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EFFICACY OF SPECTRAL CT IMAGING IN DIFFERENTIATING RENAL STONES

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Abstract

Imaging of kidney stones is a crucial diagnostic technique and the first step in determining the appropriate treatment approaches for managing kidney stones. The guidelines from the American College of Radiology, American Urological Association, and European Association of Urology vary in their recommendations for the best first imaging method to assess patients with suspected obstructive nephrolithiasis. The use of noncontrast CT scans of the abdomen and pelvis consistently yields the most precise diagnosis, however it does expose patients to ionizing radiation. Historically, ultrasonography has shown a reduced sensitivity and specificity compared to CT scans, although it does not need the use of radiation. Nevertheless, a randomized controlled research revealed that these imaging modalities exhibited comparable diagnostic accuracy when used in the emergency room. Both techniques provide benefits and drawbacks. Kidney, ureter, bladder (KUB) plain film radiography is most beneficial for assessing the increase in size of stones in individuals with a history of stone illness, but it is less effective in diagnosing acute stones. MRI has the potential for radiation-free 3D imaging, but it is expensive and presently has limitations in seeing stones. Anticipated advancements will improve the capabilities of each imaging technique used to assess and treat kidney stones in the coming years. An approach that has been suggested for imaging individuals, who have acute stones, taking into account the existing recommendations and a randomized controlled study, might be helpful for doctors.

Keywords:

1. Introduction

Medical practitioners across several specialized fields will come across people who have kidney stones. Approximately 9% of Americans get nephrolithiasis, and the incidence of this condition has risen by over 70% in the last 15 years.One, two. The use of CT scans for imaging patients with kidney stones has quadrupled from 1992 to 2009. Imaging of patients with suspected kidney stones aids in diagnosis and serves as the first step in care by determining the size and location of the stones.

Selecting the appropriate imaging technique for kidney stones requires consideration of several criteria such as the clinical context, patient's body structure, expenses, and tolerance for ionizing radiation. Various imaging modalities are accessible, but their extensive clinical use is now restricted to CT, ultrasound, and kidney ureter bladder (KUB) plain film radiography. This Review will provide an overview of each imaging modalities, including its sensitivity and specificity, as well as its pros, limitations, and prices. In addition, we take into account the clinical guideline recommendations from the three primary organizations that provide advice on stone imaging: the American Urological Association (AUA), European Association of Urology (EAU), and the American College of Radiology (ACR), as well as the most effective applications of these guidelines. In addition, we address developing fields of study, since imaging plays a crucial role in the examination of urinary stone disease5. In addition, we examine a significant randomized controlled study carried out in 2014 that compared CT with ultrasonography in the emergency room for assessing acute renal colic6.

2. Knowledge acquired using imaging techniques

Patients who arrive at the emergency room with discomfort in the side of their body and blood in their urine are likely to have their abdomen examined using medical imaging to investigate the presence of kidney stones. However, it is sometimes possible to predict the diagnosis and position of the stone without using imaging techniques, relying instead on the patient's medical history and physical examination. The process of stone creation may be intricate and varies depending on the makeup of the stones. However, stones often do not cause any symptoms while they are developing in the renal calyces. When anything blocks the passage into the ureter, it stops the flow of urine, causing the ureter and renal pelvis to become enlarged. This blockage often leads to abdominal discomfort resembling colic as the contraction of the ureter increases.

These acute episodes of pain are often accompanied by nausea and vomiting. Typically, a stone blocks the passage at the junction where the renal pelvis narrows to the size of the ureter. Pain radiating to the flank is caused by obstruction at this location. The stone experiences two further instances of constriction as it progresses towards the end, first at the point where the ureter passes over the iliac arteries, and secondly at the bladder, known as the ureterovesical junction. Pain that originates from the blockage of the iliac arteries is felt in the groin or lower abdomen. Stones located near the ureterovesical junction often result in discomfort that spreads to the scrotum or labia, inner thigh, or urethra. These stones frequently lead to increased urine frequency, urgency, and dysuria due to the irritation they generate in the bladder. Upon arrival to the emergency department, most patients are found to have stones positioned at either the ureteropelvic junction or the ureterovesical junction. The passage of these stones may also lead to abrasions on the mucosal lining of the ureter, which can result in the presence of visible or microscopic blood in the urine, known as haematuria.

