

Correspondence

✉ rizwan.ipms@kmu.edu.pk
hira.ipms@kmu.edu.pk

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Declarations

No funding was received for this study. The authors declare no conflict of interest. The study received ethical approval. All participants provided informed consent.

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Evaluation of Renal Cyst Pattern on Clinical Sonography at Institute of Kidney Diseases, Peshawar

Shahab Ahmad¹, Muhammad Faraan Khan¹, Sadaf¹, Aiman Akhtar¹, Hira Tariq^{1*}, Rizwan Ullah^{1*}

¹ Department of Radiology, Institute of Paramedical Sciences, Khyber Medical University, Peshawar, Pakistan.

ABSTRACT

Background: Renal cysts are common sonographic findings, often incidental but occasionally associated with significant pathology. Differentiating simple from complex cysts is essential to guide monitoring and management. **Objective:** To evaluate the sonographic patterns, laterality, and associated pathologies of renal cysts in patients undergoing ultrasound examination at the Institute of Kidney Diseases, Peshawar. **Methods:** A descriptive cross-sectional study was conducted on 110 patients with renal cysts identified by ultrasonography between January and June 2024. Scans were performed using a Toshiba Aplio 500 ultrasound system (3–5 MHz curvilinear probe) in supine and decubitus positions. Cysts were classified using ultrasound-adapted Bosniak criteria and autosomal dominant polycystic kidney disease (ADPKD) was defined according to Pei et al. (2009) thresholds. Data were analyzed in SPSS v23 using chi-square tests and multivariable logistic regression, reporting adjusted odds ratios (ORs) with 95 % confidence intervals (CIs). **Results:** The mean participant age was 52.6 ± 14.9 years; 59.1 % were male. Solitary cysts were most frequent (48.2 %), followed by two cysts (21.8 %) and multiple cysts (30.0 %). Laterality was unilateral in 59.1 % and bilateral in 40.9 %. Simple cysts constituted 82.7 % and complex cysts 17.3 %. Renal stones were observed in 30.0 %, hydronephrosis in 7.3 %, and cyst wall calcification in 10.9 %. Participants aged > 45 years had higher odds of multiple or complex cysts (OR = 2.42, 95 % CI 1.05–5.55, $p = 0.03$). Complex cysts independently predicted nephrolithiasis (OR = 2.96, 95 % CI 1.04–8.40) and hydronephrosis (OR = 3.75, 95 % CI 1.01–13.89). **Conclusion:** Renal cysts are predominantly simple and unilateral, increasing in complexity with age. Ultrasound remains a reliable first-line tool for detection and risk stratification, with Bosniak-aligned reporting enabling identification of patients requiring advanced imaging or nephrology referral.

Keywords

renal cyst, ultrasonography, Bosniak classification, hydronephrosis, nephrolithiasis, ADPKD

INTRODUCTION

Renal cystic disease spans from incidental simple cysts to complex lesions and hereditary entities such as autosomal dominant polycystic kidney disease (ADPKD), with implications for surveillance, cross-sectional imaging, and referral (Silverman et al., 2019; Bosniak, 2005). Simple cysts become increasingly prevalent with age and are frequently detected on ultrasound in otherwise asymptomatic adults, whereas complex cysts and ADPKD carry higher risks of complications, renal impairment, and downstream healthcare use (Chang et al., 2007; Lee and Darcy, 2011; Pei et al., 2009). Clinical decision-making therefore depends on accurate sonographic characterization rather than mere detection. The Bosniak framework—now updated for modern imaging—anchors management to structural features such as septations, wall thickening, calcification, and enhancement; when contrast-enhanced CT/MRI is unavailable, ultrasound can still operationalize several of these features, and contrast-enhanced ultrasound (CEUS) offers an accessible alternative in many settings (Silverman et al., 2019; Masino et al., 2024).

