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Original Article

Effect of Slice Thickness on the Diagnostic Accuracy of Non-Contrast CT KUB for Renal Stone Detection

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ABSTRACT

Background: Non-contrast computed tomography of the kidneys, ureters, and bladder is the reference imaging modality for suspected urinary tract calculi, but its diagnostic performance may vary according to reconstruction slice thickness. Objective: To evaluate the effect of 1 mm, 3 mm, and 5 mm axial slice thicknesses on renal stone detection, stone visibility, image noise, and radiologist diagnostic confidence in non-contrast CT KUB. Methods: This comparative cross-sectional study included 109 patients aged 18–70 years who underwent non-contrast CT KUB for suspected renal or ureteric stones. Raw CT datasets were reconstructed into 1 mm, 3 mm, and 5 mm axial series and reviewed in randomized order by a blinded radiologist. Stone detection, visibility score, perceived image noise, and diagnostic confidence were recorded. Chi-square testing, one-way ANOVA, and logistic regression were used for analysis. Results: Stone detection was highest on 1 mm slices (81.7%), followed by 3 mm (75.2%) and 5 mm slices (63.3%; $p = 0.004$). Good visibility declined from 73.4% at 1 mm to 32.1% at 5 mm, while high diagnostic confidence decreased from 56.9% to 11.9% (both $p < 0.001$). Compared with 1 mm slices, 5 mm slices showed significantly lower odds of stone detection (OR = 0.40, 95% CI: 0.23–0.70; $p = 0.002$). Conclusion: Thin-slice 1 mm reconstruction improves renal stone detection, visibility, and diagnostic confidence on non-contrast CT KUB, despite higher perceived image noise. Keywords: Non-contrast CT KUB, renal stones, slice thickness, urolithiasis, diagnostic confidence, image quality.

INTRODUCTION

Urolithiasis is a frequent and clinically important urinary tract disorder associated with acute flank pain, hematuria, nausea, urinary symptoms, recurrent healthcare visits, and potential complications such as obstruction, infection, and renal functional impairment. Prompt and accurate imaging is therefore essential for confirming stone disease, estimating stone burden, identifying obstruction, and guiding appropriate conservative, medical, or interventional management (1,2). Non-contrast computed tomography of the kidneys, ureters, and bladder has become the reference imaging modality for suspected renal and ureteric calculi because it provides rapid acquisition, high diagnostic accuracy, multiplanar assessment, and reliable visualization of stones independent of chemical composition. Beyond detection, CT KUB also allows assessment of stone size, site, density, multiplicity, and secondary signs of obstruction, all of which influence clinical decision-making and treatment planning (3,4).

Although non-contrast CT KUB is widely established as the preferred investigation for urolithiasis, its diagnostic performance is influenced by technical acquisition and reconstruction parameters. Among these, axial slice thickness is particularly important because it directly affects spatial resolution, image

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noise, partial-volume averaging, and the conspicuity of small high-density calculi. Thinner reconstructions improve anatomical detail and reduce the likelihood that small stones will be obscured within adjacent tissue planes, whereas thicker slices may reduce perceived image noise but can compromise detection by averaging small calculi with surrounding structures (5,6). This trade-off is clinically relevant because small stones may still be symptomatic, may contribute to obstruction, and may alter patient counseling, follow-up, and treatment selection. Missed calculi may lead to persistent symptoms, repeat imaging, delayed treatment, and avoidable healthcare burden (7).

Previous literature has examined CT-based urinary stone imaging and the role of multidetector CT protocols, yet the optimal reconstruction thickness for routine non-contrast CT KUB remains an important practical question. Thin-slice imaging is expected to improve detection and reader confidence, particularly for small calculi, but it may also increase image noise, interpretation time, and data volume. Conversely, thicker slices may appear cleaner but may reduce diagnostic sensitivity because of partial-volume effects. This creates a need for local and clinically applicable evidence comparing common reconstruction thicknesses using the same patient datasets rather than separate patient groups, so that differences in detection can be more directly attributed to reconstruction thickness rather than patient characteristics or scanner variation (8,9).

The present study was therefore designed to evaluate the effect of axial slice thickness on the diagnostic performance of non-contrast CT KUB for renal stone detection by comparing 1 mm, 3 mm, and 5 mm reconstructions in the same study population. The primary outcome was stone detection rate across the three slice-thickness reconstructions, while secondary outcomes included stone visibility, measurement accuracy, perceived image noise, and radiologist diagnostic confidence. The study hypothesized that 1 mm slice reconstructions would provide higher stone detection, better visibility, and greater diagnostic confidence than 3 mm and 5 mm reconstructions, despite a potential increase in perceived image noise.

