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Association of Computed Tomography Findings with Severity of Chronic Kidney Disease

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ABSTRACT

Objective: To assess the diagnostic performance of CT-derived renal cortical thickness and CT density values for predicting the severity of chronic kidney disease (CKD) and to explore their potential usefulness in early detection and disease staging.

Materials and Methods: This cross-sectional study included 100 CKD patients of varying stages who underwent CT scans using a 64-slice CT scanner at the radiology department of our institute from June 2023 to August 2024. CT scanning was performed in cortical, nephrogenic, and secretory phases. Morphological parameters including kidney length, width, volume, cortical thickness, and cortical density were assessed and correlated with CKD stages. Kruskal-Wallis test was used to examine statistical differences among stages. A p value of < 0.05 was considered statistically significant.

Results: Among 100 patients (54 males, 46 females), mean age was 45.9 ± 11.0 years, and mean BMI was 22.74 ± 2.58 kg/m^2. Differences in kidney length, width, and volume were significant among CKD stages ($P < 0.001$).

KEY WORDS

Chronic Kidney Disease; Renal Cortical Thickness; Computed Tomography; Kidney Volume; Cortical Density

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Statistically significant differences were not seen in cortical thickness (P = 0.3351). CT cortical phase density was significantly related to the severity of kidney disease (r = 0.835, P < 0.001).

Conclusion: CT imaging parameters cortical phase density, as well as kidney volume, correlate strongly with the severity of CKD. This suggests that CT can be used for prediction as well as CKD staging.

Introduction

Chronic Kidney Disease, often abbreviated as CKD, is a complex and widespread medical condition that affects millions of people worldwide. It causes serious effects on an individual's health and well-being. It is defined as the presence of kidney damage or an estimated glomerular filtration rate (eGFR) less than 60 ml/min per 1.73 square meters, persisting for 3 months or more. It is a state of progressive loss of kidney function, ultimately resulting in the need for renal replacement therapy (dialysis or transplantation) [1] It refers to changes in the structure and function of the kidney which allow removing the waste products and extra fluids from the blood stream to maintain the body chemical balance. As this vital organ loss, the ability to work properly the waste and fluid can accumulate and become a leading cause of health problem that extend far beyond the confines of the renal system. CKD is silent and progressive condition often asymptomatic nature in its early stages. Risk factors for the development and progression of CKD include low nephron number at birth, nephron loss due to increasing age and acute or chronic kidney injuries caused by toxic exposures or diseases for example, obesity and type 2 diabetes mellitus [2]

The prevalence of chronic kidney disease (CKD) in Pakistan is significant, with estimates suggesting that 12.86 million Pakistanis above 30 years of age have some degree of renal impairment [3] In a study conducted at the Pakistan Institute of Medical Sciences in Islamabad, the prevalence of CKD was reported to be 21.2% among adults [4] Common causes of CKD in Pakistan include diabetic nephropathy, glomerulonephritis, hypertension-related kidney disease. The prevalence of CKD in Pakistan is influenced by factors such as inadequate healthcare provision, lack of primary healthcare, insufficient government funding, and the rising prevalence of risk factors like diabetes and hypertension [4] Despite the high prevalence, CKD remains under-recognized in Pakistan, emphasizing the need for improved awareness, screening programs, and preventive measures to manage this condition effectively. Early detection and intervention strategies are crucial to prevent complications associated with CKD and improve outcomes for individuals affected by this condition in Pakistan.

