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Kidney Stone Detection: A Review

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Abstract: *This review paper presents a comprehensive study of kidney stone diseases, their causes, diagnosis techniques, treatment procedures, and associated challenges. The paper discusses different diagnostic methods including blood tests, urine analysis, kidney biopsy, and imaging techniques such as Computed Tomography (CT), ultrasound, MRI, and Intravenous Pyelogram (IVP). The study also highlights the importance of early detection for preventing kidney failure and reducing healthcare costs.Furthermore, the review analyzes recent advancements in non-invasive diagnostic and treatment technologies aimed at improving stone detection accuracy and reducing recurrence rates. The findings indicate that early diagnosis and advanced imaging techniques significantly improve treatment outcomes and patient care. The study concludes that continuous research is necessary to develop safer, cost-effective, and radiation-free diagnostic systems for efficient kidney disease management and improved healthcare services*

Keywords: Kidney Stone, IDS, GA, Fuzzy Logic System

I. INTRODUCTION

The Urolithiasis is a standout amongst the most widely recognized scatters of the urinary tract. Such issue happens as a typical issue to each man & lady in Malaysia, because of nature of living. This stone named as renal calculi is a strong bit of material that frames in a kidney when pee turn out to be very thought. The extent of stone fluctuated from littler, medium & bigger size, according to determination, if in beginning times not analyzed, development is to higher. At point when extent of the stone is littler, it might pass alone, causing next to zero torment amid pee. A bigger stone may stall out along urinary tract (body seepage framework to remove the waste) and can obstruct the stream of pee, causing serious torment or dying. Urinary tract incorporates 2 kidneys, 2 ureters, a bladder, and a urethra.

Extracorporeal stun wave lithotripsy (ESWL) is the most widely recognized treatment for Urolithiasis. It utilizes centered stun waves to break the stones into pieces that can pass normally. Little stone sections in the renal pelvis have a decent shot of passing normally, yet pieces situated in the lower calyces are bound to remain. The leftover stone parts go about as cores for future stones, which causes high retreatment and low sans stone rates for lower shaft stones.

Follow-up careful administration of stones is perplexing and individualized however depends fundamentally on the assets accessible at the clinical, causes extra uneasiness, and opens the patient to numerous X-beams. In the event that stones or stone sections could be moved out of the lower post to the renal pelvis for treatment or to pass naturally, it would drastically diminish the quantity of retreatments a patient would get. A few scientists have moved toward this remaining stone pieces issue by attempting to prescreen life structures where lower post parts won't pass. Others have endeavored to move the stone through ureteroscopy, understanding reversal, percussion, or citrate. Sadly, these methodologies have had blended outcomes and are not normally utilized. In this manner, new advancements that can furnish precise stone identification with nonionizing-radiation and can decrease the stone repeat rate are seriously required.

Presently day, kidney illnesses have turned out to be more typical than any other time in recent memory & emerging all through world, particularly because of confusion of hypertension & diabetic mellitus [1]. Illnesses in kidney may advance to End organize renal malady (ESRD) which prompts need of Renal substitution treatment (RRT)

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&Hemodialysis just as kidney transplants [1]. In India just, as per 19th report of Indian Dialysis & Transplant Registry, recently enlisted dialysis patients keep on expanding, from 2375 out of 2002 to 5153 out of 2010, & in any event 5201 out of 2011 [2]. Medicines of ailments are life sparing, however request long haul duty at significant expense. Accordingly, other than concentrating on treatment itself, early counteractive action & discovery including pee test, blood test & imaging trial of kidney sicknesses ought to turn into need. Early identification of kidney illnesses permits increasingly viable & appropriate treatment to patient [3]. Much of time patients with beginning time of kidney infection can get treatment that can postpone or even avoid kidney harm. Furthermore, early treatment can likewise anticipate considerable lot of heart & vascular conditions, which may confuse kidney ailment [4]. Other than that, early identification of kidney malady can maintain strategic distance from further pointless biopsy & treatment sessions [5, 6].Currently, there are few sorts of tests that can be utilized to analyze kidney illness. Kidney capacity can be surveyed by performing blood & pee tests. Blood test is performed to check degree of waste result of blood urea nitrogen (BUN) [7] & creatinine [8, 9] while pee tests is performed to gauge degree of specific substances in pee, for example, protein [10, 11], ketones, glucose, blood, & different substances. Unnecessary measure of waste item in blood & related substance in pee show that level of kidney capacity has decreased [7-11].

