Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 32s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Evaluation of Renal Parenchymal Stiffness in Chronic Kidney Disease Using Shear Wave Elastography

A V V Satya Divakar [1], Jenikar Paulraj [2], Dr. Sachin Virmani [3], Dr. Likitha Yadlapalli [4]*

[1]Junior Resident, Shri Sathya Sai medical college & Research Institute affiliated to Shri Balaji Vidyapeeth, Puducherry
Email ID : divakaradabala143@gmai.com

[2]HOD & Professor, Shri Sathya Sai medical college & Research Institute affiliated to Shri Balaji Vidyapeeth, Puducherry
Email ID : drjenikar@gmail.com

[3]Junior Resident, Shri Sathya Sai medical college & Research Institute affiliated to Shri Balaji Vidyapeeth, Puducherry
Email ID : dr.virmani29@gmail.com

[4]Junior Resident, Shri Sathya Sai medical college & Research Institute affiliated to Shri Balaji Vidyapeeth, Puducherry
Email ID : likithayadlapalli@gmail.com

Corresponding author:
Dr. Likitha Yadlapalli
Email ID : likithayadlapalli@gmail.com

Cite this paper as: A V V Satya Divakar, Jenikar Paulraj, Dr. Sachin Virmani, Dr. Likitha Yadlapalli , (2025) Evaluation of Renal Parenchymal Stiffness in Chronic Kidney Disease Using Shear Wave Elastography.. *Journal of Neonatal Surgery*, 14 (32s), 9316-9324

ABSTRACT

Background: Chronic kidney disease (CKD) is a public health burden worldwide. Conventional imaging does not measure renal stiffness or fibrosis accurately. Shear wave elastography (SWE) is an ultrasound-based non-invasive technique of tissue stiffness measurement that can potentially enhance CKD staging.

Purpose: To assess the value of SWE in the measurement of renal parenchymal stiffness in CKD patients and compare it with traditional ultrasound..

Keywords: *: Chronic kidney disease, Shear Wave Elastography, Ultrasound, diabetic nephropathy, glomerular filtration*

1. INTRODUCTION

Chronic kidney disease (CKD) is a global health issue [1]. In India, the prevalence of CKD has not been properly evaluated because there is no national renal registry. The prevalence of CKD in India is approximately 800 per million population and the incidence of end-stage. renal disease (ESRD) is about 150–200 per million population [2]. Population-based studies show that diabetic nephropathy is the most prevalent etiology of CKD. It is found in 30–40% of diabetic patients and is responsible for almost 50% of patients with renal failure [3]. CKD in its later stages is related to greater morbidity and mortality. Currently, estimated glomerular filtration rate (eGFR), which is based on serum creatinine levels, is the accepted measure of CKD staging [4]. Nevertheless, this method has numerous flaws, such as race, gender, and muscle mass confounding.Intra-renal fibrosis is a terminal common pathway in CKD evolution and is highly associated with disease severity [5]. The renal biopsy is still the gold standard to diagnose intra-renal fibrosis, but it has some major drawbacks: invasive procedure, sampling error, complications, and expense.Shear wave elastography (SWE) is a more recent, noninvasive imaging technique that measures tissue stiffness. Measurement of stiffness by SWE gives information about the elastic modulus of the kidney. Young's modulus (YM) is an index of tissue elasticity, and it is greater with more extensive fibrosis [6].

SWE, already FDA-approved for differentiating between normal and cirrhotic livers, is now being studied in renal imaging [7,8]

2. SHEAR WAVE ELASTOGRAPHY

Elastography, first described by Ophir et al., evaluates tissue stiffness using a standard ultrasound device with elastography software [6].

