Exp Biomed Res 2024; 7(2): 78-83 **https://doi.org/ 10.30714/j-ebr.2024.210**

Experimental Biomedical Research *Original article*

Relationship between 99mTc-DTPA, 99mTc-DMSA and glomerular filtration rate by calculated γ - Camera method in kidney with unilateral renal scar

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ABSTRACT

Aim: To evaluate the relationship between renal abnormalities detected by 99mTc-Dimercaptosuccinic acid (99mTc-DMSA) scans and glomerular filtration rate estimated by γ-camera method using 99mTc-DTPA (Diethylene-triamine-pentaacetate dynamic renal scintigraphy) in patients with renal parenchymal scarring.

Methods: We selected children who were followed up in our Pediatric Clinic for recurrent urinary tract infections and developed unilateral renal parenchymal scarring after these infections. We compared 99mTc-DMSA difference rates, glomerular filtration rate (GFR) calculated by γ -camera method and 99mTc-DTPA difference rates in the affected kidney.

Results: Of the 23 patients, 14 (60.9%) were female and 9 (39.1%) were male. The mean age of the patients was 10.41 ± 4.49 years. In the comparison of 99mTc-DMSA scans and glomerular filtration rate calculated by γ -camera method using 99mTc-DTPA in the renal parenchymal scarring kidney, there was no significant difference in the Tc-99m-DTPA (%) difference rates between the scarring and non-scarring kidney (p=0.750). However, there was a significant decrease in GFR (ml/min) values in the scarring kidney compared to the non-scarring kidney (p=0.025).

Conclusions: We found that GFR measurement provides earlier information than other methods in assessing renal function with DTPA and DMSA in patients with scarred kidneys, before irreversible loss of function occurs. GFR value is statistically more significant than DTPA and DMSA evaluation.

Key words: Urinary tract infection, renal scar, glomerular filtration rate, 99mTc-DTPA, 99mTc-DMSA, children.

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Received: 2023-12-12 / Revisisons: 2024-01-15

Accepted: 2024-02-04 / Published: 2024-03-15

Introduction

Urinary tract infections (UTI) are the most common group of childhood diseases after upper respiratory tract infections. If a urinary tract infection is not diagnosed and treated in time, it may cause renal scarring and chronic kidney failure [1]. The acute inflammatory response that helps to clear the body of the microorganisms that cause the urinary tract infection also damages the tissue in the infected area [2,3]. Therefore, 99mTc-Dimercaptosuccinic acid (DMSA) scans of patients who had acute pyelonephritis showed that 36-52% of them had permanent kidney damage. Chronic kidney failure due to recurrent UTIs is still a significant problem in our country [4,5].

To have a healthy young population, we should prevent irreversible organ damage from occurring during childhood. Preventive medicine

is important, but we also need to treat and prevent diseases that are treatable and preventable in a timely and correct way [6,7].

Parenchymal renal scarring is more likely to occur in children if they have recurrent or untreated urinary tract infections. 99mTc-DMSA static imaging can detect parenchymal injury as a focal area of radiopharmaceutical uptake defect. This method is considered the more appropriate imaging technique for the diagnosis of acute pyelonephritis (APN). 99mTc-DMSA scanning also provides clinically useful indices of absolute renal function and relative renal function (differential renal function), especially useful in follow-up [8-10].

Renal parenchymal loss from pyelonephritic scarring could hypothetically lead to a similar situation, with hyperfiltration and risk of glomerulosclerosis, which would be indicated by increased urine albumin excretion [4].

The aim of this study was to evaluate the relationship between renal abnormalities detected on 99mTc-DMSA scans and glomerular filtration rate calculated by γ -camera method using 99mTc-Diethylene-triamine-pentaacetate dynamic renal scintigraphy (DTPA) in kidneys with pyelonephritic scarring. The relationship between albuminuria and type of scarring, as well as other renal functional parameters, was also assessed.

Materials and metods

Patient population: The study was initiated after receiving the approval of Manisa Celal Bayar University Faculty of Medicine Health Sciences Ethics Committee (Approval date and No: 31/08/2023/ 20.478.486/ 1977). Our research is a retrospective study and covers the years 2020-2023. We selected children who were followed up in our Pediatric Clinic for recurrent urinary tract infections and developed unilateral renal parenchymal scarring after these infections. Patient selection was done randomly.