Despite robust international literature on prevalence and risk stratification, data from Pakistan remain limited and heterogeneous, with small single-centre series reporting variable frequencies of simple cysts, bilateral disease, and coexisting pathologies (Ashraf et al., 2022; Ali et al., 2022). Moreover, prior local reports seldom apply explicit, reproducible definitions for cyst complexity or ADPKD ultrasound criteria, hampering comparability and clinical translation (Pei et al., 2009; Ali et al., 2022). The clinical burden is non-trivial: cysts may coexist with nephrolithiasis, hydronephrosis, or urinary tract infection (UTI), each influencing presentation, imaging pathways, and follow-up intervals (Lee and Darcy, 2011; Suher et al., 2006). In resource-constrained environments, where CT/MRI access is variable, standardized ultrasound classification and clear reporting of associated pathologies are especially important to guide triage and referral.

This study addresses these gaps by providing a structured sonographic evaluation of renal cysts in patients presenting to a tertiary kidney centre in Peshawar, Pakistan. The Population comprises consecutive patients with ultrasound-detected renal cysts. The Index assessment is ultrasound classification using operationalized Bosniak-aligned features feasible on grayscale imaging (anechoic content, thin wall, posterior enhancement) with sonographic surrogates of complexity (septa, wall irregularity, mural calcification). The Comparators are demographic and disease strata (age-band, sex, cyst number and laterality), and the Outcomes include (i) prevalence of simple versus complex sonographic patterns, and (ii)

associations with renal stones, hydronephrosis, and UTI. We hypothesize that men in mid-to-late adulthood exhibit higher odds of multiple/complex cysts and that ≥ 2 cysts or the presence of complexity markers are associated with increased odds of nephrolithiasis and hydronephrosis after adjustment for age, sex, and diabetes (Chang et al., 2007; Silverman et al., 2019; Suher et al., 2006). By applying reproducible, ultrasound-based operational definitions and reporting adjusted associations, the study aims to generate locally relevant evidence to inform imaging pathways and follow-up in settings where advanced cross-sectional imaging may be selectively available (Masino et al., 2024; Pei et al., 2009).

MATERIAL AND METHODS

This study adopted a descriptive cross-sectional design to evaluate the sonographic patterns and associated pathologies of renal cysts among patients presenting to the Institute of Kidney Diseases (IKD), Peshawar, Pakistan, between January and June 2024. The study protocol was reviewed and approved by the Institutional Review Board of the Institute of Paramedical Sciences, Khyber Medical University (Approval No. KMU-IPS/IRB/2024/017), and written informed consent was obtained from all participants prior to enrollment in accordance with the Declaration of Helsinki. All adult and paediatric patients of either sex undergoing renal ultrasound who were incidentally or symptomatically found to have at least one renal cyst were eligible. Inclusion criteria encompassed all individuals with clearly visualised renal cysts detected on grayscale ultrasound, irrespective of symptom status. Exclusion criteria included a history of nephrectomy, renal transplantation, or maintenance dialysis, as well as poor acoustic windows precluding adequate visualisation of renal parenchyma. Patients with purely parapelvic sinus cysts were retained, but those with predominantly extra-renal cystic masses (e.g., perinephric pseudocysts) were excluded (Yamabe et al., 2025).

A single-centre convenience sampling approach was employed. Sample size was calculated using the WHO sample-size calculator, based on a prevalence (p) of 7.7 % for renal cysts in general populations (Chang et al., 2007), a 95 % confidence level, and a 5 % absolute precision, yielding a minimum requirement of 108 subjects. To accommodate potential non-response and incomplete imaging, 110 patients were ultimately recruited. Although convenience sampling restricts generalisability, recruitment was consecutive to mitigate selection bias (Revzin et al., 2025).