Two main types exist:

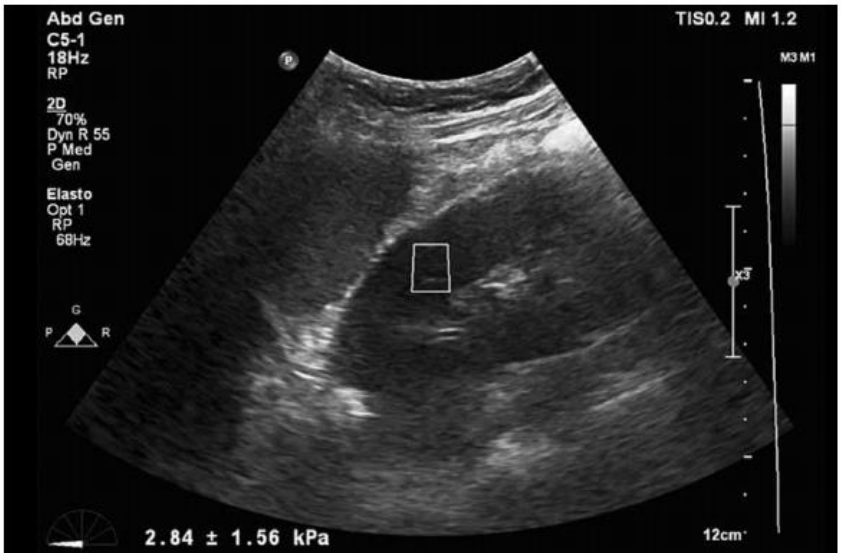
Strain elastography (SE) – quasi-static.

Dynamic methods – shear-wave elastography (SWE), acoustic radiation force impulse (ARFI), and transient elastography (TE) [7].

SWE: measures shear-wave propagation speed (m/s) to calculate elasticity (kPa). It is quantitative and operator-independent, though results may vary with renal anisotropy.

ARFI: generates shear waves via short acoustic pulses. Results are expressed in m/s and less affected by operator variability [9–11].

TE: mainly used for liver disease, less applicable to kidneys due to limitations in obesity, ascites, or focal disease.



Shear wave elastography image of kidney parenchyma. The square indicates the measurement localization. The number below the figure indicates stiffness of the tissue in the unit of kPa.

3. MATERIALS AND METHODS

Ethical Approval and Consent: The study was approved by the institutional ethics committee, and informed consent was obtained from all participants. Study Design and Setting: Cross-sectional study conducted in the Department of Radiodiagnosis, Shri Sathya Sai Medical College and Research Institute, Chennai, over 18 months.

Population: Patients from the General Medicine OPD with a clinical diagnosis of chronic kidney disease (CKD) referred for abdominal ultrasonography.

Sample Size: Based on prior studies, calculated using the formula $n = 4PQ/L^2$ (P=10%, Q=90, L=6%). The required sample was 100; with 10% non-response, final size = 110.

4. ULTRASONOGRAPHY

Both kidneys were examined using a curvilinear probe (Esaote C1-8, 1–8 MHz) in supine position. Bipolar length, cortical thickness, and renal echogenicity were assessed. Cortical thickness was measured from the outer renal border to the corticomedullary junction. Shear Wave Elastography (SWE) SWE was performed using Aixplorer (Supersonic Imagine, Paris, France) with a 2–5 MHz curved transducer by a single experienced radiologist. Patients were scanned in supine or left decubitus positions. The region of interest (ROI, ≥6 mm) was placed in the renal cortex at least 1 cm beneath the capsule, avoiding pyramids. Optimal windows, usually in the lower pole, were used. Eight to twelve readings per kidney were obtained, and the median Young's modulus (YM, kPa) recorded. SWE values were calculated using the formula $E = \rho c^2$ (ρ = tissue density, c = shear-wave velocity). Measurements were taken at end-expiration. The right kidney was prioritized unless inaccessible, in which case the left was scanned.

5. INSTRUMENTS

Ultrasound system: Supersonic Aixplorer, convex probe S6-1, 3.5–5.5 MHz, RENAL mode.

Urine protein: Bio Systems BA400 (24 h protein quantification).

Blood indices: BECKMAN COULTER Au580000.

SWE Protocol and Quality Control

Clear 2D image and stable elastography.

Capsule–cortex–medulla boundaries well defined.

ROI within cortex (7–10 mm), excluding perirenal fat.

Dispersion index (SD) ≤ 1.

Gain normalized to 50 dB.

