Research Article

Unveiling the Renal Symphony Exploring the Relationship Between Ultrasonographic Parameters and eGFR in Chronic Kidney Disease Patients

Faryal Ijaz,[1] Muhammad Salman Rafique,[2] Fatima Sehar,[3] Bakht Bilal,[4] Tooba Fatima,[5] Sikander Abdullah[6]

[1-6] *Department of Radiology, Pakistan Kidney and Liver Institute and Research Center Lahore*

Abstract

Background: Correlation of renal dimensions with renal function in healthy subjects has been firmly established, but which renal dimension correlates best with renal function in chronic kidney disease (CKD) is still debatable. Traditionally, bipolar length of the kidney has been considered a renal function indicator. However, it changes with the size of the body.

Objective: To determine the correlation between renal ultrasound parameters and eGFR for renal evaluation in patients with CKD.

Methods: This cross-sectional study was undertaken in Pakistan Kidney and Liver Institute Lahore, Radiology department from 5th August 2023 to 4th February 2024. A total of 60 patients of 18-70 years of age with the clinical diagnosis of CKD as mentioned by National Kidney Foundation guidelines (Kidney damage >3 months or decreased GFR (less than 60 mL/min/1.73 m2) for 3 months or more) were included. Patients having a history of renal malignancy or renal surgery, polycystic kidney disease, nephrolithiasis or hydronephrosis or fatty liver disease, on renal replacement therapy, and severe pulmonary, liver, or heart disease were excluded. The ultrasound renal indices like cortical and parenchymal thickness were measured for both kidneys and their respective mean was recorded and analysed.

Results: The correlation between eGFR and renal cortical thickness was moderately significant as evidenced by a p-value of 0.003 and r value of 0.372 (Table III). There was significant moderate correlation with eGFR and renal parenchymal thickness as well (p-value = 0.007, r = 0.346)

Conclusion: The renal parenchymal and cortical thickness correlate positively with eGFR in CKD patients.

Received: 04-05-2024 | **Revision:** 25-11-2024 | **Accepted:** 08-03-2025

Corresponding Author | Dr. Muhammad Salman Rafique, Consultant Radiology Department, Pakistan Kidney and Liver Institute and Research Center Lahore. **Email:** msalmanrafique@gmail.com

Keywords | Chronic Kidney Disease, Ultrasonography, Cortical Thickness.

Introduction

Chronic kidney disease (CKD) is a global health predicament with expanding incidence and prevalence reaching a prevalence of 8-16% and 12.6% in Pakistan.[1] The adverse outcomes and premium treatment cost contribute to significant mortality and morbidity. It has been estimated that the disease incurs an annual fiscal expense above $50 billion.[2] Efforts are ongoing to find alternative methods to aid in disease management. Currently, the diagnosis of CKD relies on clinical symptoms, laboratory findings including assessment of creatinine clearance estimated glomerular filtration rate (eGFR) and proteinuria, and radiological imaging including gray scale ultrasound, Doppler

Production and Hosting by KEMU

https://doi.org/10.21649/akemu.v31i1.5715

2079-7192/

ultrasound and computed tomography (CT).[3]

The estimated glomerular filtration rate (eGFR) is deemed the most reliable marker of glomerular and renal function. Serum creatinine (SCr) is the most commonly used endogenous marker in formulae that estimate GFR including the Modification of Diet in Renal Disease (MDRD) equation.[4,5]

Since kidneys are positioned retroperitoneal, the US allows easy evaluation with minimal interference of intestinal gas. Early detection of abnormalities through renal US can help slow the disease progression and mitigate the detrimental effects. Moreover, it is cost-effective, readily accessible, and simple to perform at the patient's bedside. It provides sufficient details of renal anatomy without the need for contrast and ionizing radiation exposure.[5,6,7]

CKD can be associated with different values of longitudinal kidney diameters. It increases in polycystic kidney disease, in myeloma cast nephropathy, in amyloidosis, and in the beginning of the diabetic Kimmestiel-Wilson nephropathy. Contrarily, it decreases in many other nephropathies, such as chronic glomerulonephritis, nephroangiosclerosis and chronic ischemic nephropathy.

