Sonological Based Assessment and Grading of Chronic Kidney Disease: A Pictorial Essay

Dr. Anshuman Shadangi[1], Dr. Gautam Muthu[2], Dr. Javaji Ravi Prasad[3]

[1]Post Graduate, Department of Radio-Diagnosis, Rajarajeswari Medical College & Hospital

[2]MDRD, Professor and HOD, Department of Radio-Diagnosis, Rajarajeswari Medical College & Hospital

[3]MDRD, Professor, Department of Radio-Diagnosis, Rajarajeswari Medical College & Hospital

Abstract: ***Background*** ***Chronic kidney disease (CKD) ranks among the leading causes of renal failure. Its pathophysiology includes a gradual decline in kidney function over time. Ultrasound serves as the preferred imaging technique for CKD due to its non-invasive nature and ease of access for visualizing renal structures. Key ultrasonographic indicators such as echogenicity and measurements of longitudinal length, parenchymal thickness, and cortical thickness highlight irreversible changes associated with the disease's progression. Consequently, ultrasound is considered the optimal screening tool for assessing renal insufficiency in patients.*** ***Aims*: *The study aims to define various grades of chronic kidney disease in patients referred to our department.*** ***Conclusion*: *Ultrasonography significantly aids in evaluating renal conditions associated with CKD by allowing accurate classification and monitoring disease progression while also facilitating targeted medical or surgical interventions. Implementing a Sonographic Grading System based on Renal Cortical Echogenicity enhances diagnostic precision and improves treatment outcomes. It is essential for radiologists to be well-acquainted with this classification system, along with relevant anatomical knowledge of the kidneys, to deliver effective patient care.***

Keywords: Chronic kidney disease (CKD), renal echogenicity, ultrasonography

1. Introduction

Chronic kidney disease remains one of the primary causes of renal failure due to its progressive nature, affecting kidney functionality over time. Ultrasound emerges as the foremost imaging choice for CKD owing to its non-invasive approach and straightforward accessibility for examining the kidneys. Typically regarded as both the initial and often sole imaging modality required during evaluations for chronic renal failure, ultrasonography provides critical insights even when routine urine tests are pending or unavailable.

Aim and objectives:

- To delineate different grades of chronic kidney disease among patients referred to our radiology department.
- To classify CKD utilising a Sonographic Grading System based on Renal Cortical Echogenicity.
- To underscore the significance of ultrasonography in devising medical and surgical management plans through structured reporting that recognises clinically pertinent features.

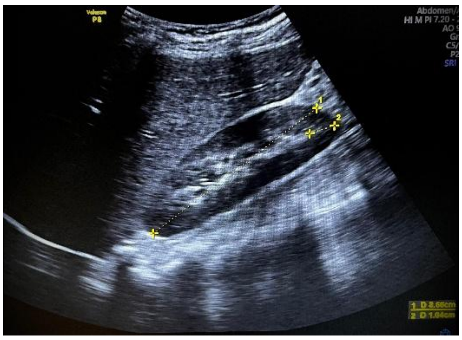
2. Research Methodology:

This prospective study received approval from our institution's ethical committee and was conducted at Rajarajeswari Medical College & Hospital over one year. We selected 32 patients aged over 30 diagnosed with CKD per National Kidney Foundation guidelines, while excluding those undergoing kidney replacement therapies or having liver conditions identified via ultrasound. Comprehensive data were collected from participants regarding demographics, such as age, sex, diabetes duration (if applicable), hypertension duration (if relevant), other causes contributing to chronic renal failure, and treatment history.

