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Magnetic Resonance Imaging for Detection of Kidney Stones in Correlation with Computed Tomography

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Abstract

The most frequent illness of the urinary system is kidney stone disease. Men in their 20s and 30s make up the vast majority of patients. An alternative to CT imaging for kidney stones is MRI, which avoids radiation risks. Since of this, traditional clinical imaging cannot catch the MR signal before it decays, because the echo times (TE's) utilised in this kind of imaging are too long. The goal of this study is to assess the effectiveness of MRI and CT in the detection of kidney stones. Methods: Those who had a kidney stone on plain X-ray, ultrasonography, or CT were part of our research. A nod of approval from the Benha University Institutional Review Board was received before the research could begin (IRB). There were 36 patients in our study, and each one signed an informed consent form after learning about the details of our research. CT and MRI scans were performed on each of them. Age ranged from 19 to 61, with 72.2 percent males and 27.8 percent females in our study sample. Workers accounted for 41.7% of the population, followed by housewives 22.2%, farmers 19.4%, and employees 16.7%. Stone density ranged from 815.63 to 340.99, with a low of 159 and a maximum of 1500, while the stone size ranged from 14.91 to 8.67, with a minimum of 6 and a maximum of 55. In contrast, the distribution of stone size and density by MRI was 15.648.16 with a minimum of 10 and a maximum of 50, respectively. We found that MRI was only able to identify 25 of the 36 instances discovered by the gold technique (CT). This indicates that MRI has a low sensitivity when it comes to stone identification (69.4 percent). The difference in stone size and density found by CT and MRI, when compared just those instances sharing positive, was extremely significant. Although CT is the gold standard for the diagnosis of renal stones because of its high sensitivity for their direct detection, MRI also plays an important role in their identification. More sequences are needed to inhibit fat in this function, which is dependent on stone size (more than 1 cm), stone position (upper or lower pole). Although CT may identify and quantify urinary tract dilatation, wall thickness, edoema and other downstream consequences of clinically active urinary stones, MRI may be more sensitive and specific in detecting and measuring these secondary effects.

Key words: Magnetic Resonance Imaging, Detection, Kidney Stones, Computed Tomography.

1. Introduction

The most frequent illness of the urinary system is kidney stone disease. Men in their 20s and 30s make up the vast majority of patients. Renal stone recurrence prevention remains a major issue in human health. [1].

Understanding how stones develop and how to avoid them is essential for prevention [2]. Chronic kidney disease [3], end-stage renal failure [2], cardiovascular disease [4], diabetes [5], and hypertension are all linked to an increased incidence of kidney stones [5]. Kidney stones may be connected to the metabolic syndrome, according to some researchers. End-stage renal disease is caused by nephrolithiasis and nephrocalcinosis, which together account for 2 to 3 percent of all cases [6].

It doesn't matter where a kidney stone forms: in the kidney, ureter, or bladder. It takes a long time before any symptoms appear as a result of stone growth. Urinary tract infections, obstruction of urine flow, and hydronephrosis are all later indications and symptoms of kidney stone illness. Renal colic and flank pain are the most common signs and symptoms, as are hematuria and obstructive uropathy (dilation of the kidney). Patients with a stone incident may have nausea and vomiting as a consequence of these disorders [7].

In the treatment of individuals with kidney stones, imaging studies serve a critical role. Techniques that may be used include a simple x-ray of the abdomen; ultrasonography; intravenous urogram; CT; and MRI (MRI) A basic nephrostogram Imaging of the urinary tract using a CT scan [8].

To confirm and locate the location of calcifications, as well as to plan treatment, IVU provides important information such as anatomical abnormalities of the collecting system, infundibulo-pelvic angle in the case of lower-pole calcifications, and for assessing the length and diameters of the infundibula of calyces. IVU is still useful. In contrast to CT, the radiation dosage is smaller and the anatomy is better understood than in the axial CT images. There is some useful information provided by IVU, however it is not quantified [9].