In B-mode US (also known as greyscale imaging), renal parameters mostly used are renal longitudinal dimension, renal echogenicity, cortical and parenchymal thickness. In CKD patients, these parameters are quite helpful in establishing ultrasonographic diagnosis of CKD as they give indirect but useful information regarding the irreversible renal morphostructural changes occurring in the course of the disease.[8]

Correlation of renal dimensions with renal function in healthy subjects has been firmly established,[1] but which renal dimension correlates best with renal function in CKD is still debatable. Traditionally, bipolar length of the kidney has been considered a renal function indicator but it changes with the body habitus.[1] Besides, renal bipolar dimension can vary according to the etiology underlying CKD; in polycystic kidney disease, amyloidosis and myeloma cast nephropathy it enlarges whereas in a variety of rest of the nephropathies it diminishes.[8] Other alternatives like renal echogenicity, cortical and parenchymal thickness are presumed to be better forecasters of renal function in patients with CKD. The renal parenchymal thickness can readily distinguish acute kidney injury (AKI) from CKD. Moreover, CKD results in a gradual and stepwise decrease in renal parenchymal thickness with eGFR. Particularly, the renal cortical thickness is associated with least interobserver variability, thus rendering it more suitable for renal function assessment and monitoring.[9,10]

In Pakistan, very limited data is available on which B-mode sonographic renal parameters are correlated with eGFR. One study performed in Pakistan concluded a strong correlation of renal function with renal cortical thickness in individuals affected by CKD.[1]

Therefore, we formulated this project to correlate aforementioned renal parameters with eGFR to ascertain that which of these is most suitable for this purpose. This analysis will also help establish effective utilization of renal ultrasonography for a more comprehensive evaluation of CKD status.

Methods

After authorization from the institutional review board, we undertook this cross-sectional study in Pakistan Kidney and Liver Institute Lahore, Department of Radiology, from 5th August 2023 to 4th February 2024. A consecutive, non-probability sampling technique was used. To estimate the sample size, the expected value of correlation was taken as 0.508.[1] Using a 5% level of significance and 10% absolute precision the sample size came out to be 60 patients with CKD.

Patients 18-70 years of age with the clinical diagnosis of CKD as mentioned by NFK guidelines (Kidney damage >3 months or decreased GFR (less than 60 mL/min/1.73 m2) for 3 months or more) were included. Patients having a history of renal malignancy or renal surgery, a diagnosis of polycystic kidney disease, nephrolithiasis, hydronephrosis, or fatty liver disease, patients on renal replacement therapy, and patients with end-stage pulmonary, cardiac, or hepatic disease were excluded.

Informed consent was taken from the patients who

satisfied the standards for inclusion. A proforma was constructed to collect the patient's biodata, radiological findings, and laboratory values. Serum Creatinine value was used to calculate the GFR through the Modification of Diet in Renal Disease (MDRD) Equation. For standardization, one radiologist who was blinded to the patient's eGFR values, performed renal ultrasound using GE LOGIQ P7 and GE LOGIQ S8 machines with curvilinear probe 3.5-6.5 MHz. The sonographic renal parameters like cortical thickness and parenchymal thickness were calculated for both kidneys and their mean was recorded.

The data was analyzed by SPSS version 20.0. Gender and age were presented in frequency and percentage and quantitative variables like cortical and parenchymal thickness and eGFR were presented in mean ± SD. Pearson correlation was used to find a relationship between above mentioned sonographic renal parameters and eGFR. The p-value ≤0.05 was deemed significant. After stratification for gender and age, Pearson correlation was applied.

Results

The patient ages ranged from 13 to 83 years (mean 44.22 ± 11.24 years). A greater part of the patient population (32 in number, 53 %) fell in the 40 to 83 years age range. There were 44 (73%) male and 16 (27%) female patients. The female to male ratio was 1:2.8. The mean value of eGFR was 13.29 ± 6.50. The mean renal cortical thickness was 0.56 ± 0.19 cm. The average parenchymal thickness was 1.16 ± 0.37 cm. The renal cortical thickness and eGFR were moderately positively correlated as indicated by a p-value = 0.003 (r = 0.372, Table 1). There was a significant moderate correlation between eGFR and renal parenchymal thickness (p = 0.007, r = 0.346) as shown in Table 2.

