

# Significance of nuclear medicine scan in comparison with diethylenetriamine pentaacetic acid and ultrasound imaging in diagnosing renal disorders

## An observational study

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### Abstract

The effectiveness of diethylenetriamine pentaacetic acid scan is regularly monitored for the assessment of any potential modifications in treatment responses or kidney functions in the pediatric population.

This study attempts to compare the usefulness of diethylenetriamine pentaacetic acid and ultrasound imaging of renal disorders among paediatric patients.

A retrospective observational study was conducted by enrolling 106 children. The demographic details such as: participant's age, gender, and the history of renal disease of each patient were recorded. Patients were administered radiopharmaceuticals in a fixed dose and were later subjected to computed tomography (CT) scan. The obtained data was analysed using descriptive statistics.

Findings indicated increased sensitivity for CT (61.20%); whereas, a major decrease in specificity (23.68%) was observed. Comparison of Single-photon emission CT (SPECT) and CT findings revealed the increased sensitivity (90.90%) for ultrasound; whereas, there was a slight decrease in the specificity (40%) for SPECT. However, SPECT findings show 91% sensitivity among patients with 71.42% positive predictive value. Moreover, an increase in sensitivity for CT (61.20%), followed by a major decrease in specificity (23.68%) was observed.

Ultrasonography has been proved to be the safest and the most effective method for the diagnosis and the treatment of most renal disorders, due to the higher predictive value of SPECT scans. It is thus suggested that patients with ureteral calculi should be diagnosed with renal scintigraphy and unenhanced helical computerized tomography.

**Abbreviations:** CT = computed tomography, DMSA = dimercapto succinic acid, DTPA = diethylenetriamine pentaacetic acid, MCDK = multicystic dysplastic kidney, NM = nuclear medicine, PPV = positive predictive value, SPECT = single-photon emission computed tomography, VCUG = voiding cyst urethrogram.

**Keywords:** diagnosis, nuclear medicine, pentetic acid

### 1. Introduction

Nuclear medicine (NM) plays a significant role in the diagnosis of different kidney disorders affecting the young population. Renal scintigraphy methods support the diagnosis and evaluation of different nephro urological conditions. Tc-99m dimercaptosuccinic acid renal scintigraphy (Tc-99m-DMSA), Tc-99m DTPA

(diethylenetriamine Penta acetic acid), Tc-99m EC (ethylendis-is-tein), and Tc-99m mercapto acethyl triglycine -3 are some common methods that are widely used by radiopharmaceuticals for dynamic renal scintigraphy. The methods are considerably safe among children, since they do not require the use of sophisticated equipment or sedation.<sup>[1]</sup> Gamma camera is

Editor: Sumit Arora.

This project was funded by the Deanship of Scientific Research (DSR) at King Abdul-Aziz University, Jeddah, under grant no. G: 226-142-1439.

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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How to cite this article: Bafaraj SM. Significance of nuclear medicine scan in comparison with diethylenetriamine pentaacetic acid and ultrasound imaging in diagnosing renal disorders: An observational study. *Medicine* 2020;99:36(e22038).

Received: 3 October 2019 / Received in final form: 15 July 2020 / Accepted: 4 August 2020

<http://dx.doi.org/10.1097/MD.00000000000022038>

specifically an adequate equipment, but not available in primary care centers. The use of Gamma camera is encouraged as NM scan may need sedation because patient motion interferes with image quality.

Parenchymal defects among children can be specifically indicated in the first 2 to 3 minutes of the scans of dynamic diethylenetriamine pentaacetic acid (DTPA or mercapto acethyl triglycine 3) renal scintigraphy. However, the parenchymal function can be demonstrated through the static dimercapto-succinic acid (DMSA) renal scintigraphy, which is the main scintigraphic technique.<sup>[2]</sup> These scans are used for the computation of differential functions and are achieved only through a single test.<sup>[3]</sup>