To accurately detect kidney stones, computed tomography (CT) is the imaging modality of choice for kidney stone detection. Additionally, the CT has the capacity to distinguish between uric acid (UA) and non-UA stones, which is essential since alternative treatment techniques may be necessary for the best results [10].

Despite MRI's success in kidney anatomical and functional imaging, its relevance in imaging renal stones has historically been restricted. Stones show as nonspecific signal voids on standard MR imaging, making them easy to ignore or mistake for other structures or abnormalities. MRI is no longer considered a viable imaging modality for kidney stones because of this restriction, and radiologists no longer try to find stones on MRI pictures. It was the goal of this study to evaluate the performance of MRI and CT in the detection of kidney stones.

Methods and Patients

A prospective cohort research was conducted at our university hospitals in the radiology department from November 1, 2019 to August 31, 2021, after clearance from the institution's scientific committee.

Participants in the research

We began this research with 45 cases, however we were only able to recruit 36 since we had to eliminate 9 patients: Only three patients had the procedure, two had claustrophobia, and four declined to participate in the research.

Our research methodology was explained in detail to the 36 individuals who were recruited. On plain X-ray, ultrasonography, or CT, each of them had a kidney stone of varying sizes.

Criteria for inclusion:

CT and MRI scans confirmed the presence of a kidney stone in the patients.

For example, patients with pacemakers are ruled out of the research, as are those who have other medical conditions that render them ineligible for MRI or CT.

Patients who have a metal sliver in their eye or a hip replacement with a foreign body

Patients who have a significant fear of being enclosed in a small space.

Pupils whose backs have been implanted with iron implants

A patient who is very overweight is being treated.

6. Women who are or will be pregnant.

Nine patients were ruled out of the trial, therefore there were 36 participants in total.

Methodology

Each patient was given an explanation of the study's purpose and given the opportunity to provide their informed consent.

1-History:

Each patient's personal history, complaint, history of current disease, and previous medical and surgical history were thoroughly gathered.

Examining the patient at the clinic

After a thorough physical examination, doctors focused on the scars left by past surgeries.

Investigations in the laboratory

The renal function and pregnancy tests for females were performed as part of a complete laboratory study. Pregnant women, who cannot get a CT scan, are also excluded from the study since they are unable to do so.

4-Radiological investigations.

An outpatient clinic's pelviabdominal ultrasound and KUB were used to make the first diagnosis of renal stone in these patients.

Afterwards, they had a CT of the urinary tract without contrast and an MRI as part of our research, which allowed them to participate.

Contrast-free CT of the urinary tract

Patients are put through their paces before to their procedure.

Patients were instructed to consume water 30 minutes before to the research to ensure adequate hydration and a full bladder. Urinary catheters were removed one hour before to examination in individuals who had one.

Technique: A CT scanner was used to assess the patients (64 slice GE light speed VCT). CT pictures were taken at 0.625 mm with a gap of 1 mm between each image. From the diaphragm to the pubic symphysis, the scanning region included both kidneys and the bladder.

Anteroposterior and lateral CTIs were produced at 10 and 20 milliamperes, respectively. Transverse and coronal slices with a thickness of 2.5 mm were used for reconstruction. Both perpendicular and angled photos of the kidney's longitudinal axis were used to create the coronal reconstruction images. The CTI featured a pixel density of 1.7 9 1.9 pixels per millimetre.

The density and size of the kidney stone were measured in the Hounsfield unit.

The patient's preparations for an MRI

Patients were instructed to consume water 30 minutes before to the research to ensure adequate hydration and a full bladder. The urethral catheter was dilated one hour before to the assessment in individuals having a catheter.

Technique:

Every subject had a 1.5 Tesla MR scan (Siemens Healthcare, Erlangen, Germany).