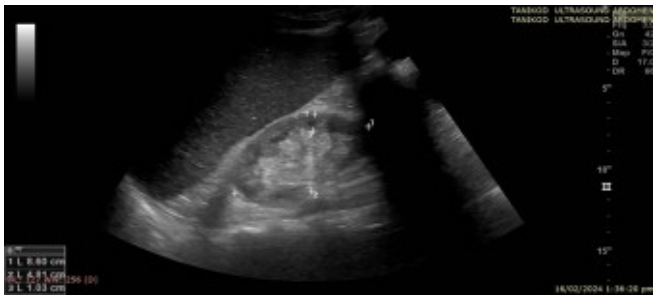

Figure-1: *Measurement of renal parenchymal thickness in a CKD patient.*

Table 1: *Correlation between eGFR and cortical thickness for the assessment of renal function in CKD patients.*

		Renal cortical thickness	eGFR
Renal cortical thickness	Pearson Correlation	1	0.372
	Sig. (2-tailed)		0.003
	N	60	60
eGFR	Pearson Correlation	0.372	1
	Sig. (2-tailed)	0.003	
	N	60	60

Table 2: *Correlation between renal parenchymal thickness and eGFR for the evaluation of renal function in CKD patients*

		Renal parenchymal thickness	eGFR
Renal parenchymal thickness	Pearson Correlation	1	0.346
	Sig. (2-tailed)		0.007
	N	60	60
eGFR	Pearson Correlation	0.346	1
	Sig. (2-tailed)	0.007	
	N	60	60

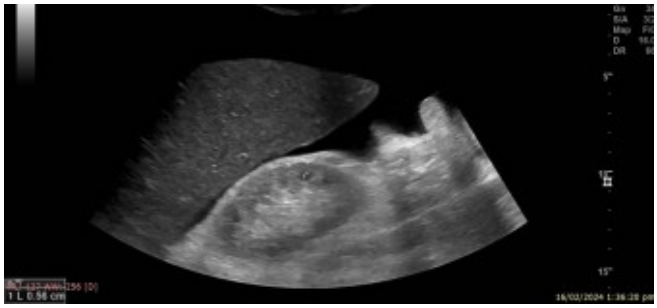

Figure-2: *Measurement of renal cortical thickness in the same CKD patient.*

Discussion

CKD has emerged as an extremely significant, chronic, noncommunicable disease worldwide. According to the guidelines laid down by American National Kidney Foundation for CKD, chronic kidney disease is defined as renal damage or suboptimal renal function (reduced GFR) for 3 months or more (level A recommendation). On the other hand, to be labeled as renal failure one of the

following two conditions should be fulfilled:

1. GFR < 15 mL/min per 1.73 m2, which is frequently associated with a uremic clinical picture.

2. A necessity to initiate a renal replacement therapy (transplantation or dialysis).[11]

Longitudnal renal lengths are reported in renal ultrasounds as a routine practice since it is a traditional belief that bipolar renal dimensions are indicators of renal function in CKD, but this parameter has a low specificity to foretell a diminished renal function.[12] Renal sizes differ with body mass. Moreover, a kidney with a diminished length can have a normal function and a kidney with normal bipolar length can have abnormal function. Another frequently used parameter, raised echogenicity, is not a reliable indicator of fibrosis because it also results from cellular infiltrates. Although cortical thinning is a reasonable marker of CKD, the converse is untrue; even in advanced diabetic nephropathy, a normal or increased cortical thickness can be observed.[13] Ultrasound assessment of renal volume is a more precise indicator of kidney function than the renal length.[14,15] A recent study revealed that statistical shape analysis of kidneys with MRI incorporating length and parenchymal thickness of the kidneys, in patients with CKD can better categorise diseases underlying CKD.[16]

One of the studies performed in Pakistan concluded a substantial association between renal function and cortical thickness in CKD patients evidenced by a p-value < 0.001, (r2 = 0.508). The parenchymal thickness had a weak positive correlation with a p-value of 0.001 and r2 of 0.216. In the same study, the longitudinal renal size was not significantly correlated with renal function in CKD patients (p-value 0.609).[1]

In an attempt to link ultrasonograhic renal parameters with serum creatinine levels, Chhetri et al[17] studied these indices in 60 CKD patients. They stated a considerable negative relationship between parenchymal thickness and serum creatinine (r = -0.945; p<0.001) as well as between cortical thickness and serum creatinine (r = -0.980; p<0.001).