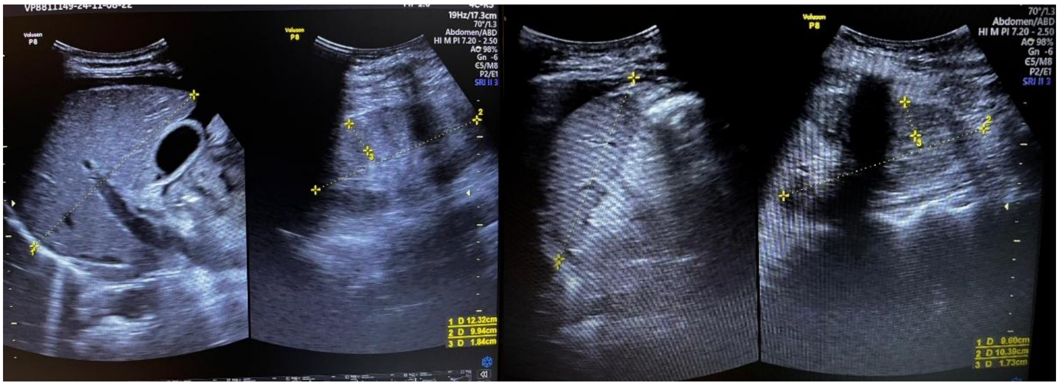
Using a standard B-mode grayscale ultrasound (Voluson GE P8 and E8), we performed ultrasounds on kidneys and livers employing curved array transducers operating at 2.5- 4 MHz frequencies while adjusting gain manually along with time gain compensation (TGC). Measurements included:

- Kidney Length: Measured pole-to-pole.
- Parenchymal Thickness: Measured from the hilum to the maximum convex border at the lateral margin.
- Cortical Thickness: Assessed in a sagittal plane across a medullary pyramid perpendicular to the capsule.

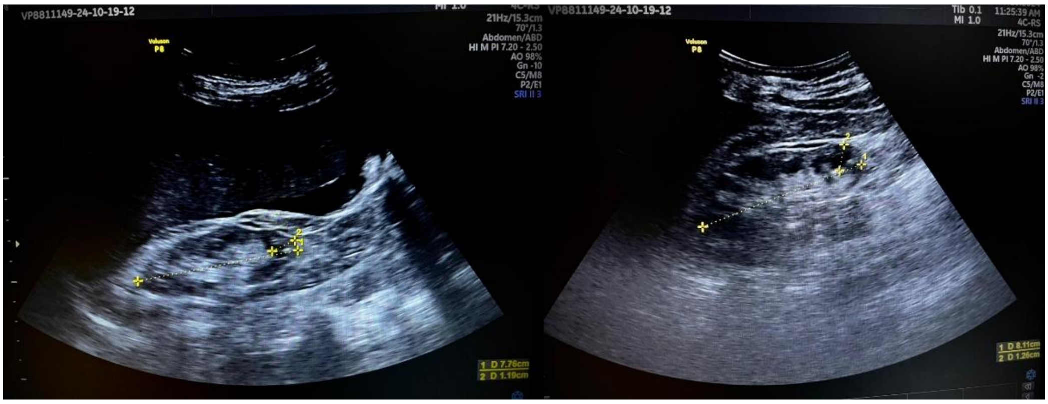
In every case, the mean values of the right and left renal longitudinal size, parenchymal thickness, and cortical thickness were calculated. Evaluation parameters included mean values of dimensions like renal longitudinal size alongside assessments of parenchymal thickness, cortical thickness, and cortical echogenicity compared against that of liver tissue while establishing cortical-medullary differentiation criteria across grading scales from Grade 0 (normal) through Grade 4 (severe echogenicity).



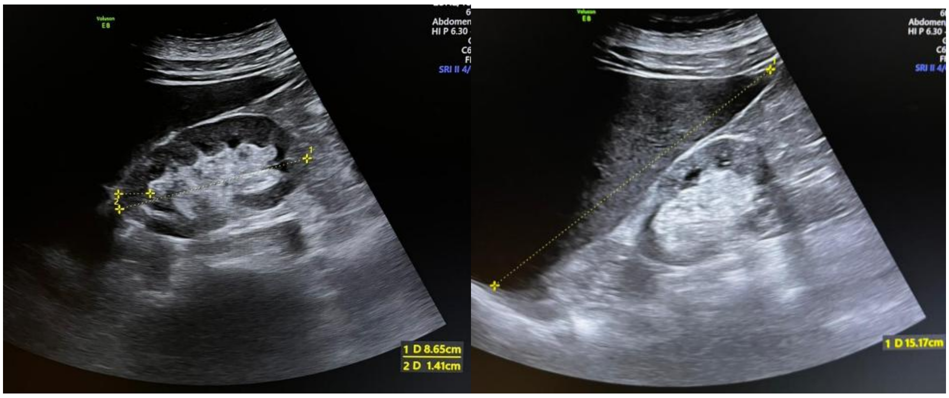
Grade 0: Normal echogenicity less than that of the liver, with maintained corticomedullary definition