Obstructing stones often first appear in the emergency department. A diagnosis of this kind may be suspected even without the use of imaging. However, medical professionals must consider a broad range of potential diagnoses for individuals experiencing intense stomach and/or flank discomfort. Imaging techniques that have a high level of sensitivity provide the practitioner assurance that symptoms are due to a different medical condition when no stones are detected. Alternatively, imaging techniques with great specificity provide visible evidence that a patient's symptoms are caused by stones. The measurements of sensitivity and specificity might exhibit significant variation across different studies due to several variables, such as the choice of reference standard used to obtain true-positive and true-negative results, as well as the characteristics of the patient group under investigation.

Initial imaging is the first stage in illness management, in addition to diagnosis. Imaging may be used to determine the size and placement of a stone, which helps in assessing the risk of the stone passing naturally without surgery. Nevertheless, the chances of a stone passing through the urinary tract are influenced by several factors. The possibility of a stone passing naturally reduces as the size of the stone increases, but improves if the stone is located farther down the ureter. The patient's discomfort may fluctuate or even disappear entirely as the stone progresses down the ureter, despite the ongoing blockage caused by the stone. The presence of this phenomenon renders the elimination of symptoms an unreliable indicator of the passage of the stone. If the asymptomatic blockage persists, it might result in irreversible damage to the kidney or even kidney failure. Therefore, in cases when there is suspicion of a stone passing through the body, but the patient has not personally seen it, imaging is required to conclusively verify the stone's transit. Serial imaging may be used to track the advancement of a moving stone, and may also be utilized by the urologist and/or nephrologist to observe nonobstructing stones for any increase in size. Generally, the imaging techniques that may be used include CT, ultrasonography, KUB radiography, and MRI. The modalities differ in terms of sensitivity, specificity, ionizing radiation dosage, and relative prices.

3. Unenhanced CT

CT encompasses a wide range of imaging scans that may or may not use contrast and have varying image timing, depending on the specific clinical topic being addressed. The most often used imaging techniques for individuals with nephrolithiasis are non-contrast CT or CT-KUB radiography. Computed tomography (CT) takes use of the varying levels at which various biological tissues absorb radiation. Multiple data points are acquired by rotating a radiation source and a detector on the opposite side of the patient, and these data are then analyzed by a computer to generate three-dimensional pictures. Due to their distinct composition, kidney stones absorb a much higher amount of radiation compared to renal parenchyma and urine. As a result, they may be clearly seen without the use of contrast (Figure 1).

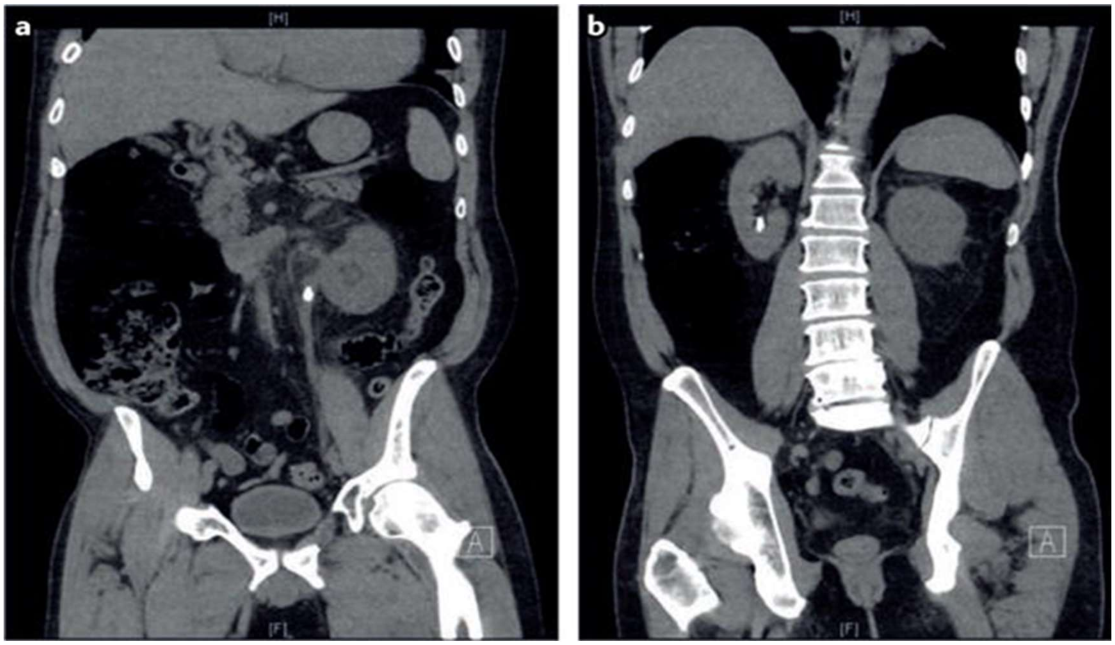

Figure 1. A bilateral 8 mm nephrolithiasis on a noncontrast CT scan, as seen in the coronal view.