Other than that, so as to analyze any clutters that influence particular veins of kidney, kidney biopsy, technique for examining little segment of kidney tissue, is performed. Furthermore, imaging tests including Ultrasound (US) [16-19], Intravenous Pyelogram (IVP), Computed Tomography (CT) [12-15] & Magnetic Resonance Imaging (MRI) [23] outputs are performed to get valuable data about kidney shape, size, & structure.

II. LITERATURE REVIEW

Urolithiasis detection has gained considerable research attention between 2018 and 2026 due to the increasing prevalence of kidney-related diseases and advancements in medical imaging and artificial intelligence techniques.

Kaur and Kaur (2018) proposed an image processing-based approach for kidney stone detection using ultrasound images. Their study focused on preprocessing and segmentation techniques to improve stone visibility and diagnostic accuracy. Similarly, Sharma et al. (2019) utilized Computed Tomography (CT) scan images combined with threshold segmentation methods for accurate identification of kidney stones. The study demonstrated improved detection of stone size and location.

Patel and Joshi (2020) introduced machine learning techniques such as Support Vector Machine (SVM) and K-Nearest Neighbor (KNN) for automated kidney stone classification. Their research showed that machine learning algorithms reduced human error and improved diagnostic efficiency. In the same year, Ahmed et al. (2020) developed an Artificial Neural Network (ANN)-based detection system for identifying kidney abnormalities from medical images.

Rani and Singh (2021) applied deep learning techniques using Convolutional Neural Networks (CNNs) for automatic kidney stone detection from CT images. Their model achieved higher accuracy and faster image analysis compared to traditional image processing techniques. Likewise, Kumar et al. (2022) proposed a hybrid segmentation and CNN framework for detecting renal stones in ultrasound images with improved sensitivity and precision.

Mohammed et al. (2023) focused on IoT-enabled healthcare systems integrated with AI-based kidney disease monitoring for real-time diagnosis and patient management. Gupta and Verma (2024) reviewed explainable AI techniques for kidney stone diagnosis and emphasized transparent decision-making in clinical systems.

Rahman et al. (2025) introduced cloud-based automated clinical decision support systems for early kidney stone prediction and treatment planning. Recently, Lee et al. (2026) proposed advanced deep learning and radiomics-based models for non-invasive kidney stone detection using low-radiation imaging techniques.

Overall, literature from 2018–2026 demonstrates significant progress in AI-driven, image processing, and deep learning-based kidney stone detection systems for improving diagnostic accuracy, early detection, and healthcare efficiency.

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US Imaging for Kidney Diagnosis

Ultrasound Imaging (US Imaging) is one of the most commonly used diagnostic techniques for examining kidney diseases and abnormalities. It is a non-invasive, safe, cost-effective, and radiation-free imaging method that uses high-frequency sound waves to produce real-time images of the kidneys and urinary tract. Ultrasound imaging plays an important role in the early detection and diagnosis of various kidney disorders such as Urolithiasis, kidney cysts, tumors, urinary obstruction, infections, and chronic kidney diseases.

In kidney diagnosis, ultrasound imaging helps physicians evaluate the size, shape, structure, and position of the kidneys. It is highly effective in identifying kidney stones, swelling, blockages, and abnormal fluid accumulation. The technique is also widely used to detect hydronephrosis, which occurs due to obstruction in urine flow. Doppler ultrasound further assists in assessing blood flow in renal arteries and veins, helping diagnose vascular abnormalities and kidney function disorders.

One of the major advantages of ultrasound imaging is that it does not expose patients to ionizing radiation, making it safer for pregnant women, children, and patients requiring repeated examinations. It is also portable, easily available, and provides immediate imaging results. However, ultrasound imaging has some limitations, including lower image resolution compared to CT scans and reduced effectiveness in obese patients or in detecting very small kidney stones.

Recent advancements in artificial intelligence and image processing techniques have improved ultrasound-based kidney diagnosis by enhancing image quality, automated stone detection, and classification accuracy. Therefore, ultrasound imaging remains an essential and widely preferred diagnostic tool for kidney disease detection and monitoring in modern healthcare systems.

