

Renal Power Doppler Ultrasonographic Evaluation of Children with Acute Pyelonephritis

Ahmad Shajari¹, Reza Nafisi-Moghadam², Mahrooz Malek³, Agha Smaili¹, Mahmud Fallah², and Ali Pahlusi¹

¹ Department of Pediatric Nephrology, Shahid Sadoughi University of Medical Sciences, Yazd, Iran

² Department of Radiology, Shahid Sadoughi University of Medical Sciences, Yazd, Iran

³ Department of Radiology, Tehran University of Medical Sciences, Tehran, Iran

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Abstract- Urinary tract infections are common in children. The available gold standard method for diagnosis, Tc-99m dimercaptosuccinic acid scan is expensive and exposes patients to considerable amount of radiation. This study was performed to compare and assess the efficacy of Power Doppler Ultrasound versus Tc-99m DMSA scan for diagnosis of acute pyelonephritis. A quasi experimental study was conducted on 34 children with mean age of 2.8 ± 2.7 years who were hospitalized with their first episode of febrile urinary tract infection. All children were evaluated in the first 3 days of admission by Doppler Ultrasound and Tc-99m DMSA scan. Patients with congenital structural anomalies were excluded. Each kidney was divided into three zones. The comparison between efficacy of Doppler Ultrasound and DMSA scan was carried out based on number of patients and on classified renal units. Based on the number of patients enrolled; the sensitivity, specificity, positive and negative predictive values and accuracy of Doppler Ultrasound were 89%, 53%, 70%, 80% and 74%, respectively but based on the renal units, it was 66%, 81%, 46%, 91% and 79%, respectively. Although Doppler Ultrasound has the potential for identifying acute pyelonephritis in children, but it is still soon to replace DMSA scan.

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Introduction

Urinary tract infections (UTIs) are among the most common illnesses of children and are more prevalent in girls after the first year of life (1). There is a spectrum of urinary tract infections and only acute pyelonephritis (APN) with involvement of renal parenchyma, if not promptly diagnosed and treated, can lead to renal scarring, subsequent hypertension and chronic renal failure (2).

Unfortunately, the clinical signs and symptoms of APN are vague and differentiating between upper and lower UTIs, are difficult in young infants and children (3). According to the literature, Tc-99m dimercaptosuccinic acid (DMSA) scan and CT scan are the gold standard methods for diagnosing APN but they have the disadvantage of ionizing radiation exposure (4-6). Therefore, an early, reliable, inexpensive and non-radiating method would be preferable over others for detecting APN.

This study was undertaken to assess the efficacy of power Doppler ultrasound (PDU) in detecting APN in comparison to DMSA scan and to determine if PDU can replace Tc-99m DMSA scan in diagnosis of APN in children.

Patients and Methods

Thirty-four infants and children (age range: 2 months to 14 years; mean age: 2.8 ± 2.7 years old) who were admitted in the pediatrics ward with acute febrile UTI, documented by positive bacterial cultures were prospectively evaluated. Bacterial cultures were considered positive with bacterial count greater than 10^5 colony forming units (CFUs) per ml in midstream urine samples, more than 10^4 CFUs/ml in a urethral catheterized specimen or any growth of microorganism in a suprapubic sample. Patients with several episodes of UTI or with structural urinary tract anomaly were excluded. All children were examined by PDU and Tc-

Corresponding Author: Reza Nafisi-Moghadam

Department of Radiology, Shahid Sadoughi University of Medical Sciences, Yazd, Iran
Tel: +98 351 8224000, Fax: +98 351 8229209, E-mail: nafisi@ssu.ac.ir

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99m Tc DMSA scan within the 72 hours of admission. Young non-cooperative patients were sedated before examinations. Tc-99m DMSA scintigraphy was performed using a standard protocol (7) and started by injecting a dose of 1.5 to 2 MBq/kg intravenously, adjusted for body weight, with a minimal dose of 15 MBq per patient (7,8). Planar anterior, posterior, right and left posterior oblique, right lateral and left lateral images of the kidneys were obtained 2-4 hours after injection using an Orbiter Siemens gamma camera with a low-energy all purpose collimator. Images were obtained for 500,000 counts on a 256x256 matrix format. To interpret the Tc-99m DMSA scan results, international radionuclide nephrourology group (IRN) consensus criteria was used for the normal appearance of Tc-99m DMSA planar imaging (9). A scintigraphic study was defined abnormal if a defect in cortical uptake or diffuse hypoactivity was present. Localization (upper pole, midzone, lower pole), size and number of defects, margins of kidneys and differential renal functions were evaluated.

