Zagazig University Medical Journal
www.zumj.journals.ekb.eg
https://doi.org/10.21608/zumj.2024.234154.2873 Volume 30, Issue 4, July 2024
Manuscript ID ZUMJ-2109-2356 (R4)
DOI 10.21608/ZUMJ.2021.97460.2356

Original Article

Validating Point Shear Wave Elastography (pSWE) Normal Values Of Renal Cortical Elasticity In The Healthy Native Kidney

Dalia Swelem Saad-Zaghlool*, Mohamad Hamed Abo warda, Hosam Nabil Almassry and Dalia Salah El Deen

Radiodiagnosis department, Zagazig University, Zagazig, Egypt.

*** Corresponding author:**
Dalia Swelem Saad-Zaghlool
E-mail:
docdalia92@gmail.com

Submit Date 22-09-2021
Revise Date 04-10-2021
Accept Date 11-10-2021

ABSTRACT

Background: Shear wave elastography (SWE) is one of the promising techniques that allow the non-invasive estimation of tissue stiffness. It is approved by Food and drug administration (FDA) in liver disease. It shows high sensitivity and specificity to differentiate normal from cirrhotic liver. While there are few studies applied on the kidney with the same technique, we performed this study to validate normal values of renal cortical elasticity in normal native kidneyto differentiate normal kidneys from those with renal disease. As pSWE values above the normal values would indicate early changes in renal cortex indicating early renal disease.

Materials and methods: this study was executed at the Radiodiagnosis Department, Zagazig University from June 2019 to April 2020. The study included 84 healthy volunteers (48 females and 36 males) who showed normal kidney function test by laboratory examination. We examined the renal cortex with conventional ultrasound and point shear wave elastography (pSWE), measuring the Young's modulus (YMs) for the renal cortical elasticity.All analyses were done using the Statistical Package for theSocial Sciences 20.0 software.

Results: The mean value of SWE (kPa) in healthy volunteers was 3.1±0.94 kPa.Both age (r=0.50; P=.000) and kidney depth (r=0.23; P=.38) showed a significant positive correlation with pSWE measurements, moderate correlation with age and mild correlation with kidney depth.

Conclusion: Our results suggest that the mean value of normal pSWE measurement of the renal cortex is 3.1±0.94 kPa. The pSWE values correlates positively with age and kidney depth.

Keywords: kidney, shear wave elastography, renal cortex, YMs.

INTRODUCTION

Shear wave elastography (SWE) is one of the promising techniques that allow the non-invasive estimation of tissue stiffness. Its principle depends on focused acoustic force impulses that cause microscopic tissue displacement, which makes perpendicular shear waves that are traced through tissue measuring their velocities. The Stiffer the tissue, the higher velocity of shear waves through it[1]. Tissue Young's modulus (YM), measured in kilopascals (kPa) is calculated

from shear wave velocity that correlates with the degree of fibrosis [1-2].

Shear wave elastography is an approved technique by Food and drug administration (FDA) in liver disease. It shows high sensitivity and specificity in differentiating normal from the cirrhotic liver [3]. It also has been employed for studying other organs like breast, thyroid and renal allografts [4-6]. Therefore, we established this study to validate values for the normal elasticity of adult native kidneys and assess the effect of some variables on the elasticity values like age, gender, renal length, and depth.

As the produced acoustic pulses induce mechanical vibrations automatically, acoustic radiation force impulse (ARFI)-on which the pSWE depends-is operator-independent and can quantitate tissue elasticity. It also can be done on a conventional ultrasound machine with an ordinary ultrasound probe [7].

While the morphological ultrasound features of the renal medical disease are not sensitive as the renal length, cortical depth or echogenicity may appear normal in diseased kidneys. We believe shear wave elastography would apply a reliable biomarker of renal stiffness.

METHODS

Our work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. We obtained approval from the institutional review board, Faculty of Medicine, Zagazig University and consent from all participants before the study was held. This study was held in the radio diagnosis Department of Zagazig University Hospitals from June 2019 to April 2020.

This study included healthy volunteers. The inclusion criteria included: adults older than 18 years old, with native non-transplanted kidneys, normal kidney function and normal eGFR, and absence of any disease that could modify the results (diabetes, hypertension, malignancy, cardiovascular diseases and chronic hepatic diseases) and normal kidneys on conventional ultrasound. While the exclusion criteria included: individuals whose Body mass index (BMI)is more than 35 kg/m^2 or any cause of abdominal enlargement that impedesimagining of the kidney by ultrasound as marked ascites and any kidney abnormalities either surgical as renal stones or masses or medical as chronic renal disease.