Another study from the subcontinent performed by Garg et al.[18] in 2022 evaluated the same parameters and inferred a significant correlation between renal cortical thickness and eGFR (r = 0.86, p < 0.001). They further suggested that this parameter is more beneficial in earlier phase of chronic kidney disease owing to a better corticomedullar differentiation, which in more advanced disease diminishes. However, it is worthy to note that we stratified our data for age and gender which was not done in this study which is one of their limitations. Cho et al[19] also showed that MRI derived body surface area adjusted total kidney volumes and renal function were strongly correlated.

Our mean renal cortical thickness (0.56 ± 0.19 cm) was close to that reported by Mayeden et al. (0.66 + cm).[20] Our average parenchymal thickness was 1.16 ± 0.37 cm which is reasonably close to that calculated by Gupta et al. (1.55 + 0.42 cm).[21]

Our mean cortical thickness was also very similar to that reported by Kodikara et al (0.6 cm).[22] One parameter that they studied was association of renal cortical thickness with CKD severity; they concluded that particularly in early phase of the CKD, parenchymal thickness and renal cortical thickness outperformed absolute and relative renal length for reliable CKD diagnosis. The other parameter that they investigated was the association of renal cortical thickness with common CKD etiologies like diabetes mellitus (DM) and cardiovascular disease. Here they revealed that renal cortical thickness deteriorated more significantly in patients with cardiovascular disease than patients with non-cardiovascular CKD. For the DM group the converse was true; renal cortical thickness was normal in 77% of this subset compared with non-DM subset in which 51% of the patient had a normal renal cortical thickness.

Quite recently, the mean cortical thickness has surfaced as a new index to assess CKD patients. It is fruitful in early CKD being significantly correlated with eGFR, an important reason for which is that the renal pyramids can be visualized better in early CKD. On the contrary, later on in CKD, owing to a diminished corticomedullary differentiation, it becomes an uphill task to accurately determine the corticomedullary interface which is a major pitfall.

Comparing our study with that by Gupta et al.[21], it is

revealed that the cause of a strong positive correlation of cortical thickness with eGFR is the renal cortex being composed of glomeruli and collecting tubules within the renal pyramids. Ongoing renal disease destroys the glomeruli, thinning the renal cortex. Further progression of renal disease damages both the glomeruli and collecting tubules, leading to a compromised renal volume and loss of corticomedullary differentiation. Therefore ultrasound findings in early CKD show a decreased renal cortical thickness, and in advanced disease the renal volume also shrinks proportionately.

We determined that the association between eGFR and renal parenchymal thickness was significant with a moderately positive correlation (r = 0.346). Similar conclusions were drawn by Andrulli et al. 2024. They further emphasized that renal length was weakly positively correlated with eGFR (r2=0.064), and that the extent of proteinuria and histopathological diagnosis of renal disease had an additional positive correlation with the eGFR.[8] Another recent work by Chawla et al revealed that renal cortical thickness was beteer correlated with eGFR than the renal length ($p< 0.0001$) and therefore, in diabetic renal disease this parameter should be used in preference compared with bipolar length ($p < 0.001$).[23]

In 2021, Uduagbamen et al. following their study concluded that renal cortical thickness was more strongly correlated with eGFR as compared to renal length and thus has more value in assessment of renal function. Moreever according to them, eGFR and renal cortical thickness decreased proportionately with increasing chronic kidney disease stage.[24] Kharel et al. 2024 concluded that eGFR and renal parenchymal thickness were moderately positively correlated ($rs = 0.51$, $p < 0.05$). A similar correlation was discovered between eGFR and renal length ($rs = 0.46$, $p < 0.05$). However, eGFR and renal width were weakly positively correlated ($rs = 0.3$, $p < 0.05$). They also observed a significant association between eGFR and renal cortical echogenecity grade ($p < 0.05$).[25] Our study is limited by a small sample size chosen due to time constraints. Therefore, we suggest conducting the study on a larger population to enhance the generalizability of the findings.

Conclusion

This study concludes that in CKD, renal cortical and parenchymal thickness are positively correlated with renal function. We recommend that since ultrasonography is cost-effective, non-invasive, and readily available for renal disease assessment, and the ultrasonographic parameters serve as reliable biomarkers of renal function deterioration, renal cortical and parenchymal thickness should be routinely included in ultrasonography reports.