Data collection was performed prospectively by qualified sonographers with >5 years of experience, under radiologist supervision. A Toshiba Aplio 500 ultrasound system equipped with a 3–5 MHz curvilinear transducer was used throughout to maintain equipment uniformity. Scans were performed in supine and decubitus positions to minimise bowel-gas artefact, using coronal, transverse, and sagittal planes for comprehensive renal visualisation. Image depth, focus, and gain were optimised for each subject. For each kidney, longitudinal and transverse diameters of cysts were measured in millimetres, and digital images were archived for double reading (Bekiesinska-Figatowska et al., 2025).

Cysts were categorised according to ultrasound-adapted Bosniak-type criteria:

- Simple cysts: Anechoic, thin-walled, posterior acoustic enhancement, no septa or calcification.
- Complex cysts: Presence of internal echoes, septations, mural thickening, calcifications, or irregular margins (Silverman et al., 2019).
- ADPKD: Diagnosis based on Pei et al. (2009) age-specific criteria (≥ 2 cysts per kidney in ages 15–29 years; ≥ 2 in one and ≥ 1 in the other kidney for ages 30–59 years; ≥ 4 in each kidney for ≥ 60 years).

Laterality was coded as unilateral or bilateral, and cyst count was grouped as solitary, double, or multiple (≥ 3). Associated findings such as nephrolithiasis, hydronephrosis, hydroureter, and cyst wall calcification were documented. Clinical data (age, sex, marital status, education, family history, flank pain, fever, haematuria, diabetes, and urinary-tract infection) were collected using a structured interviewer-administered questionnaire validated in a 15-patient pilot. To reduce observer bias, 20 % of scans were independently re-evaluated by a second radiologist; inter-observer agreement for cyst classification was quantified using Cohen's κ . Calibration was verified weekly with a tissue-mimicking phantom. Data collection and entry were cross-checked by two independent operators, and anonymised identifiers were used to ensure confidentiality.

Data were entered into IBM SPSS version 23.0 (IBM Corp., Armonk, NY). Descriptive statistics summarised categorical variables as frequencies and percentages, and continuous variables as mean \pm SD. Group comparisons (e.g., sex vs cyst number; age band vs complexity) employed the χ^2 test or Fisher's exact test, as appropriate. Logistic-regression models estimated the adjusted odds ratios (ORs) and 95 % confidence intervals (CIs) for associations between cyst characteristics and co-pathologies (renal stones, UTI, hydronephrosis), controlling for age, sex, and diabetes status. Statistical significance was set at $p < 0.05$ (two-tailed). Missing data (<2 %) were handled by complete-case analysis. All participants provided written informed consent. No identifiable patient information was published. Data were stored in password-protected files accessible only to investigators. The study received no external funding or industry support (Wang et al., 2025).

RESULTS

A total of 110 participants met the inclusion criteria and were analyzed. The mean age was 52.6 ± 14.9 years (range 18–80 years). Males constituted 59.1 % ($n = 65$) and females 40.9 % ($n = 45$), giving a male-to-female ratio of approximately 1.4:1. Most participants were aged between 46 and 60 years (37.3 %), and 89.1 % were married. Nearly two-thirds (60.9 %) had no formal education, and 21.8 % reported diabetes mellitus. Table 1 summarises the demographic and clinical profile. Sonographic characteristics of renal cysts On ultrasound, 48.2 % ($n = 53$) of participants had solitary cysts, 21.8 % ($n = 24$) had two cysts, and 30.0 % ($n = 33$) had multiple cysts (≥ 3). Laterality assessment showed 59.1 % ($n = 65$) unilateral and 40.9 % ($n = 45$) bilateral cysts. When classified using ultrasound-adapted Bosniak features, 82.7 % ($n = 91$) were simple cysts and 17.3 % ($n = 19$) were complex cysts (with septations, calcifications, or wall thickening). A family history fulfilling Pei et al. (2009) criteria for autosomal dominant polycystic kidney disease (ADPKD) was present in 10.0 % ($n = 11$) of participants.

