Establishing Normal Values for Shear-Wave Elastography of the Renal Cortex in Healthy Adults

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Abstract

Background: Shear-wave elastography of the kidney has emerged as a potential clinical application of this novel imaging tool. However, normal velocity values for shear-wave elastography involving the cortex of healthy kidneys have not been definitively established, and both inter- and intraobserver reliability has yet to be comprehensively evaluated. **Methods:** This prospective study involved ultrasound examination of 11 healthy adults. Shear-wave velocity values were obtained at the renal cortex in the longitudinal and transverse planes by both junior (fellow) and senior (attending) radiologists. **Results:** The mean shear-wave velocity values ranged between 2.82 and 2.9 m/s, which did not vary significantly between observers (junior vs. senior) or method of measurement (longitudinal vs. transverse planes), $P = 0.533$. However, there was a wide variation for these measurements (0.51–4.99 m/s). Separate analysis of the measurement depth demonstrated no statistically significant association with the shear-wave velocity values, $P = 0.477$. **Conclusion:** Our results agree with previous publications and help establish normal shear-wave velocity values and their range for the renal cortex in adults.

Keywords: Elasticity imaging techniques, kidney cortex, observer variation

Introduction

Ultrasound elastography of the kidneys is a potential application of this novel imaging tool that may become a clinical biomarker for disease. For example, qualitative strain elastography of renal transplant cortex and the corticomedullary strain ratio have been shown to correlate with renal cortical fibrosis.[1,2] Quantitative shear-wave elastography utilizing acoustic radiation force impulse (ARFI) has demonstrated clinical applications in many areas of imaging, particularly liver imaging.[4] However, there is limited published work concerning normal shear-wave velocity values for the adult kidney.[5-7] Therefore, we designed a prospective study to determine these values in healthy adults and evaluate both inter- and intraobserver reliability. In addition, we sought to determine the effect of measurement depth on shear-wave velocity values.

Methods

This prospective study was performed at an academic radiology department at a large tertiary care center in New York, NY, USA. The study was conducted in accordance with the Declaration of Helsinki and was approved by the local ethics committee of the institute. Informed written consent was obtained from all patients prior to their enrollment in this study. Eleven healthy adults without any reported history of kidney disease were recruited for this study.

The Acuson S3000 HELX (Siemens Medical Solutions, Malvern, PA, USA) equipped with a 6C1 (1.5–6.0 MHz) curved linear array transducer was used for acquiring grayscale, spectral Doppler, and virtual touch tissue quantification on ARFI imaging in the healthy adults.

During each encounter, both kidneys were evaluated. The participant was placed in the left and right lateral decubitus positions for imaging the right and left kidney, respectively. Before scanning each participant, standardized machine acquisition settings were set, which included MI 1.4, image

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depth 12–15 cm, scanning frequency 3.5 MHz, single focus, dynamic range 65, harmonic imaging, Map E/Space-time 2, and total gain 0–1. The presence or absence of hydronephrosis, calculi, masses, and perinephric collections was also assessed; the presence of any of these findings served as exclusion criteria.

For each participant, the following values were obtained during suspended respiration: kidney size in the longitudinal plane; main renal artery peak systolic velocity (PSV), end diastolic velocity (EDV), and resistive index (RI); inferior interlobular artery PSV, EDV, and RI; mid-interlobular artery PSV, EDV, and RI; superior interlobular artery PSV, EDV, and RI; shear-wave velocity values at the renal cortex (five measurements in the longitudinal plane at the upper, upper-mid, mid, mid-lower,

Table 1: Descriptive statistics for shear-wave velocity (m/s) measured in the longitudinal and transverse planes by junior and senior observers

Descriptive Statistics

	SR LONG	SR TRANS	JR LONG	JR TRANS
Valid	233	132	234	131
Missing	1	102	0	103
Mean	2.800	2.844	2.908	2.790
Std. Error of Mean	0.05810	0.07488	0.05800	0.08801
Median	2.800	2.980	2.895	2.810
Mode	2.160[a]	3.030	2.670	1.860
Std. Deviation	0.8869	0.8603	0.8873	1.007
Variance	0.7866	0.7401	0.7872	1.015
Range	4.480	3.820	4.330	4.270
Minimum	0.5100	1.010	0.6300	0.7100
Maximum	4.990	4.830	4.960	4.980

[a] More than one mode exists, only the first is reported

Table 2: Statistical analysis of the shear-wave velocity using ANOVA found no statistically significant difference between shear-wave velocity values measured in the longitudinal or transverse planes by junior or senior observers ($P = 0.533$)