In routine practice, we obtained 99mTc-DMSA static kidney scintigraphy, which was performed for clinical necessity, and 99mTc-DTPA dynamic kidney scintigraphy, which also measured glomerular filtration rate (GFR) with the camera method, from the archive and processed them with a special program on the workstation computer in the same week. We created time-activity curves, individual differential kidney function, radiopharmaceutical uptake, and other numerical data such as percentage and GFR values.

^{99m}Tc DMSA scanning and ^{99m}Tc DTPA dynamic technical features: 99mTc DMSA scintigraphy was performed according to our usual clinical protocol. The administered dose was 200μ/kg of body weight (at least 37 MBq). One anterior, one posterior and 2 posterior oblique projections were recorded beginning 3 h after dose administration, with the patient lying supine and the γ- camera head directly beneath the examination bed. A large-field-of-view γ-camera (Infinia- GE) interfaced with a Xeleris Workstation (GE) was equipped with a low-energy (140 keV), high resolution collimator for a 256 x 256 matrix acquisition. The total count of each image was 300,000. Images were stored on computer to allow digital image enhancement for better evaluation. An experienced observer, unaware of the other patient data, evaluated the images. Renal parenchymal involvement seen on ^{99m}Tc -DMSA scans was graded as 0 (normal), 1 (1 lesion), 2 (2 lesions), or 3 (diffuse damage with renal parenchymal subversion).

Dynamic renal scintigraphy and to determinate of glomerular filtration rate by γ-camera method was performed. About 200 μCi/kg of ^{99m}Tc-DTPA were prepared in a 5 mL syringe and the contained volume was increased to 2 mL with saline. Before the patient

examination began, the full syringe was positioned on a specially prepared 5 cm thick acrylic support and placed in contact with the collimator surface on the examination table. Activity was measured by the γ-camera; one 60-sec static image was acquired in a 64 x 64 matrix by a %20 window centered over the 99mTc 140-keV energy peak. After this measurement, ^{99m}Tc-DTPA was injected as a bolus and data were acquired by a 2-phase dynamic acquisition (60 frames x 1 s per frame and 39 frames x 60 s per frame). After the dynamic acquisition the empty syringe and injection site was measured 60 s static image.

Statistical analysis: Statistical analyzes were performed using the SPSS 27.0 (Statistical Package for the Social Sciences, USA) program. Descriptive statistics were presented as mean ± standard deviation for those with normal distribution, as the median value in the min-max range for those who were not normally distributed, and as numbers (n) and percentages (%) for those with nominal distribution. In the study, whether there were differences between groups in terms of continuous variables was evaluated with Student's t Test / Mann-Whitney U Test in Independent groups. Whether there were differences in continuous variables between the patients' kidneys (right kidney, left kidney) was evaluated with the Wilcoxon test. Pearson chi-square / Fisher Exact Test were used in theanalysis of nominal variables. For $p<0.05$, the results were considered statistically significant.

Results

Of the 23 patients, 14 (60,9%) were female and 9 (39,1%) were male. The mean age of the patients was 10.41 ± 4.49 years (Table 1).

Table 1. Demographic findings of the patients.

Parameters	**N, %, mean ± SD**
Gender	
Female	14 (60, 9%)
Male	9 (39, 1%)
Age (Year)	10.41 ± 4.49

Comparison of 99mTc-DMSA scans and glomerular filtration rate that calculated γ -camera method estimated by 99mTc-DTPA at evolved renal parenchymal scarring kidney was showed in the table 2. 18 of 23 patients were 99mTc-DMSA grade 1, while 5 patients were 2. Although there was a numerical decrease in the 99mTc–DTPA (%) difference rates in the scarring kidney compared to the non-scaring kidney, there was no statistical significance (p=0.750). There was a statistically significant decrease in GFR (ml/min) values in scarring kidney compared to non-scaring kidney (p=0.025). Although there was a numerical decrease in 99mTc-DMSA (%) difference rates in scarring kidney compared to non-scaring kidney, there was no statistical significance (p=0.552).

Table 2. Comparison of 99mTc-DMSA scans and glomerular filtration rate that calculated γ -camera method estimated by 99mTc-DTPA at evolved renal parenchymal scarring kidney.

	99mTc–DTPA (%)	GFR (ml/min)	99mTc-DMSA (%)
Non-scaring kidney	50.087	85.657	50.782
Scaring kidney	49.913	80.980	49.218
p value	0.750	0.025	0.552

DTPA: 99mTc- Diethylene-triamine-pentaacetate dynamic renal scintigraphy; DMSA: 99mTc-Dimercaptosuccinic acid; GFR: glomerular filtration rate.