Measurements were taken at upper, mid, and lower poles of both kidneys, three times each. Mean values per kidney were calculated; bilateral averages represented patient YM. All scans were saved in DICOM format and reviewed by a senior sonographer for completeness and accuracy.

Data Analysis

Data were entered in MS Excel and analyzed in SPSS v17. Descriptive statistics and appropriate inferential tests were applied with a 5% significance level and 95% confidence interval.

6. RESULTS AND OBSERVATION

STATISTICAL ANALYSIS

Table 1 :Statisticalanalysisofusg And Swe Parameters In Stage Ii Ckd (N=10)

STAGE IICKD (n=10)	**STATISTICAL ANALYSIS OFUSGANDSWEPARAMETERS**			
	Right kidney (Mean ±SD) **USG**	Right kidney (Mean ±SD) **SWE**	Left kidney (Mean ±SD) **USG**	Left kidney (Mean ±SD) **SWE**
Kidney length(cm)	9.956±0.123	9.956±0.123	10.09± 0.116	10.09± 0.116
Width(cm)	4.967±0.086	4.967±0.086	5.111± 0.092	5.111± 0.092
Cortical thickness(mm)	7.667±0.291	7.667±0.291	7.856± 0.235	7.856± 0.235

In**stage IICKD,**kidney length(cm),Width (cm)and Cortical thickness (mm)wasmoreinleftkidney(10.09±0.116,5.111±0.092,and7.856 ±0.235)compared torightkidney(9.956±0.123,,4.967±0.086and 7.667±0.291)respectively.

Table 2 :Statisticalanalysisofusg And Sweparameters In Stage Iii Ckd (N=36)

STAGE III CKD(n=36)	**STATISTICALANALYSISOFUSGANDSWE PARAMETERSinSTAGE3CKD(n=36)**			
	Right kidney (Mean ±SD) **USG**	Right kidney (Mean ±SD) **SWE**	Left kidney (Mean ±SD) **USG**	Left kidney (Mean ±SD) **SWE**
Kidney length(cm)	8.256±1.540	8.256±1.540	8.658± 0.7744	8.658± 0.7744
Width(cm)	4.653±0.1765	4.653±0.1765	4.728± 0.1750	4.728± 0.1750
Corticalthickness (mm)	7.272±0.3708	7.272±0.3708	7.481± 0.3875	7.481± 0.3875

In **stage III CKD,** kidney length(cm),Width (cm) and Cortical thickness(mm)was more in left kidney (8.658±0.7744,4.728±0.1750 and 7.481±0.3875)compared to right kidney(8.256±1.540,,4.653± 0.1765and7.272±0.3708) respectively

Table 3 :Statisticalanalysisofusg And Sweparameters In Stage Iv Ckd (N=65)

STAGE IVCKD (n=65)	**STATISTICALANALYSISOFUSGANDSWE PARAMETERS in STAGE IVCKD(n=65)**			
	Right kidney (Mean ±SD) **USG**	Right kidney (Mean ±SD) **SWE**	Left kidney (Mean ±SD) **USG**	Left kidney (Mean ±SD) **SWE**
Kidney length(cm)	5.718±1.028	5.718±1.028	5.897± 0.7973	5.897± 0.7973
Width(cm)	3.775± 0.2345	3.775± 0.2345	3.914± 0.2591	3.914± 0.2591

Cortical thickness (mm)	5.911± 0.3217	5.911± 0.3217	6.118± 0.3326	6.118± 0.3326

In **stage IVCKD,** kidney length (cm),Width(cm)and Cortical thickness(mm) was more in left kidney (5.897±0.7973,3.914± 0.2591and6.118±0.3326) compared to right kidney(5.718±1.028,,