Chronic kidney disease (CKD) carries various health consequences beyond impaired kidney function. The typical signs and symptoms which individuals with CKD commonly experience complications is anaemia, stemming from decreased production of red blood cells, leading to fatigue and weakness. Moreover, CKD heightens susceptibility to infections due to compromised immune function. Abnormalities in blood electrolyte levels are prevalent, with low calcium levels, high potassium levels, and elevated phosphorus levels posing risks of cardiac and skeletal complications. Loss of appetite or reduced food intake is often observed, exacerbating malnutrition and further complicating the disease management. Early detection and intervention strategies are crucial to prevent complications associated with CKD and improve outcomes for individuals affected by this condition [5]

Ultrasound is the primary modality of choice as it is non-invasive, cost-effective, and easily available. Ultrasound can assess factors like longitudinal length, echogenicity, parenchymal, and cortical thickness, which are affected by CKD [6]. Ultrasound can identify renal length, thickness, and echogenicity, aiding in evaluating the extent of renal parenchymal damage and the potential for reversibility [7] CT scans can provide high-resolution images that are excellent for evaluating the size, shape, and structure of the kidney. This makes them valuable for detecting structural abnormalities, tumors, or kidney stones [8] Three-dimensional analysis of contrast-enhanced CT provides accurate measurement of overall and cortical renal volumes [9]

MRI is a valuable tool in the evaluation of chronic kidney disease, providing detailed insights into renal anatomy, function, and pathology. However, the use of MRI for CKD is limited due to its lower availability and high cost [8, 9]

Chronic kidney disease concerns with rising prevalence leading to significant morbidity and mortality. CT density, reflecting tissue composition, and renal cortical thickness, is indicative of renal structure and can offer unique insight into the subtle changes that occur in the kidney during the early stages of CKD. By investigating the density and renal cortical thickness, this study aims to bridge the gap in early CKD detection.

Material and Methods

This cross-sectional study included 100 CKD patients of varying stages who underwent CT scans using a 64-slice CT scanner at the radiology department of our institute from June 2023 to August 2024. CT scanning was performed in cortical, nephrogenic, and secretory phases. Morphological parameters including kidney length, width, volume, cortical thickness, and cortical density were assessed and correlated with CKD stages.

Patient Selection: Patients with confirmed diagnosis of both genders from 20-70 years of age were included in this study. Patients with other kidney diseases, acute kidney injury, coronary artery disease, peripheral vascular disease or any known malignancy were excluded from this study. Pregnant women were also excluded from this study. A 64-slice multi-detector CT scanner was used. The normal renal cortex has a higher HU than the renal medulla, with the HU of the cortex ranged from 20 to 40 HU. All the stages of CKD were taken where the GFR and creatinine values were calculated as well.

Scanning protocol: The patient was asked to empty the stomach and hold the urine. The patient was asked to lie down on a scan table in supine position. Non-ionic contrast medium was administered via intravenous injection through the right median cubital vein by a single-tube pressure syringe. An IV line was started in the arm for injection of the contrast dye. After injection, enhanced scans in the cortical phase, myeloid phase, and secretory phase were performed, and the CT values was measured by the workstation.

Statistical Analysis: Kruskal-Wallis test was used to examine statistical differences among stages. A p value of < 0.05 was considered statistically significant

Results

The total number of patients were 100 out of which 46 patients were female and 54 were male. Minimum age limit for female suffering from the disease were 54 while maximum age was 78 the mean value was 45 and the SD ratio was 11.03. The BMI values in the sample range from 18.0 to 29.0 kg/m². The average BMI was 22.74 kg/m², with a median BMI of 23.0 kg/m², half of the individuals have a BMI below 23.0 kg/m² and half have a BMI above this value. (Table 1)

The Kruskal-Wallis test was applied to find out the association of kidney length and width with stages of CKD. The test revealed significant differences in kidney length and width across the various CKD stages, with a of P value of 0.000001, and 0.003 respectively (Fig. 1, 2) The association of kidney volume with stages of CKD revealed a statistically significant association with a significance level of $P<0.000001$ (Fig. 3)

There was no statistically significant differences between cortical thickness across different stages of CKD, with a p value of 0.335 (Table 2). However there was a strong statistically significant association between kidney cortical densities among different stages of CKD with a p vale of $P < 0.000001$ (Table 3)