Imaging acquisition:

A single observer performed the ultrasound and the pSWE Examination using Philips iU22 Ultrasound machine, (Philips Medical System, Bothell, WA) equipped with ELAST PQ software using C5-1 (1-5 MHz) convex probe.

A routine examination was done by conventional ultrasound on both kidneys. The length of each kidney was measured- in the coronal plane- as the full length between the two poles. The depth of the kidney from the skin was also recorded.

For the pSWE examination using the Elast PQ software, the probe was set at the right angle with the capsule of the kidney applying the minimal pressure possible. The region of interest (ROI) was positioned in the kidney cortex parallel to the renal pyramids and away from other kidney structures allowing only cortical tissue to be in the ROI. At fullinspiration, with patients retaining breath The YMs were measured. At least ten valid measurements were documented, and the mean value was calculated.

Statistical analysis:

We used the Statistical Package for the Social Sciences software (IBM Corporation, v. 20.0, Armonk, NY) for performing the data analysis. We simplified our qualitative data as numbers and percentages and our quantitative data as the arithmetic mean ± Standard deviation (SD). Pearson's correlation coefficient (r) was used to analyze Influencing factors. One-way

analysis of variance (ANOVA) was used to identify the significant difference between males' and females' measurements. P<0.05 was acknowledged as statistically significant.

RESULTS

84 healthy adult volunteers were included in this prospective study, 48 females and 36 males. Their data is presented in **Table 1.**

The mean Young`s modulus (YM) value of the healthy volunteers was 3.1±0.94 kPa. Their mean age was 36.01±11.95 years, mean BMI was 23.93±3.06 kg/m^2, mean kidney length was 10.49±1.03 cm, and mean kidney depth was 3.98±0.91 cm.

- **Potential influencing factors:**

Both age(r=0.50; P=.000) and kidney depth (r=0.23; P=.38) showed a significant positive correlation with pSWE measurements, moderate correlation with age **Figure 1** andmild correlation with kidney depth **Figure 2**.

While BMI (r=-0.02; P=.835) and kidney length (r=0.14; P=.201) showed no significant correlation with pSWE **Table 2**. There was also no significant difference in pSWE between males and females (2.46±0.8kPa vs. 2.35±1.04kPa, P=.742) **Table 3.**

Table 1: Mean values for participants' characteristics**.**

Characteristic	Mean value
Age (years)	36.01±11.95
BMI (kg/m^2)	23.93±3.06
Kidney length (cm)	10.49±1.03
Kidney depth (cm)	3.98±0.91
YM (kPa)	3.1±0.94

Variables are expressed as mean ± SD
BMI: Body mass index, YM: Young`s modulus, kPa: kilopascal

Table 2. Correlation between pSWE and influencing factors.

	R	P
Age	0.50	.000
BMI	-0.02	.835
Kidney length	0.14	.201
Kidney depth	0.23	.038

Correlation between pSWE and variables are analyzed using Pearson'scorrelation coefficients. P is significant if <0.05.
BMI: Body mass index

Table 3: Comparison between male and female YM measurements.

Male No.=36	Female No. =48	p
2.46±0.8	2.35±1.04	.742

One way ANOVA is used to analyze the difference between the two groups. P is significant if <0.05