MATERIALS AND METHODS

This comparative cross-sectional study was conducted to evaluate the effect of different axial reconstruction slice thicknesses on the diagnostic performance of non-contrast CT KUB for renal stone detection. The study compared 1 mm, 3 mm, and 5 mm reconstructed image series generated from the same patient CT datasets, allowing within-patient assessment of how reconstruction thickness influenced stone detection, visibility, measurement accuracy, image noise, and radiologist diagnostic confidence. The study was carried out in the Radiology Departments of Punjab Rangers Teaching Hospital, Services Hospital Lahore, and Gulab Devi Hospital, Lahore, Pakistan, where non-contrast CT KUB is routinely performed for patients with suspected urolithiasis. These tertiary-care centers were selected because they manage a high volume of renal colic and suspected stone cases and are equipped with multidetector CT scanners suitable for thin-slice reconstruction.

Patients were eligible for inclusion if they were male or female adults aged 18–70 years, were referred for non-contrast CT KUB because of suspected renal or ureteric calculi, had complete reconstructed CT datasets available at 1 mm, 3 mm, and 5 mm slice thicknesses, and demonstrated renal calculi on at least one reconstructed slice-thickness series. Patients were excluded if they had renal masses, congenital renal anomalies, surgically altered kidneys, known renal malignancy, renal infection, hydronephrosis unrelated to calculi, pregnancy, incomplete CT datasets, missing reconstruction series, or poor-quality images affected by significant motion or metallic artifacts. A purposive sampling technique was used, and all eligible patients meeting the selection criteria during the study period were included after screening.

The sample size was calculated using Cochran's formula for estimating proportions, assuming a 95% confidence level, an expected diagnostic accuracy of 90%, and a 5% margin of error. Using $Z = 1.96$, $p = 0.90$, $q = 0.10$, and $e = 0.05$, the initial calculated sample size was 139. Because the estimated annual CT KUB case population was 500, finite population correction was applied, resulting in a corrected

minimum sample size of 109 patients. This sample size was considered adequate for comparing diagnostic outcomes across the three reconstruction thicknesses within the same patient cohort.

Eligible patients were screened at the participating radiology departments before CT examination. The purpose of the study was explained, and written informed consent was obtained before enrollment. Demographic and clinical information, including age, gender, referring department, and relevant clinical indication, was recorded on a structured pro forma. All patients underwent non-contrast CT KUB in the supine position using multidetector CT scanners according to standardized departmental protocols. Scans were acquired during a single breath-hold to minimize motion artifact. The imaging protocol included non-contrast acquisition at 120 kVp with automatic mAs modulation and an approximate pitch of 1.2. No intravenous or oral contrast agent was administered. Radiation safety principles were followed during all examinations, and dose-length product values were recorded when available.

Raw axial CT data were retained and reconstructed into three separate axial image series with slice thicknesses of 1 mm, 3 mm, and 5 mm using scanner workstation software. Each reconstructed series was anonymized and coded before assessment to maintain patient confidentiality. To reduce interpretation bias, reconstructed image series were reviewed in random order by a trained radiologist who was blinded to the slice-thickness category during assessment. For each reconstruction series, the radiologist recorded the presence or absence of renal calculi, largest axial stone diameter in millimeters, stone visibility score, perceived image noise, and overall diagnostic confidence. Stone visibility was assessed using a five-point Likert scale, where lower scores indicated poor visibility and higher scores indicated excellent visibility. For analysis, visibility was categorized as poor, average, or good. Diagnostic confidence was categorized as low, moderate, or high, while perceived image noise was categorized as low, moderate, or high.

The primary study outcome was stone detection rate across 1 mm, 3 mm, and 5 mm reconstructions. Secondary outcomes included visibility score, radiologist diagnostic confidence, perceived image noise, and stone measurement consistency across reconstruction thicknesses. Slice thickness was the main independent variable. Patient age, gender, referring department, CT scanner type, and perceived image noise were treated as potential covariates. Bias was addressed by using the same raw CT dataset for all three reconstructions, anonymizing cases, randomizing image-review order, and blinding the radiologist to slice-thickness labels during interpretation. A pilot assessment of five CT scans was conducted before formal data collection to standardize scoring and measurement procedures. Uncertain findings were re-evaluated after 48 hours to improve measurement consistency.