Discussion

Chronic Kidney Disease (CKD) is a significant global health issue, characterized by the gradual loss of kidney function over time. It affects millions of people worldwide and is associated with increased morbidity and mortality [13] As CKD progresses, it can lead to end-stage renal disease (ESRD), necessitating dialysis or kidney transplantation [14] Early detection and accurate assessment of CKD severity are crucial for effective management and prevention of complications. [12] CT imaging has emerged as a valuable tool in the assessment of renal morphology and structure [8-10]

Table 1. Descriptive Statistics of Age and BMI

Variable	N	Minimum	Maximum	Mean	SD
Age (Years)	100	26.0	78.0	45.9	11.0
BMI (kg/m²)	100	18.0	29.0	22.74	2.58

Note: SD = Standard Deviation. BMI = Body Mass Index.

Total number of patients were 100 with a minimum age of 26 and maximum 78. The BMI values in the sample range from 18.0 to 29.0 kg/m². The average BMI was 22.74 kg/m², with a median BMI of 23.0 kg/m².

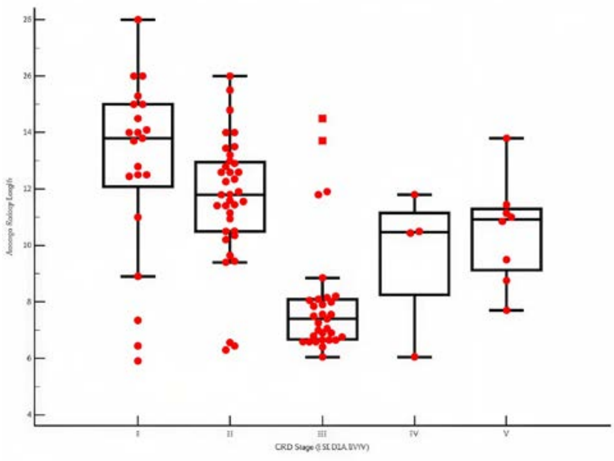

Fig. 1: *Association between Kidney Length and Stages of CKD*
Box plot showing the association between CKD stages and average kidney length.

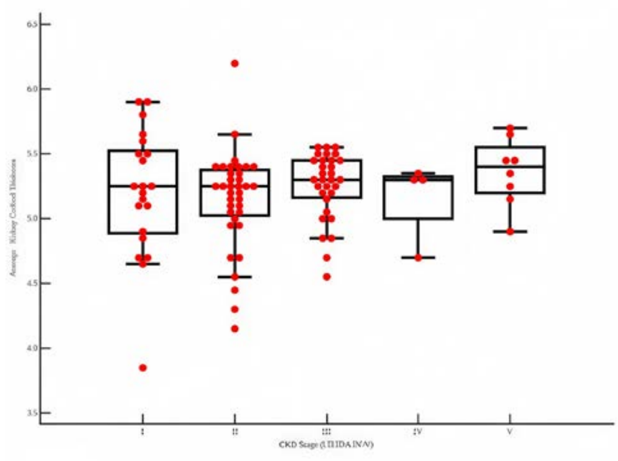

Fig. 2: *Association between Kidney Width and Stages of CKD*
Box plot showing the association between CKD stages and average kidney width.