FIGURES

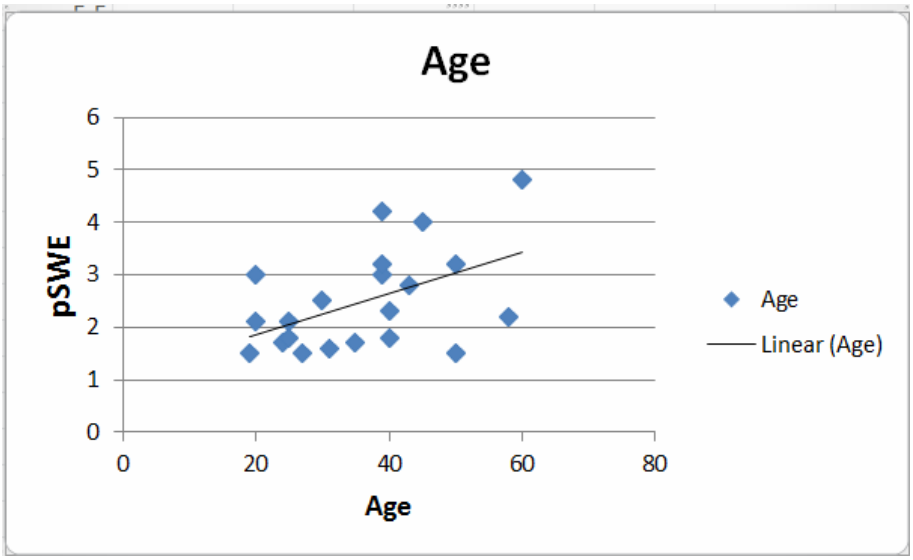

Figure 1: Scatter plot shows positive correlation between Age and pSWE

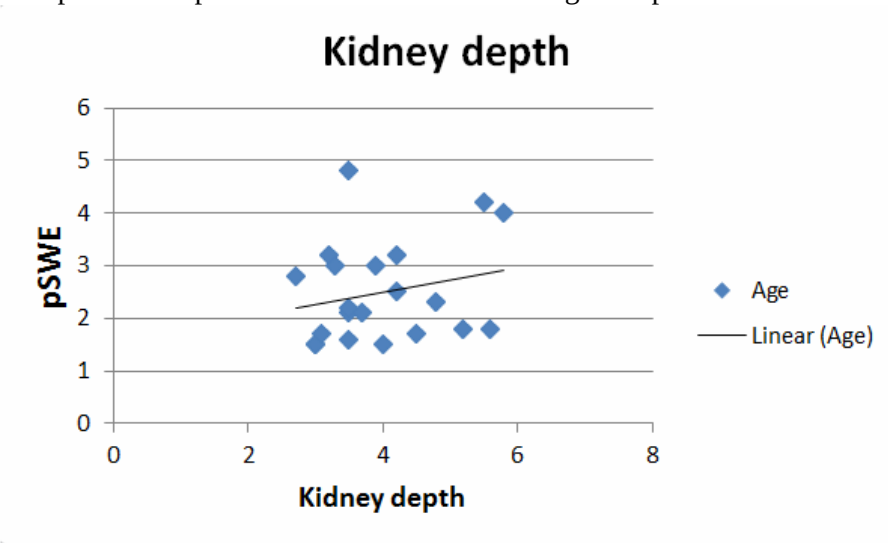

Figure 2: Scatter plot shows positive correlation between kidney depth and pSWE

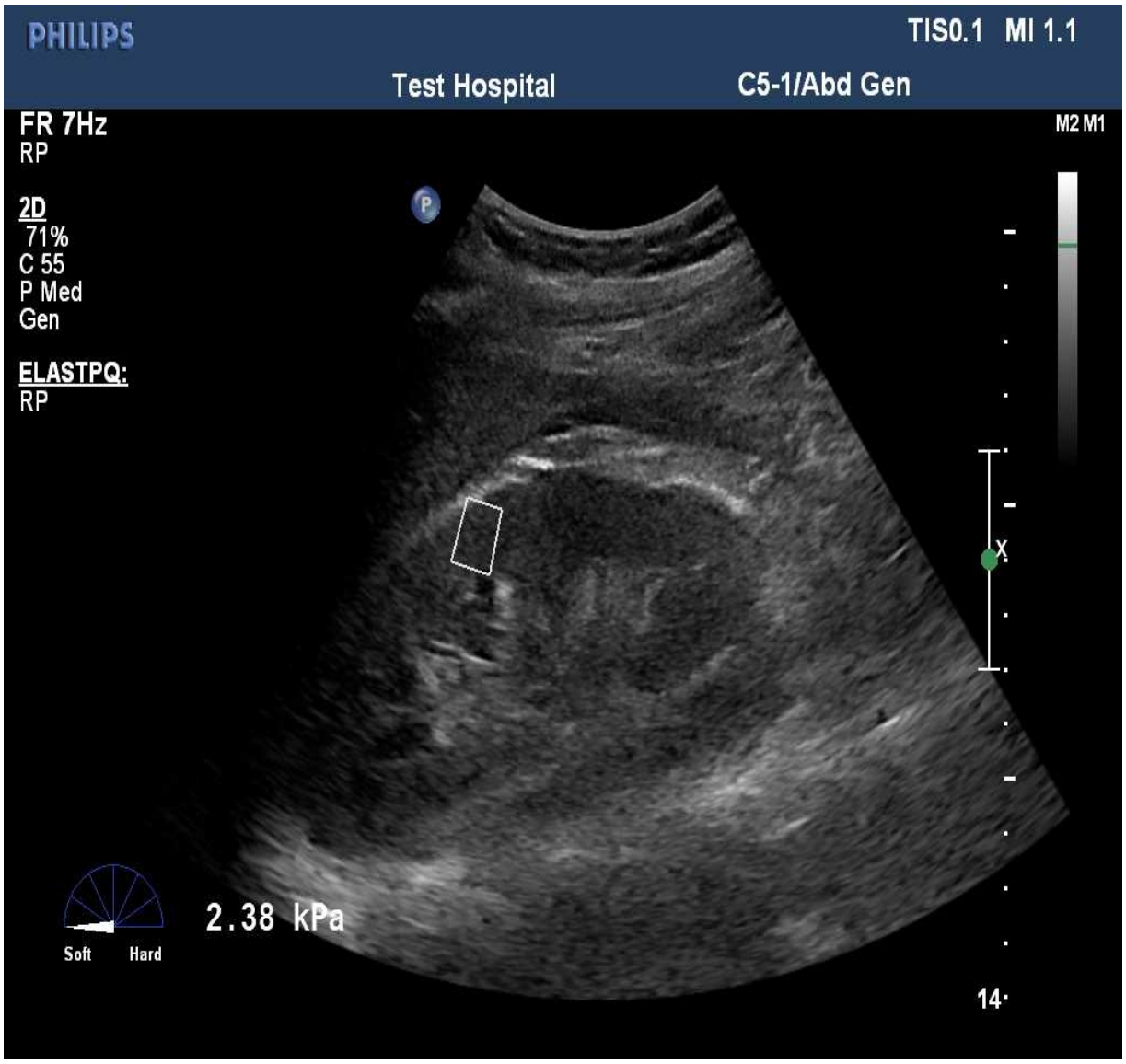

Figure 3A: A 25 year-old female, her BMI was 21.2kg/m2, creatinine level was 0.8 mg/dl and BUN was 22 mg/dl. Her right kidney showed normal site, shape, and size (measured 10.9 x 4.4 cm) and normal parenchymal thickness (measured about 1.3cm). No stone, cysts, masses, or backpressure changes could be detected. The mean value of her renal cortical elastography was 3.05 kPa. The ten measured values were (2.38, 2.8, 2.92, 3.21, 2.8, 2.61, 2.44, 3.35, 3.9, and 4.1).