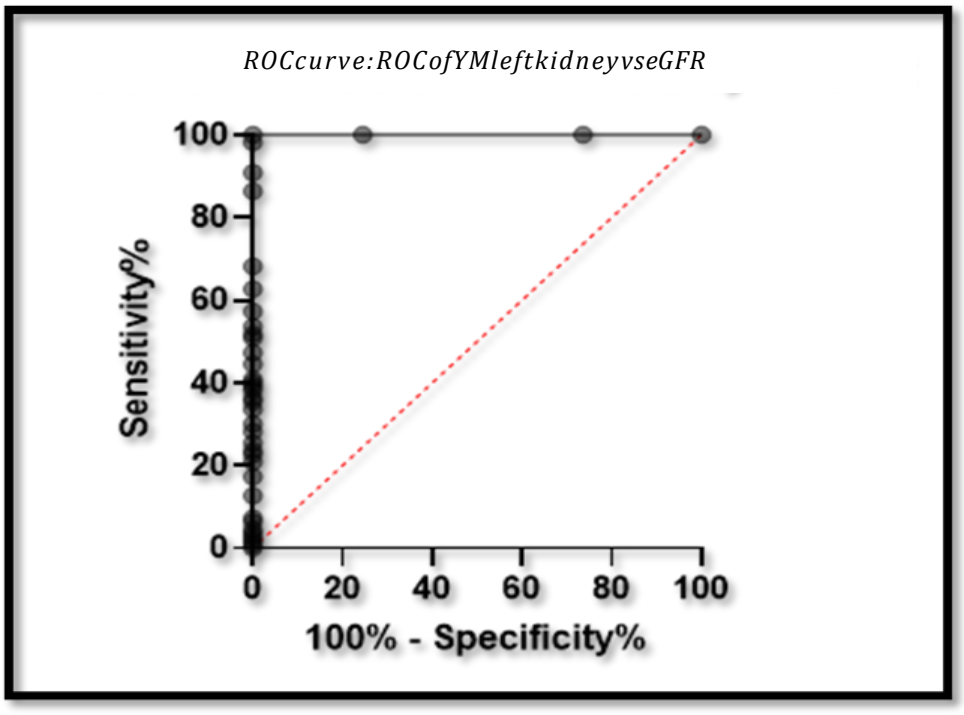
3.775±0.2345 and 5.911±0.3217) respectively

Table 4: Spearman Correlation Of Ym Leftkidney On Swe With Renal Function Tests

AreaundertheROCcurveYMleftkidneyvsGFR	
Area	1.000
Std.Error	0.000
95%confidenceinterval	1.000to1.000
Pvalue	**<0.0001**

Table14showingsignificantcorrelation(pvalue**<0.0001)**

Of YM left kidney on SWE with renal function tests.



Graph10:Bardiagramshowing ROCcurveofYMleftkidneyvsEgf

r

Table 5: Spearman Correlation Of Ym Right Kidney On Swe With Renal Function Tests

AreaundertheROCcurveYMrightkidneyvsGFR	
Area	1.000
Std.Error	0.000
95%confidenceinterval	1.000to1.000
Pvalue	**<0.0001**

YM right kidney on SWE with renal function tests(intable15)showing significant correlation with p value**<0.0001.**

Table 6 : Comparision Of Right Kidney Parameters Across Ckd Stages

RightKidney USG/SWE	STAGE2 (Mean±SD)	STAGE3 (Mean±SD)	STAGE4 (Mean±SD)	pvalue
Kidneylength(cm)	9.956±0.123	8.256±1.540	5.718± 1.028	<0.0001 ****
Width(cm)	4.967±0.086	4.653±0.1765	3.775± 0.2345	<0.0001 ****
Cortical thickness(mm)	7.667±0.291	7.272±0.3708	5.911± 0.3217	<0.0001 ****

One-wayANOVATest,P<0.05,=Significant,ns=notsignificant*

Stages of CKD ,right Kidney length(cm),Width(cm),Cortical thickness showed significant correlation with value**<0.0001.**