Ethical Approval: The Institutional Review Baord, Pakistan Kidney and Liver Institute and Research Center Lahore approved this study vide Ref. PKLI-IRB/AP/205.

Conflict of Interest: The authors declare no conflict of interest.

Funding Source: None

Author Contribution

FI: Conception & design, acquisition of data, drafting of article

MSR: Final approval of the version to be published

FS: Acquisition of data, analysis & interpretation

BB: Drafting of article

TF: Critical revision for important intellectual content

SA: Acquisition of data, analysis & interpretation of data.

References

1. Mansoor A, Ramzan A, Chaudhary AN. Determination of best grey-scale ultrasonography parameter for assessment of renal function in chronic kidney disease. Ann Pak Inst Med Sci. 2016;12(4):191-4.
2. Xie Z, Peng S, Ou G, Zhou X, Zhang G, Jiang H, et al. U-shaped association between dietary niacin intake and chronic kidney disease among US elderly: a nationwide cross-sectional study. Front Endocrinol (Lausanne). 2024 ;15(1):1438373. doi: 10.3389/-fendo.2024.1438373. PMID: 39497801; PMCID: PMC11532146.
3. Vaidya S, Aedulla N. Chronic kidney disease [Internet]. Nih gov. StatPearls Publishing; 2024. [Cited 2 jan 2025]. http://www.ncbi.nlm.nih.gov/-books/NBK535404/.