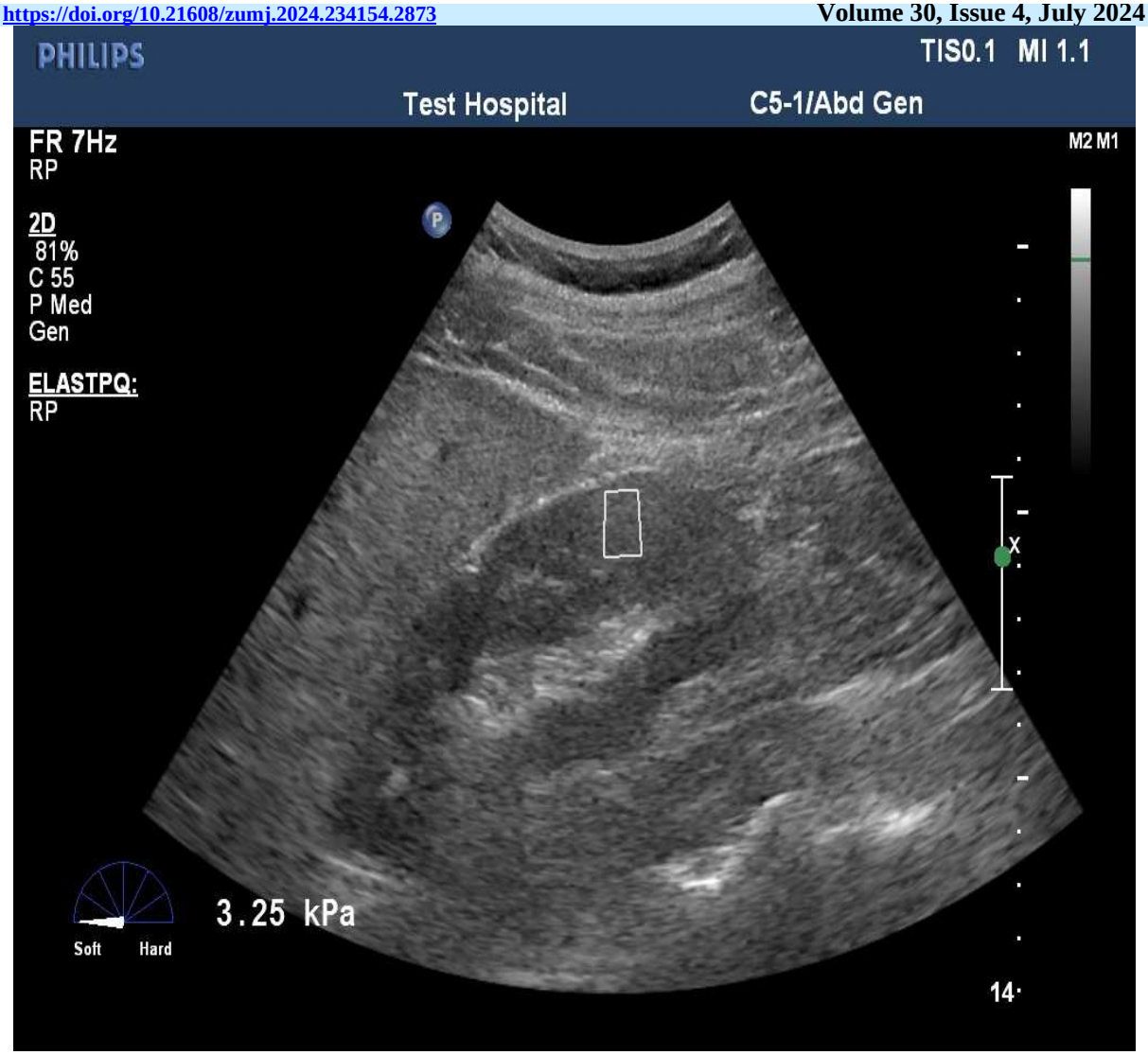

Figure 3B: Her left kidney showed normal site, shape, and size (measured 10.7 x 4.1 cm) and normal cortical thickness (measured about 1.2 cm). No stone, cysts, masses, or backpressure changes could be detected.The mean value of her renal cortical elastography 3.15 kPa. The ten measured values were (1.85, 3.89, 3.9, 3.45, 3.4, 2.81, 2.85, 2.38, 3.25, and 3.7) BMI: body mass index, BUN: Blood urea nitrogen, kPa: kilo Pascal.

