Acoustic Radiation Force Impulse Imaging of the Transplant Kidney: Correlation Between Cortical Stiffness and Arterial Resistance in Early Post-transplant Period

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ABSTRACT

Background. Acoustic radiation force impulse (ARFI) imaging is a noninvasive imaging modality for quantitative assessment of tissue stiffness. This study utilized ARFI imaging to assess the stiffness of a transplant renal cortex within the first month after renal transplantation and to explore the correlation between the cortical stiffness and arterial resistance of the transplant kidney.

Methods. Forty renal transplant recipients (male/female = 26/14; mean age: 45.3 years; deceased donor/living related donor = 27/13) were included in this study. ARFI imaging with virtual touch tissue imaging quantification was applied to assess the stiffness of the transplant renal cortex by using a linear ultrasound transducer. Arterial resistance was acquired by spectral Doppler examination of the main artery and intrarenal arteries of the transplant kidney using a curvilinear ultrasound transducer.

Results. The stiffness of transplant renal cortex was expressed as shear wave velocity (m/s). The mean value of cortical stiffness was 3.19 ± 1.01 m/s (range: 1.55–5.54). The stiffness of transplant renal cortex was positively correlated with the resistance index of the main renal artery ($r = 0.55$, $P = .001$), segmental artery ($r = 0.43$, $P = .005$), and interlobar artery ($r = 0.42$, $P = .006$).

Conclusion. The stiffness of a transplant renal cortex is positively correlated with the arterial resistance of the renal transplant in the early post-transplant period. This result indicates that, in addition to renal fibrosis, the stiffness of the transplant renal cortex is also influenced by the hemodynamics of the transplant kidney.

ACOUSTIC radiation force impulse (ARFI) imaging is an ultrasound-based technology for quantitative assessment of tissue stiffness. It is currently widely utilized in the assessment of liver fibrosis and cirrhosis [1]. Several studies have been conducted to explore the usage of ARFI in kidney and renal transplantation for diagnosis of chronic renal disease and renal fibrosis. However, the results of these investigations were inconclusive [2–6]. In addition to interstitial fibrosis, renal stiffness can be affected by other factors, such as external compression, renal perfusion, tissue composition, and anatomical orientation of the renal tissue [7–10]. Currently, the relationship between cortical stiffness and Doppler parameters of the transplant kidney is not well understood. The aim of this study is to apply the ARFI technique to explore the relationship between the stiffness of transplant renal cortex and arterial resistance of the transplant kidney in the early post-transplant period.

MATERIALS AND METHODS

This study was approved by institution review board. Forty renal transplant recipients (male/female = 26/14; mean age: 45.3 years; deceased donor graft/living related donor graft = 27/13) were included in this study. All subjects received ARFI imaging and

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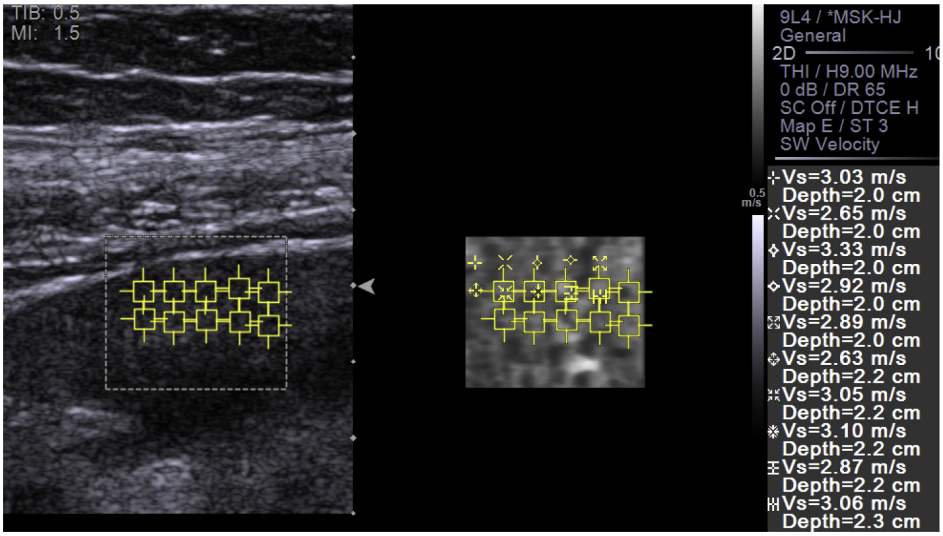