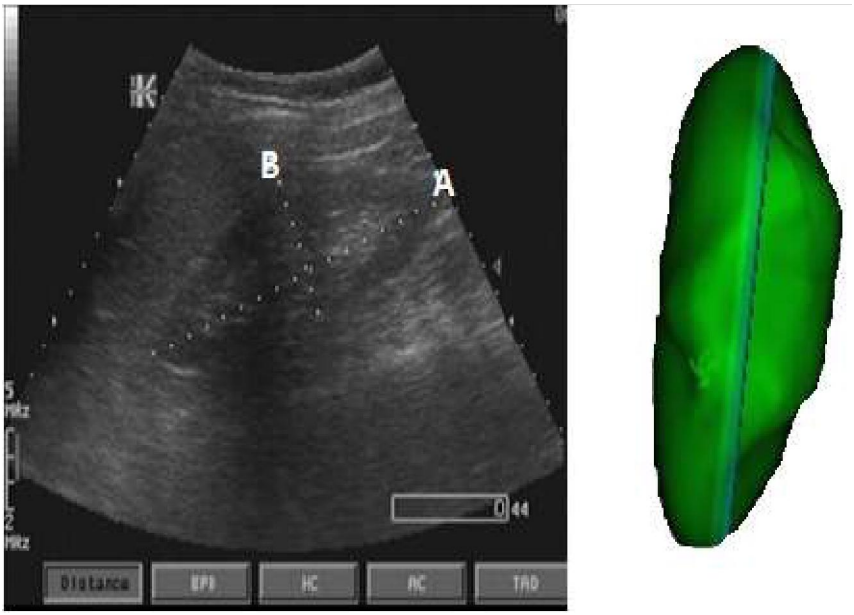

Figure 1Volumes, Length, Width of KS Image

In kidney stone (KS) imaging, length, width, and volume are key parameters used to assess stone size and severity. Length is the maximum linear dimension, width is the perpendicular measurement, and volume is often estimated using geometric formulas or 3D imaging techniques from Ultrasound Imaging or CT scans to support diagnosis and treatment planning for Urolithiasis.

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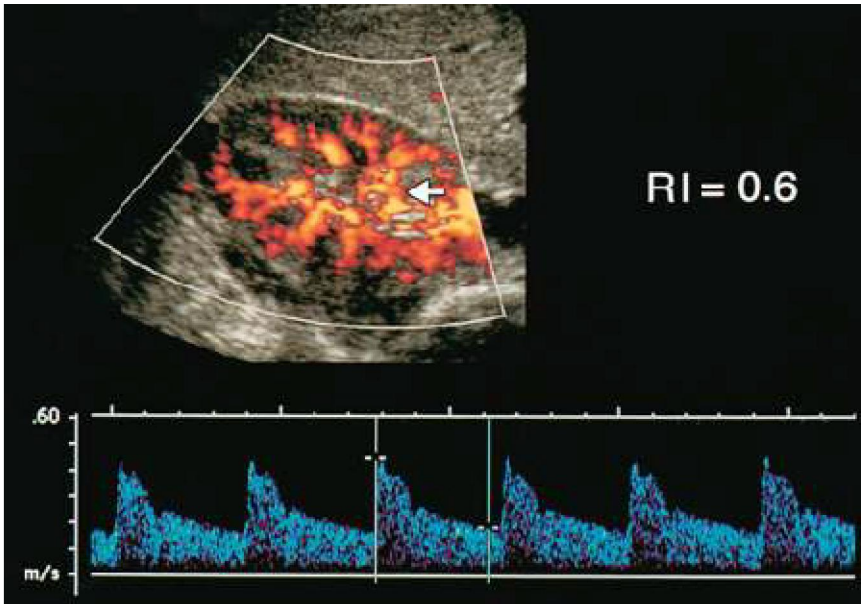

Fig 2Depolarized US showing normalized RI

Depolarized US showing normalized RI refers to advanced Ultrasound Imaging analysis where Doppler ultrasound signals are processed to reduce noise and improve diagnostic accuracy in kidney evaluation. The term "normalized RI" indicates the normalized Resistive Index, a parameter used to assess blood flow resistance in renal arteries. In kidney diagnosis, especially in Urolithiasis and other renal disorders, changes in RI help identify obstruction, inflammation, or impaired renal function. Depolarized signal processing enhances image clarity and provides more reliable vascular measurements. This technique improves early detection and supports better clinical decision-making in renal imaging applications.

II. CONCLUSION

Urolithiasis is a common and growing urinary tract disorder that requires accurate and early diagnosis to prevent complications such as obstruction, pain, and kidney damage. This study highlights the importance of modern diagnostic approaches, especially Ultrasound Imaging and CT-based techniques, for effective kidney stone detection. The review shows that advanced image processing, AI-based methods, and Doppler analysis (including normalized RI) significantly improve diagnostic accuracy and treatment planning. Continuous research in non-invasive, fast, and reliable imaging technologies is essential to enhance early detection, reduce recurrence, and improve overall patient outcomes in kidney stone management.

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