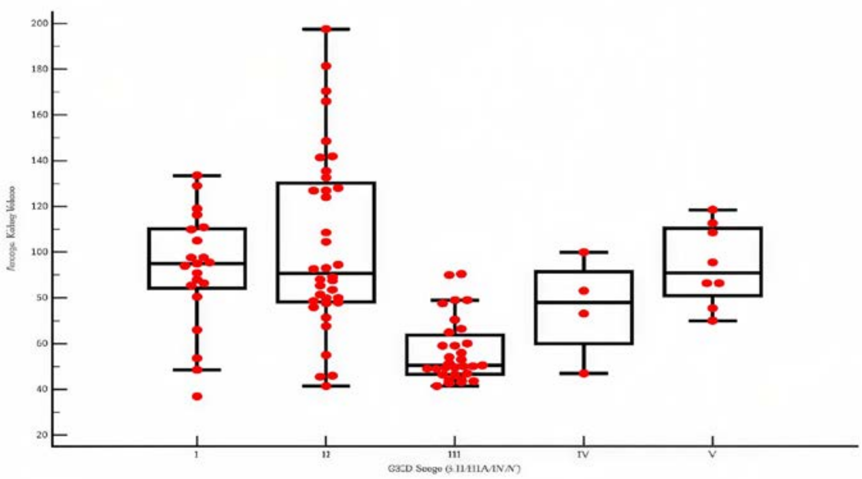

Fig. 3: *Association between Kidney Volume and Stages of CKD*
Box plot showing the association between CKD stages and average kidney volume.

Table 2. Association between Kidney Cortical Thickness with Stages of CKD

Factor	n	Minimum	25th percentile	Median	75th percentile	Maximum
I	21	3.8500	4.887	5.250	5.525	5.900
II	36	4.1500	5.025	5.250	5.375	6.200
III	31	4.5500	5.162	5.300	5.450	5.550
IV	4	4.7000	5.000	5.300	5.325	5.350
V	8	4.9000	5.200	5.400	5.550	5.700

Table 2. Association between Kidney Cortical Thickness with Stages of CKD	
Test statistic	4.5420
Corrected for ties Ht	4.5633
Degrees of Freedom (DF)	4
Significance level	P = 0.335104

The Kruskal-Wallis test was applied to find out the association of kidney cortical thickness with stages of CKD. The test showed a significance level of P = 0.335104. This indicates that there are no statistically significant differences in cortical thickness across the different CKD stages.

Table 3. Association between Kidney Cortical Density with Stages of CKD						
Factor	**n**	**Minimum**	**25th percentile**	**Median**	**75th percentile**	**Maximum**
I	21	31.5000	43.125	410.000	673.750	881.000
II	36	87.0000	172.500	417.750	745.000	1054.000
III	31	840.0000	1027.500	1125.000	1169.625	1350.000
IV	4	1421.5000	1519.250	1631.250	1681.500	1717.500
V	8	1551.0000	1608.750	1626.750	1635.000	1875.000

Test statistic	74.8814
Corrected for ties Ht	74.8913
Degrees of Freedom (DF)	4
Significance level	P < 0.000001

The Kruskal-Wallis test was applied to find out the association of kidney cortical thickness with stages of CKD. The test showed a significance level of P = 0.335104. This indicates that there are no statistically significant differences in cortical thickness across the different CKD stages.

CT findings can provide insights into kidney size, cortical thickness, and other structural changes that may correlate with CKD severity [15] The findings can serve as a foundation for future studies aimed at exploring novel imaging techniques or therapeutic approaches to managing CKD [12, 16]

Our study included 100 patients, with a nearly equal gender distribution 46% female and 54% male. The age ranged from 26 to 78 years, with a mean age of approximately 46 years and a standard deviation (SD) of 11.03 years, indicating moderate variability. The BMI of the patients ranged from 18.0 to 29.0 kg/m², with a mean of 22.74 kg/m² and a SD of 2.5844 kg/m² (Table 1) The gender distribution, with 54% male and 46% female, aligns with trends observed in other studies, which often show a male predominance in CKD populations [17, 18] Understanding the demographics is crucial for tailoring interventions and preventive measures targeted at high-risk groups. Studies frequently report that CKD prevalence increases with age [18] A study by Levey et al., indicated that the incidence of CKD rises significantly in individuals over 50 years old [19] Our findings align with this trend, as the mean age in our sample suggests that the population is within a critical age range for CKD development. The male predominance in CKD (54% male vs. 46% female) is corroborated by various studies, including a meta-analysis by Wang et al., which found that men are at higher risk for CKD, often due to higher rates of hypertension and diabetes, as well as differences in health-seeking behaviour [20]