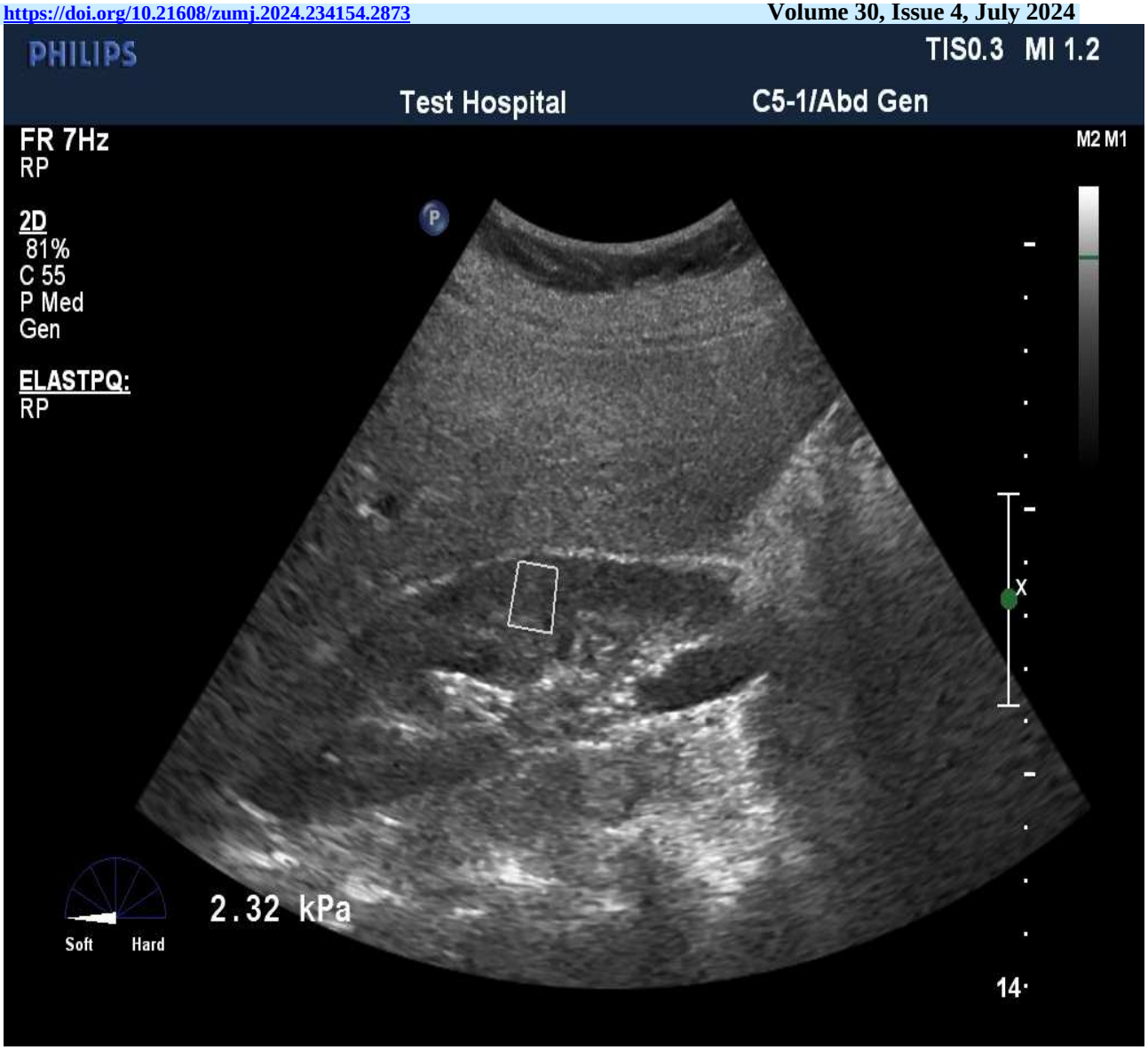

Figure 4 A: A 37 year-old male, his BMI was 23.6 kg/m^2, creatinine level was 0.9 mg/dl and BUN was 20 mg/dl. His right kidney showed normal site, shape, and size (measures 10.7 x 4.1 cm) and normal parenchymal thickness (measures about 1.3cm). No stone, cysts, masses, or backpressure changes could be detected. The mean value of his renal cortical elastography was 3.1 kPa. The ten measured values were (2.9, 1.98, 2.87, 3.5, 2.32, 3.79, 3.48, 2.78, 3.8, and 3.58) BMI: body mass index, BUN: Blood urea nitrogen, kPa: kilo Pascal.

