Tc-99m-Mercaptoacetyltriglycine and Tc-99m-Dimercaptosuccinic Acid Scintigraphies for the Evaluation of Renal Parenchymal Lesions in Infants

Bebeklerdeki Renal Parankim Lezyonlarının Değerlendirilmesinde Tc-99m-Merkaptoasetiltriglisin ve Tc-99m-Dimerkaptosüksinik Asit Sintigrafileri

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ABSTRACT Objective: Scintigraphy with Tc-99m dimercaptosuccinic acid (DMSA) is considered a reference method for the assessment of renal parenchymal lesions and estimation of differential renal function (DRF). Compared with Tc-99m mercaptoacetyltriglycin (MAG3), the disadvantages of DMSA are relatively higher radiation exposure to the kidney and longer procedural time. The aim of this study was to evaluate the performance of Tc-99m MAG3 dynamic renal scintigraphy in the detection of renal parenchymal defects and in the estimation of DRF in comparison with Tc-99m DMSA scintigraphy. **Material and Methods:** A retrospective review of the records indicated that 29 infants (20 boys and 9 girls) aged less than 1 year underwent both DMSA and MAG3 scintigraphies. The parenchymal phases of MAG3 scintigraphy were compared to DMSA images. Differential function was calculated based on the MAG3 and DMSA methods and the results were compared. **Results:** The findings of the two methods corresponded completely in 90% of patients. There was no significant difference between calculated DRF from DMSA and MAG3 images. There was a high correlation between the DRF obtained using the two methods ($r= 0.91$ and $r= 0.90$ for the left and right kidney, $p< 0.01$). The sensitivity and specificity of the MAG3 cortical images were calculated as 92% and 78%. **Conclusion:** We suggest that either a MAG3 or a DMSA scan can be used for the calculation of DRF. However, because of the low specificity of MAG3 cortical analysis, DMSA scintigraphy is required for the definitive diagnosis and management of renal cortical lesions.

Key Words: Radioisotope renography; kidney cortex; kidney cortex necrosis; technetium tc-99m dimercaptosuccinic acid; technetium tc-99m mertiatide

ÖZET Amaç: Differansiye renal fonksiyonu (DRF)'nun hesaplanmasında ve renal parankimal lezyonların değerlendirilmesinde Tc-99m dimerkaptosüksinik asit (DMSA) sintigrafisi referans yöntem olarak kabul edilmiştir. Teknesyum-99m merkaptoasetiltriglisin (MAG3) ile karşılaştırıldığında Tc-99m DMSA'nın dezavantajları, böbrekler üzerindeki görece daha yüksek radyasyon dozu ve işlemin uzun sürmesidir. Bu çalışmanın amacı, Tc-99m MAG3 dinamik renal sintigrafinin DMSA sintigrafisi ile karşılaştırılmasıyla, renal parankim defektlerinin değerlendirilmesindeki ve DRF'nin hesaplanmasındaki performansını belirlemektir. **Gereç ve Yöntemler:** Bir yaş altındaki toplam 29 bebeğin (20 erkek, 9 kız), hem Tc-99m MAG3 hem de Tc-99m DMSA sintigrafileri retrospektif olarak incelenmiştir. Renal MAG3 sintigrafisinin parankimal fazı DMSA görüntüleri ile karşılaştırılmıştır. Diferansiye fonksiyonlar MAG3 ve DMSA yöntemleri ile hesaplanmış ve sonuçlar karşılaştırılmıştır. **Bulgular:** İki yöntemin bulguları %90 hastada uyumlu bulunmuştur. Teknesyum-99m DMSA ve MAG3 görüntülerinden hesaplanan DRF değerleri arasında istatistiksel olarak anlamlı fark yoktur. İki yöntemin kullanılması ile elde edilen DRF değerleri yüksek korelasyon göstermektedir ($r= 0.91$ ve $r= 0.90$; sol ve sağ böbrek için, $p< 0.01$). Kortikal faz MAG3 görüntülerinin duyarlılık ve özgüllüğü %92 ve %78 olarak hesaplanmıştır. **Sonuç:** Biz, DRF hesaplanmasında Tc-99m MAG3 veya Tc-99m DMSA sintigrafisinin kullanılabileceğini düşünüyoruz. Ancak, kortikal analizde Tc-99m MAG3 özgüllüğünün düşük olması nedeni ile renal kortikal lezyonların kesin tanısı ve tedavisinde Tc-99m DMSA sintigrafisi tercih edilmelidir.