A thorough examination of the whole abdomen from the diaphragm to the pubic bone was conducted using the following procedure:

Images were obtained using Siemens MRI scanners (Siemen's Healthcare, Erlangen) with these imaging parameters: matrix = 177 256; resolution = 1.4 1.4 mm2; slice thickness = 6mm; flip angle = 150°; echo train length = 256; echo time (TE)=84 ms; repetition time (TR)=1200 ms; number of averages = 1; and readout bandwidth = 362 Hz/pixel. Records were kept of whether or not a kidney stone had been found. Size and signal intensity of the renal stone have been calculated and recognised.

Interpretation

CT and MRI of the same patient were evaluated to see whether the kidney stone had been found or not, and the results were compared. They were also compared in terms of accurately estimating the size of stones.

Dimensions of the stone found using computed tomography (CT)

Stone's biggest diameter was picked and the following variables were recorded: perpendicular diameter (D2), HU value at centre of the stone and mean HU value (HUM), which was computed by establishing an extended circular Region of Interest (ROI) based on the axial plane (ROI). D1 and D2's HU values at the stone's perimeter (HUP) were averaged together to get this number. As previously stated, HUD is the product of HUM divided by D1. It was determined by subtracting HUC from HUP (the difference in HU between the stone's centre and its perimeter). As a result of these calculations, the stone's A and V dimensions have been determined. CT scans in the coronal plane revealed a maximal diameter of D3.

MRI signal intensity

the relative signal intensity of tissues in an MRI image is determined by factors such as

- The radiofrequency pulse and gradient waveforms used to obtain the image.
- Intrinsic T1 and T2 characteristics of different tissues
- The proton density of different tissues

By controlling the radiofrequency pulse and gradient waveforms, computer programs produce specific pulse sequences that determine how an image is obtained (weighted) and how various tissues appear. Images can be

- T1-weighted
- T2-weighted
- Proton density–weighted

Data collected throughout history, basic clinical examination, laboratory investigations and outcome measures coded, entered, and analyzed using Microsoft Excel software. Data were then imported into Statistical Package for the Social Sciences (SPSS version 20.0) **(Statistical Package for the Social Sciences)** software for analysis.

3. Results

Table (1) Age and sex distribution among studied group.

		Age	
Mean± SD		37.75±11.75	
Median (Range)		38.0 (19-61)	
		N	**%**
Sex	**Female**	10	27.8
	Male	26	72.2
	Total	36	100.0

Age was distributed as 37.75±11.75 with minimum 19 and maximum 61 years, regard sex distribution male were majority with 72.2% and female 27.8%

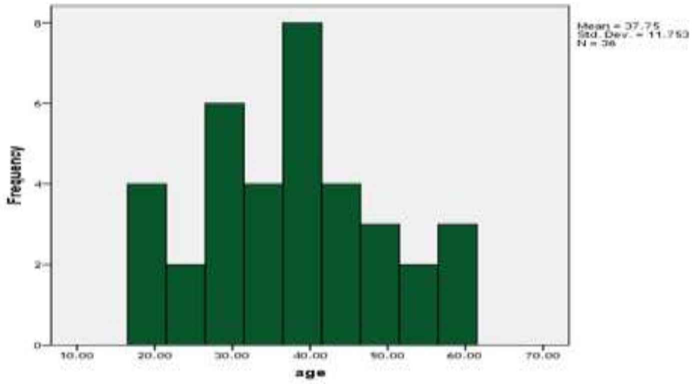

Chart (1) Age and sex distribution among studied group.

Table (2) Stone size by CT distribution among studied group.