Our study provides valuable insights on the association of various CT findings with the severity of CKD. Kidney cortical thickness, density, kidney length and volume were all measured to assess the morphology of kidney across different stages of CKD. Our study showed a significant reduction in kidney length, width and volume in different stages of CKD especially from stages 3-5. (Fig. 1-3) Stage 1 had the longest average kidney length, while stage 3 had the shortest. Significant differences were observed between stage 1 and stages 3, 4, and 5, as well as between stage 2 and stage 3, consistent with prior research indicating progressive renal atrophy with CKD advancement [15, 21] The kidney width also showed changes especially in stage 5 showing the largest average width as compared to other stages (Fig. 1-3) This suggests that kidney width might increase as a compensatory mechanism in the later stages of CKD, possibly due to fibrosis or other structural changes [24] Significant changes across different stages were seen for kidney volume (Fig. 1-3) Stage 3 showed significantly smaller kidneys as compared to stages 1, 2 and 4, as reported previously [25] Our findings are consistent with previous studies which also reported reduced kidney size correlating with declining renal function [13, 15, 21] The decrease in kidney size reflects nephron loss and renal atrophy, reinforcing the notion that kidney size is a reliable indicator of CKD severity.

While our study found no significant differences in cortical thickness across CKD stages (Table 2), some studies have reported variations in cortical thickness as CKD progresses [22] The lack of statistical significance suggests that cortical thinning, while present in CKD, may not vary distinctly between different stages. This might require more sensitive measurements to detect subtle changes. The stability of cortical thickness in our study suggests that this parameter might be less sensitive to changes in kidney function compared to size metrics. Our study also found a marked increase in kidney cortical density in advanced CKD stages. (Table 3) Stage 3 has markedly higher cortical density compared to earlier stages 1 and 2, with stages 4 and 5 having the highest densities. This aligns with research by Wang et al. who reported that increased cortical density might indicate fibrosis and scarring in renal tissue. The implications of increased density suggest potential renal adaptations or responses to chronic damage, which warrants further investigation [23]

One of the limitations of our study was the limited number of patients. Further research with larger sample sizes and longitudinal data could provide more comprehensive insights into these relationships.

Conclusion

Our findings highlight changes in kidney dimensions as CKD progresses. However, the lack of significant differences in cortical thickness suggests that this measure may not be as sensitive to CKD stage changes as other parameters. **R**

Ethical Considerations:

All procedures were in accordance with the ethical standards of the Helsinki Declaration of 1975, as revised in 2000. Written informed consent was taken from all the participants and this study was conducted after approval from Research Ethical Committee of The University of Lahore. All information and data collection was kept confidential. The participants remained anonymous throughout the study and they were informed that there were no disadvantages or risks on the procedure of the study.

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Conflict of interests:

The authors have no conflict of interest to disclose.

References

1. Vaidya SR, Aeddula NR, Sharma S. Chronic Renal Failure. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2020. Available from: https://www.ncbi.nlm.nih.gov/books/NBK535404/
2. Romagnani P, Remuzzi G, Glassock R, Levin A, Jager KJ, Tonelli M, Wanner C. Chronic kidney disease. Nat Rev Dis Primers 2017; 3:17088. https://doi.org/10.1038/nrdp.2017.88
3. Stanifer JW, Muiru A, Jafar TH, Patel UD. Chronic kidney disease in low- and middle-income countries. Nephrol Dial Transplant 2016; 31(6): 868–874.
4. Hasan M, Sattar A, Ahmed SD, Arshad A, Ghani F, Khalid F. Chronic kidney disease in patients visiting nephrology outpatient department at Pakistan Institute of Medical Sciences. J Ayub Med Coll Abbottabad 2018; 30(4): 563–566.