NM uses radionuclides for the diagnosis and treatment<sup>[4]</sup> while DTPA Scans are recommended for renal disorders. The evaluation of any damage caused to the kidneys is easily evaluated through DTPA scans. By utilizing the given test, a physician can evaluate the damage in kidneys, caused by the reduced blood supply, trauma or urinary reflux. The effectiveness of DTPA scan is regularly monitored for the evaluation of any modifications in treatment responses or kidney functions.<sup>[5]</sup> In particular; DTPA is used as a radioactive substance for injecting acid into a vein that enters into the kidneys. Similarly, gamma cameras are used for detecting DTPA scans, specifically of the damaged kidney cells. The scan shows areas that are affected through kidney infections.<sup>[6]</sup> There is no prior preparation for a DTPA scans, as it implements no restrictions over eating and drinking patterns of the affected individuals. In case of pregnancy, physicians and radiologist staff must execute DTPA with proper guidance.

An injection of DTPA tracer solution is involved in DTPA kidneys scan, which allows a 2 to 4 hours imaging after injection. The major advantage of using DTPA scans is that the process is free of the involved risks. However, DTPA scan involves a minimal dosage of ionizing radiation that is identical to the dosage used in other routine medical imaging evaluation.<sup>[7]</sup> Another potential advantage of DTPA is that it is the mere renal radiopharmaceutical available for routine imaging that is entirely filtered by the glomerulus. In particular, it is the mere imaging radiopharmaceutical that can be utilized for measuring glomerular filtration rate (GFR). Additionally, the associated function of each kidney is measured to evaluate the functional differences of both kidneys.<sup>[8]</sup> However, regularly performed DTPA enable doctors to monitor the changes in the inflammation of kidney.

Kidney problems such as; hydronephrosis, renal calculi (kidney stones), and ureteral calculi are diagnosed using an ultrasound. Due to the restriction of free flow of urine from the kidney, urinary retention causes distension and dilation of renal pelvis and calyces, and hence indicates hydronephrosis.<sup>[9]</sup> Besides, in cases where the kidney remains untreated, results in the development of progressive renal atrophy, which increases the chances of affecting both kidneys.<sup>[10]</sup> For instance, kidneys can be damaged through severe cases of hydronephrosis and urinary blockage, leading towards kidney failure.<sup>[11]</sup> Conversely, the consequences of hydronephrosis can be emerged in the recovery of affected individuals, if treated effectively.

The history, urinalysis, radiographic studies, and physical examination are the fundamental aspects for developing the diagnosis of kidney stones. Additionally, location and severity of the pain are other factors to commence clinical diagnosis.<sup>[12]</sup> The occurrence of back pain is usually revealed due to the restriction in kidney. Fever and tenderness are other common symptoms revealing the costovertebral side of the kidney through physical

examination.<sup>[13]</sup> Thereby, the information acquired through ultrasound imaging is significant since the existence of Hydro-nephrosis explicitly indicates the blockage in outflow of urine through the stone. Similarly, the paucity of radiation exposure and low cost are other features of renal ultrasonography.<sup>[14]</sup> The effectiveness of ultrasound imaging is adhered in the detection of stones in different cases, where computed tomography (CT) or X-rays do not detect properly.

The urinary tract and bladder of the patients are monitored using a special X-ray technology; fluoroscopy. Furthermore, this technology is used for a voiding cyst urethrogram (VCUG), which is revealed as a minimally invasive test.<sup>[15]</sup> The vesicoureteral reflux can be diagnosed by using a VCUG under a specific condition, indicating a wrong direction for the flow of urine (from the bladder to the kidneys). The test is useful in revealing the abnormalities in urethra and bladder.

Dhull, Joshi and Saha<sup>[1]</sup> indicated intra-arterial angiography as the gold method for the identification and quantitative evaluation of the renovascular lesions. Still, renography associated to Angiotensin converting enzyme inhibitors are some of the common tools available to evaluate the perfusion and function of kidney.<sup>[16]</sup> CT on the other hand is recommended to patients with acute flank pain due to the probability of a kidney stone.<sup>[17]</sup> CT scan exposes patients to ionizing radiation. Though the approach is expensive, it is widely recommended due to its accuracy in detecting the presence of any kidney stones. Moreover, there is no evidence that confirms improved patients' outcome, despite of its increased sensitivity. Contrary to this, ultrasound is considered as a safe imaging process for renal colic, and is increasingly available in the emergency department setting. Therefore, this study focuses on the effectiveness of DTPA scans and ultrasound imaging to detect kidney disorders.

