The chamber was connected to a large audio speaker with a sealed tube. Shear waves at frequencies of 50-100 Hz were generated in tissue through mode conversion of the longitudinal motion of the membrane. In addition to standard imaging gradients, the MRI sequence incorporates oscillating motion-sensitizing gradients, which are synchronized with the acoustic shear waves. The sequence provides images, which effectively represent quantitative snapshots of tissue displacements caused by propagating mechanical waves. A continuous-drive, 40 ms TR acquisition was used to allow for a 7-8 second breath hold per phase offset. FSE images acquired at the same plane provided anatomic correlation for the shear modulus measurements. The data was analyzed using a local frequency estimating algorithm to compute quantitative shear stiffness maps [4]. A threshold, based on the displacement SNR, was applied to the shear stiffness estimates to mask regions with low displacement amplitude.

Results: No artifacts were visible around the "drum" driver. The breath hold scans limited the effects of respiratory motion. No discomfort was reported by the volunteers. Shear wave illumination was achieved for the first 10 mm of the kidney, which should give an adequate representation of the cortex. Figure 1 shows a wave image and inversion for a healthy male volunteer. The shear stiffness of the kidney, where the displacement SNR is adequate, was 16.3 + 5 kPa.

Discussion: This study established the feasibility of performing in vivo MRE of the kidney. The stiffness results were higher than those of specimens found in the literature [5]. However, this result was not unexpected given the fluid pressure in an in vivo kidney. The continuous drive technique also allows for acquisition of all 8 offsets in a single breath hold, for very fit volunteers. Further improvement in driver design may lead to improved wave penetration.

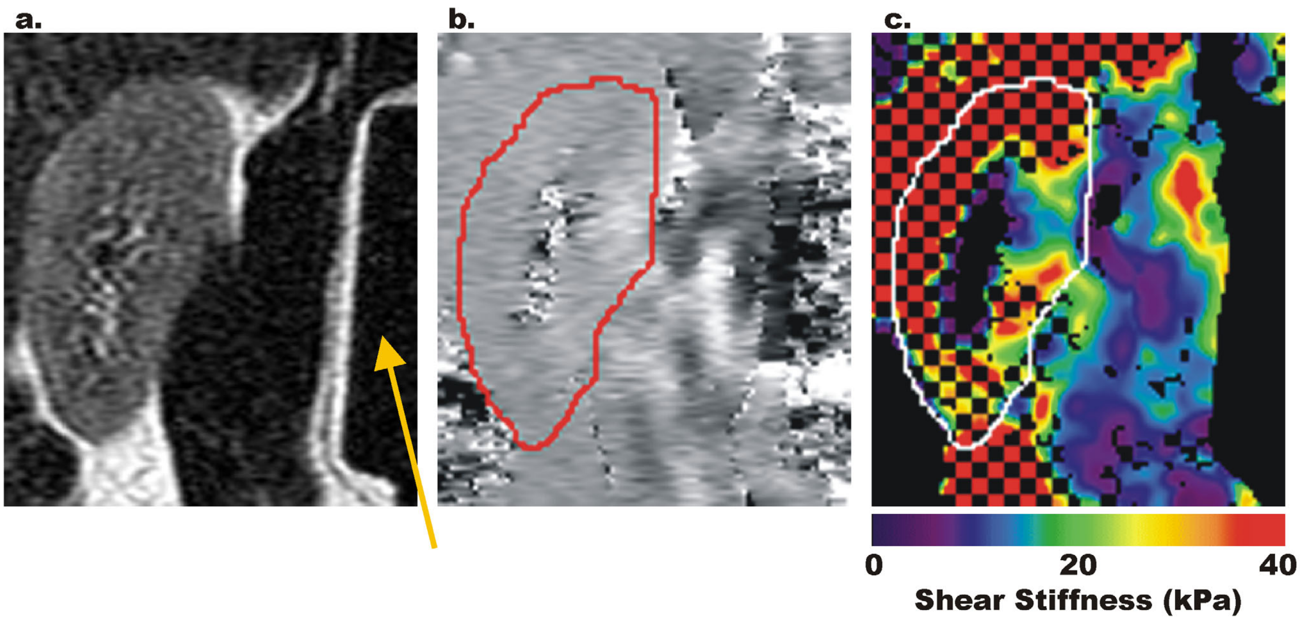

Figure 1. a. The sagittal T2-weighted FSE image shows the position of the "drum" driver (arrow). b. The wave image shows the displacement of the waves propagating into the kidney. c. The checked areas on the shear stiffness map represent regions with insufficient displacement SNR for accurate characterization.

References

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