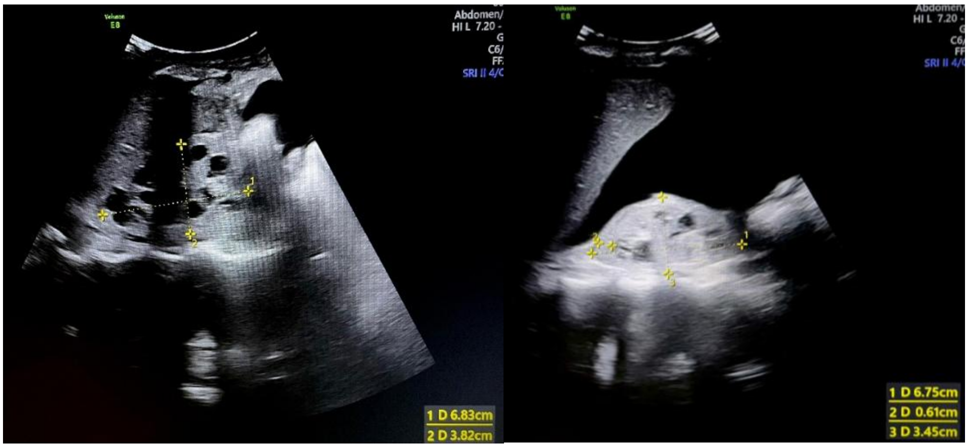
Grade 1: Echogenicity is the same as that of the liver, with maintained corticomedullary definition



Grade 2: Echogenicity greater than that of the liver, with maintained corticomedullary definition



Grade 3: Echogenicity greater than that of the liver, with poorly maintained corticomedullary definition



Grade 4: Echogenicity greater than that of the liver, with a loss of corticomedullary definition

3. Results

Among 32 selected subjects- 22 males and 10 females- 15 patients (48.3%) displayed sonological Grade 1 CKD; 11 patients (35%) exhibited Grade 2; 04 patients (11.7%) had Grade 3; 02 individuals (5%) represented Grade 4 CKD (Table 1). The mean longitudinal size was 101.38 mm for Grade 1 (range: 76-124 mm), 91.43 mm for Grade 2 (range: 63-115 mm), 89.43 mm for Grade 3 (range: 60-111 mm), and 78 mm for Grade 4 (range: 67-91 mm) (Table 2). The mean parenchymal thickness was 47.38 mm for Grade 1 (range: 37-61 mm), 41.14 mm for Grade 2 (range: 30-61 mm), 40 mm for Grade 3 (range: 21-50 mm), and 37.33 mm for Grade 4 (range: 31-44 mm) (Table 3). The mean cortical thickness was 15.59 mm for Grade 1 (range: 10-24 mm), 12.86 mm for Grade 2 (range: 7-21 mm), and 11.33 mm for Grade 3 (range: 9-14 mm). The cortical thickness cannot be measured in Grade 4 CKD due to loss of corticomedullary definition (Table 4).

Table 1

CKD Grade	Patients (n)	Percentage
Grade 1	15	48.30%
Grade 2	11	35%
Grade 3	4	11.70%
Grade 4	2	5%

