Comparison of Shear Wave Elastography and Dimercaptosuccinic Acid Findings in the Evaluation of Renal Parenchyma

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Abstract

Aim: Dimercaptosuccinic acid (DMSA) renal cortical scintigraphy is the reference standard for the non-invasive diagnosis of renal scar tissue; however, it involves exposure to low doses of radiation. Shear wave elastography (SWE) has recently emerged as a radiation-free, easily applicable technique to measure renal stiffness in renal scar tissue examination. This study aimed to compare the results of DMSA and SWE tests and evaluate whether SWE could serve as an alternative to DMSA in patients.

Methods: This study included 72 patients who underwent elastography of both kidneys prospectively between January 2017 and May 2024 in patients who underwent DMSA examination for various indications. SWE values and stiffness average, standard deviation (SD), median, interquartile range (IQR), and IQR/median values were recorded. Regions of interest were measured in nine areas, three from each of the upper, middle, and lower poles, and mean values were calculated.

Results: The mean age of the patients was 21.8±12.9 years. Among the patients, 47 (33.1%) had ectopic kidneys, and 48 (33.8%) had horseshoe kidneys. The mean SWE value was 7.06±1.1 kPa, the stiffness average was 8.63±5.2 kPa, the stiffness SD was 5.77±3.5 kPA, the stiffness median was 4.15±2.3 kPa, the stiffness IQR was 1.20±1.0 kPa, and the stiffness IQR/median was 16.9±15.1%. A statistically significant correlation was observed between the SWE value and DMSA results (p=0.002).

Conclusions: The SWE value is successful in evaluating renal parenchyma and shows significant correlation with DMSA results.

Keywords: *Shear wave elastography; DMSA; kidney; chronic kidney disease; ultrasonography*

1. Introduction

Amniotic Kidney disease (KD) is a significant public health concern. Therefore, it is particularly crucial to quantitatively assess the extent of early kidney damage and implement timely interventions.[1] Studies have demonstrated that regardless of the initiating factor or the activated signaling pathway, the main pathophysiological changes in chronic progressive kidney damage are inflammation and fibrosis.[2] Inflammation arises from the infiltration of inflammatory cells triggered by local tissue damage, which exacerbates kidney damage through the release of inflammatory mediators and initiates the repair process. Fibrosis is fundamentally an excessive reparative process that leads to a continuous loss of renal parenchyma and the relentless progression of KD.[3] Thus, in addition to routine biochemical markers, monitoring the degree of renal fibrosis constitutes a critical element in assessing the treatment status of patients with chronic kidney disease (CKD).[3]

The primary nuclear medicine modality employed for assessing renal parenchymal status and determining the level of fibrosis is dimercaptosuccinic acid (DMSA) scintigraphy. However, as a nuclear imaging method, DMSA scintigraphy requires an extended

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patient preparation period and contributes to higher costs, particularly in patient populations requiring follow-up.[4]

Shear wave elastography (SWE) technology is a non-invasive, rapid, straightforward, and objective method for quantitatively assessing tissue stiffness.[5] Today, SWE is widely used in ultrasound imaging and constitutes a substantial portion of the contemporary literature on ultrasonography (USG). SWE has a substantial body of discoveries and experiences related to solid organs such as the liver and pancreas, demonstrating notable progress in its clinical applications. On an international scale, the use of SWE technology for the quantitative assessment of liver fibrosis has gained widespread acceptance. In recent years, numerous studies have also been conducted on the application of SWE in evaluating renal fibrosis.[5]

In this study, our objective was to evaluate whether SWE parameters, including elasticity value, stiffness average (avg), and interquartile range (IQR), correlated with DMSA findings in patients undergoing DMSA examination due to the risk of KD.

2. Materials and Methods

2.1. Patient selection and study design

The study was conducted in accordance with the tenets of the Declaration of Helsinki and approved by the Ethics Committee of Adana City Training and Research Hospital on November 4, 2024 (number: 2024/3145). Since the study was retrospective, the requirement for informed consent was waived. Following ethics committee approval, additional authors were included in the study to review the clinical information of patients, ensuring that the four radiologists remained blinded to the patient data.