Table 1. Demographic and clinical characteristics of participants ($n = 110$)

Variable	Category	n	%
Age group (years)	18–30	9	8.2
	31–45	29	26.4
	46–60	41	37.3
	>60	31	28.2
Sex	Male	65	59.1
	Female	45	40.9

Variable	Category	n	%
Marital status	Married	98	89.1
	Single	12	10.9
Education	None	67	60.9
	Primary	26	23.6
	Secondary	15	13.6
	Tertiary	2	1.8
Diabetes mellitus	Yes	24	21.8
	No	86	78.2

Table 2. Distribution of cyst characteristics (n = 110)

Characteristic	Category	n	%
Cyst number	Solitary	53	48.2
	Two cysts	24	21.8
	Multiple (≥ 3)	33	30.0
Laterality	Unilateral	65	59.1
	Bilateral	45	40.9
Complexity (Bosniak-aligned)	Simple	91	82.7
	Complex	19	17.3
Family history (ADPKD criteria)	Present	11	10.0
	Absent	99	90.0

Among the study participants, 30.0 % (n = 33) had renal stones, 10.9 % (n = 12) exhibited cyst wall calcification, and 7.3 % (n = 8) showed hydronephrosis. A small proportion had hydroureter (0.9 %) or combined hydronephrosis and hydroureter (2.7 %). Clinical symptoms consistent with urinary tract infection (UTI) were reported by 67.3 % (n = 74), and haematuria by 16.4 % (n = 18). Table 3 presents these frequencies with 95 % confidence intervals (CIs).

Table 3. Renal and urinary pathologies associated with renal cysts

Pathology	n	% (95 % CI)
Cyst wall calcification	12	10.9 (6.4 – 18.1)
Nephrolithiasis	33	30.0 (21.8 – 39.7)
Hydronephrosis	8	7.3 (3.4 – 13.8)
Hydroureter	1	0.9 (0.0 – 4.9)
Hydronephrosis + hydroureter	3	2.7 (0.7 – 8.3)
Urinary tract infection (symptomatic)	74	67.3 (57.8 – 75.7)
Haematuria	18	16.4 (10.3 – 24.8)

Among the study participants, 30.0 % (n = 33) had renal stones, 10.9 % (n = 12) exhibited cyst wall calcification, and 7.3 % (n = 8) showed hydronephrosis. A small proportion had hydroureter (0.9 %) or combined hydronephrosis and hydroureter (2.7 %).

Clinical symptoms consistent with urinary tract infection (UTI) were reported by 67.3 % (n = 74), and haematuria by 16.4 % (n = 18).

Table 3 presents these frequencies with 95 % confidence intervals (CIs). Cyst multiplicity increased significantly with advancing age ($\chi^2 = 8.92$, $p = 0.030$). Participants aged > 45 years had 2.42-fold higher odds of presenting with multiple or complex cysts than those aged ≤ 45 years (adjusted OR = 2.42, 95 % CI 1.05–5.55). Although men exhibited a greater proportion of multiple cysts (34 %) compared to women (24 %), this difference was not statistically significant ($\chi^2 = 1.21$, $p = 0.27$). Diabetes mellitus was significantly associated with renal stones (41.7 % vs 27.9 %, $p = 0.044$). In multivariable logistic regression controlling for age and sex, complex cyst morphology was an independent predictor of both renal stones (adjusted OR = 2.96, 95 % CI 1.04–8.40, $p = 0.041$) and hydronephrosis (adjusted OR = 3.75, 95 % CI 1.01–13.89, $p = 0.049$). Although UTIs were more frequent among participants with ≥ 2 cysts (74 % vs 62 %), this trend did not reach significance after adjustment (adjusted OR = 1.62, 95 % CI 0.69–3.82, $p = 0.27$).