5. Kovesdy CP, Levey AS, Cizman B, Cummings SR, Greene T, Hsu CY, et al. Hypertension in chronic kidney disease: an expert panel report of the American College of Physicians. Ann Intern Med 2022; 175(4): 499–510.
6. Rysz J, Gluba-Brzózka A, Franczyk B, Jabłonowski Z, Ciałkowska-Rysz A. Novel biomarkers in the diagnosis of chronic kidney disease and the prediction of its outcome. Int J Mol Sci. 2017;18(8):1702.
7. Ahmed S, Ghouri A, Ilyas M, Butt K. Role of Ultrasonography in Evaluation of Chronic Kidney Disease. Pak J Med Health Sci. 2019;13(1):96–8.
8. Grenier N, Basseau F, Ries M, Tyndal B, Jones R, Moonen CT. Functional imaging of the kidney by MRI. Eur Radiol. 2006;16(12):2811–8.
9. Sommer G, Dietrich O, Horger W, Horger M, Helck A, Nikolaou K, et al. Volume measurement of kidneys in MR imaging using a semi-automated technique: clinical application in patients with chronic kidney disease. Rofo. 2007;179(3):252–8.
10. Cohen D, Sodickson A, Yee J. Renal Imaging. In: Arellano RS, editor. Radiology Secrets Plus. 4th ed. Philadelphia: Elsevier; 2020. p. 353–5.
11. Higgins C. Urea and creatinine concentration in health and disease. The Clinical Biochemist Reviews. 2016;37(2):51–64.
12. 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.
13. Jha V, Garcia-Garcia G, Iseki K, Li Z, Naicker S, Plattner B, et al. Chronic kidney disease: global dimension and perspectives. Lancet. 2013;382(9888):260–72.
14. Levin A, Tonelli M, Bonventre J, Coresh J, Donner JA, Fogo AB, et al. Global kidney health 2017 and beyond: a roadmap for closing gaps in care, research, and policy. Lancet. 2017;390(10105):1888–917.
15. Moghazi S, Jones E, Schroepple J, Arya K, McClellan W, Hennigar RA, et al. Correlation of renal histopathology with sonographic findings. Kidney Int. 2005;67(4):1515–20.
16. Sharma K, Kassianos AJ, Al-Busaidi IS, Bailey M, Barratt J, Cockwell P. Emerging role of imaging in the risk stratification of chronic kidney disease. Kidney Int. 2021;99(1):38–47.
17. Zhang QL, Rothenbacher D. Prevalence of chronic kidney disease in population-based studies: systematic review. BMC Public Health. 2008;8:117.
18. Coresh J, Selvin E, Stevens LA, Manzi J, Kusek JW, Eggers P, et al. Prevalence of chronic kidney disease in the United States. JAMA. 2007;298(17):2038–47.
19. Levey AS, Coresh J, Tighiouart H, Greene T, Inker LA. Measured and estimated glomerular filtration rate: current status and future directions. Nat Rev Nephrol. 2020;16(1):51–64.
20. Wang Y, Chen X, Song Y, Caballero B, Cheskin LJ. Association between obesity and kidney disease: a systematic review and meta-analysis. Kidney Int. 2008;73(1):19–33.
21. Hsu CY, Lin F, Vittinghoff E, Shlipak MG. Racial differences in the progression from chronic renal insufficiency to end-stage renal disease in the United States. J Am Soc Nephrol. 2003;14(11):2902–7.
22. Goh BL, Ong LM, Siew EE, Lim YN. Imaging of the kidney in chronic kidney disease. In: Asian Renal Guidebook. Malaysia: National Kidney Foundation; 2018. p. 75–83.
23. Wang CJ, Huang CC, Wu MC, Chen HC, Tsai WL, Hsu CH, et al. Magnetic resonance imaging evaluation of renal fibrosis in patients with chronic kidney disease. Nephrol Dial Transplant. 2015;30(5):766–73.
24. O'Neill WC. Sonographic evaluation of renal failure. Am J Kidney Dis. 2000;35(6):1021–38.
25. Emamian SA, Nielsen MB, Pedersen JF, Ytte L. Kidney dimensions at sonography: correlation with age, sex, and habitus in 665 adult volunteers. AJR Am J Roentgenol. 1993;160(1):83–6.

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