4. Ahmed S, Jafri L, Khan AH. Evaluation of'CKD-EPI Pakistan'equation for estimated glomerular filtration rate (eGFR): a comparison of eGFR prediction equations in Pakistani population. J Coll Physicians Surg Pak. 2017;27(7):414-18.
5. Bosede O, Adeyekun AA, Irabor P, Okokhere P, Izevbekhai S. Correlation of ultrasonographic findings of the kidneys to serum creatinine levels in Lassa fever patients in a tertiary health facility in Sub-Saharan Africa. J Infect Dis Epidemiol. 2024;10(1):322. doi:10.23937/2474-3658/1510322.
6. Koukoutegos K, Heeren R, Wever L, De Keyzer F, Maes F, Bosmans H. Segmentation-based quantitative measurements in renal CT imaging using deep learning. Eur Radiol Exp. 2024;8(1):110. doi:10.1186/s41747-024-00507-4.
7. Assenyi S, Adekanmi AJ. Ultrasonographic Renal Dimensions Amongst Adult Nigerian Diabetics: Correlation with Clinical, Anthropometric and Metabolic Risk Factors. Afr J Biomed Res. 2020 ;23(1):85-91. PMID: 35783238; PMCID: PMC9248893.
8. Andrulli S, Gigante A, Rossini M, D'Angio' P, Vischini G, Luchetta F, et al.; ITA-KID-BIOPSY Group. How histopathological diagnosis interacts with kidney ultrasound parameters and glomerular filtration rate. Intern Emerg Med. 2024;19(8):2121-32. doi: 10.1007/s11739-024-03711-7. Epub 2024 Sep 13. PMID: 39269540; PMCID: PMC11582157.
9. Harmindasatya C, Violetta L, Setiawati R. Correlation analysis of ultrasonography kidney morphological profiles and the classification of persistent and transient acute kidney injury (AKI) in children during the pandemic period at the Dr. Soetomo General Teaching Hospital. Int J Res Publ. 2024;145(1):23-33. doi:10.47119/-IJRP1001451-320246182.
10. Moses AA, Fernandez HE. Ultrasonography in acute kidney injury. POCUS J. 2022;7(1):35-44. doi:10.24908/pocus.v7iKidney.14989. PMID: 36896100; PMCID: PMC9994307.
11. Kheirandish M, Eftekhar E, Azarbad A, Salarpour E, Shahmoradi M, Ghazizadeh S, et al. Prevalence of Chronic Kidney Disease and Associated Factors among the Diabetic and Prediabetic Population in the Bandare-Kong Cohort Study; A Population-Based Study. Arch Iran Med. 2024;27(9):470-8. doi: 10.34172/aim.31194. Epub 2024 Sep 1. PMID: 39465521; PMCID: PMC11496602.
12. Chen Z, Jiang J, Gunda S, Han X, Wu C, Ying M et al. Ultrasonic renal length as an indicator of renal fibrosis severity in non-diabetic patients with chronic kidney disease. Clin Exp Nephrol. 2024; 19(1):1-9.https://doi.org/10.1007/s10157-024-02598-0.
13. Ham Y, Lee E, Kim H, Jeon J, Na K, Lee K et al. Ultrasound renal score to predict the renal disease prognosis in patients with diabetic kidney disease: an investigative study. Diagnostics (Basel). 2023;13(3):515. doi:10.3390/diagnostics13030515. PMID: 36766619; PMCID: PMC9913982.
14. Gargiulo S, Barone V, Bonente D, Tamborrino T, Inzalaco G, Gherardini L, et al. Integrated ultrasound characterization of the diet-induced obesity (DIO) model in young adult C57BL/6J mice: assessment of cardiovascular, renal and hepatic changes. J Imaging. 2024;10(1):217. doi:10.3390/jimaging10090217.
15. Phakdeekitcharoen B, Treesinchai W, Wibulpolprasert P, Boongird S, Klytrayong P. The correlation between kidney volume and measured glomerular filtration rate in an Asian ADPKD population: a prospective cohort study. BMC Nephrol. 2021;22(1):178. doi: 10.1186/s12882-021-02392-0. PMID: 33992075; PMCID: PMC8126117.
16. Thanaj M, Basty N, Cule M, Sorokin EP, Whitcher B, Srinivasan R et al. Kidney shape statistical analysis: associations with disease and anthropometric factors. BMC Nephrol. 2023;24(1):362. doi:10.1186/-s12882-023-03407-8. PMID: 38057740; PMCID: PMC10698953.
17. Chhetri P, Basnet S. Ultrasonography in patients with chronic kidney disease. J Chitwan Med Coll. 2021;11(1):110-4. doi:10.54530/jcmc.342.
18. Garg A, Jhobta A, Kapila S, Rathour D. Correlation of sonographic parameters with renal function in patients with newly diagnosed chronic kidney disease. J Ultrasonogr. 2022;22(1):216-21. doi:10.15557/JoU.2022.0036.
19. Cho J, Koh J, Kim S, Lee S, Kim Y, Cho S et al. Associations of MRI-derived kidney volume, kidney function, body composition, and physical performance in ≈38,000 UK Biobank participants: a population-based observational study. Clin Kidney J. 2024 ;17(4):068. doi:10.1093/ckj/sfae068. PMID: 38660121; PMCID: PMC11040514.
20. Mayeden R, Klenam D, Mensah Y, Ohene-Botwe B, Acheampong F, Dadson E et al. Renal cortical thickness and bipolar renal length and their correlation with estimated glomerular filtration rate of chronic kidney disease patients: a study at a teaching hospital in Ghana.Chin J Acad Radiol.2024;7(1):253-63. 10.1007/s42058-024-00165-w.

21. Gupta P, Chatterjee S, Debnath J, Nayan N, Gupta SD. Ultrasonographic predictors in chronic kidney disease: a hospital-based case-control study. J Clin Ultrasound. 2021;49(7):715-9. doi:10.1002/-jcu.23026. Epub 2021 Jun 4. PMID: 34085292.

22. Kodikara I, Gamage DTK, Nanayakkara G, Ilayperuma I. Diagnostic performance of renal ultrasonography in detecting chronic kidney disease of various severity. Asian Biomed (Res Rev News). 2020 ;14(5):195-202. doi: 10.1515/abm-2020-0028. PMID: 37551269; PMCID: PMC10373390.

23. Chawla R, Zala S, Punyani H, Dhingra J. Correlation between cortical renal thickness and estimated glomerular filtration rate in diabetic nephropathy patients. J Diabetol. 2020;11(1):158-62.

24. Uduagbamen PK, Odunlami OA, Yusuf AO, Thompson MJ, Ojo NK, Ajiboye OF, et al. Clinical utility of kidney cortical thickness in assessing severity of CKD in low-income settings. West Afr J Med. 2021;38(12):1224-30

25. Kharel A, Shrestha S, Karki DB. Correlation of ultrasonographic findings with estimated glomerular filtration rate in chronic kidney disease. JNHLS.2024;3(2):102-8.