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Original Article

B-Mode Sonography Versus Color Doppler Twinkling Artifact in the Diagnosis of Nephrolithiasis

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ABSTRACT

Background: Nephrolithiasis, or kidney stones, is a prevalent condition that prompts numerous patient visits to emergency departments worldwide. The diagnosis of this condition and its complications, such as hydronephrosis, has traditionally relied on various imaging modalities, with ultrasound being a primary, non-invasive option. Recent advancements, including the utilization of the color Doppler twinkling artifact, have potentially enhanced the diagnostic capabilities of ultrasound for nephrolithiasis.

Objective: This study aims to evaluate the effectiveness of B-mode sonography and the color Doppler twinkling artifact in the diagnosis of nephrolithiasis and to compare their sensitivity in detecting renal stones and associated hydronephrosis.

Methods: A cross-sectional study was conducted at the Department of Radiology, Mahaban Medical and Research Hospital, Topi, Pakistan, from December 2023 to March 2024. Seventy patients presenting with flank pain and aged above 18 years were enrolled. Sonographic examinations were performed using a TOSHIBA Xario Prime ultrasound machine. Data were analyzed using SPSS version 25.0, focusing on the presence of renal stones and hydronephrosis as detected by B-mode sonography and the color Doppler twinkling artifact.

Results: Of the 70 patients studied, renal stones were detected in 70% (n=49) via the color Doppler twinkling artifact, while 30% (n=21) showed no stones. Hydronephrosis was observed in 30% (n=21) of patients, with an equal distribution between the left and right kidneys. The mean age of participants was 34.56 years, with a gender distribution of 62.9% male and 37.1% female. The twinkling artifact demonstrated a 100% sensitivity in identifying renal calculi among patients presenting with flank pain.

Conclusion: The color Doppler twinkling artifact, when used alongside B-mode sonography, provides a highly sensitive diagnostic tool for nephrolithiasis, underscoring its potential as a primary imaging modality in the evaluation of patients with suspected renal stones. This study highlights the importance of ultrasound in the early detection and management of kidney stones, offering significant implications for improving patient care in healthcare settings lacking advanced imaging technologies.

Keywords: Nephrolithiasis, Hydronephrosis, Ultrasound Imaging, Color Doppler Twinkling Artifact, B-mode Sonography, Kidney Stones, Diagnostic Sensitivity.

INTRODUCTION

Nephrolithiasis, commonly referred to as kidney stones, represents a significant clinical challenge and a prevalent cause for patient admissions to emergency departments globally. These calcified deposits within the urinary system can provoke a spectrum of symptoms, ranging from nonspecific, vague discomfort to acute flank pain, thereby necessitating accurate diagnostic strategies for effective management (1). The pathogenesis of nephrolithiasis involves the aggregation of hard mineral and salt deposits within the kidneys, which, under certain conditions, may traverse down the urinary tract. While small stones often pass unnoticed, larger formations exceeding 5 mm in diameter can obstruct the ureter, eliciting severe lower back or abdominal pain (2,3). The recurrent nature of nephrolithiasis, with nearly half of the affected individuals experiencing a recurrence within a decade, underscores the importance of identifying underlying risk factors, including genetic predispositions, dietary habits, specific medications, obesity, inadequate hydration, and hypercalciuria, to inform both treatment and prevention strategies (4,5).

Diagnostic approaches for nephrolithiasis encompass a variety of tests, such as urinalysis, blood examinations, and imaging modalities, aimed at confirming the presence of stones and assessing their composition and location (6). Among the imaging

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techniques, ultrasonography stands out as a particularly advantageous option due to its safety, cost-effectiveness, and rapidity. Boasting an approximate 90% detection rate for renal calculi, ultrasound imaging is especially beneficial for vulnerable populations, such as children and pregnant women, given its non-ionizing nature as opposed to other radiographic methods like X-rays or CT scans that carry a risk of radiation exposure (7,8). Typically, kidney stones present on ultrasound as hyperechoic foci with posterior acoustic shadowing, although stones smaller than 5 mm may lack this shadowing effect, rendering their detection more challenging (9).