	Size by CT
Mean± SD	14.91±8.67
Median (Range)	13.5 (6-55)

Size was distributed as 14.91±8.67 with minimum 6 and maximum 55

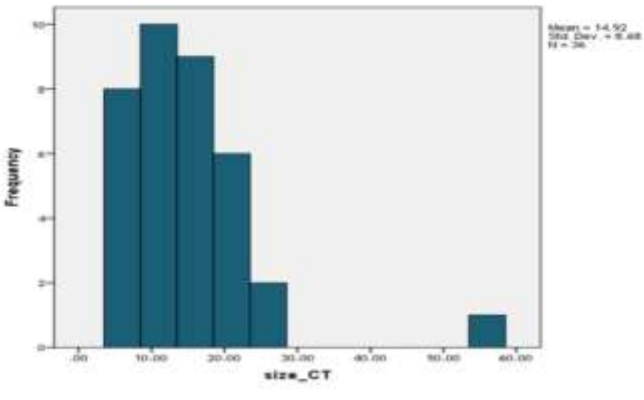

Chart (2) Stone size by CT distribution among studied group.

Table (3) Stone density by CT distribution among studied group.

	Density CT
Mean± SD	815.63±340.99
Median (Range)	875.0 (159-1500)

Size was distributed as **815.63±340.99** with minimum 159 and maximum 1500

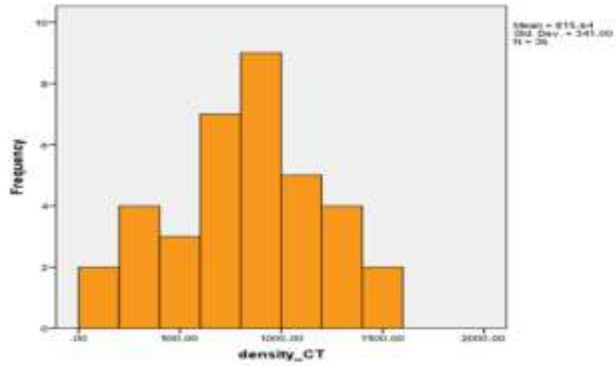

Chart (3) Stone density by CT distribution among studied group.

Table (4) Stone size by MRI distribution among studied group.

	Size MRI
Mean± SD	15.64±8.16
Median (Range)	13.0 (10-50)

Size were distributed as **15.64±8.16** with minimum 10 and maximum 50

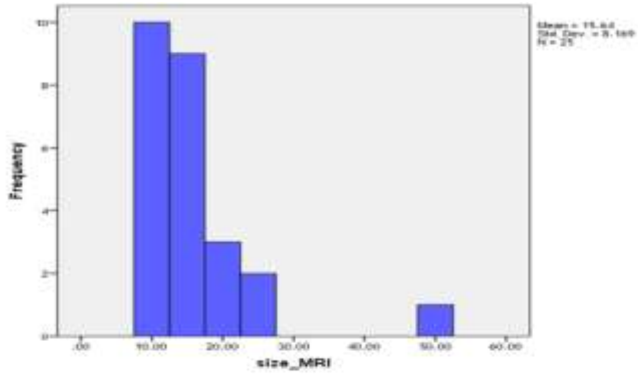

Chart (4) Stone size by MRI distribution among studied group.

Table (5) Stone signal intensity by MRI distribution among studied group.

	Density MRI
Mean± SD	206.0±66.64
Median (Range)	185.0 (130-350)

Size were distributed as **206.0±66.64** with minimum 130 and maximum 350

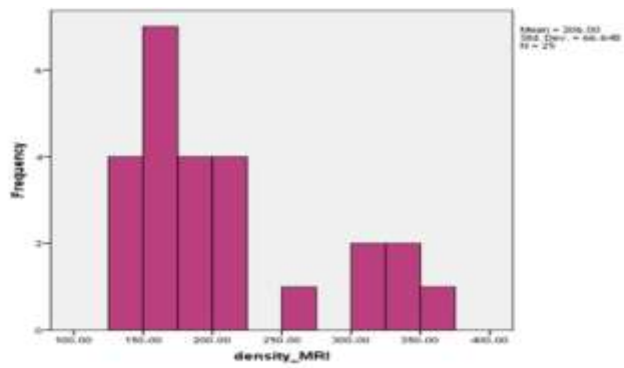

Chart (5) Stone signal intensity by MRI distribution among studied group.