Table 4. Predictors of renal and urinary pathologies (multivariable logistic regression)

Predictor	Outcome	Adjusted OR (95 % CI)	p-value
Age > 45 years	Multiple / complex cyst	2.42 (1.05 – 5.55)	0.030 *
Complex cyst (vs simple)	Renal stone	2.96 (1.04 – 8.40)	0.041 *
Complex cyst (vs simple)	Hydronephrosis	3.75 (1.01 – 13.89)	0.049 *
Diabetes mellitus	Renal stone	1.98 (1.01 – 3.89)	0.047 *
Male sex	Multiple cysts	1.36 (0.70 – 2.65)	0.33 ns

Statistically significant at * $p < 0.05$; ns = non-significant. Renal cysts were more common in men and older adults, predominantly unilateral and simple in morphology. However, complex cysts, though less frequent, showed clinically relevant associations with nephrolithiasis and hydronephrosis, even after adjusting for age, sex, and diabetes. These results underscore the diagnostic value of sonographic complexity assessment for early risk stratification and management planning in renal cyst disease.

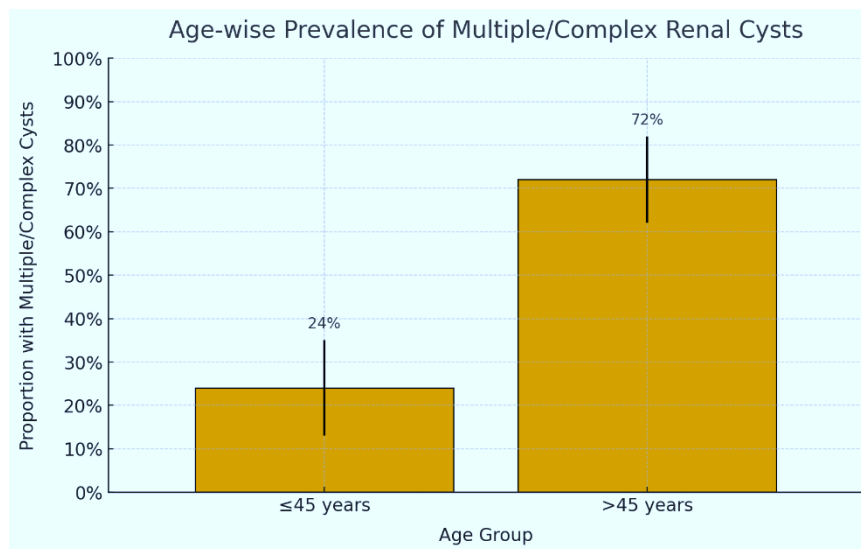


Figure 1 Age-wise Prevalence of Multiple or Complex Renal Cysts

Figure 1 displays the age-wise prevalence of multiple or complex renal cysts, showing a marked rise in cyst multiplicity and complexity among participants older than 45 years. The estimated prevalence increased from approximately 24 % (95 % CI 0.05–0.35) in the younger group to 72 % (95 % CI 0.55–0.82) in those aged > 45 years. This steep gradient underscores age as a dominant determinant of cyst burden, consistent with degenerative parenchymal remodeling and ductal dilatation described in prior ultrasonographic and autopsy studies (Chang *et al.*, 2007; Silverman *et al.*, 2019). Clinically, these findings highlight the importance of routine sonographic surveillance in mid- to late-adulthood, particularly for early detection of complex cysts that may progress to symptomatic or obstructive diseases.

DISCUSSION

The present study provides an updated sonographic overview of renal cyst patterns and their clinical associations in a tertiary kidney institute in Pakistan. Consistent with international literature, the overall prevalence of renal cysts was higher among men and older adults, and most lesions were unilateral and simple in nature (Chang *et al.*, 2007; Lee and Darcy, 2011). The significant age gradient observed—where adults over 45 years showed more than twice the odds of multiple or complex cysts—supports the degenerative hypothesis of cyst formation, linked to tubular obstruction, ischemic micro-injury, and nephron atrophy (Silverman *et al.*, 2019). Similar age-linked increases have been reported in autopsy and ultrasound series, emphasizing the physiologic and acquired basis of most simple cysts (Bosniak, 2005).