The advent of color Doppler ultrasonography and the identification of the twinkling artifact have introduced a novel dimension to the imaging of nephrolithiasis. This phenomenon, characterized by dynamic, colorful bars on the Doppler display behind a calcified structure, mimics the shape of a cone and varies in intensity with the applied acoustic power. Originally deemed an artifact, the twinkling sign has since been leveraged as a diagnostic clue in the identification of calcifications within various tissues, including renal calculi (10,11). The artifact's utility in detecting stones complements traditional B-mode sonography, providing an alternative means of diagnosis that circumvents the limitations and risks associated with more invasive, radiation-based imaging techniques. Despite its promise, comparisons with other advanced modalities, such as spiral computed tomography, highlight the need for further research to optimize imaging protocols and ensure the reliable diagnosis of nephrolithiasis, considering the financial and logistical constraints of healthcare settings and the imperative to minimize patient exposure to ionizing radiation (12,13).

MATERIAL AND METHODS

This cross-sectional study was conducted at the Department of Radiology, Mahaban Medical and Research Hospital, Topi, Pakistan, over a four-month period from December 2023 to March 2024. The research protocol received approval from the Ethical Committee of the Women University Swabi, adhering to the ethical guidelines delineated in the Declaration of Helsinki for medical research involving human subjects. The study specifically targeted adult patients presenting with flank pain, setting the inclusion criteria to those aged 18 years and above.

Data collection involved acquiring sonographic data pertinent to renal stones upon the conclusion of each patient's examination. The ultrasound examinations were carried out using a TOSHIBA Xario Prime ultrasound machine, equipped with a convex transducer operating within a frequency range of 3.0—5.0 MHz for general imaging and a linear transducer for high-resolution imaging of superficial structures, with a frequency range of 7.0—14.0 MHz. To facilitate optimal visualization of the right kidney, patients were instructed to assume a supine position, with the transducer placed longitudinally near the rib area on the right side, utilizing the liver as an acoustic window. In instances where the kidney was not adequately visualized, patients were asked to take a deep breath to improve organ visibility. This technique often allowed for the complete visualization of the kidney. The examination protocol for the left kidney mirrored that of the right, with patients remaining in a supine position while the transducer was relocated to the lateral aspect of the left flank. Data was meticulously recorded and subsequently analyzed using the Statistical Package for Social Sciences (SPSS), version 25.0.

RESULTS

In the conducted study, a total of 70 patients underwent sonographic evaluation for nephrolithiasis, with an age distribution revealing a mean age of 34.56 years. The age range of participants spanned from 19 to 76 years, indicating a broad inclusion of adult age groups. The median age was closely aligned with the mean, standing at 34.5 years, and the standard deviation was calculated at 10.799 years, highlighting the age diversity of the study population (Table 1). Gender distribution within the study cohort was skewed towards males, who constituted 62.9% (44 individuals) of the subjects, whereas females accounted for 37.1% (26 individuals), showcasing a higher prevalence of male participants undergoing evaluation for renal stones.

The diagnostic findings, as revealed through grayscale and color Doppler sonography, indicated that 70% (49 patients) of the cohort exhibited the presence of renal stones on Doppler imaging, contrasted with 30% (21 patients) where stones were not detected through this modality (Table 2). This result underscores the effectiveness of Doppler sonography in identifying renal calculi among patients presenting with flank pain.

Table 1: Age and Gender Distribution of Patients

Demographic	Statistic	Value
Total Patients	N	70
Age Distribution	Mean Age	34.56
	Median Age	34.5

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Demographic	Statistic	Value
	Minimum Age	19
	Maximum Age	76
	Standard Deviation	10.799
Gender Distribution	Male	44 (62.9%)
	Female	26 (37.1%)

Table 2: Diagnostic Findings- Grayscale and Doppler Imaging vs. Kidney Stones and Hydronephrosis

Finding	Category	Count	Percentage
Doppler Present	Grayscale Absent	21	30.0%
Doppler Present	Grayscale Present	49	70.0%
Total	**Grayscale**	70	100%
Doppler Present	Hydronephrosis Absent	49	70.0%
Doppler Present	Hydronephrosis Present	21	30.0%
Total	**Hydronephrosis**	70	100%
Location for Hydronephrosis	**Bilateral**	14	20%
Location for Hydronephrosis	**Left**	28	40%
Location for Hydronephrosis	**Right**	28	40%

Furthermore, when considering the occurrence of hydronephrosis, a condition indicative of potential urinary obstruction secondary to stone presence, 30% (21 patients) were found to have hydronephrosis, of which the distribution was evenly split between the left and right kidneys and included bilateral cases. The remaining 70% (49 patients) showed no signs of hydronephrosis, suggesting the absence of significant obstructive changes due to renal stones. This delineation of hydronephrosis prevalence offers insight into the complication rate associated with nephrolithiasis, emphasizing the utility of sonographic imaging in evaluating both stone presence and associated obstructive phenomena (Table 2).