Data were entered and analyzed using SPSS version 25. Descriptive statistics were calculated for demographic, clinical, and imaging variables. Frequencies and percentages were used for categorical variables, while mean and standard deviation were used for continuous variables where appropriate. Chi-square tests were applied to compare stone detection rates, diagnostic confidence categories, visibility categories, and image-noise categories across slice thicknesses. One-way analysis of variance was used to compare continuous or ordinally summarized measurement-related outcomes across reconstruction groups when applicable. Logistic regression analysis was performed to identify factors associated with stone detection, with stone detection as the dependent variable and slice thickness as the principal predictor. The 1 mm reconstruction was used as the reference category. Age, gender, referring department, and image noise were entered as covariates to assess whether slice thickness independently predicted detection. Odds ratios with 95% confidence intervals were reported, and a p-value of less than 0.05 was considered statistically significant.

Data integrity was maintained through anonymized patient coding, structured pro forma-based data collection, separate entry of reconstruction-specific findings, and verification of entered data before analysis. Cases with incomplete reconstruction datasets were excluded before final analysis to preserve comparability across the three slice-thickness groups. Ethical approval was obtained according to

institutional requirements, and written informed consent was obtained from all participants. Patient confidentiality was maintained throughout the study by removing personal identifiers from image series and analysis files.

RESULTS

A total of 109 patients were included. Most participants were male (65.1%), and the largest age group was 31–40 years (25.7%). Urology was the most common referring department (37.6%), followed by Emergency (31.2%) and Nephrology (20.2%).

Table 1. Demographic Characteristics of Study Participants (n = 109)

Variable	Category	n	%
Age group	Under 20	6	5.5
	21–30	22	20.2
	31–40	28	25.7
	41–50	24	22.0
	51–60	21	19.3
	Over 60	8	7.3
Gender	Male	71	65.1
	Female	38	34.9
Referring department	Emergency	34	31.2
	Urology	41	37.6
	Nephrology	22	20.2
	Others	12	11.0

Most scans were performed on 64-slice CT scanners (66.1%). Radiation dose was most commonly within the 500–1000 DLP range (51.4%), while 19.3% had DLP values below 500 and 16.5% exceeded 1000. All examinations were non-contrast CT KUB scans performed in the supine position.

Table 2. CT Scanning Characteristics (n = 109)

Variable	Category	n	%
CT machine	16-slice	29	26.6
	64-slice	72	66.1
	Other	8	7.3
Radiation dose	<500 DLP	21	19.3
	500–1000 DLP	56	51.4
	>1000 DLP	18	16.5
	Not recorded	14	12.8
CT type	Non-contrast CT KUB	109	100
Position	Supine	109	100

Stone detection did not differ significantly by age group, gender, or referring department. Detection was slightly higher among males than females (83.1% vs 78.9%; $p = 0.694$) and highest among patients referred from Nephrology (86.4%), but these differences were not statistically significant.

Table 3. Association of Demographic Variables with Stone Detection

Variable	Category	Detected n (%)	Not Detected n (%)	p-value
Age group	Under 20	5 (83.3)	1 (16.7)	0.812
	21–30	18 (81.8)	4 (18.2)	
	31–40	24 (85.7)	4 (14.3)	
	41–50	19 (79.2)	5 (20.8)	
	51–60	17 (81.0)	4 (19.0)	
	Over 60	6 (75.0)	2 (25.0)	
Gender	Male	59 (83.1)	12 (16.9)	0.694
	Female	30 (78.9)	8 (21.1)	
Department	Emergency	27 (79.4)	7 (20.6)	0.623
	Urology	34 (82.9)	7 (17.1)	
	Nephrology	19 (86.4)	3 (13.6)	
	Others	9 (75.0)	3 (25.0)	

Slice thickness showed a significant relationship with all diagnostic and image-quality outcomes. Stone detection was highest with 1 mm slices (81.7%), followed by 3 mm (75.2%) and 5 mm (63.3%; p = 0.004). Good visibility was also most frequent at 1 mm (73.4%) and declined progressively at 3 mm (55.0%) and 5 mm (32.1%; p < 0.001). High diagnostic confidence followed the same gradient, decreasing from 56.9% at 1 mm to 31.2% at 3 mm and 11.9% at 5 mm (p < 0.001). In contrast, low image noise increased with slice thickness, rising from 19.3% at 1 mm to 57.8% at 5 mm (p = 0.002), indicating that thicker slices reduced noise but compromised diagnostic yield.