For this study, patients who underwent DMSA scintigraphy between January 2017 and May 2024 were identified and subsequently underwent renal USG and shear wave USG. Patients were excluded from the study if they exhibited renal atrophy (n = 29), grade 2 or higher echogenicity increase on grayscale USG (as renal parenchymal boundaries may be compromised) (n = 32), hydronephrosis (n = 14), renal parenchymal thickness under 1 cm (due to the region of interest [ROI] size being set at 1 cm) (n = 37), inadequate respiratory cooperation during shear wave USG (n = 18), or obesity with a skin thickness exceeding 10 cm (n = 24). A total of 72 patients were included in the study. The difference in DMSA (%) values between the two kidneys of each patient was calculated, and the correlation between these differences and the SWE parameters of the affected kidney was analyzed.

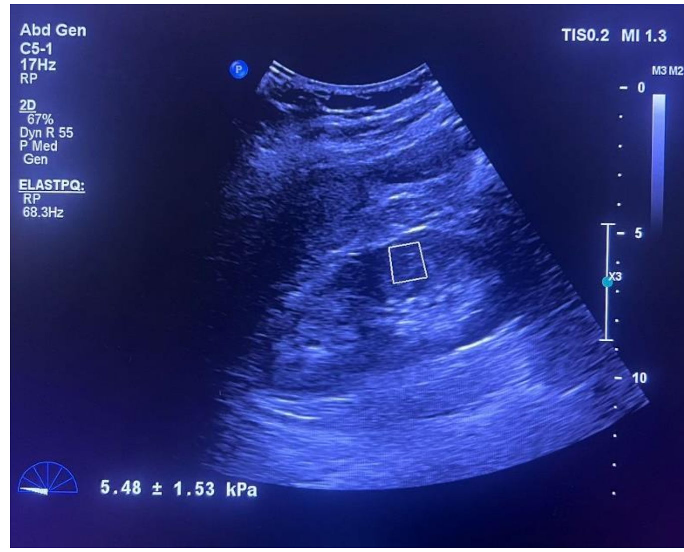
2.2. Renal Ultrasonography

In this study, renal USG was performed using a high-resolution USG device (Philips EPIQ 7) with a 1–5 MHz high-resolution convex probe (Philips Health Care, Bothell, WA, USA). All USG images were obtained after at least six hours of fasting and 20 minutes of rest. Initial images were acquired using grayscale B-mode USG, followed by the acquisition of quantitative shear wave parameters.

Kidney size, cortical thickness, and parenchymal echogenicity were evaluated using grayscale imaging. Patients with grade 2 or higher echogenicity were excluded from the study. Kidney length was measured from the upper to the lower pole. The distance between the renal hilum and the renal capsule was measured in the coronal plane at the inter-polar level. Cortical thickness was measured between the base of the central medullary pyramid and the renal capsule. Renal USG was performed in the right and left lateral decubitus positions. Minimal compression was applied to the probe, and the patients were asked to hold their breath for a few seconds to minimize kidney movement during respiration (Fig.1).

Figure 1

Shear wave elastography (SWE) measurement



Measurements were taken after placing ROI on targets in grayscale renal USG images. The ROI was vertically placed on a renal cortex area free of vessels or cysts. The primary axis of the ROI was adjusted to be parallel to the axis of the renal pyramid. Measurements were obtained at the shortest possible ROI target distance, with the ROI size fixed at 1 cm. Efforts were made to minimize compression during imaging to avoid mechanical pressure on the kidneys. Both kidneys were imaged using the same technique. For each kidney, nine valid measurements (three each from the upper, middle, and lower poles) were obtained, and the avg value was calculated. The results were expressed in kPa. Conventional, Doppler, and SWE examinations were conducted by two experienced radiologists. The total USG examination time was approximately 25–30 minutes.

2.3. Renal Scintigraphy

A dose of 99mTc-DMSA (185 MBq) was injected intravenously into patients, and static planar views of the kidneys in anterior and posterior projections were acquired after three hours. Renal counts were obtained in a posterior projection using a gamma camera (Optima NM/CT 640, General Electric, USA). Counts in each kidney were normalized for perirenal background reading, tissue absorption, and radionuclide decay. The renal uptake of 99mTc-DMSA was expressed as a percentage of the net injected activity fixed in each kidney, providing a relative functional percentage for each kidney. Kidneys with higher percentages of 99mTc-DMSA uptake were considered dominant. The sum of the individual renal function percentages was 100% on both sides.