Computed tomography (CT) produces a three-dimensional (3D) picture of the stone and the surrounding anatomy. This image may be rebuilt into several viewing planes. The sensitivity of computed tomography (CT) in identifying kidney stones is the greatest among all the current imaging techniques, and acceptable estimates indicate that it is around 95%.12. While CT scans are effective in detecting most big stones, smaller stones (less than 3 mm) may go unnoticed since they may pass through the scanned tissue planes without being identified. According to the ACR, the specificity of CT is estimated to be 98% when a patient has acute flank discomfort that is suspected to be caused by a stone blocking the urinary tract. CT imaging may be utilized to view the majority of stones, except for those that result from the precipitation of protease-inhibitor medicines in the urine14.

CT imaging may also provide data on the composition of stones. Attenuation refers to the level of obstruction faced by photons as they travel from the radiation source to the detector. The Hounsfield unit (HU) is a quantitative measure of the degree to which a material or tissue attenuates (weakens) X-ray or CT scan radiation. On this scale, water is assigned a value of 0 Hounsfield Units (HU), air is -1,000 HU, and dense bone is 1,000 HU. The Hounsfield units of a stone may provide information on its kind, since various stone compositions absorb varying quantities of radiation. Uric acid stones usually have a density of 200-400 Hounsfield Units (HU), whereas calcium oxalate stones have a density of around 600-1,200 HU. CT attenuation may serve as a predictor of responsiveness to shockwave lithotripsy, since higher attenuation values are associated with a greater number of shocks needed and worse success rates16,17.

Attenuation is complicated by the need for accurate procedure. For instance, if the attenuation is averaged across a voxel that is bigger than a stone, it might result in a reduction of the observed Hounsfield units for the stone. The change in density might lead to the incorrect interpretation of a dense, hard stone as being less dense, which would not be suitable for shockwave lithotripsy. To address this problem, the use of dual-energy CT scanners may be used. These scanners allow for the imaging of patients' tissues at two different voltages, which enables the comparison of data from two distinct detectors. These scanners also allow for the assessment of tissues at different energy levels, enhancing the precision of determining the composition of stones19–22.

The precision of CT is a crucial attribute while doing imaging on obese patients23. CT scans are often more accurate than ultrasonography, especially when imaging obese individuals. However, there is currently no conclusive research that directly compares the two methods for imaging kidney stones in obese patients. The challenge of imaging obese people has been conclusively shown by imaging studies of patients with cholelithiasis, where CT scans were found to be more accurate and precise than ultrasonography24. According to the ACR, AUA, and EAU12,25,26, standard CT is the preferred imaging method for patients with a BMI greater than 30. In the future, it will be crucial to take into account the obesity of patients due to the imaging requirements of the obese population and the growing occurrence of stones, which is directly correlated with the increasing rates of obesity24.

4. Summary

The assessment of individuals experiencing discomfort in the side of the body and the presence of blood in the urine is contingent upon the age, body mass index (BMI), and pregnancy status of the patient. Ultrasonography is the recommended and most important imaging method for patients under the age of 14 and pregnant individuals. It is advisable to use this approach for all individuals who may have kidney stones when there is a high likelihood of stones, especially in patients who have a low body mass index (BMI <30). The AUA and ACR now regard CT as the most reliable method for assessing patients with sudden side discomfort when there is a suspected presence of kidney stones.

There is currently strong evidence to support the use of ultrasonography as the first choice imaging technique in nonobese people with a BMI less than 30. Although presently a subject of controversy, this discovery has the potential to lead to a higher use of ultrasonography as the primary imaging method for patients with acute stones. Irrespective of the initial imaging technique, doctors should strive to minimize radiation exposure to the lowest possible level. When assessing a patient using ultrasonography, it is normal to encounter equivocal findings. In such cases, it is fair to consider employing low-dose CT imaging. Furthermore, ongoing advancements in CT, ultrasonography, KUB radiography, and MRI technologies are expected to enhance these modalities in the future.

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