Power Doppler sonography was performed using the Logiq 500 GE scanner, with a 3.5-5 MHz curved array transducer, with patients in the supine and prone positions. The parameters of power doppler sonography, including color gain and pulse-repetition frequency (PRF), were individualized for every kidney in each patient for optimized visualization of a real parenchymal power Doppler map. Whole parts of each kidney were examined at axial and longitudinal planes at first in a gray scale for evaluation of size, echogenicity, stasis and possible associated pathologies. Also, the ureters and urinary bladder were evaluated in each patient to visualize any signs of inflammation or other associated pathologies. In power Doppler mode, again each kidney was examined at axial and longitudinal planes to provide a parenchymal vascular map of kidneys. Each kidney was divided into three zones as of upper, mid and lower zone. The presence of an area of decreased or absent flow in different zones (compared with the other parts of the same kidney at the same depth) was considered abnormal.

The examinations were done by an expert radiologist unaware of the findings of DMSA scan results. To compare the scintigraphic and sonographic findings, the presence or absence of pyelonephritis in each patient and zone were evaluated. Tc-99m DMSA study was considered the gold standard for diagnosis of pyelonephritis.

Table 1. Comparative results of DMSA scan and PDU in 34 children

DMSA scan	Power Doppler Ultrasonography		
	Acute pyelonephritis	Normal	Total
Acute Pyelonephritis	17	2	19
Normal	7	8	15
Total	24	10	34

Results

PDU and DMSA scan were performed successfully in all 34 children. Nineteen out of 34 children (56%) appeared abnormal on DMSA scan. In 17 patients, hypoperfusion was also detected by PDU. In two patients that DMSA scan revealed disease, PDU showed anormal flow. In 15 patients out of 34, no pathology was found by DMSA scan but in 7 out of 15, PDU detected hypoperfusion. PDU showed a sensitivity of 89% with a specificity of 53%, a positive predictive value of 70%, a negative predictive value of 80% and accuracy of 74% (Table 1).

When considering the number of lesions in each zone of kidneys, the sensitivity and specificity for detection and localization of the pyelonephritic lesions in the renal zones changed to 66% and 81% respectively (Table 2).

DMSA scan detected 39 affected zones in 22 diseased kidneys but PDU detected hypoperfusion only in 26 out of 39 zones and 13 additional lesions were missed. On the basis of diagnosing the affected zones, positive and negative predictive values and accuracy for PDU were 46.91% and 79%, respectively.

Discussion

Urinary tract infection (UTI) is one of the most common bacterial diseases in children and occurs in 1% of boys and 3-5% of girls (1). Because of nonspecific sign and symptoms, the clinical differentiation of acute pyelonephritis (APN) and cystitis is difficult. Furthermore, permanent renal damage develops in about

Table 2. Comparative results of DMSA scan and PDU in 204 (68x3) zones in 68 kidneys

DMSA scan	Power Doppler Ultrasonography		
	Acute pyelonephritis	Normal	Total
Acute Pyelonephritis	26	13	39
Normal	30	135	165
Total	56	148	204

36-52% of kidneys affected by pyelonephritis (10) and can lead to hypertension, impaired renal function and serious outcomes for concomitant pregnancies (2). Therefore, to reduce morbidity, the precise and prompt diagnosis of APN is very important.