ANOVA - Velocity ▼

Cases	Sum of Squares	df	Mean Square	F	p
Observer	1.798	3	0.599	0.731	0.533
Residual	594.780	726	0.819		

Note. Type III Sum of Squares

Post Hoc Tests

Post Hoc Comparisons - Observer

		Mean Difference	SE	t	p_{tukey}	$p_{scheffe}$
JR LONG	JR TRANS	0.118	0.099	1.200	0.625	0.696
	SR LONG	0.108	0.084	1.294	0.565	0.643
	SR TRANS	0.064	0.099	0.651	0.914	0.935
JR TRANS	SR LONG	−0.010	0.099	−0.102	1.000	1.000
	SR TRANS	−0.054	0.112	−0.487	0.962	0.971
SR LONG	SR TRANS	−0.044	0.099	−0.448	0.970	0.977

Descriptives

Descriptives - Velocity

Observer	Mean	SD	N
JR LONG	2.908	0.887	234
JR TRANS	2.790	1.007	131
SR LONG	2.800	0.887	233
SR TRANS	2.844	0.860	132

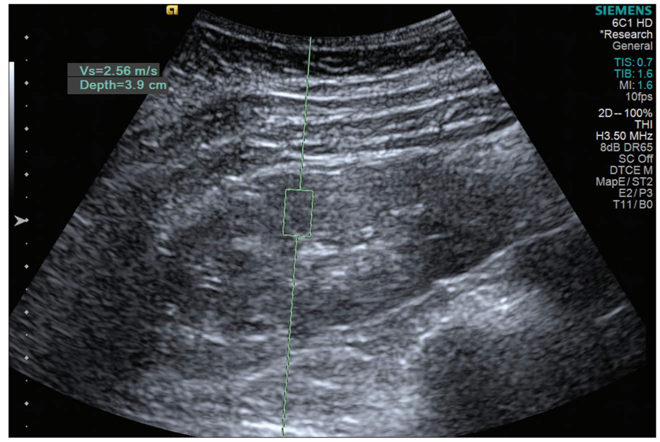

Figure 1: Examples of shear-wave velocity measurement at the renal cortex in the longitudinal and transverse planes, respectively

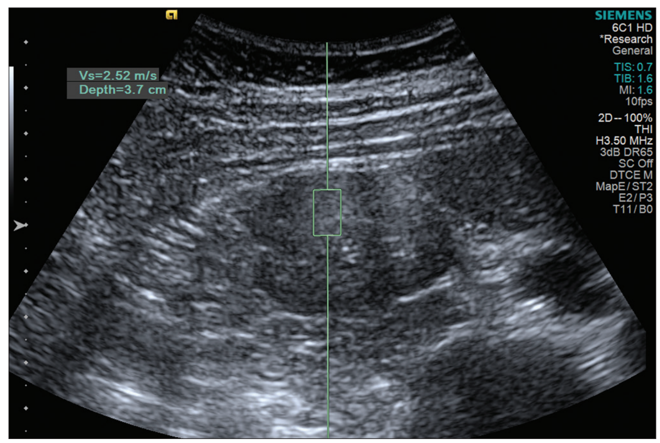

Figure 2: Examples of shear-wave velocity measurement at the renal cortex in the longitudinal and transverse planes, respectively

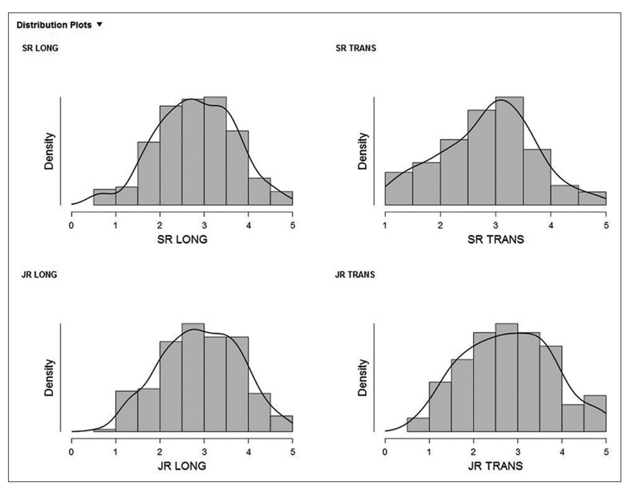

Figure 3: Distribution plots for shear-wave velocity (m/s) measured in the longitudinal and transverse planes by junior and senior observers

