

Infection/Inflammation

Diagnosing Acute Pyelonephritis with CT, ^{99m}Tc-DMSA SPECT, and Doppler Ultrasound: A Comparative Study

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Purpose: With growing interest in early imaging, the aim of our study was to define the most practical modality for routine clinical use for the diagnosis of acute pyelonephritis (APN). We compared the sensitivity of enhanced computerized tomography (CT), dimercaptosuccinic acid (DMSA) scintigraphy, and Doppler ultrasonography (DUS) by using clinical findings as the standard of reference.

Materials and Methods: A total of 207 APN patients (191 women, 16 men; mean age, 49.4 years; range, 17-88 years) were enrolled in this study. All the patients underwent imaging modalities during hospitalization. SPECT images were obtained 4 hours after injection of ^{99m}Tc-DMSA. Transverse and coronal CT images were obtained before and after injection of the contrast agent. DUS was performed in the longitudinal, transverse, and coronal planes. All the images were read independently by a single radiologist and a nuclear medicine specialist. The sensitivity of each modality for detecting APN was compared.

Results: CT showed significantly superior sensitivity compared with that of DUS (81.0% vs. 33.3%, respectively, n=147). DMSA scintigraphy also showed significantly superior sensitivity compared with that of DUS (74.7% vs. 33.3%, respectively, n=150). Compared with DMSA scintigraphy, CT showed superior sensitivity, but the difference was not statistically significant (81.0% vs. 74.8%, respectively, n=147, p=0.163).

Conclusions: For cases of clinically suspected APN, CT and DMSA scintigraphy appear to be equally sensitive and reliable for detecting APN, although CT is more practical in various fields. DUS was significantly less sensitive.

Key Words: Diagnostic imaging; Pyelonephritis

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INTRODUCTION

Acute pyelonephritis (APN) primarily results from bacterial infection of the kidney by an ascending route that causes a tubulointerstitial inflammation of the renal parenchyma. The diagnosis is traditionally based on a combination of laboratory findings and typical clinical features, including flank pain, high-grade fever (> 38.5°C), and urinary tract infection (UTI) [1]. Imaging is not routinely indicated in patients with APN, and treatment, which consists of intravenous antibiotics, can be started on the basis of typical clinical and laboratory features [2].

Sometimes, however, the clinical and biological findings of patients with APN are of limited value. Many atypical presentations can be encountered [3], and histologic speci-

mens are difficult to obtain [4], thus making the accurate diagnosis of APN on the basis of these findings difficult. Furthermore, making an exact clinical correlation with the various stages of inflammation that cause abscess, calculi, or obstruction, all of which require immediate intervention or an appropriate surgical procedure, is impossible [4]. In this context, recent studies have emphasized the importance of early imaging [5,6]. Improving prognosis by identifying abnormalities, such as complications, that cannot be detected by clinical findings or laboratory findings is important. Therefore, physicians should select the most effective diagnostic modality.

There is currently no definitely recommended modality of choice for renal imaging in order to diagnose APN. Enhanced computerized tomography (CT) [7,8] and dimer-

captosuccinic acid (DMSA) scintigraphy [9,10] have been reported to be better able than Doppler ultrasonography (DUS) to visualize the renal changes in APN patients. However, DMSA scintigraphy cannot differentiate pyelonephritic foci from permanent renal scars. The final diagnosis is usually reached 6 months later by follow-up scintigraphy [11]. Both techniques (DMSA scintigraphy and CT) are invasive, and they share other disadvantages: they deliver ionizing radiation, an intravenous agent is injected, and sedation is frequently used [12]. On the other hand, DUS needs no radiation, but it is markedly inferior to enhanced CT [7,13,14] or DMSA scintigraphy [15] for demonstrating the parenchymal abnormalities caused by renal infection and for delineating the extent of the disease. Therefore, the purpose of this study was to compare the sensitivity of the three renal imaging techniques (enhanced CT, DMSA scintigraphy, and DUS) for the detection and localization of APN by use of strict clinical criteria as the standard of reference.

MATERIALS AND METHODS

Among patients who were hospitalized in our department from April 2008 to August 2009, 207 adults with a clinical diagnosis of APN were enrolled in this retrospective study.