Discussion

In this study, we evaluated 23 pediatric patients who had single kidney hypoplasia, renal agenesis, or nephrectomy in one kidney and parenchymal scar in the other kidney in some cases. We emphasized that changes in GFR would be significant in a scarred, hypoplastic or agenesic kidney and that it should be monitored not only with static 99mTc-DMSA kidney scintigraphy but also with dynamic 99mTc-DTPA kidney scintigraphy and GFR measurement with DTPA.

Masaaki Imamura et al. (2018) reported that DMSA renal screening recommendations may be useful in identifying patients with spina bifida and renal scarring who are already showing symptoms of chronic kidney disease in the transition to adolescence [11]. They analyzed 87 patients (36 men and 51 women), and found that 28 patients (32%) had renal scarring. Patients with renal scarring had significantly higher rates of hypertension (n=13, 46%) and reduced eGFR (n=5, 18%). However, there was no difference in proteinuria between the groups, and the renal scar group had significantly lower eGFR [11]. In our study, we observed a statistically significant decrease in GFR (ml/min) values in the scarring kidney compared to the non-scarring kidney. We also noted a numerical decrease in 99mTc-DTPA (%) and 99mTc-DMSA (%) in the scarring kidney compared to the non-scarring kidney, but this was not statistically significant.

Martin Wennerström et al. (2018) compared 57 patients with non-obstructive renal scarring and 51 patients without renal scarring, and found that the median GFR was 99 in both groups [12]. In patients with unilateral scarring, the individual GFR of scarred kidneys decreased significantly from 46 to 39 over time, while the total GFR remained unchanged. In 7 patients with bilateral scars, GFR decreased from 94 to 84 (p=0.14); this was significantly lower than the GFR of those with unilateral scar at follow-up (p=0.007). Median urine albumin-creatinine ratio was 1.2 and 0.6 mg/mmol in patients with and without scarring, respectively (p = 0.30) [13]. In our study, we also observed a significant decrease in individual GFR of scarred kidneys from 85.6 to 80.9 (p=0.025).

GFR is well preserved until two decades after the first recognized UTI in childhood. However, a significant decrease in individual renal GFR in unilateral scarred kidneys indicates that further follow-up is required. Patients with bilateral scars may have a more serious prognosis, although their number is small. It is reported that renal dysfunction occurs in 10-21% of patients with a single kidney [14]. In a study conducted in Turkey in 2016, the clinical characteristics and follow-up results of children with unilateral renal agenesis and hypoplasia were examined and hyperfiltration was detected in 58% of this group of patients. Compensatory hypertrophy and hyperfiltration, which develop in response to the decrease in renal mass and nephron number, may cause deterioration in renal functions in the long term [15]. Although kidney function tests may be normal in the first two decades, new markers that can detect kidney damage at an early stage and close follow-up of patients from the early stages are important to prevent the development of end-stage renal failure [15,16]. In our study, we aimed to prevent patients in the childhood age group from facing renal failure in the future by closely monitoring patients with renal parenchymal scars and scars, especially in a single kidney, and a decrease in individual kidney GFR values. We recommend close and frequent follow-up of patients who develop permanent renal parenchymal damage, and DMSA scans and frequent checks and follow-ups of renal functions. Thus, kidney functions can be preserved without reaching the end stage.

Our study has some limitations. It is a retrospective study. The number of patients in our study was small because the number of pediatric patients who developed unilateral renal parenchymal scarring was low. However, our study is valuable because it addresses a topic that has been little explored in Turkey and it supports future studies.

Conclusions

In conclusion, we found that GFR measurement provides earlier information than other methods in assessing renal function with DTPA and DMSA in patients with scarred kidneys, before irreversible loss of function occurs. GFR value is statistically more significant than DTPA and DMSA evaluation. Early detection of kidney damage is vital. Our study findings need to be validated by a larger patient group.

***Acknowledgement**: I would like to thank Prof. Dr. İpek Önunan*

***Funding:** The authors received no financial support for the research, authorship, and/or publication of this article.*

***Conflict of interest:** The authors declare that they have no conflict of interest.*

***Informed Consent:** All participants in the study provided informed consent and written permission to publish their data.*

***Ethical statement:** The study was initiated after receiving the approval of Manisa Celal Bayar University Faculty of Medicine Health Sciences Ethics Committee (Approval date and No: 31/08/2023/ 20.478.486/ 1977).*

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