There are several imaging techniques for diagnosis of APN but none of them are 100% reliable and some have even disadvantages for clinical use. Considering its high cost, requirement for prolonged sedation and less availability, MRI is not a practical tool for identifying all cases of APN. DMSA scan and spiral CT are also associated with ionizing radiation exposure (11). However, because DMSA scan has less ionizing radiation exposure compared to CT, has reasonable cost and also ability to assess split renal function it is considered as the gold standard method for the diagnosis of APN with overall sensitivity of 86% and specificity of 91% (12).

Power Doppler ultrasonography (PDU) is a non-radiation technique for renal vascular visualization and recent studies are promising regarding its use for the diagnosis of APN (13). However, some experimental and clinical studies do not fully support this issue (11). The pathophysiologic mechanism responsible for imaging abnormalities are focal ischemia due to vascular compression induced by interstitial edema (11,14,15).

Based on the evaluation of renal zones, our study revealed a sensitivity of 66%, specificity of 81%, positive predictive value of 46% and negative predictive value of 91% for PDU in identifying DMSA scan. The results of our study are in accordance pyelonephritic zones as compared with Tc-99m with the experimental work of Majd *et al.* that showed less accuracy of PDU (sensitivity of 56.6% and specificity of 81.4%) for localizing APN as compared with other imaging methods (11). Similar to Majd *et al.* study, low sensitivity and high false positive results reported here can be attributed to technical features, rib artifact, intestinal gas and breathing motion (11). Obesity was not the cause of false positive results in none of our patients (13). Furthermore, according to Rushton *et al.* in some cases PDU may reveal lesions that remain invisible in DMSA scan (6).

Although specificity in Majd *et al.* study are the same as ours (81%), but there are less false negative results in our study (9% in the present study vs 19% in Majd *et al.* study). The reason for this difference is selection of two different gold standard methods and it is clear that histology is more accurate in comparison with radioisotope for detecting pathologic zones. In general, the false negative results can be explained by venous

congestion caused by edema and sluggish blood flow through involved area (11). In rare occasions, the normal heterogeneity of Tc-99m DMSA uptake may mimic abnormal areas of isotope uptake (16).

Estimation of the value of PDU with respect to the actual number of children revealed sensitivity, specificity, positive predictive value, negative predictive value and accuracy of 89%, 53%, 70%, 80% and 74% respectively. Therefore, from clinical point of view, PDU has apparently reasonable capability to detect children with APN. The PDU missed only two patients but it didn't show 13 renal units. The 11 missing zones were present in patients with multifocal lesions and the other two were in two children in the upper pole of the left kidney. The inability of PDU to visualize the latter lesions may be attributed to the absence of the hepatic acoustic window for better demonstration of blood flow in the upper pole of the left kidney.

We observed two conflicting reports regarding the value of PDU from one center. Bykov *et al.* suggested that PDU has a low sensitivity (58%) and a high specificity (94%) when compared with scintigraphy having only 6% false positive and high false negative results (26%) (17). Halvey *et al.* from the same group and center demonstrated a sensitivity of (87%) and a specificity of (92.3%) for PDU in identifying APN (18). The reason for this discrepancy may be due to increased number of cases, more precise definition of APN in the latter study and also due to two different methods for comparison between PDU and DMSA scan. In the former study, conclusion was based on affected zones and in the latter study on the number of patients.

There are several other studies supporting the role of PDU in evaluating children with APN but they have limitations (19,20). The studies of Winters (19) and Sakaya *et al.* (20) illustrated complete specificity and relatively high sensitivity for PDU but in these reports only 12 and 11 children were evaluated, respectively. Dachter *et al.* demonstrated high sensitivity for PDU compared with CT scan but due to exclusion of uncooperative children, it can not be indicative of the value of PDU in the general pediatric population (21).

The limitations of our study include the relatively small sample size, selection bias and low contribution of B-mode ultrasonography. However, it should be noted that since the finding of hypovascular lesions on PDU is not specific for APN, we excluded the children with congenital renal anomalies, which is in accordance with other studies (17,18,22).

In conclusion, although PDU has the potential to detect APN in children but considering its low accuracy,

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it is still soon to replace the DMSA scan.

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