The criteria for inclusion were clinical symptoms such as unilateral or bilateral acute pain within the flank (radiat-

ing to the loin, abdomen, and/or groin), costovertebral angle tenderness, a fever of 38.0°C or more, a leukocytosis count exceeding 10,000/μl, the presence of white blood cells of more than 5/high-power fields (HPF) on the urinary analysis, and/or a positive urine culture with a colony count of at least 10⁵ colony-forming units/mm. Patients with 3 or more of these findings were diagnosed as having APN [11,12,16,17]. The authors selected clinical and laboratory findings as the standard of reference because, except in the case of nephrectomy due to pyonephrosis or life-threatening emphysematous pyelonephritis, pathologic samples, which are the most ideal standard, are difficult to obtain as written in textbooks or other journals [4].

The criteria for exclusion from the study included a single kidney or other febrile disease such as colitis, pneumonia, acute prostatitis, acute epididymitis, or pelvic inflammatory disease [18,19].

Each patient with proven APN underwent renal imaging techniques during hospitalization. CT was performed in 199 patients, DUS was performed in 163 patients, and DMSA scintigraphy was performed in 157 patients. CT and DUS were performed in 147 patients (Group 1), DUS and DMSA were performed in 150 patients (Group 2), and CT and DMSA were performed in 147 patients (Group 3).

For CT, the criterion for the diagnosis of APN was a wedge-shaped, linear, or patchy area of decreased attenuation in the renal cortex. Striation in the enhanced cortex



FIG. 1. (A) The coronary spiral CT scan obtained after intravenous administration of contrast agent demonstrates well-defined foci (arrows) of decreased attenuation in the lower pole of the right kidney. (B) A large area of parenchymal hypo-attenuation in the posterior aspect of the right kidney (arrow).

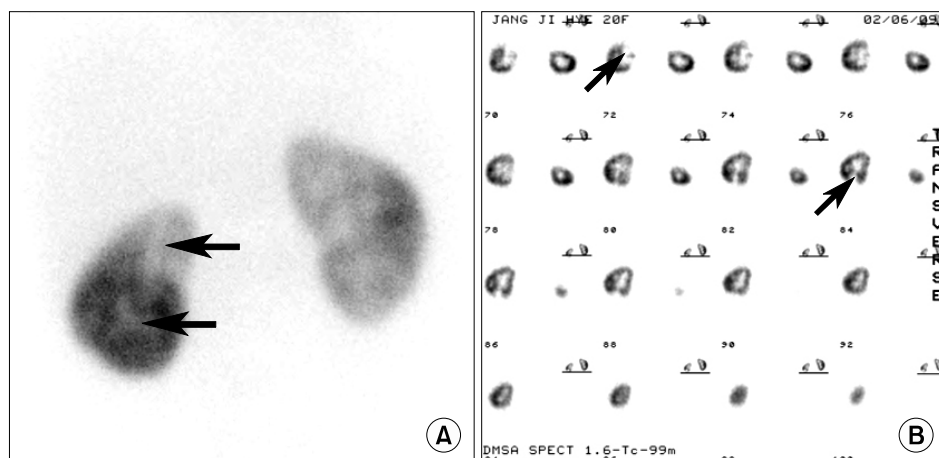


FIG. 2. (A) Dimercaptosuccinic acid (DMSA) scintigraphy demonstrates decreased uptake in the upper half and the lower portion of the right kidney (arrows). (B) The transverse images show a more accurate area of decreased uptake in the right kidney, especially in the anterior and the posterior aspect of the right kidney (arrows).

was also considered to represent APN (Fig. 1) [4,15]. For DMSA scintigraphy, the anterior, posterior, transverse, and sagittal views of the kidneys were obtained. The criterion for making a diagnosis of APN was subjective evidence of focal areas of decreased uptake seen on at least two projections, decreased overall uptake, or an atrophied kidney with a reduced relative function of less than 25% (Fig. 2) [4,15,20]. For DUS, the presence of a triangular zone of decreased or absent flow in the parenchyma, a renal parenchymal hypoechoic area, or an occasional hyperechoic area with or without the loss of the normal corticomedullary junction differentiation was considered diagnostic for APN (Fig. 3) [4,12,15,20]. All the images for each modality were interpreted independently by a single radiologist and a nuclear medicine specialist who were blinded to the results of the other imaging studies and the clinical diagnosis. The imaging findings were classified as true-positive findings for the affected kidney if clinically proven APN had been correctly diagnosed.

On the basis of the above criteria, the imaging findings of each modality were classified as positive or negative, and then the diagnostic sensitivity of each imaging technique was compared with that of the other technique as cross tabs. McNemar tests were then used to test the null hypothesis that there was no difference between the two modalities for the detection of APN in each group and to measure the agreement between the findings of the clinical laboratory examination with the findings from each of the imaging modalities. Commercially available software (SPSS version 13.0, SPSS Inc., Chicago, USA) was used for the statistical analysis. p-values less than 0.05 were considered significant.