Fig 1. Acoustic radiation force impulse imaging assessment of shear wave velocity of transplant renal cortex. The region of interest (dashed line in the left column) was selected to include the entire superficial renal cortex of transplant kidney. Ten rectangular quantification cursors (2 × 2 mm in size) were placed within the region of interest along the center of the renal cortex (left and middle column), with the value of shear wave velocity (meter per second) in each quantification cursor provided (right column).

spectral Doppler ultrasound examination concurrently within 30 days after renal transplantation, using an Acuson S3000 ultrasound system (Siemens, Mountain View, Calif, USA). All studies were performed by a single investigator.

Measurement of Stiffness in Transplant Renal Cortex

ARFI imaging in virtual touch tissue imaging quantification mode was applied to assess the stiffness of transplant renal cortex by using a linear transducer (frequency range: 4–9 MHz). We performed the examination with minimal transducer compression to avoid excessive external compression on the transplant kidney. The procedure was carried out as follows (Fig 1): A properly sized region of interest (ROI) was selected to include the entire superficial renal cortex of the transplant kidney, followed by activation of virtual touch tissue imaging quantification mode with acquisition of shear wave velocity in the ROI, which was displayed on a coded map. Then, 10 rectangular quantification cursors (2 × 2 mm in size) were placed within the ROI along the center of the renal cortex, with the value of shear wave velocity (m/s) in each quantification cursor provided. The median value of shear wave velocity of 10 quantification cursors was calculated, which represent the stiffness of the transplant renal cortex.

Doppler Examination of Transplant Kidney

The arterial resistance of the main artery and intrarenal arteries of the transplant kidney were assessed by spectral Doppler examination using a curvilinear transducer (frequency range: 1–6 MHz). The Doppler spectrums of the renal artery, segmental artery, and interlobar artery of the transplant kidney were acquired after proper angle correction. The ultrasound machine automatically recognized the peak systolic velocity/end diastolic velocity and calculated the resistive index (RI). RI was defined as follows: RI = (peak systolic velocity − end diastolic velocity)/peak systolic velocity.

RESULTS

The basic characteristics of all 40 patients are summarized in Table 1. The mean depth of the transplant renal cortex was 2.1 cm (range: 1.4–2.7 cm) beneath the skin. The mean value of cortical stiffness was 3.19 ± 1.01 m/s (range: 1.55–5.54). The mean interquartile range/median of shear wave velocity of 10 rectangular cursors was 0.10 (range: 0.04–0.21). The stiffness of the transplant renal cortex was positively correlated with the RI of the main renal artery ($r = 0.55$, $P = .001$, n = 32), segmental artery ($r = 0.43$, $P = .005$, n = 40), and interlobar artery ($r = 0.42$, $P = .006$, n = 40) (Fig 2).

DISCUSSION

ARFI imaging, an ultrasound elastography technique, has been developed for noninvasive, quantitative assessment of tissue stiffness. This technique measures the shear wave velocity of the tissue in response to a low-frequency impulse, which is proportional to tissue stiffness. Implementation of the ARFI technique into a conventional ultrasound machine has enabled us to simultaneously measure tissue stiffness and evaluate tissue perfusion using Doppler ultrasound.

Several studies have explored that use of ultrasound elastography in kidney and renal transplantation [2–6]. It is proposed that renal fibrosis following chronic renal disease may result in elevated renal stiffness, which can potentially be detected by elastography. However, several reports have shown that renal stiffness was not correlated with the degree of renal fibrosis nor chronic renal parenchymal disease [5,6]. Failure to detect renal fibrosis by elastography may be explained by the effects of biological confounders and