Anahtar Kelimeler: Radyoizotop renografi; böbrek korteksi; böbrek kortikal nekrozu; teknesyum-99m dimerkaptosüksinik asit; teknesyum-99m merkaptoasetiltriglisin

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Renal parenchymal (cortical) scintigraphy is indicated for the diagnosis and follow-up of focal (functional or anatomical) disorders of the kidneys, especially in children.[1-3] Scintigraphy with Technetium-99m dimercaptosuccinic acid (Tc-99m DMSA) is considered a reference method for the assessment of parenchymal lesions and the estimation of DRF.[1,4] Technetium-99m DMSA is highly sensitive in the detection of focal defects, and remains the gold standard method because of its well known advantages.[3,4] However, it has also some disadvantages, such as the fact that the static imaging procedure is performed 3-6 hr after the intravenous (i.v.) injection of the radiopharmaceutical, it requires effective immobilization of the patient for 30-60 min and it involves a relatively high radiation exposure rate, especially in young children.[1,5]

Technetium-99m mercaptoacetyltriglycin (MAG3) is a renal imaging agent, excreting mainly tubular secretions and is used for planar dynamic studies.[4,6] Global renal perfusion and functions (concentration and excretion) can be assessed with Tc-99m-MAG3.[5,7,8] For most organs, the absorbed radiation dose of Tc-99m-MAG3 were lower than that from Tc-99m-DMSA.[5] Moreover, simultaneous injection of Tc-99m-MAG3 and a diuretic (F0 protocol) resulted in lower than the usually reported radiation dose for the urinary bladder (target organ) and the gonads, and allowed evaluation of the drainage system.[1,4,5] The MAG3 dynamic studies do not require any waiting period after injection of the radiopharmaceutical and their acquisition time is about 20-30 min.[1,7,9] Some investigators have evaluated the use of planar dynamic MAG3 scintigraphy for investigating the renal parenchyma in urinary tract infection patients, with variable results being reported.[1,4,7,9]

This study was planned to evaluate the performance of Tc-99m MAG3 dynamic renal scintigraphy in the detection of renal parenchymal lesions and in the estimation of DRF and to compare the results of this method with those of Tc-99m DMSA scintigraphy in infants.

MATERIAL AND METHODS

A total of 29 infants (20 boys and 9 girls; totaling 58 kidneys) aged 0-1 year (mean, 0.48 ± 0.5 months), were included in the study. Informed consent was obtained in all cases before any tests were performed. All patients underwent urinalysis and routine blood tests for urinary infection prior to scintigraphic studies (Table 1). All patients with various kidney disorders, including clinical indications for renal parenchymal evaluation and suspicion for unilateral or bilateral cortical areas with decreased function, underwent both DMSA and MAG3 scintigraphy within three weeks of each other.

18-56 MBq (0.5-1.5 mCi) Tc-99m DMSA was injected intravenously. After 3-6 hours, planar Tc-99m DMSA images at anterior, posterior, and right and left posterior oblique positions were acquired for 500 kcounts. A CamStar AC/T gamma camera (GE-Milwaukee, Wisc., USA) equipped with a LE-AP collimator was used. Imaging parameters were selected at 256 x 256 matrix and 140 keV ± 20% energy window. All patients were sedated with chloral hydrate for effective immobilization during the study. Static images were visually evaluated for focal defects. The fractional left and right renal activity was calculated, using the background-corrected geometric mean method.

TABLE 1: Routine laboratory values for urinary infection analysis for all 29 patients in the study.

WBC		CRP		RBC in urine		WBC in urine		Urinary microorganisms	
N	A	N	A	N	A	N	A	P	Ne
19	10	19	10	16	13	17	12	11	18

WBC: white blood cells; CRP: C-reactive protein; RBC: red blood cells

N Case numbers with normal values, A Case numbers with abnormal values, P Case numbers with positive microorganism in urine, Ne Case numbers with negative microorganism in urine.