The mean longitudinal size varied across grades (Table 2)**:**

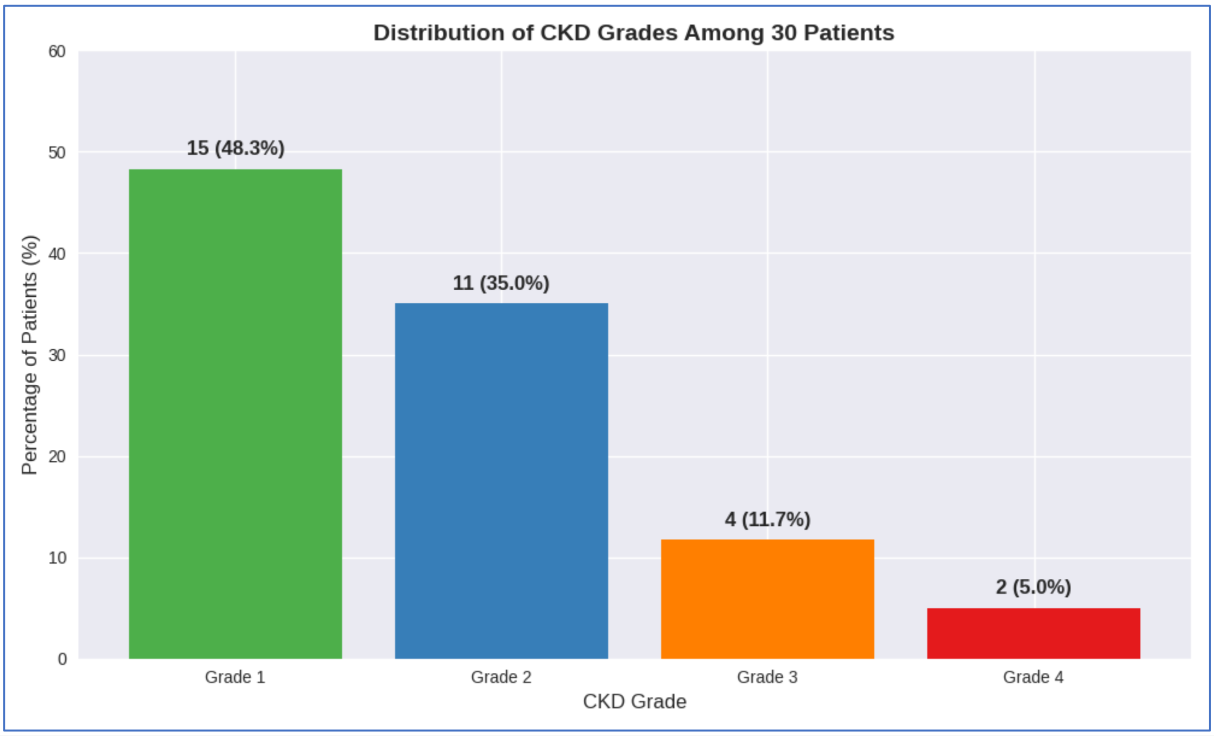
CKD Grade	Mean (mm)	Range (mm)
Grade 1	101.38	76–124
Grade 2	91.43	63–115
Grade 3	89.43	60–111
Grade 4	78	67–91

The mean parenchymal thickness findings were (Table 3)**:**

CKD Grade	Mean (mm)	Range (mm)
Grade 1	47.38	37–61
Grade 2	41.14	30–61
Grade 3	40	21–50
Grade 4	37.33	31–44

The mean cortical thickness metrics were (Table 4)**:**

CKD Grade	Mean (mm)	Range (mm)
Grade 1	15.59	10–24
Grade 2	12.86	7–21
Grade 3	11.33	9–14
Grade 4	—	—



A graphical representation indicates distributions among subjects: Sonological grade one CKD: 15 patients accounting for 48.3%; Grade two comprising 11 patients at 35%; Grade three indicating 04 patients representing 11.7%; Grade four consisting of 02 individuals making up 5%.

Clinical Insight:

- The bar graph reflects general CKD population falls under the screening category, where early stages (Grade 1 and 2) dominate.
- Advanced CKD (Grade 3 and 4) is less frequent but clinically more critical, and needs follow-up scans for closer monitoring and intervention.
- Visual representation helps in recognising the burden of early CKD and the importance of early detection.

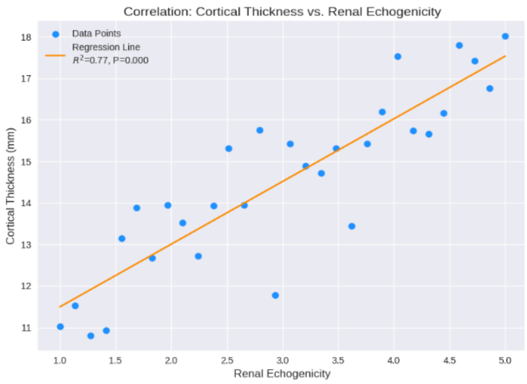
4. Discussion

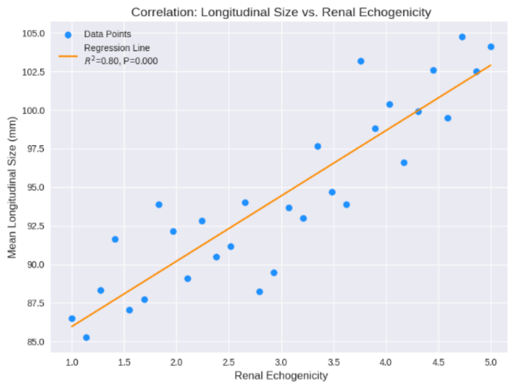
Our analysis revealed significant positive correlations between mean longitudinal size alongside various measures pertaining to renal echogenicity including parenchymal

