MR Elastography in Renal Transplant Patients: A Feasibility Study

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Introduction. Ultrasound-guided kidney transplant (KTx) biopsies regularly performed for interval assessment of the allograft generally require multiple core-needle biopsies in order to meet the strict criteria for tissue adequacy as outlined by Banff 97, an international schema developed in the early 1990's for classifying renal allograft pathology. The potential for tissue inadequacy is further exacerbated by the inherent risks associated with this procedure, namely bleeding, infection, and development of pseudoaneurysms and/or arteriovenous fistulae. Yet, the benefits outweigh the risks as fibrosis with inflammation at one year has been associated with not only reduced graft function and survival but also a rejection-like gene expression signature [1]. The purpose of this investigation is to explore the feasibility of using quantitative images of KTx stiffness from MR elastography (MRE) to assess the condition of the allograft.

Methods: MRE was performed on eleven adult male or non-pregnant female KTx patients who were otherwise healthy and returning for their annual or post-annual evaluation including biopsy. Each patient was positioned feet first and supine in a 3T MR scanner (SIGNA MR750, GE Healthcare, Waukesha, WI) and imaged with an 8-channel receive-only torso phased-array coil. MRE acquisitions were performed using 120-Hz vibrations and a flow-compensated, single-shot, spin-echo EPI MRE imaging sequence. The source of vibrations was an active pneumatic driver located outside of the scan room as described in [2] with the passive driver replaced by a 12x12x2-cm soft flexible driver [3] placed directly above the allograft. Other imaging parameters included FOV = 32-40 cm, 96×96 acquisition matrix reconstructed to 128×128, ASSET acceleration factor of 3, 30-40 3-4-mm contiguous slices, TR/TE = 1700-1850/48-60 ms, and motion sensitivity of 19.5 μm/π rad. The acquisitions were performed with free breathing. The renal tissue stiffness was calculated by performing a direct inversion of the Helmholtz wave equation using the curl of the measured displacement field and directional filtering [4, 5]. The renal parenchyma was manually segmented to provide regions of interests from which to obtain estimates of the mean and standard deviation of the tissue stiffness. All patients underwent ultrasound-guided core needle biopsy per standard protocol at our institution near the time of the MRE.

Results: The mean age of the patients was 50 years ranging from 31-71 years; 6/11 (55%) were male. One of the eleven patients had had prior renal transplants; and one had two concurrent renal transplants, one atrophic and dysfunctional. Table 1 shows the degree of interstitial fibrosis from pathology and calculated mean stiffness values from MRE for each patient. Figure 1 shows examples of the MRE results.

Patient	Interstitial fibrosis (Pathology)	Mean Stiffness (kPa)
1	Mild	8.1 ± 1.7
2	Moderate	9.6 ± 2.2
3	Inadequate biopsy	8.5 ± 1.7
4	Moderate	8.8 ± 2.3
5	Mild	8.1 ± 1.9
6	Mild	9.3 ± 2.1
7	None	9.4 ± 2.3
8	Mild	6.0 ± 1.6
9	Mild	8.0 ± 1.5
10	Mild	8.1 ± 1.6
11	Mild	13.2 ±4.0
		6.2 ±1.4*

Table 1. Comparison of pathology with mean stiffness in all patients including the patient with a concurrent atrophic transplant*.

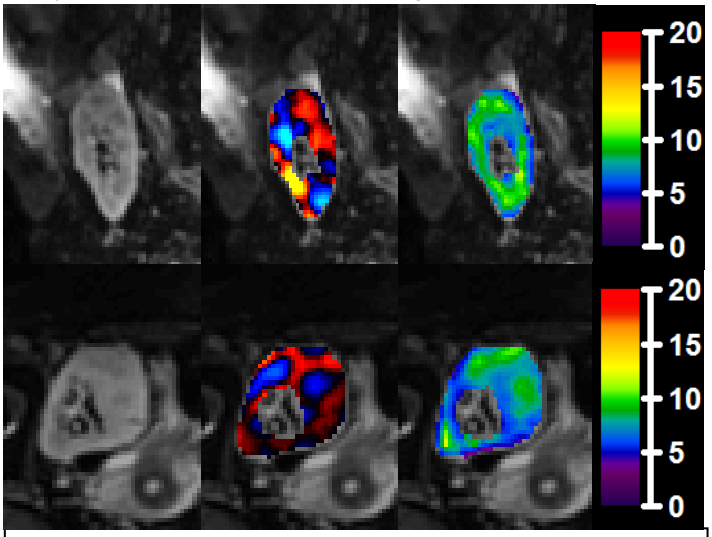

Figure 1. Example MRE results showing MR magnitude images from the MRE acquisition (left), wave images showing the propagating shear waves in the kidney (middle), and the calculated elastogram (right, in kPa).

Discussion: With a few modifications to the standard setup for MRE of the liver, this study has demonstrated the feasibility of performing MRE on renal transplant patients. All the patients tolerated the scans well. A few observations can be made. The single case without interstitial fibrosis demonstrated a higher calculated tissue stiffness than all but one with mild-to-moderate interstitial fibrosis. While two cases with moderate interstitial fibrosis demonstrated higher tissue stiffness values than the six cases with mild interstitial fibrosis, the difference is not subjectively large. There may be a range of stiffness values which could be better stratified based on biopsy. In addition to any fibrosis-related changes in kidney stiffness, there could also be perfusion-related effects on the measured stiffness that may have to be accounted for to assess the condition of these allografts [6].

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