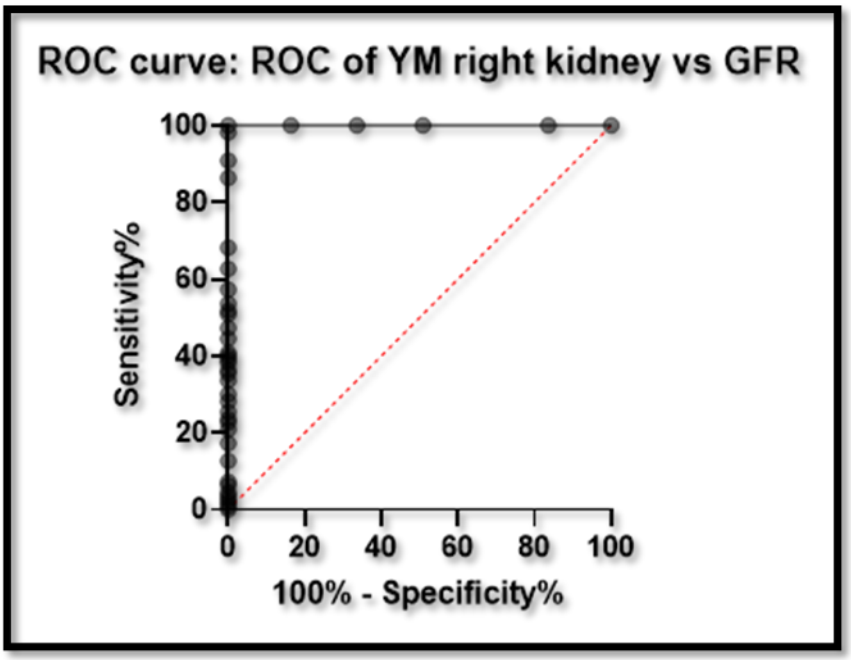


Table 7 :Area Under The Roc Curve Ym Right Kidney Vs Gfr

Area under the ROC curve YM right kidney vs GFR	P value
Area	1.000
Std. Error	0.000
95% confidence interval	1.000 to 1.000
P value	**<0.0001**

In our study Area under the ROC curve YM right kidney vs GFR shows statistical significant correlation with p value **<0.0001**

7. DISCUSSION

The incidence of CKD is very high worldwide. Progressive histological changes include glomerulosclerosis, vascular sclerosis, tubular and interstitial injury, resulting in fibrosis and tubular atrophy [1,5]. Biopsy remains the gold standard, but its invasiveness limits routine use.

CKD causes tissue stiffness to increase, allowing shear waves to propagate more quickly [6]. Thus, renal stiffness correlates with fibrosis and declining GFR.

Several reports have investigated elastography in kidney disease [9–18]. Results, however, have been inconsistent:

Lower SWV in CKD: Guo et al. found significantly lower SWVs in CKD patients compared to healthy controls [10].

Elasticity declines with CKD stage: Cui et al. and Wang et al. reported decreasing elasticity with CKD progression [12,15].

Stiffness positively correlated with function: Some studies in glomerulonephritis and nephrosclerosis showed SWV correlated with GFR [13].

Inverse correlation: Hassan et al. and Makita et al. found increased stiffness in diabetic kidney disease and biopsy-proven CKD, correlating negatively with eGFR [14,16].

Pediatric applications have also been studied: Goya et al. found decreasing SWV in higher grades of reflux nephropathy [11], while Dilmen et al. reported limited utility in hydronephrosis differentiation [17].

In renal mass evaluation, Tan et al. demonstrated elastography could aid in distinguishing angiomyolipoma from RCC [18].

These findings highlight variability: unlike liver elastography, kidney SWE results depend not only on fibrosis but also on hemodynamics, perfusion, and pathology.

8. CONCLUSION

SWE shows promise over conventional ultrasound in CKD assessment. It is noninvasive, reproducible, and may detect renal scarring with greater sensitivity. SWE-derived stiffness values are generally higher in advanced CKD and correlate with fibrosis severity, though inconsistencies remain.

While SWE cannot replace biopsy, it may supplement CKD staging, fibrosis monitoring, and diabetic nephropathy evaluation. Larger, standardized studies are required to establish cut-off values and validate SWE as a reliable biomarker.

SWE may also extend to pediatric and oncological renal applications, aiding in conditions such as VUR, hydronephrosis, and renal tumors

REFERENCES

[1] Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. Kidney Int Suppl. 2013;3(1):1–150.