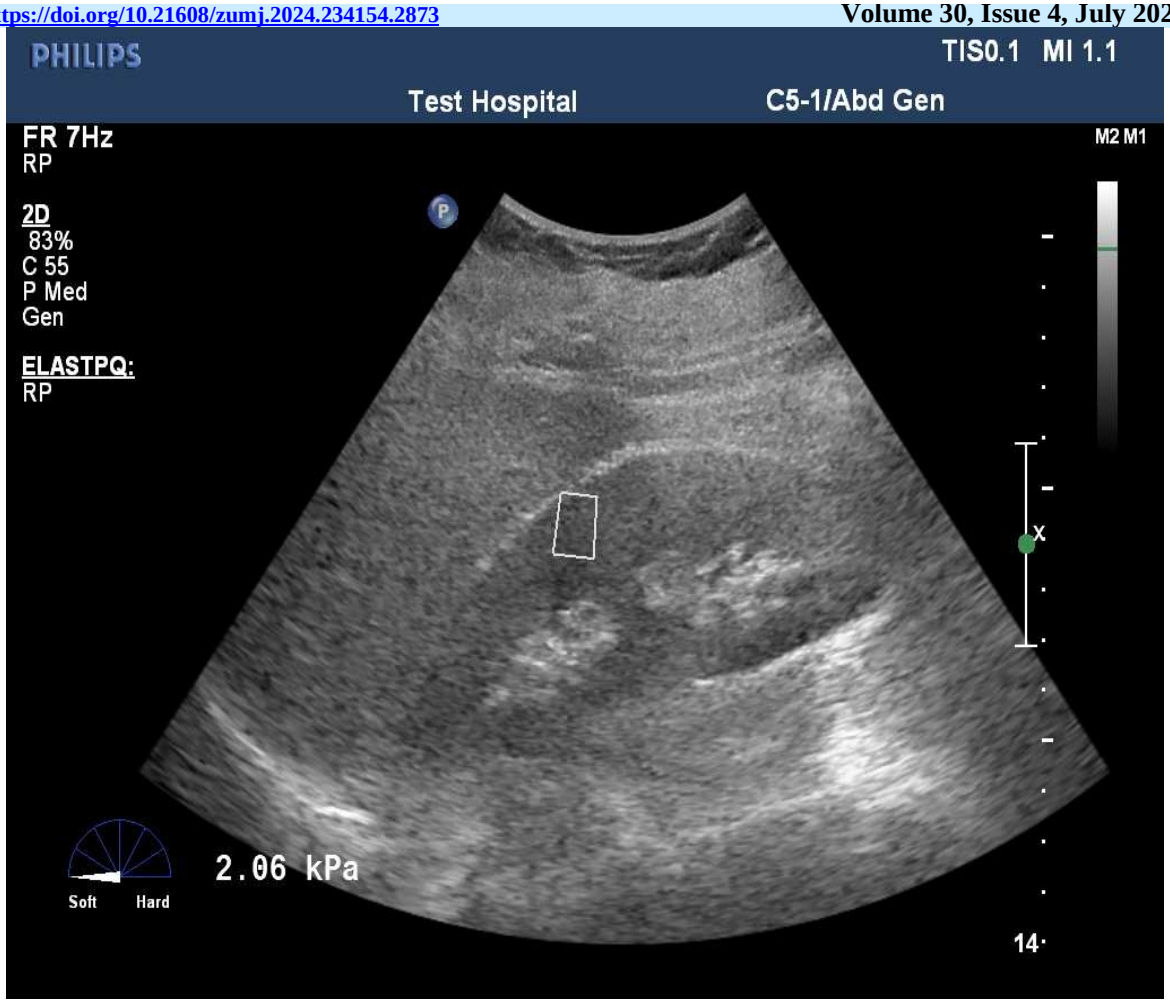

Figure 4B: His left kidney showed normal site, shape, and size (measured 10.5 x 3.9 cm) and normal cortical thickness (measured about 1.4 cm). No stone, cysts, masses, or backpressure changes could be detected.The mean value of his renal cortical elastography was 3.18 kPa. The ten measured values were (2.09, 3.75, 2.96, 4.01, 2.59, 3.21, 3.8, 2.06, 3.42, and 3.92)

DISCUSSION

Ultrasound-based elastography is one of the most remarkable imaging techniques that evaluate the degree of tissue stiffness in living tissues, giving qualitative and quantitative data [8].

AFRI, one of the elastography-based techniques, assesses the mechanical properties of tissues using short-duration, high-intensity pulses of acoustic radiation force to produce localized displacements in tissue and track the tissue dynamic response [9].

PSWE is operator-independent and gives quantitative measurements. It also can be done on a conventional ultrasound machine with an ordinary ultrasound probe [7].

Most studies to validate the normal values of renal cortical elasticity using SWE techniques used SWV instead of YM measurements like Gallotti *et al.* [10]., Guo *et al.* [11]., and Sandhu et al., [12]. who found that the mean shear-wave velocity value of normal renal

cortical elasticity to be 2.24 m/s, 2.15 m/s, and 2.87 m/s respectively.

As we used the pSWE and YM measurement,we found a few similar studies to compare with. In our study we found that the mean pSWE measurement of the normal kidneys of the healthy volunteers was 3.1±0.94 kPa which was close to Leong et al. [13]who found- in a mixed population of healthy individuals and patients with renal disease- that the mean YM measurement of the normal kidneys was 3.55 ± 1.59 kPa. While Arda et al. [14]. found that the mean value of the renal cortex was 5.0 ± 2.9 kPa. The reason for the discrepancy between our results and Arda et al. results is unclear.

We investigated some potential influencing factors like age, BMI, kidney length, gender, and kidney depth. Only age and kidney depth showed a correlation with estimated renal parenchymal SWE measurements. **Leong et al.** [13]., **and Peride et al.** [15]., also described a positive correlation between Age and YM measurements. This could be clarified by the progress of glomerulosclerosis, interstitial fibrosis, arteriosclerosis, and tubular atrophy with aging.

This study faced some limitations like the study was implemented by one radiologist and the sensitivity to breathing movement artifact was challenging to obtain reliable measurements.

CONCLUSIONS

Our results suggest that the mean value of normal pSWE measurement of the renal cortex is 3.1±0.94 kPa. The pSWE values correlates positively with age and kidney depth.