Table 4. Diagnostic Performance and Image Quality by Slice Thickness

Outcome	Category	1 mm n (%)	3 mm n (%)	5 mm n (%)	p-value
Stone detection	Yes	89 (81.7)	82 (75.2)	69 (63.3)	0.004
	No	20 (18.3)	27 (24.8)	40 (36.7)	
Visibility score	Poor	8 (7.3)	15 (13.8)	33 (30.3)	<0.001
	Average	21 (19.3)	34 (31.2)	41 (37.6)	
	Good	80 (73.4)	60 (55.0)	35 (32.1)	
Diagnostic confidence	High	62 (56.9)	34 (31.2)	13 (11.9)	<0.001
	Moderate	27 (24.8)	45 (41.3)	37 (33.9)	
	Low	20 (18.3)	30 (27.5)	59 (54.1)	
Image noise	Low	21 (19.3)	44 (40.4)	63 (57.8)	0.002
	Moderate	63 (57.8)	47 (43.1)	34 (31.2)	
	High	25 (22.9)	18 (16.5)	12 (11.0)	

Logistic regression confirmed that slice thickness independently predicted stone detection. Compared with 1 mm slices, 3 mm slices were associated with a 34% reduction in the odds of detection (OR = 0.66, 95% CI: 0.44–0.99; p = 0.045), while 5 mm slices were associated with a 60% reduction (OR = 0.40, 95% CI: 0.23–0.70; p = 0.002). High image noise was also associated with reduced detection odds (OR = 0.46, 95% CI: 0.23–0.91). Age, gender, and referring department were not significant predictors.

Table 5. Logistic Regression Analysis of Factors Associated with Stone Detection

Variable	Category	B	SE	OR	95% CI	p-value
Slice thickness	3 mm vs 1 mm	-0.42	0.21	0.66	0.44–0.99	0.045
	5 mm vs 1 mm	-0.91	0.28	0.40	0.23–0.70	0.002
Age	Per year	0.01	0.01	1.01	0.99–1.03	0.510
Gender	Female vs Male	-0.21	0.25	0.81	0.45–1.45	
Department	Emergency vs Urology	-0.15	0.30	0.86	0.49–1.52	
	Nephrology vs Urology	0.21	0.33	1.23	0.65–2.33	
	Others vs Urology	-0.48	0.42	0.62	0.27–1.40	
Image noise	Moderate vs Low	-0.33	0.22	0.72	0.47–1.11	
	High vs Low	-0.78	0.31	0.46	0.23–0.91	

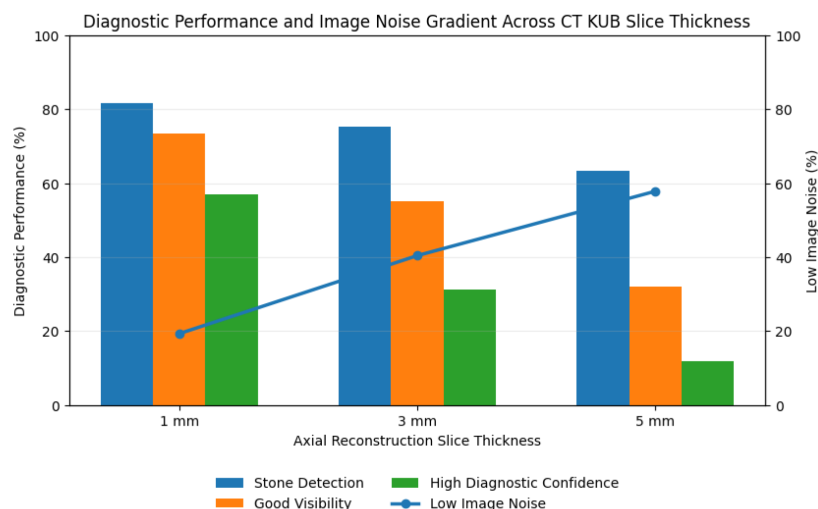

Figure 1. Diagnostic Performance and Image Noise Gradient Across CT KUB Slice Thickness

The figure demonstrates a clinically meaningful inverse gradient between diagnostic performance and perceived image smoothness across increasing slice thickness. Stone detection decreased from 81.7% at 1 mm to 75.2% at 3 mm and 63.3% at 5 mm, while good visibility declined more sharply from 73.4% to 55.0% and 32.1%, respectively. High diagnostic confidence showed the steepest reduction, falling from 56.9% at 1 mm to only 11.9% at 5 mm. In contrast, low image noise increased from 19.3% at 1 mm to 57.8% at 5 mm, confirming that thicker slices produced visually smoother images but at the cost of lower stone detectability, poorer visibility, and reduced radiologist confidence. These findings support the diagnostic advantage of 1 mm reconstruction for renal stone evaluation on non-contrast CT KUB.