In transverse sections, the operator identified the slice representing the kidney and outlined a ROI around the organ. For volumetric measurements (in cubic centimeters), the number of pixels above the threshold in all slices was multiplied by the slice thickness. For concentration measurements, the threshold value was subtracted from all pixels in the ROI in all slices. Non-zero pixels with counts above the threshold were used to calculate concentration. Counts per voxel were converted to concentration units (kBq/cm^3) using a regression line obtained from previous phantom measurements. The percentage injected dose per cubic centimeter (%ID/cm^3) was calculated using this corrected value for radioactivity decay (Fig.2). Renal uptake was then determined by multiplying this value by the renal volume (in cubic centimeters).

Figure 2

Total relative Dimercaptosuccinic acid (DMSA) uptake % distribution of both kidneys

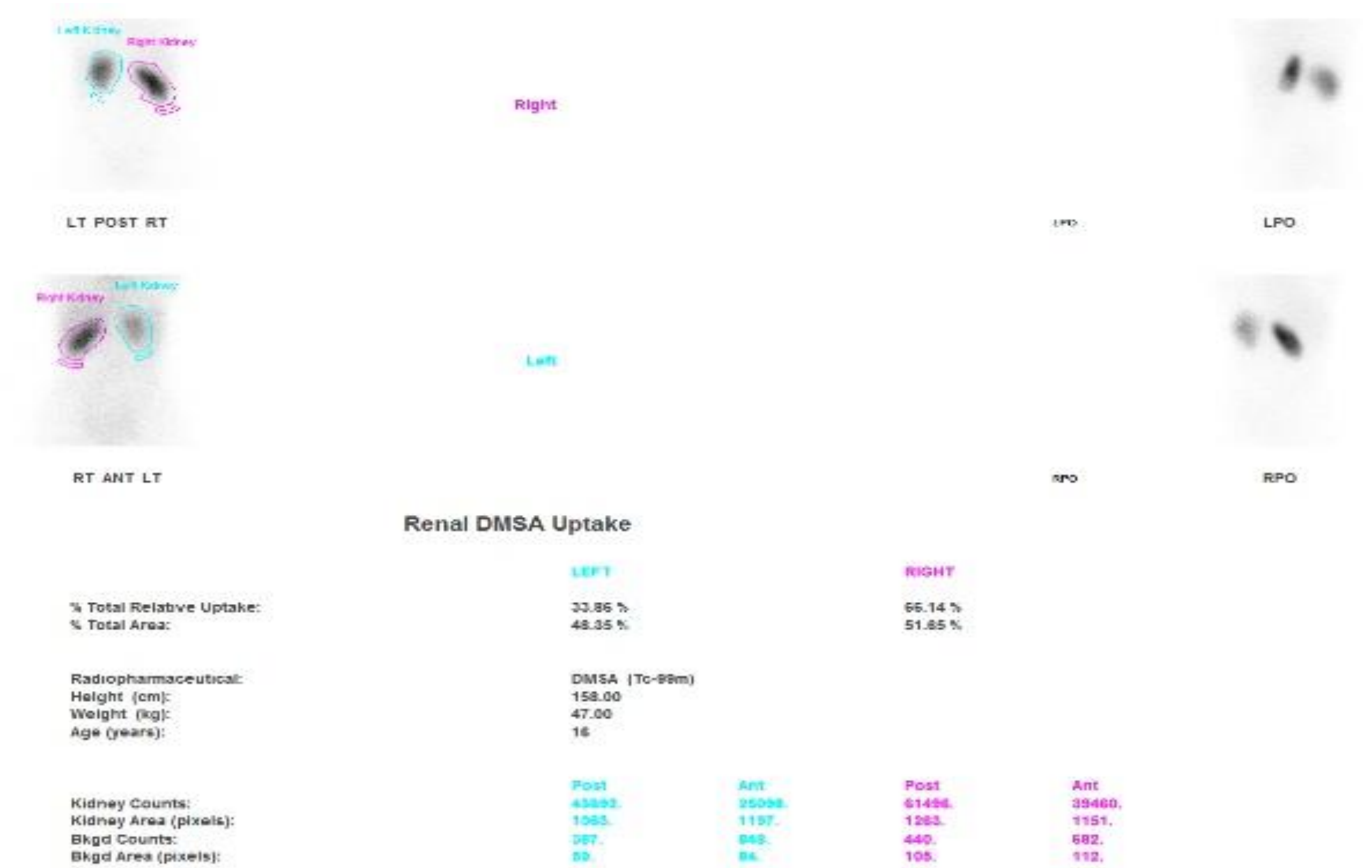


Table 1

Distribution of demographic data and DMSA and shear wave elastography values

	Number (n)	Percentage (%)
Sex		
Female	37	51,4
Male	35	48,6
Kidney (right/left)		
Right	39	54.2
Left	33	45.8
Ectopic kidney	7	9.8
Horseshoe kidney	13	18.1
Vesicoureteral reflux	28	38.8
Allogenic graft rejection	24	33.3
	Mean ± SD	Median (Min–Max)
Age	21.8 ± 12.9	17 (2–34)
Right kidney DMSA %	50.7 ± 11.0	52 (11.05–79.2)
Left kidney DMSA %	48.6 ± 12.3	48 (0.33–88.95)
Renal parenchymal thickness (mm)	13.5 ± 2.2	13.3 (10–25)
Renal long axis (mm)	99.3 ± 17.6	95.5 (71–162)
Kidney-skin distance (mm) (average of lower, middle, and upper poles)	45.6 ± 10.3	44 (22–70)
Shear wave elastography value	7.06 ± 1.1	7.14 (3.22–12.1)