RESULTS

1. Patient demographics

The 207 subjects forming the total study group were made up of 16 men and 191 women who ranged in age from 17

to 88 years (mean age: 49.4 years). The mean number of hospitalized days was 4.3 days, and this ranged from 1 to 15 days. The right kidney was affected more frequently than the left: the ratio between the right to the left kidney was 115/67 (1.72), and there were 25 cases of bilateral APN. Including complicated UTI, abnormal findings on the imaging tests were presented in 55 cases (26.6%): renal abscess (24 patients), renal stone (14 patients), incomplete duplication (5 patients), bladder stone (3 patients), ureteropelvic junction stone (3 patients), ureterovesical junction

TABLE 1. The patients' demographics

	Overall (n=207)		Group 1 ^a (n=147)		Group 2 ^b (n=150)		Group 3 ^c (n=147)	
	no.	%	no.	%	no.	%	no.	%
Age								
Mean	49.4		49.2		49.1		49.0	
Range	17-88		17-88		17-88		17-88	
Hospital day								
Mean	4.3		4.2		4.3		4.3	
Range	1-15		2-10		2-10		2-11	
Gender								
Male	16	7.7	5	3.4	5	3.3	6	4.1
Female	191	92.3	142	96.6	145	96.7	141	95.9
Laterality								
Right	115	55.6	84	57.1	82	54.7	81	55.1
Left	67	32.4	49	33.3	51	34.0	51	34.7
Bilateral	25	12.0	14	9.6	17	11.3	15	10.2
Complicated								
Yes	55	26.6	44	29.9	41	27.3	41	27.9
No	152	73.4	103	70.1	109	72.7	106	72.1

^a: computerized tomography (CT) & Doppler ultrasonography (DUS) was performed, ^b: DUS & dimercaptosuccinic acid (DMSA) scintigraphy was performed, ^c: CT & DMSA scintigraphy was performed, Laterality: laterality of clinical diagnosis as the standard of reference

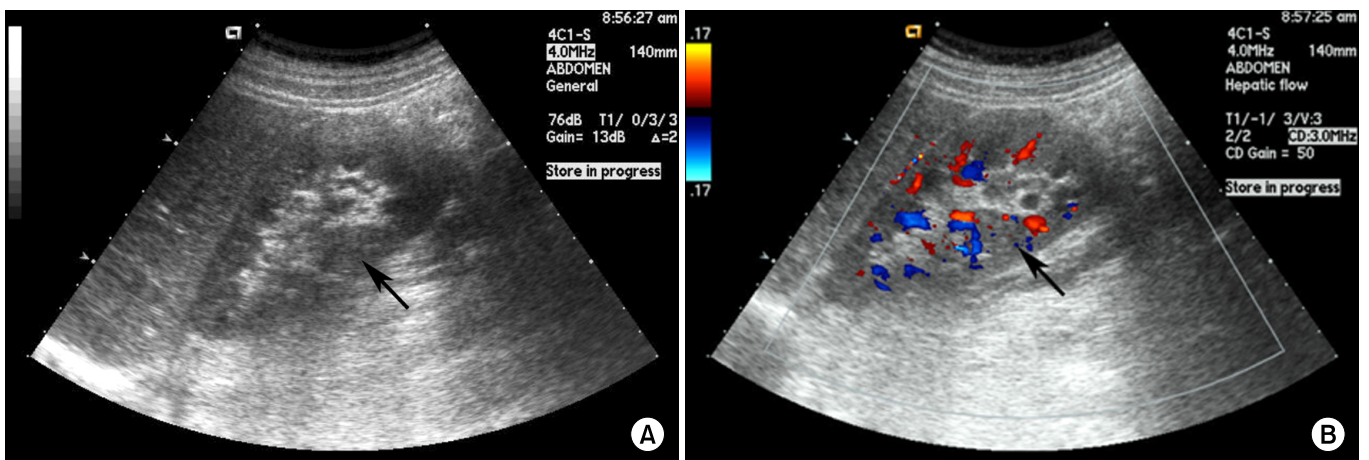


FIG. 3. (A) Renal Doppler ultrasonography (DUS) shows mild swelling and a wedge-shaped hypoechoic focus (arrow) of the right kidney related to acute pyelonephritis. (B) The color flow DUS image demonstrates diminished flow through the involved area (arrow).

stone (3 patients), ureter stone (2 patients), renal tuberculosis (2 patients), urinary diversion (1 patient), and extrarenal pelvis (1 patient). The overall demographic information of the total study group and of the three subgroups is shown in Table 1.