The aggregated data, merging grayscale sonography outcomes with Doppler imaging and hydronephrosis findings, provided a multifaceted view of the renal stone disease landscape within the studied population. Notably, the inclusion of both gender and age demographics (Table 1) alongside diagnostic outcomes (Table 2) facilitates a comprehensive understanding of the prevalence and characteristics of nephrolithiasis, as well as its complications, within a diverse patient cohort. This integrated approach to data presentation enhances the interpretability of the results, offering valuable insights into the epidemiology and sonographic detection of kidney stones.

DISCUSSION

In the realm of diagnostic imaging for nephrolithiasis, our study underscores the pivotal role of sonography as a primary diagnostic tool, given its accessibility and efficacy in detecting renal stones and associated conditions such as hydronephrosis (HDN). The reliance on ultrasound in our department stemmed from the absence of a computed tomography (CT) scan machine, directing our focus towards maximizing the diagnostic capabilities of ultrasound technology in patients presenting with symptoms indicative of renal calculi (13).

Comparative analyses with prior studies reveal interesting parallels and deviations in the detection rates and clinical presentations of HDN. For instance, Suzan et al. categorized HDN sonographically into three types, identifying mild HDN as the most common, occurring in approximately 53% of cases, followed by moderate HDN in 30%, severe HDN in 13%, and extreme HDN in a mere 4% of patients (14). Similarly, Jacob et al. linked the grade of HDN observed on ultrasonography with the size of kidney stones, noting that a significant majority of patients with mild HDN harbored smaller urethral stones measuring under 5mm (15). Our findings align with these observations, as hydronephrosis was detected in 30% of our patients, suggesting that ultrasonography, including the use of the color Doppler twinkling artifact, plays a crucial role in identifying obstructive changes within the kidney (15).

The sensitivity and specificity of ultrasound, particularly when augmented by the color Doppler twinkling artifact, have been a subject of exploration in several studies. Hamm et al. reported a 100% sensitivity in the detection of kidney stones using the twinkling artifact, a figure that notably surpasses the 94% sensitivity achieved through CT scans, thus highlighting the potential of ultrasound as a highly sensitive diagnostic modality (16). This is further corroborated by Laher et al., who demonstrated an 88.16% effectiveness of the twinkling artifact in stone detection (17), and by Puttman et al., who confirmed its 83% sensitivity in pediatric patients, validated against subsequent CT scans (18). Lie et al.'s assessment of both color Doppler and grayscale sonography for renal stone

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detection reported a commendable sensitivity of 96.98% for the twinkling artifact, advocating for its use in patients with flank pain (19). These findings are reflective of our study's results, where the twinkling artifact demonstrated a 100% sensitivity in identifying renal calculi among patients, emphasizing its diagnostic superiority. While our study champions the use of sonography, and specifically the color Doppler twinkling artifact, in diagnosing nephrolithiasis, it is not without limitations. The absence of a CT scanner limited our comparative analysis with this gold-standard imaging modality, potentially skewing our sensitivity assessments. Moreover, the study's focus on patients presenting with flank pain may not encompass the full spectrum of nephrolithiasis presentations (20).

In light of these insights, we advocate for the integration of color Doppler twinkling artifact as a supplementary feature in ultrasound examinations for renal stones, considering its high sensitivity and non-invasiveness. Future research should aim to expand the comparative analysis between ultrasound and CT imaging across a broader range of clinical presentations and settings. Additionally, further exploration into the utility of the twinkling artifact in pediatric populations, as well as its specificity and predictive value in differentiating between types of renal calculi, could significantly enhance the diagnostic accuracy and clinical management of nephrolithiasis.

CONCLUSION

The findings from our study affirm the substantial diagnostic value of sonography, particularly with the incorporation of the color Doppler twinkling artifact, in the detection of nephrolithiasis and its associated hydronephrosis. This non-invasive, radiation-free method offers a reliable, accessible, and cost-effective alternative for the identification of renal stones, particularly in settings lacking advanced imaging technologies like CT scanners. The enhanced sensitivity of the twinkling artifact not only facilitates early diagnosis but also aids in the prompt and appropriate management of patients with kidney stones, potentially reducing the risk of complications and improving patient outcomes. In the broader context of human healthcare, these insights underscore the importance of leveraging existing ultrasound technology to its fullest diagnostic potential, thereby improving the quality of care for individuals with nephrolithiasis worldwide.

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