Table (6) Stone Detected by MRI distribution among studied group compared to CT.

		N	%
MRI	**-VE**	11	30.6
	+VE	25	69.4
	Total	36	100.0

MRI detect 25 cases only from total of 36 cases detected by gold method (CT) so sensitivity of MRI regard stone detection (69.4%)

Table (7) Comparison between CT and MRI regard stone size among only cases shared positivity.

	CT	MRI	Sign	P
Mean ±SD	18.12±8.62	15.64±8.16	10.38	0.00**
Median (Range)	17.0 (11-55)	13.0 (10-50)		

Highly significant difference between size detected by CT and MRI

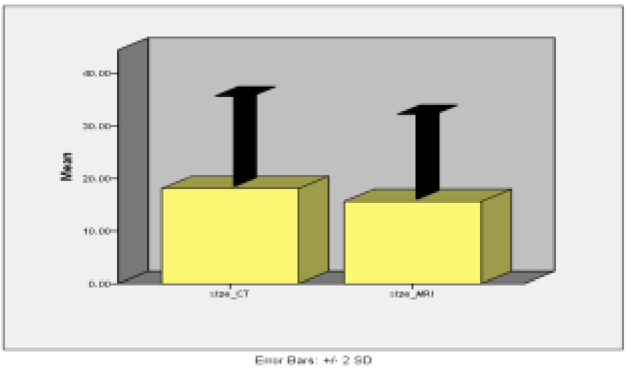

Chart (5) Comparison between CT and MRI regard stone size among only cases shared positivity.

Cases:

<u>Case (1)</u>

Male patient complaining of left loin pain.

Fig.(1 A) CTUT without contrast coronal image, soft tissue window. The left kidney showing hyperdense stage horn stone stage 55 mm.

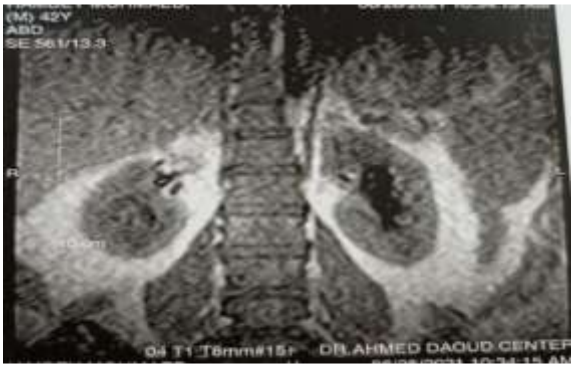

Fig.(1 B) Coronal T1 MRI of urinary tract showing left renal stone measuring about 50 mm

In this case the MRI can easily detect the stone filling the renal pelvis and calyces like CTUT. The stone size is more or less similar in MRI and CT in these images.

Case (2)

Male patient complaining of left loin pain.

Fig.(2 A) Ct UT axial film, soft tissue window. The left kidney showing hyperdense calyceal stone about 12 mm.

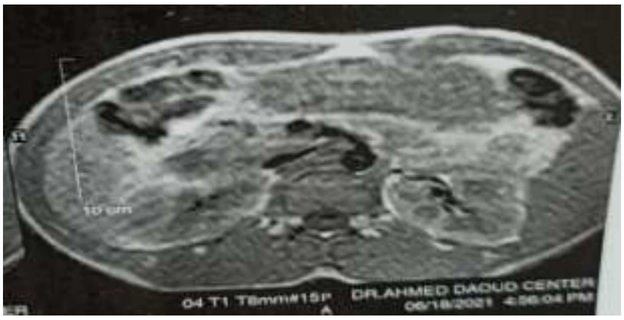

Fig.(2 B) Axial T1 MRI. the left kidney showing stone measuring about 10 mm.