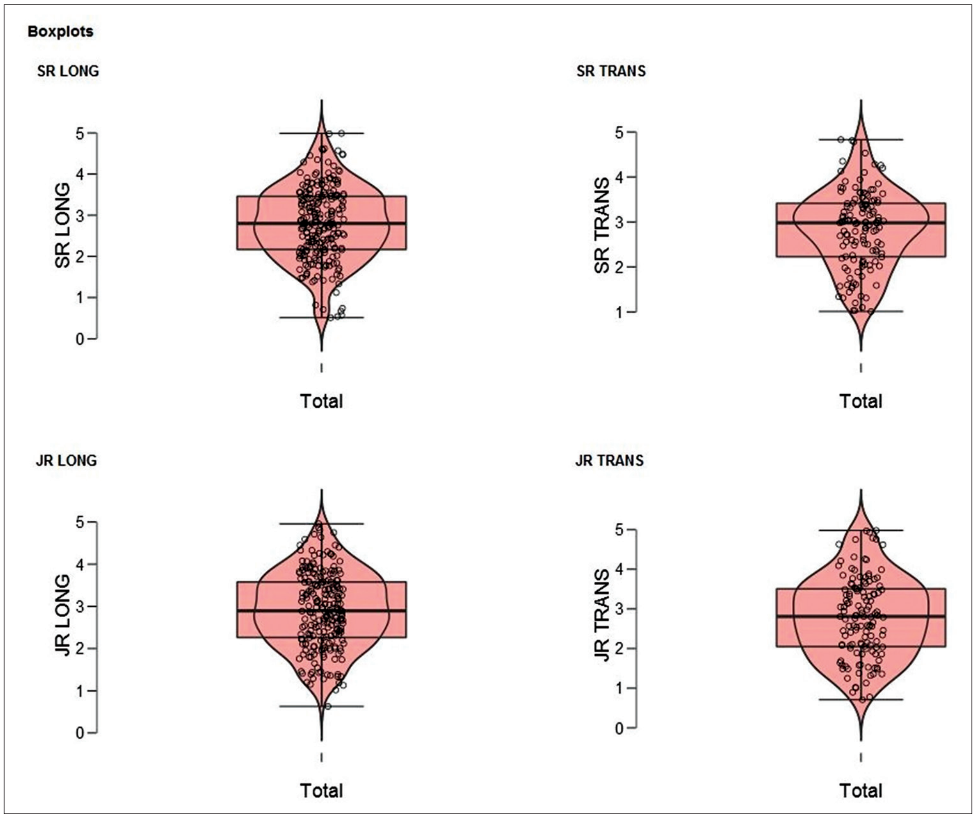

Figure 4: Box plots (including violin and jitter elements) for shear-wave velocity (m/s) measured in the longitudinal and transverse planes by junior and senior observers

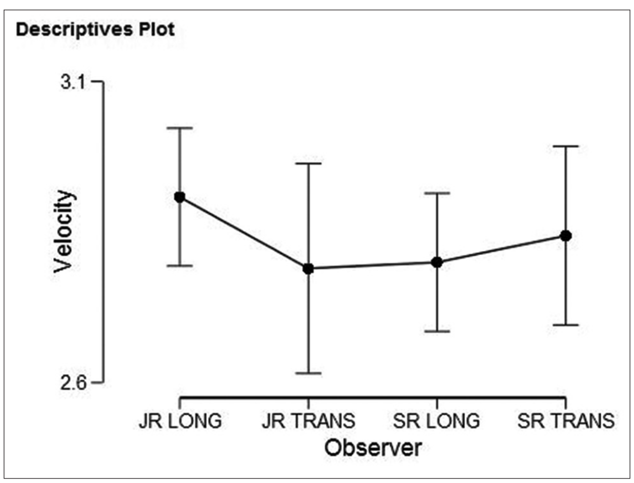

Figure 5: Statistical analysis using ANOVA found no statistically significant difference between the shear-wave velocity values obtained by each observer in the longitudinal or transverse planes (error bars represent the 95% confidence intervals)

and lower poles and three measurements in the transverse plane at upper, mid, and lower poles) [Figures 1 and 2]. All measurements were repeated yielding two measurements per parameter per observer. Each patient was scanned by both junior (fellow) and senior (attending) radiologists separately during the same visit. Measurements were stored as static images. Statistical analysis of the results (including ANOVA and Pearson's correlation coefficient analysis) was performed in Microsoft Excel version 15.11.2 and JASP version 0.8.0.1 Available from: https:www.//jasp-stats.org.