2. Comparison of diagnostic sensitivity between the imaging techniques

For group 1, the sensitivity of the imaging modalities for the detection of the affected kidneys was 81.0% (119/147) for CT, which was significantly superior to the 33.3% (49/147) sensitivity for DUS ($p < 0.05$, Table 2). For group 2, the sensitivity was 74.7% (112/150) for DMSA scintigraphy, which was significantly better than the 33.3% (50/150) sensitivity for DUS ($p < 0.05$, Table 3). For group 3, the sensitivity was 81.0% (119/147) for CT and 74.8%

(110/147) for DMSA scintigraphy. The sensitivity was slightly higher for CT than for DMSA scintigraphy, but the difference was not statistically significant ($p=0.163$, Table 4).

DISCUSSION

Recent studies have emphasized the importance of early imaging. The following studies support the notion that early imaging should be performed. Johansen reported that in patients with APN, DUS and plain films of the kidney, ureter, and bladder are recommended and that this should be followed by intravenous pyelography (IVP) in case of positive findings [5]. Shen and Brown suggested that early imaging is a cost-effective part of management and they recommended renal imaging for all patients who required hospital admission for APN. In this journal, 16% of patients were found to have new and clinically significant abnormal findings. But there was no significant difference between the groups with abnormal renal imaging and those with normal renal imaging in terms of any easily detectable clinical parameter, such as change in serum creatinine, pre-morbid conditions, age, days for fever to resolve, or white cell count on admission [6]. This finding suggests that early imaging is a cost-effective part of management. Because interest in early imaging has been growing, many researchers have conducted studies to choose the best modalities for diagnosing APN on the basis of objective evidence by comparing the diagnostic sensitivity of the commonly used renal imaging techniques (enhanced CT, DMSA scintigraphy, and DUS).

CT is considered to be markedly superior to IVP [21] and DUS [7,13,14] for demonstrating the parenchymal abnormalities caused by APN and for delineating the extent of the disease. Unenhanced CT has become the standard for demonstrating calculi, gas-forming infections, hemorrhage [22], obstruction, and inflammatory masses. An enhanced study is essential for completely evaluating patients with renal inflammatory disease to demonstrate alterations in renal parenchymal perfusion and excretion of the contrast material, which occur as a result of the inflammatory process. The most common enhanced CT findings of APN are ill-defined wedge-shaped lesions of decreased attenuation that radiate from the papilla in the medulla to the cortical surface with or without swelling (focal or global). On occasion, linear bands of alternating hyperattenuation and hypoattenuation that are oriented parallel to the axes of the tubules and collecting ducts may be revealed [4]. In our study, these findings were observed in most of the patients. Although APN in adults had previously been thought not to cause significant permanent anatomic or physiologic sequelae, some degree of scarring may eventually appear on a CT examination in up to 50% of patients who have acute infections with or without abscess formation [23]. In our study, most of the patients did not undergo further CT after discharge from the hospital, except as a result of recurrent APN or for diagnostic pur-

TABLE 2. The CT and DUS findings and comparison of the diagnostic sensitivity for group 1

CT	DUS		Total
	Positive	Negative	
Positive	45	74	119
Negative	4	24	28
Total	49	98	147

Group 1: computerized tomography (CT) & Doppler ultrasonography (DUS) was performed, Diagnostic sensitivity: CT 81.0%, DUS 33.3%, $p < 0.05$

TABLE 3. The DUS and DMSA findings and comparison of the diagnostic sensitivity for group 2

DUS	DMSA		Total
	Positive	Negative	
Positive	43	7	50
Negative	69	31	100
Total	112	38	150

Group 2: Doppler ultrasonography (DUS) & dimercaptosuccinic acid (DMSA) scintigraphy was performed, Diagnostic sensitivity: DMSA 74.7%, DUS 33.3%, $p < 0.05$

TABLE 4. The CT and DMSA findings and comparison of the diagnostic sensitivity for group 3

CT	DMSA		Total
	Positive	Negative	
Positive	98	21	119
Negative	12	16	28
Total	110	37	147

Group 3: computerized tomography (CT) & dimercaptosuccinic acid (DMSA) scintigraphy was performed, Diagnostic sensitivity: CT 81.0%, DMSA 74.8%, $p=0.163$

poses in other departments. Therefore, a comparative study of the frequency of renal scarring was not possible. However, as discussed in the Introduction, CT is more practical for differentiating acute lesions and previous renal scarring than is DMSA scintigraphy in patients with recurrent APN. Residual nephrographic abnormalities may last for several weeks to months, well after the clinical symptoms and laboratory findings have returned to normal [4]. It is important not to confuse these CT-detected residual changes with active infection that requires continued therapy. In this respect, the clinical usefulness of CT is superior to that of other imaging techniques.