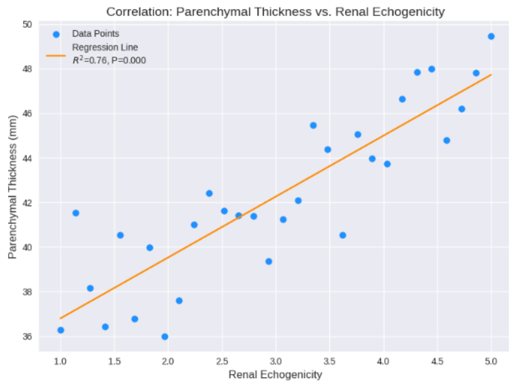
Paper ID: SR26131192742 DOI: https://dx.doi.org/10.21275/SR26131192742

thickness demonstrating how increased echogenicity correlates inversely with average parenchymal assessment values—a finding consistent throughout existing literature highlighting similar relationships observed between histopathologic characteristics noted during ultrasonographic evaluations like tubular atrophy or interstitial fibrosis correlation studies referenced previously by researchers such as Moghazi et al., who articulated "renal echogenicity has strongest correlation with histologic parameters." Previous work by Päivänsalo suggested "a highly echogenic cortex was the most common abnormality" Our results diverge somewhat from those reported by Platt et al., who indicated "renal echogenicity equivalent to that observed within liver does not serve effectively as an indicator." Rosenfield and Siegel described in their study that "normal renal echogenicity is less than that of the liver in the normal population and shows better difference in echogenicity between the liver and renal cortex".

A notable statistically significant positive correlation was observed between grading levels assigned based upon echogenic traits compared against average longitudinal size (P=0.006) metrics, leading us towards concluding estimation regarding lengths should be prioritised over volume measurements when assessing overall function levels because renal length decreases with decreasing renal function. A study by Miletić et al, revealed that "relative size of kidney (measured using kidney length to body height ratio) preferably represents kidney size more than absolute renal length (measurements of longitudinal renal diameter) because it eliminates sex and height differences."







There was a statistically significant positive correlation was observed between renal echogenicity grading and parenchymal thickness (P = 0.009). As the echogenicity enhances, the mean parenchymal thickness declines. A study by Moghazi et al, showed that "instead of cortical thickness, parenchymal thickness correlated with tubular atrophy [8]".

There was a statistically significant positive correlation between renal echogenicity grading and cortical thickness (P = 0.008). As the echogenicity enhanced, there was a decline in mean cortical thickness.

The P value of renal echogenicity (P = 0.004) was statistically more significant than the P values for mean longitudinal size (P = 0.006), mean parenchymal thickness (P = 0.009), and mean cortical thickness (P = 0.008) (Table 5).

Since changes in renal echogenicity are irreversible, a sonological grading of CKD can be carried out, allowing the severity of CKD to be assessed.

Table 5: Statistical correlation between renal echogenicity and mean longitudinal size, mean parenchymal thickness, and mean cortical thickness

Parameter	Correlation with Renal Echogenicity	P-value	Significance
Mean Longitudinal Size	Positive	0.006	Statistically significant
Mean Parenchymal Thickness	Positive	0.009	Statistically significant
Mean Cortical Thickness	Positive	0.008	Statistically significant

5. Conclusions

Renal echogenicity and its grading correlate with ultrasonographic parameters like longitudinal size, parenchymal thickness, and cortical thickness. Renal echogenicity is a preferred parameter to estimate renal function with the added advantage of irreversibility when compared to serum creatinine, which improves with kidney replacement therapy like -hemo-dialysis, peritoneal dialysis, and kidney grafting, in chronic kidney disease.[17]

Thus, ultrasonography plays a decisive role in evaluating the kidneys in cases of chronic kidney disease, enabling precise classification, keeping the track of progression of the disease, screening for the disease and facilitating tailored medical or surgical management. Adoption of the Sonographic Grading of Renal Cortical Echogenicity improves diagnostic accuracy and treatment outcomes. Radiologists must be familiar with this classification and relevant kidney anatomy to provide optimal care.

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