[2] Harambat J, van Stralen KJ, Kim JJ, Tizard EJ. Epidemiology of chronic kidney disease in children. Pediatr Nephrol. 2012;27(3):363–73.

[3] Tuttle KR, Bakris GL, Bilous RW, Chiang JL, de Boer IH, Goldstein-Fuchs J, et al. Diabetic kidney disease: a report from an ADA Consensus Conference. Am J Kidney Dis. 2014;64(4):510–33.

[4] Stevens PE, Levin A; Kidney Disease: Improving Global Outcomes Chronic Kidney Disease Guideline Development Work Group Members. Evaluation and management of chronic kidney disease: synopsis of the KDIGO 2012 clinical practice guideline. Ann Intern Med. 2013;158(11):825–30.

[5] Cosgrove D, Piscaglia F, Bamber J, Bojunga J, Correas JM, Gilja OH, et al. EFSUMB guidelines and recommendations on the clinical use of ultrasound elastography. Part 2: Clinical applications. Ultraschall Med. 2013;34(3):238–53.

[6] Ophir J, Cespedes I, Ponnekanti H, Yazdi Y, Li X. Elastography: A quantitative method for imaging the elasticity of biological tissues. Ultrasound Med Biol. 1991;18(3):283–92.

[7] Vivante A, Hildebrandt F. Exploring the genetic basis of early-onset chronic kidney disease. Nat Rev Nephrol. 2016;12(3):133–46.

[8] Barr RG, Zhang Z, Shear-Wave Elastography of the Kidney: Imaging for Renal Fibrosis? Semin Ultrasound CT MR. 2020;41(5):453–61.

[9] Onur MR, Poyraz AK, Bozgeyik Z, Firdolas F, Orhan I. Shear-wave elastography of the kidneys: Normal values and variability in healthy volunteers. Ultrasound Med Biol. 2015;41(4):960–6.

[10] Guo LH, Xu HX, Fu HJ, Peng A, Zhang YF, Liu LN. Acoustic radiation force impulse imaging for noninvasive evaluation of renal parenchyma elasticity: Preliminary findings. PLoS One. 2013;8(7):e68925.

[11] Goya C, Hamidi C, Ece A, Koca G, Yavuz A, Cetincakmak MG, et al. Acoustic radiation force impulse (ARFI) elastography for detection of renal damage in children. J Med Ultrason. 2015;42(3):403–9.

[12] Cui G, Yang Z, Zhang W, Wang K, Li L, Su L, et al. Evaluation of acoustic radiation force impulse imaging for the renal parenchyma in patients with chronic kidney disease. PLoS One. 2013;8(7):e68925.

[13] Makita Y, Fukuda S, Tsuji Y, Ishii T, Maeda I, Fukuda K, et al. Evaluation of renal shear wave elastography for non-invasive diagnosis of renal fibrosis in patients with chronic kidney disease. Kidney Int Rep. 2020;5(11):1923–31.

[14] Hassan K, Loberant N, Abbas N, Fadi H, Abassi Z. Shear wave elastography imaging for assessing renal fibrosis in diabetic kidney disease: A pilot study. Int J Nephrol Renovasc Dis.2017;10:209–14.

[15] Wang L, Xia P, Lv K, Han J, Dai Q. Acoustic radiation force impulse elastography for non-invasive assessment of renal histopathology in chronic kidney disease. Ultrasound Med Biol. 2014;40(12):2757–65.

[16] Asano K, Ogata A, Tanaka K, Ito J, Ando T, Takata T, et al. Acoustic radiation force impulse elastography of the kidney in chronic kidney disease: Correlation with renal function and histology. Int J Urol. 2014;21(7):686–92.

[17] Dilmen G, Goya C, Arslan S, Ece A, Kantarci M. Diagnostic value of acoustic radiation force impulse elastography for differentiation of obstructive and non-obstructive hydronephrosis in children. Br J Radiol. 2015;88(1054):20140521.

[18] Tan S, Lee YH, Tan PH, Teo M, Teo H, Venkatesh SK. Real-time elastography in the characterization of renal tumours. Clin Radiol. 2013;68(6):e307–14.