DMSA scintigraphy is almost as sensitive as CT for detecting focal abnormalities in adult patients with APN [24]. In our study, the sensitivity of DMSA was similar to that of CT and better than that of DUS, the same as was reported by previous studies. In contrast with its common usage in evaluating pediatric patients, DMSA scintigraphy is infrequently used in adults because the focal areas of decreased uptake on the renal cortical scans are not specific for acute APN. These areas may represent abscess, infarct, cyst, or tumor. In our study, a portion of the positive findings on DMSA scintigraphy was revealed to be noninflammatory lesions or complicated APN, which cannot be differentiated by only focal areas of decreased uptake [4]. In these cases, other imaging techniques, especially CT, are necessary to make a clear distinction.

DUS has a definite advantage because it requires no ionizing radiation, and has been viewed as a basic renal imaging technique for several decades. But the poor sensitivity and specificity of DUS are limitations in practical applications. In the study by Dacher et al and Clautice-Engle et al, DUS yielded a lower detection rate than did CT [12,25]. Winters reported that the sensitivity of DUS was inferior to that of CT and DMSA scintigraphy [26]. In our study, similar to previous reports, the sensitivity of DUS was poor and there was a statistically significant difference between the sensitivity of DUS and that of the other imaging modalities. The reasons for the lower sensitivity of DUS are not clear. They may include insufficient ischemia and technical factors such as interference from intestinal gas, breathing motion, and rib artifacts. Heavy breathing motions and hiccups are sometimes problems. Similarly, an uncooperative patient can be a major restricting factor. The evolving use of DUS contrast material promises to improve the detection of APN, but the clinical applications of DUS with contrast material are currently poorly defined.

In conclusion, DUS has the advantage of not using ionizing radiation and it allows evaluation of the perinephric space. However, DUS has poorer sensitivity and specificity than CT or DMSA scintigraphy, as was previously reported and as was seen in our study. DMSA scintigraphy is highly sensitive and specific for the detection of APN, and in our experience it can be performed without the use of sedation. It is readily available and its cost is reasonable. More importantly, it allows for the qualitative and quantitative assessment of individual renal function, which at the pre-

sent time is not feasible with other imaging modalities. However, the major disadvantage of DMSA scintigraphy is that the focal areas of decreased uptake are not a specific finding for APN. Differentiation of acute lesions from previous scars is impossible. In our study, unless the DMSA scintigraphy findings were certain, other imaging techniques were necessary and CT was especially helpful. The advantages of CT are as follows: (1) images of the other intra-abdominal organs are available when the diagnosis of APN is uncertain; (2) it is possible to demonstrate complicated APN, such as obstruction owing to calculi, which requires immediate intervention or appropriate surgical procedure; (3) appropriate further management is available after the diagnosis of recurrent APN that is due to a congenital abnormality such as a duplicated system or a case that is refractory to antibiotics due to renal abscess.

The limitations of this study are as follows: (1) clinical and laboratory findings were used as the standard of reference to define APN; (2) we could not identify the sensitivity of the different modalities; (3) all images from each modality were interpreted once by a single reader without evaluation of intra- and interobserver agreement.

In our study, we validated the advantages of CT and they were decisive factors in patient management. In brief, CT is more clinically applicable than DMSA scintigraphy or DUS for diagnosing APN.

CONCLUSIONS

We evaluated the sensitivity of three renal imaging modalities for the detection of clinically diagnosed APN. The comparison showed a lower detection rate for DUS than for the other imaging modalities. CT and DMSA showed similar sensitivity and are significantly more reliable. However, DMSA scintigraphy cannot differentiate an acute lesion from a previous scar, the final diagnosis needs follow-up after 6 months, and a positive finding is not specific to APN. In conclusion, CT presently appears to be the most practical modality for routine clinical use to diagnose APN.

Conflicts of Interest

The authors have nothing to disclose.

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