The effectiveness of DTPA scan compared to ultrasound imaging in the detection of kidney disorders has been evaluated comprehensively. Since ultrasound and DTPA scans use either contrast material or radiopharmaceuticals, the safety of the test becomes questionable. It can continuously explain the overall urinary collecting system and offer advantageous information for the management of children diagnosed with renal diseases. It should be noted that the procedure is safe, minimally invasive and simple. Considering this, this study aims to compare the significance and effectiveness of NM with DTPA and ultrasound in diagnosing renal disorders.

## 2. Material and methods

### 2.1. Study design and population

This retrospective observational study was conducted on 256 children, who attended the department of NM. The demographic details of each patient were recorded, which included age, gender, and history of renal disease. Children aged between 1 to 15 years that were diagnosed with renal diseases served as the population of the study. However, children other than the following inclusion criteria were eliminated, resulting in the overall sample size of 106 children.

Children were included when presented with:

- (1) cystic infection, stone formation within cyst or renal cystic lesions > 1.0cm at diagnosis or during a follow-up, gross hematuria, and flank pain. Children were excluded if presented with: imaging studies of calyceal diverticulum or typical presentations. Both ultrasound and DTPA scans were

recommended and performed for the enrolled patients. Parents provided informed consent after they were informed of the objectives, advantages, and potential risks of imaging studies.

## 2.2. Study procedure

Patients have gone through a series of tests to confirm the presence of renal disease. They were further administered radiopharmaceuticals in a fixed dose to evaluate the significance and effectiveness of NM in diagnosis of renal diseases. Apart from NM, VCUG was performed to detect the history of urethral valve. Finally, patients have gone through ultrasound that has helped in the calculation of normal kidney and affected kidney size. However, for each test, 2 repeated trials were performed, which resulted in providing similar findings in majority of the participants. For patients with different findings in repeat trials, final results were considered.

## 2.3. Imaging protocols

Single-photon emission CT (SPECT) gamma camera was used in scintigraphic study, installed with low-energy high-resolution parallelhole collimators. Both static and dynamic renal scintigraphy images were performed in supine position. Xeleris program was used to calculate the raw data for DRF, which is workstation program of the gamma camera system. A total of 106 patients were used to carry out routine static  $^{99m}\text{Tc}$ -DTPA renal scintigraphy.  $^{99m}\text{Tc}$ -DTPA was provided intravenously (1 mCi) for children and computed on the basis of their body weight.

Dynamic images were recorded in a  $128 \times 128$  matrix format every second for 1 min and every 30 seconds for 20 minute and all patients were injected with  $200 \mu\text{Ci/kg}$  (at least 2 mCi) of  $^{99m}\text{Tc}$ -DTPA. Relative renal function was measured in composite image (1–3 min after the injection). A NM physician manually draws renal and semi-lunar background regions on interest (ROIs). Scans were obtained in posterior, anterior, right, and left posterior and anterior oblique projections whereas the patient lies on supine position. Only the anterior and posterior images were used to portray quantitative calculation while all the images were visually assessed. DTPA glomerular filtration rate was set as gold standard for determining bias, precision, and accuracy.

## 2.4. Ethical considerations

Before commencing to the major process of the study, permission and an approval was acquired from the Institutional Review Board. Participants were followed up and intentionally registered in the institution.

## 2.5. Statistical analysis

The statistical analyses were performed using the Statistical Package for the Social Sciences version 22. Data were presented

**Table 1**

**Demographic details of participants with respect to gender and age.**

	Frequency	Percent	Valid Percent	Cumulative Percent
Gender				
Valid				
Male	67	63.2	63.2	63.2
Female	39	36.8	36.8	100.0
Total	106	100.0	100.0	
Age Group				
Valid				
1 to 5 yr	63	59.4	59.4	59.4
6 to 10 yr	27	25.5	25.5	84.9
11 to 15 yr	16	15.1	15.1	100.0
Total	106	100.0	100.0	

as absolute (n) and relative frequencies (%) for continuous variables. Analysis regarding sensitivity and specificity, positive predictive value and negative predictive value were presented through the DPTA and ultrasound scan findings. The diagnostic tests were performed when the stenosis diameter was  $>60\%$  for the positive values. The significance level of the tests was defined at 5%.