Results

The kidneys of 11 healthy adults with normal body mass index were scanned (5 men and 6 women). The left kidney of one male participant was excluded from the analysis due to hydronephrosis. Measurements were obtained from all patients with analysis of over 700 shear-wave velocity values [Table 1, Figures 3 and 4]. The average shear-wave velocity value for the renal cortex was 2.87 m/s with a wide range of values (0.51–4.99 m/s). The average shear-wave velocity values for the renal cortex in the longitudinal and transverse planes were 2.85 and 2.9 m/s, respectively. The average shear-wave velocity values for the renal cortex obtained by junior and senior observers were 2.84 and 2.82 m/s, respectively. Statistical analysis using ANOVA demonstrated that there was no statistically significant difference between the shear-wave velocity values with respect to plane of acquisition or observer ($P > 0.050$) [Table 2 and Figure 5]. Subsequent analysis showed no statistically significant difference between shear-wave velocity values and gender ($P > 0.050$). Pearson correlation coefficient analysis of shear-wave velocity versus depth found a small strength of association, which was not statistically significant ($P = 0.477$) [Figure 6].

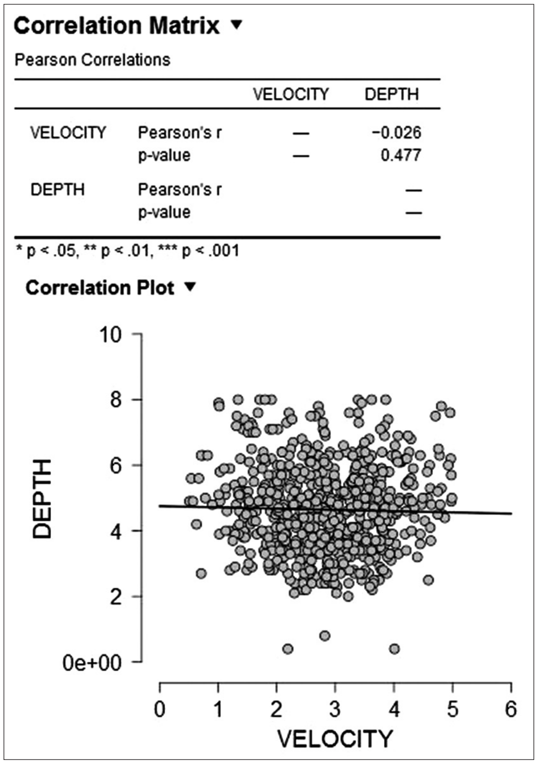

Figure 6: Pearson's correlation coefficient analysis with correlation plot for shear-wave velocity values versus depth demonstrated a small strength of association, which was not statistically significant ($P = 0.477$)

Discussion

Shear-wave elastography of the kidney utilizing ARFI is a potential clinical application of this novel imaging tool, which has demonstrated successful clinical applications in other organs.[4] In the kidney, this tool has shown promise in the evaluation of chronic kidney disease, renal transplant function, and renal vein thrombosis.[1-4] Concerning the normal values for shear-wave velocity values, Gallotti *et al*. examined 35 healthy participants and found a mean shear-wave velocity value of 2.24 m/s.[6] Bob *et al*. examined shear-wave velocity values in a mixed population of 88 patients including both healthy patients and those with renal disease, yielding median values of 2.29–2.45 m/s with a range of 0.58–4.14 m/s. Their subanalysis of patients without renal disease demonstrated median shear-wave velocity values of 2.42 and 2.54 m/s.[5] Similarly, Guo *et al*. demonstrated a mean shear-wave velocity value of 2.15 m/s in 327 healthy participants.[7] Our investigation of the shear-wave velocity values at the renal cortex in 11 healthy adults agrees with prior publications and confirms the reproducibility of these measurements. We demonstrated that observer experience and plane of acquisition do not significantly affect shear-wave velocity measurements of the renal cortex. In addition, we confirmed that these shear-wave velocity measurements are not affected by depth (within the depth range recommended by the manufacturer since depths exceeding this range will not yield any result). Our limitations mirror those of Bob *et al*. and include limited sample size and lack of objective data to confirm that healthy participants truly did not have any renal disease.[5] An additional limitation of our study is that the adult participants did not disclose their age, so subanalysis of any effect of age could not be performed. Our results build upon previously published results to establish a groundwork for determining normal values and their range. As suggested by Guo *et al*., future work examining shear-wave velocity values in renal disease states should correlate their findings with these results to determine if significant differences exist that can be used as potential biomarkers for disease.[7]

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Conflicts of interest

There are no conflicts of interest.

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