Stiffness avg (kPa)	8.63 ± 5.2	7.51 (1.32–45.7)
Stiffness SD (kPa)	5.77 ± 3.5	5.13 (0.34–25.5)
Stiffness median (kPa)	4.15 ± 2.3	3.87 (1.01–18.6)
Stiffness IQR (kPa)	1.20 ± 1.0	0.89 (0.08–6.81)
Stiffness IQR/median (%)	16.9 ± 15.1	12 (1.2–77.9)

DMSA: dimercaptosuccinic acid, avg: average, SD: standard deviation, IQR: interquartile range

2.4. Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 25.0. Categorical measurements were summarized as counts and percentages, while continuous variables were expressed as means and standard deviations [SDs] (with median and minimum–maximum values where necessary). Cohen's kappa coefficient was used for both intra- and inter-reader assessments. Receiver operating characteristic (ROC) curve analysis was conducted to determine the area under the curve (AUC), sensitivity, and specificity. A significance level of 0.05 was used for all tests. 1.

Table 2

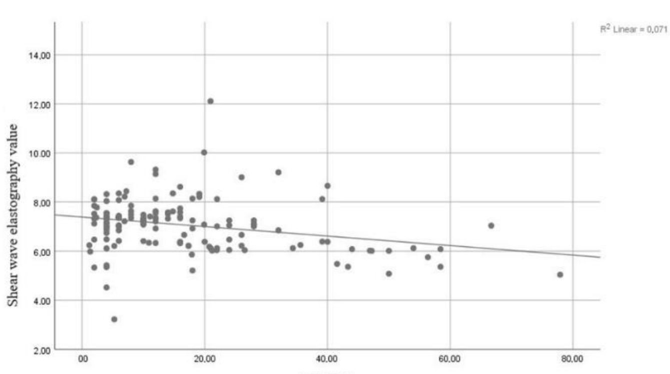
Correlation between changes in DMSA (%) and shear wave elastography parameters

	DMSA % change	
	r	p
Age	0.143	0.090
Renal parenchymal thickness (mm)	-0.101	0.231
Renal long axis (mm)	-0.143	0.089
Kidney-skin distance (mm) (average of lower, middle, and upper poles)	0.084	0.380
Shear wave elastography value	-0.255**	0.002
Stiffness avg (kPa)	0.027	0.746
Stiffness SD (kPa)	-0.132	0.116
Stiffness median (kPa)	-0.027	0.751
Stiffness IQR (kPa)	0.116	0.169
Stiffness IQR/median (%)	0.111	0.187

*$p < 0.05$, **$p < 0.01$, Spearman's rho. DMSA: dimercaptosuccinic acid, avg: average, SD: standard deviation, IQR: interquartile range*

Figure 3

Correlation distribution between DMSA and SWE values (DMSA: dimercaptosuccinic acid, SWE: shear wave elastography).