In this case the MRI can easily detect the stone like CTUT. The stone size is more or less similar in MRI and CT in these images.

Case (3)

Female patient, complaining of left loin pain.

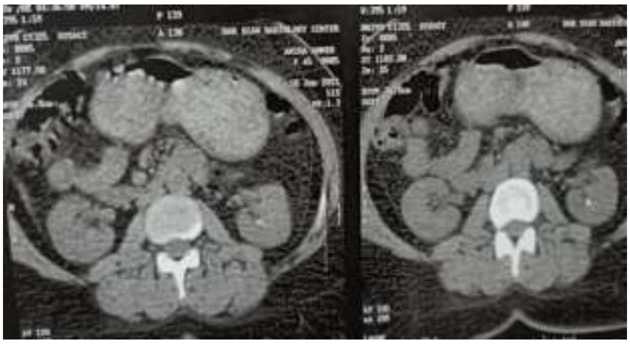

Fig.(3 A) Axial CT UT soft tissue window, the left kidney showing hyperdense stone about 7 mm.

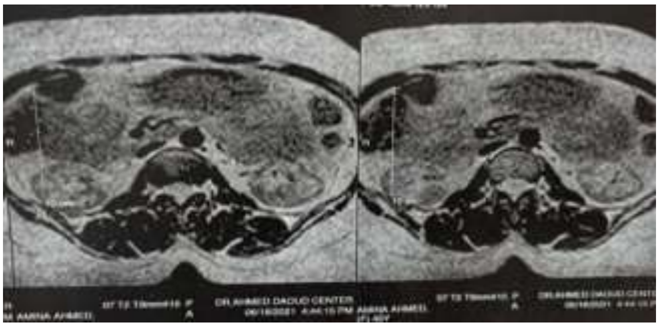

Fig.(3 B) Axial T2 MRI urinary tract, the stone cannot be visualized (signal void).

In this case the MRI couldn’t detect the stone due to its small size (less than 1 cm). However, CT without contrast detected the stone.

Case 4

Male patient, complaining of right loin pain.

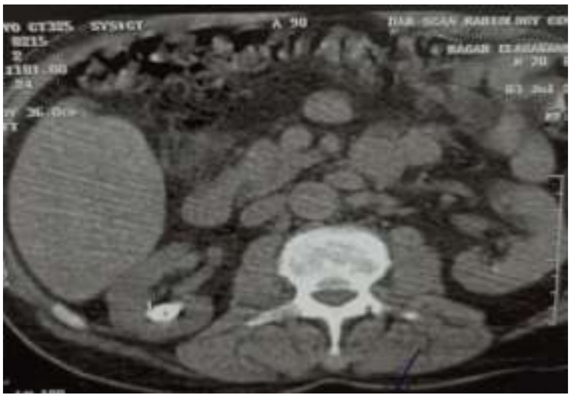

Fig.(4 A) Axial CT UT without contrast, soft tissue window, the right kidney showing hyperdense calyceal stone about 22 mm.

Fig.(4 B)T2 MRI UT coronal view, right kidney showing calyceal stone about 20 mm.

In this case the MRI can easily detect the calyceal stone like CTUT. The stone size is more or less similar in MRI and CT in these images

4. Discussion

MRI plays a significant function in the identification of stones, and this involvement is dependent on the size of the stone. – Out of a total of 36 stones found using the gold standard approach (CT), only 25 were discovered using MRI (all measuring more than 1 cm). This shows the sensitivity of MRI for stone detection (69.4 percent). Also, in our investigation, MRI was unable to identify stones smaller than 1 cm.

There were eleven instances in our research when MRI was unable to detect renal stones that were smaller than 1 cm in diameter. This might be because we only utilised T1 and T2, and if we had employed fat suppression on more sequences, we would have been able to see the stones. It is also possible that renal sinus fat may have covered the stones in the renal pelvis, which would have made them more visible if they had been at the higher or lower pole.