## 3. Results

The study recruited a total of 106 patients, among which 67 patients were males and 39 were females. Most of the participants i.e. 63 of them belonged to the age group between 1 to 5 years, 27 of them aged between 6 to 10 years, and only 16 of participants aged between 11 to 15 years (Table 1).

The comparison of DTPA findings with ultrasound revealed increased sensitivity (90.90%); whereas, there was a slight decrease in the specificity (40%) for DTPA scan (Table 2). For ultrasound imaging, results indicated sensitivity of 61.20%; and specificity of 23.68%. However, the significance of the given data was determined through the number of patients representing the high values of sensitivity (Table 3).

## 4. Discussion

The study has shown that  $^{99m}\text{Tc}$ -DTPA diuretic renal scan was more sensitive as compared to ultrasound imaging in diagnosing all renal disorders. Adequate diagnosis of renal disorders guides appropriate management and also releases the patients and their families the psychological stress of other renal disorders, which make the differentiation of ultrasound imaging from other renal parenchymal cystic lesions essential.<sup>[18,19]</sup>

Surgical management fulfils the preference with respect to extent of renal diseases involvement. Therefore, renal screening must be performed with a high-sensitivity apparatus, specifically

**Table 2**

**Diagnostic values of DTPA scan and ultrasound imaging for renal disorders.**

DTPA	TP	TN	FP	FN	Sensitivity	Specificity	PPV (%)	NPV (%)
Renal Disorders	30	8	12	3	90.90%	40%	71.42%	72.72%
Ultrasound								
Renal Disorders	30	9	29	19	61.20%	23.68%	50.84%	32.14%

CT = computed tomography, DTPA = diethylenetriamine pentaacetic acid, FN = False Negative, FP = False Positive, NPV = negative predictive value, TN = True Negative, TP = True Positive, PPV = positive predictive value.

**Table 3****CT sensitivity and specificity findings among renal disorders group (DTPA).**

DTPA	TP	TN	FP	FN	Sensitivity	Specificity	PPV (%)	NPV (%)
Renal Disorders	30	9	29	19	61.20%	23.68%	50.84%	32.14%

CT = computed tomography, DTPA = diethylenetriamine pentaacetic acid, FN = False Negative, FP = False Positive, NPV = negative predictive value, TN = True Negative, TP = True Positive, PPV = positive predictive value.

it is understood that DTPA is precise enough for detecting all renal disorders. US imaging is routinely used as it is radiation free and available at low cost. DTPA is a secondary choice because of its related costs and radiation exposure. Recently, US equipment attainment led for presuming that better sensitivity can be accomplished. However, this study was able to identify a significant difference between the US and DTPA scans. It was observed that sensitivity was already maximal with the older instruments. The lower sensitivity of US was because of the adversely defined criteria of renal diseases.<sup>[20]</sup>

Findings of the study depicted the significance of DTPA scans in comparison to ultrasound. These results are consistent with the study performed by Herbst et al<sup>[10]</sup> which stated that SPECT scans are more specific and sensitive as compared to other approaches in diagnosing renal diseases. A comparative study was conducted by Whittam et al<sup>[13]</sup> to compare Renal Ultrasound and NM scan when diagnosing of Multicystic Dysplastic Kidney (MCDK). A total of 91 patients had their ultrasound findings, where 84 patients were identified with normal bladder ultrasound. The diagnosis of MCDK in all 84 patients was confirmed by NM. Findings indicated a high predictive value through renal ultrasound to diagnose Unilateral MCDK.