3. Results

Of the patients included in the study, 77 (54.2%) were female. Within the patient group, 47 (33.1%) had ectopic kidneys, and 48 (33.8%) had horseshoe kidneys. The mean age of the patient group was 21.8 ± 12.9 years. The mean renal parenchymal thickness was 13.5 ± 2.2 mm, and the mean kidney length was 99.3 ± 17.6 mm. Among the patients followed up for CKD, 73 had their left kidney and 69 had their right kidney identified as being at risk (Table 1).

No statistically significant relationship was found between DMSA distribution and patient age, renal parenchymal thickness, renal longitudinal axis, or the distance of the kidney from the skin. Similarly, no relationship was observed between DMSA distribution and stiffness values (avg, SD, median, IQR, IQR/median [%]) derived from SWE findings (Table 2).

A significant correlation at a substantial level of agreement was identified between the SWE values and DMSA values (κ = 0.071) (Table 2, Figure 3).

4. Discussion

Despite its association with low-dose radiation exposure, DMSA renal cortical scintigraphy remains the gold standard imaging method for the non-invasive diagnosis of renal scar tissue.[6] Recently, SWE has emerged as a technique for assessing renal stiffness in the evaluation of renal scarring. Renal parenchymal fibrosis is the most significant marker of KD and leads to changes in the mechanical properties of the kidneys, which can be objectively measured with DMSA.[7] DMSA is frequently used in the diagnosis of ectopic kidneys, horseshoe kidneys, and vesicoureteral reflux in pediatric patients, as well as in detecting fibrosis in suspected cases of allogeneic graft rejection.[8] Certain conventional renal ultrasonography findings, such as decreased kidney size, reduced cortical thickness, and increased echogenicity in the cortex, may indicate parenchymal KD.[9] However, by the time these findings are typically observed, fibrosis has progressed, and the patient is often already diagnosed with CKD. Thus, there is a clear need for parameters that can assist in earlier diagnosis.

Given the current popularity of SWE in identifying pancreatic and liver fibrosis, it is not surprising that efforts have been made to investigate its potential in detecting renal fibrosis.[3] The stiffness values obtained from SWE tests have also gained prominence recently. However, SWE has certain limitations, including inconsistent availability in clinical settings and the absence of standardized normal stiffness values for different patient groups.[10] Another primary disadvantage of SWE is the lack of an established cut-off value for fibrosis in solid organs. This limitation is particularly evident in renal assessments, where the inconsistencies and gaps in the literature are pronounced due to the novelty of the method.[11] Renal SWE findings are not routinely documented in conventional ultrasonography results, and stiffness values are only measured in specific diseases or studies.[12] SWE is a cost-effective, reliable, and non-invasive USG technique for determining tissue elasticity.[13,14] However, the current study also found no relationship between DMSA values and stiffness parameters. The success of stiffness parameters in reflecting renal fibrosis remains unclear. There is a need for further studies with larger patient cohorts to clarify this issue.

The study has some limitations. First, the study was conducted at a single center with a relatively small number of patients. Second, other parameters used to evaluate renal function, such as diethylenetriamine pentaacetate and glomerular filtration rate, were not utilized in this study.

5. Conclusion

The correlation between SWE values and DMSA demonstrates its potential role in detecting fibrosis. SWE can be utilized in the follow-up evaluations of patients suspected of having renal fibrosis.

Statement of ethics

The study was conducted in accordance with the tenets of the

Declaration of Helsinki and approved by the Ethics Committee of Adana City Training and Research Hospital on November 4, 2024 (number: 2024/3145).

Funding

None to declare.

Conflict of interest statement

The authors declare that they have no conflict of interest.

Availability of data and materials

The available data are maintained by Adana City Training and Research Hospital and are securely stored within the institution. These data cannot be shared without prior authorization. Researchers who meet the criteria for accessing confidential data are encouraged to contact the Ethics Committee of Adana City Hospital for further assistance. Data Access/Ethics Committee: adanasehir.etikkurul@saglik.gov.tr

Author contributions

Conceptualization, SS, TDA.; Data curation, SS, ZOU, APK.; Investigation, SS, HBO, APK.; Methodology, F.A. and T.K.; Project administration, SS.; Resources, SS, HA, TDA, ZOU, APK, HBO.; Writing – original draft, SS, HA, TDA,.; Writing – review & editing, SS, HA, TDA, ZOU, APK, HBO.

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