Renard and colleagues disproved the theory that MRI scans don't show calculi. The T1- or T2-weighted sequence signal is devoid of any traces left by the rocks. Perirenal high-intensity signal, occlusion, and obstruction may be promptly detected using T2-weighted sequences, enabling the identification of urinary tract disorders. Ureteral dilatation is routinely utilised to identify ureteral calculi related to blockage. [12]

Sudah and colleagues observed that sensitivity increases with the size of the calculus, and that renal calculi smaller than 1 cm are seldom apparent, but may become clearly visible when they are above 1 cm in diameter. Because hydronephrosis causes an increase in urine volume around the calculus, the degree of sensitivity to renal stones will be higher. The related diseases such as hydronephrosis and renal cyst were clearly recognised by MRI in our investigation.

Uretero-hydronephrosis was detected using MRI with a 90% sensitivity and a 100% specificity. According to the study's results, sensitivity and specificity were 64 and 80 percent and 84.4 to 91.1 percent for particular filling defects such as calculus. Because it does not include the use of ionising radiation like ultrasound, MRI may be used to evaluate pregnant and paediatric patients alike. Indirect consequences of a blocked urinary system may be shown by MRI despite its low sensitivity for the identification of tiny renal stones. Urinary blockage and acute flank discomfort have both been studied extensively using magnetic resonance imaging (MRI). When compared to CT, MRI is better for the identification of perirenal fluid as an early indicator of acute ureteric blockage due to stone disease, according to Regan and colleagues Regan and colleagues demonstrated that urinary stones can be identified on MRI as a signal void within the collecting system, and that stone visibility with MR is facilitated by larger size (greater than 1 cm) and the presence of surrounding high signal intensity urine, a finding that is frequently present in obstructed collecting systems. It is possible to capture T2W images in a single shot approach with high reported accuracy in the diagnosis of blockage, which is particularly accurate in assessing obstruction's degree and severity. There has been a lack of use of renal stone imaging MRI in the past, despite its usefulness in anatomic and functional imaging of the kidneys. Stones may be confused for other items or disorders on standard MR imaging because of the nonspecific signal holes they produce. Radiologists have stopped looking for kidney stones in MRI images because of this constraint, and MRI is now not recommended as an imaging tool for this purpose. The gold standard for detecting calcifications associated with stone disease even in the absence of surrounding urine is CT, not MRI. MRI may imaging big renal stones surrounded by urine. Obstructive urolithiasis, however, has the largest potential influence on patients in terms of clinical therapy because of its downstream effects on the collecting system and on renal function. – It's easier to see perirenal fluid associated with acute ureteric blockage because of the MRI's soft tissue contrast. Due to its high accuracy, speed, and convenience of collection, noncontrast CT has an essential role in the emergency assessment for suspected urolithiasis [12]. Noncontrast CT scans have been reported to be useful in the diagnosis of urolithiasis in several trials, however the proportion of patients with no signs of stone illness on imaging has remained steady even as the total number of CT scans conducted for this purpose has increased. [16]

5. Limitations of the study

1. Some cases suffered from claustrophobia and couldn't do MRI
2. Some cases escaped the study and underwent early operation after CT.
3. We used only T1 and T2 only and we didn't do more MRI sequences such as fat suppression.
4. The study included 36 patients only, and the results may be different if we used larger sample size.
5. In our study we compared image modality with another image modality for accurate stone size estimation, but we should compare both modalities with in vitro stone size after operation.

6. Conclusion

CT is the gold standard for the diagnosis of renal stones since it has the highest sensitivity for their direct detection, although MRI also plays an important role in their identification. More sequences are needed to inhibit fat in this function, which is dependent on stone size (more than 1 cm), stone position (upper or lower pole). Although CT may identify and quantify urinary tract dilatation, wall thickness, edoema and other downstream consequences of clinically active urinary stones, MRI may be more sensitive and specific in detecting and measuring these secondary effects.

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