CONFLICT OF INTEREST

None

FINANCIAL DISCLOSURE

The research is funded by the authors

REFERENCES

1. **Urban MW, Chen S, Fatemi M.** A Review of Shearwave Dispersion Ultrasound Vibrometry (SDUV) and its Applications. Curr Med Imaging Rev. 2012;8 (1):27–36. doi:10.2174/157340512799220625.
2. **Kotlyar DS, Blonski W, Rustgi VK.** Noninvasive monitoring of hepatitis C fibrosis progression. Clin Liver Dis. 2008;12 (3):557–viii. doi:10.1016/j.cld.2008.03.006.
3. **Chen S, Sanchez W, Callstrom MR,Gorman B, Lewis JT, Sanderson SO, et al.** Assessment of liver viscoelasticity by using shear waves induced by ultrasound radiation force. *Radiology*. 2013; 266 (3):964–70. doi:10.1148/radiol.12120837.
4. **Bai M, Du L, Gu J, Li F, Jia X.** Virtual touch tissue quantification using acoustic radiation force impulse technology: initial clinical experience with solid breast masses. *J Ultrasound Med*. 2012;31(2):289–94. doi:10.7863/jum.2012.31.2.289.
5. **Zhang YF, Xu HX, He Y, Liu C, Guo LH, Liu LN, et al.** Virtual touch tissue quantification of acoustic radiation force impulse: a new ultrasound elastic imaging in the diagnosis of thyroid nodules. *PLoS One*. 2012;7 (11):e49094. doi:10.1371/journal.pone.0049094.
6. **Grenier N, Poulain S, Lepreux S, Gennisson JL, Dallaudière B, Lebras Y,et al.** Quantitative elastography of renal transplants using supersonic shear imaging: a pilot study. *Eur Radiol*. 2012;22 (10):2138–46. doi:10.1007/s00330-012-2471-9.
7. **Friedrich-Rust M, Nierhoff J, Lupsor M, Sporea I, Fierbinteanu-Braticevici C, Strobel D, et al.** Performance of Acoustic Radiation Force Impulse imaging for the staging of liver fibrosis: a pooled meta-analysis. *J Viral Hepat*. 2012;19 (2):e212-e219. doi:10.1111/j.1365–2893.2011.01537.x.
8. **Li GY, Cao Y.** Mechanics of ultrasound elastography. *Proc Math Phys Eng Sci*. 2017;473(2199):20160841. doi:10.1098/rspa.2016.0841.
9. **Gennisson JL, Deffieux T, Fink M, Tanter M.** Ultrasound elastography: principles and techniques. *Diagn Interv Imaging*. 2013;94 (5):487–95. doi:10.1016/j.diii.2013.01.022.
10. **Gallotti A, D'Onofrio M, PozziMucelli R.** Acoustic Radiation Force Impulse (ARFI) technique in ultrasound with Virtual Touch tissue

quantification of the upper abdomen. *Radiol Med*. 2010;115 (6):889–97.doi:10.1007/s11547-010-0504-5.

11. **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. doi:10.1371/journal.pone.0068925.
12. **Sandhu RS, Shin J, Wehrli NE, Gao J.** Establishing Normal Values for Shear-Wave Elastography of the Renal Cortex in Healthy Adults. *J Med Ultrasound*. 2018;26 (2):81–4. doi:10.4103/JMU.JMU_9_17.
13. **Leong SS, Wong JHD, Md Shah MN, Vijayananthan A, Jalalonmuhali M, Ng KH.** Shear wave elastography in the evaluation of renal parenchymal stiffness in patients with chronic kidney disease. *Br J Radiol*. 2018; 91(1089):20180235. doi:10.1259/bjr.20180235.
14. **Arda K, Ciledag N, Aktas E, Aribas BK, Köse K.** Quantitative assessment of normal soft-tissue elasticity using shear-wave ultrasound elastography. *AJR Am J Roentgenol*. 2011;197(3):532–36. doi:10.2214/AJR.10.5449.
15. **Peride I, Rădulescu D, Niculae A, Ene V, Bratu OG, Checheriță IA.** Value of ultrasound elastography in the diagnosis of native kidney fibrosis. *Med Ultrason*. 2016;18(3):362–69. doi:10.11152/mu.2013.2066.183.per.

Citation:

Saad-zaghlool, D., Abo warda, M., Elmassry, H., Anwar, D. Validating Point Shear Wave Elastography (pSWE) Normal Values of Renal Cortical Elasticity in The Normal Adult Native Kidney. *Zagazig University Medical Journal*, 2024; (2261-2270): -. doi: 10.21608/zumj.2021.97460.2356