DISCUSSION

The present study demonstrated that axial slice thickness significantly influences the diagnostic performance of non-contrast CT KUB for renal stone detection. The highest stone detection rate was observed with 1 mm reconstructions, followed by 3 mm and 5 mm slices, confirming that thinner sections improve stone conspicuity and reduce the likelihood of missed calculi. This finding is technically plausible because thinner reconstructions reduce partial-volume averaging, allowing small high-density stones to remain visually distinct from adjacent renal parenchyma, collecting system structures, and surrounding soft tissues. The diagnostic advantage of 1 mm slices was further supported by higher visibility scores and greater radiologist confidence, indicating that thin-slice imaging improves not only objective detection but also interpretive certainty during reporting. These results are consistent with previous evidence showing that CT is highly effective for urinary stone assessment and that thinner reconstructions improve detection of small calculi, particularly where spatial resolution is clinically important (1,14,16,20).

The inverse relationship between slice thickness and stone detection was also confirmed by logistic regression. Compared with 1 mm reconstructions, 3 mm slices showed reduced odds of stone detection, while 5 mm slices demonstrated an even larger reduction, indicating a progressive decline in diagnostic yield as reconstruction thickness increased. This effect remained clinically meaningful even though thicker slices were associated with lower perceived image noise. The finding highlights an important diagnostic trade-off: thicker slices may appear visually smoother, but this improvement in perceived noise does not compensate for the loss of spatial detail required for stone identification. In high-contrast imaging tasks such as renal calculus detection, the clinical priority is often lesion conspicuity rather than image smoothness alone, particularly when small stones may influence patient management, follow-up, or urological referral (17,18).

The study also found that patient-related factors, including age, gender, and referring department, were not significantly associated with stone detection. This suggests that within the present dataset, technical imaging parameters contributed more strongly to diagnostic performance than demographic or referral-source characteristics. Although males formed the majority of the cohort and urology was the most common referral source, these variables did not materially alter detection outcomes. This strengthens the practical implication that protocol optimization, particularly reconstruction thickness, should be prioritized across patient subgroups rather than selectively applied based on demographic characteristics.

The results have important implications for routine CT KUB practice. A 1 mm reconstruction protocol may be particularly useful in patients with suspected small calculi, equivocal symptoms, recurrent renal colic, or cases where accurate stone characterization may affect conservative versus interventional management. At the same time, the observed increase in perceived noise on thinner slices should be acknowledged. The findings do not imply that thicker reconstructions have no value; rather, thicker slices may still be useful for rapid overview, reduced data burden, or complementary review. A practical approach may involve reconstructing thin slices for diagnostic assessment while retaining thicker reconstructions for overview interpretation and workflow efficiency. Modern reconstruction methods,

including iterative reconstruction and denoising approaches, may further reduce the noise disadvantage of thin-slice imaging while preserving diagnostic detail.

Several limitations should be considered. The study used a purposive sampling approach, which may introduce selection bias and limit generalizability. All scans were interpreted by a single radiologist; therefore, inter-observer agreement could not be assessed. Perceived image noise was categorized subjectively rather than quantified using objective noise measurements. The study also did not compare stone detection against an external reference standard such as surgical retrieval, ureteroscopy, or follow-up imaging. Some regression p-values were not fully reported in the available dataset and should be verified from the original SPSS output before final submission. Despite these limitations, the within-patient comparison of 1 mm, 3 mm, and 5 mm reconstructions provides useful evidence that reconstruction thickness is a clinically relevant determinant of CT KUB performance. Overall, the study supports the preferential use of thin-slice reconstructions for renal stone evaluation, particularly when diagnostic confidence and small-stone detection are priorities.

CONCLUSION

Axial slice thickness is a significant technical determinant of renal stone detection on non-contrast CT KUB. In this study, 1 mm reconstructions provided the highest stone detection rate, best visibility, and greatest radiologist diagnostic confidence compared with 3 mm and 5 mm slices. Although thicker slices reduced perceived image noise, they were associated with lower diagnostic performance, supporting the conclusion that improved spatial resolution is more clinically valuable than image smoothness alone for urinary calculus detection. Thin-slice reconstruction should therefore be considered an important component of optimized CT KUB protocols, particularly when small stones are suspected or when confident radiological interpretation is required.

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