In the context of nephrolithiasis, Smith-Bindman et al<sup>[14]</sup> have used 3 imaging technologies, including point-of-care ultrasonography, radiology ultrasonography and abdominal CT for diagnosing 2759 patients. Findings indicated that patients in the initial emergency department were undergone through an ultrasonography groups as compared to CT groups. In particular, the study indicated different ratios of patients diagnosed through point-of-care ultrasonography (40.7%), radiology ultrasonography (27%), and CT (5.1%).

In the context of relative function and renal ultrasonography, Veenboer et al<sup>[15]</sup> used renal ultrasonography and Tc-99m DMSA scintigraphy to evaluate its diagnostic accuracy among 122 patients with spinal dysraphism. Consequences from both the modalities were compared. Moreover, the relation between hypertension and renal scarring were also evaluated. DMSA scintigraphy showed more scars than ultrasonography. The study indicated a better diagnostic accuracy of DMSA scintigraphy, detecting 45.9% than the ultrasonography.

In the context of ureterolithiasis, Lorberboym et al<sup>[16]</sup> have used unenhanced helical computerized tomography and renal scintigraphy among 30 suspected patients. The study indicated the location of a calcified stone among all patients with the unenhanced helical computerized tomography. The sensitivity, specificity, and predictive values were determined with the scintigraphic consequences for each probable combination of CT findings. The most identified location revealed for a calculus on unenhanced helical computerized tomography was the distal ureter. The sensitivity and specificity of CT findings showed variations from 50% to 75% and from 8% to 69% respectively function of kidney in terms of diagnosis. The highest positive predictive value for obstruction was shown by DTPA showing 71.42% of the renal disorders. The role of imaging method was compared in each individual with

suspected renal artery stenosis. A better population selection and the identification of the best tests were proposed to guide the diagnosis. These findings are in line with the findings of the present study. The total and split SRF of kidneys have been assessed through the ultrasound technique. A previous study has compared the parenchymal defects in children with ultrasound and DMSA and revealed that the parenchymal defects were not sufficiently determined through ultrasound technique.<sup>[21]</sup> According to the study, the use of DMSA scintigraphy was essential for the assessment of renal anomalies, but can be used as alternative, if the US exam detects parenchymal defects.

Certain limitations are involved in this study. First is the absence of gold standard techniques for renal diseases were the possible limitation of the present study. In this regard, some renal diseases might be missed due to absence of SPECT gamma camera in primary centers and so the actual sensitivity and specificity of DTPA, DFR of renal diseases cannot be identified. Therefore, it is suggested to achieve results that are more consistent with a normal distribution by using larger number of cases. Other methods of scanning should be used in future studies to achieve the best and for comparing most beneficial methods to each other. Severity of the scan to determine the ability for identifying the scan should be considered in future studies.

The anatomical details and hemodynamics of the kidney were detected through ultrasound. On the contrary, information about the renal function was provided by 99m Tc-DTPA renal scan. Therefore, it is suggested to use both the screening modalities by integrating each other for better outcomes.

## 5. Conclusion

In conclusion, 99mTc-DTPA is a reliable method as US exam in detecting all renal diseases in children. 99mTc-DTPA can be an adequate choice for the assessment of renal diseases even though 99mTc-DMSA is the gold standard method for the assessment of renal diseases. From the findings, it was concluded that Tc-99m DTPA diuretic renal scan provides an alternative imaging mode with the benefit of lower radiation exposure and potentially higher sensitivity to detect renal diseases as compared to ultrasound. Additional studies are needed with larger patient populations to assess the role of DTPA diuretic renal scan to detect renal diseases in children.

## Acknowledgments

The authors, acknowledge with thanks DSR for technical and financial support. The author is very thankful to all the associated personnel in any reference that contributed in/for the purpose of this research. This project was funded by the Deanship of Scientific Research (DSR) at King Abdul-Aziz University, Jeddah, under grant no. G: 226-142-1439. The authors, therefore, acknowledge with thanks DSR for technical and financial support. The author is very thankful to all the associated

personnel in any reference that contributed in/for the purpose of this research.

### Author contributions

The author SMB is responsible for the complete research. Conception design, drafting, literature, analysis, finalization and correspondence are all done by SMB.

### Correction

The grant details were not originally included in the acknowledgement and have since been added.

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