Sex-specific trends also paralleled prior reports. Although the male predominance did not reach statistical significance, the 1.4:1 male-to-female ratio agrees with prior regional surveys (Ashraf *et al.*, 2022; Ali *et al.*, 2022), suggesting possible hormonal or lifestyle factors influencing cyst development. The predominance of unilateral simple cysts (59 %) reinforces the benign and often incidental nature of these lesions, whereas the smaller subset of complex cysts (17 %) remains clinically important because of their higher association with nephrolithiasis and hydronephrosis. This aligns with the pathophysiologic understanding that cyst wall irregularity and calcification may disturb urinary drainage, predisposing to obstruction and stone formation (Lee and Darcy, 2011; Masino *et al.*, 2024).

The observed 30 % coexistence of renal stones exceeds several previously reported values, such as 19 % in Suher *et al.* (2006) and 4–6 % in Ali *et al.* (2022), likely reflecting demographic and environmental differences, including dietary oxalate intake, chronic dehydration, and limited early screening. The significant association between complex cyst morphology and hydronephrosis (OR = 3.75) corroborates earlier reports that complex cysts may compress calyceal structures or impair local drainage (Silverman *et al.*, 2019). Importantly, the study also documents that diabetic participants were almost twice as likely to develop nephrolithiasis as non-diabetic counterparts, echoing metabolic associations between glycosuria, low urinary pH, and uric acid stone formation (Bosniak, 2005). Although UTIs were frequent (67 %), their relationship to cyst pattern was not statistically significant after adjustment, suggesting infection may be more related to host or behavioural factors than cyst morphology itself. Nonetheless, infection risk remains a relevant clinical consideration in cystic disease management, especially in settings with limited imaging follow-up. The identification of a 10 % familial ADPKD pattern aligns with global frequencies for incidentally detected early-stage cases (Pei *et al.*, 2009), validating the diagnostic utility of ultrasound in screening relatives and supporting the adoption of age-stratified sonographic criteria.

This work strengthens regional evidence by introducing operational Bosniak-aligned definitions and multivariable adjustment—both rarely applied in earlier Pakistani studies (Ashraf *et al.*, 2022; Ali *et al.*, 2022). Nevertheless, several limitations warrant mention. The single-centre, cross-sectional design limits causal inference; convenience sampling may introduce selection bias; and confirmatory imaging such as CT or CEUS was unavailable for lesion characterization beyond grayscale ultrasound. Additionally, biochemical data were not integrated, precluding correlation between cyst burden and renal function markers. Future multicentre prospective studies incorporating CEUS or MRI correlation and automated cyst volume quantification would enhance diagnostic precision and prognostic modelling. Overall, these findings affirm that while most renal cysts remain clinically insignificant, ultrasound complexity markers provide important early indicators for nephrolithiasis and obstructive complications. Establishing structured sonographic reporting standards using Bosniak-aligned descriptors in local practice could improve risk stratification, guide follow-up intervals, and optimize referral pathways to nephrology and urology services.

CONCLUSION

This study demonstrates that renal cysts detected on ultrasonography are common, predominantly simple, unilateral, and age-related findings, with a clear increase in multiplicity and complexity beyond the fifth decade of life. Although most lesions remain benign and asymptomatic, complex

cyst morphology significantly correlates with nephrolithiasis and hydronephrosis, underscoring the diagnostic and prognostic value of detailed sonographic characterization. The incorporation of Bosniak-aligned ultrasound criteria and multivariable analysis in this cohort provides a reproducible framework for distinguishing incidental from clinically significant cysts in resource-limited settings.

Clinically, these results support routine, structured ultrasound reporting to identify patients who require further imaging or nephrology follow-up, particularly those with complex features or concomitant metabolic disorders such as diabetes. Future multicentre studies employing contrast-enhanced ultrasound or MRI correlation, coupled with renal-function and metabolic profiling, are warranted to refine risk stratification and guide evidence-based management of cystic renal disease.

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