On a separate day, after a bolus injection of Tc-99m MAG3, renography was carried out with the patients well hydrated and in a supine position with a dynamic 25 min acquisition at 1s/fr for 60 sec, 15s/fr for 4 min, and 30s/f for 20 min. The patients were injected with a dose of 18-74 MBq (0.5-2 mCi; IV) Tc-99m MAG3. Imaging parameters were selected at a 128 x 128 matrix and 140 keV ± 20% energy window. Renal and perirenal regions were created and time-activity curves were generated for both kidneys. The DRF was calculated from the slope of the background-subtracted renal curves. The analysis was performed with an image obtained 60-300 sec following the injection. The DRF results of MAG3 scintigraphy were compared to DMSA results for each kidney. Then, the parenchymal phase (4 min) images of MAG3 were compared to DMSA images for right and left kidneys separately.

Statistical analysis using a paired Student's t test and Chi-Square test was performed in this retrospective study, in which DMSA scintigraphy was considered the gold standard.

RESULTS

The findings corresponded completely in 90% of patients for both kidneys. Differential renal function of both radiopharmaceuticals correlated very well and the correlation coefficient between the two methods was 0.99 ($p \leq 0.01$) for both kidneys (Figure 1A, 1B and 2A, 2B).

Comparison between the summed Tc-99m MAG3 image and the Tc-99m DMSA images for 29 left kidneys yielded 100% sensitivity, 66% specificity and 86% accuracy (Table 2). For the right kidneys (n= 29), the sensitivity was 95%, the specificity 89% and the accuracy 86% (Table 3).

The image quality was evaluated for each kidney via visual inspection by two observers. A kidney was considered abnormal if the DRF was <43% and/or if a focal defect was seen on the DMSA. For imaging renal parenchyma, the MAG3 and DMSA studies were in agreement in 50/58 kidneys and 25/29 infants (Figure 1A, B). In three kidneys, the MAG3 image was evaluated as normal while the DMSA was abnormal for the right kidney (Figure 2A, B). In five kidneys, the MAG3 images were evaluated as abnormal while the DMSA were nor-

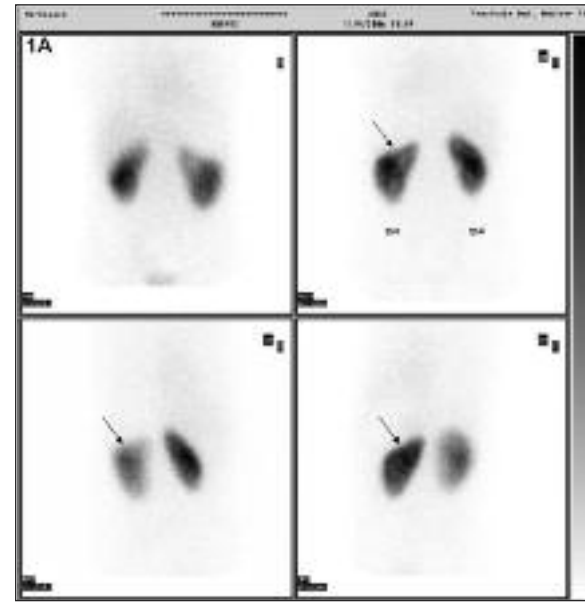

FIGURE 1A: Tc-99m DMSA scan of an infant shows a focal parenchymal defect in the left upper pole. Differential renal function (DRF) of each kidney is 50%.

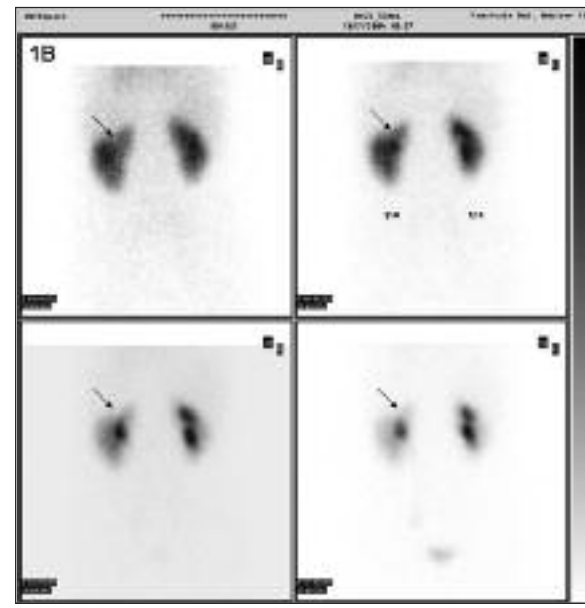

FIGURE 1B: Regional parenchymal dysfunction in the left upper pole is detected on a dynamic MAG3 study at 2-3-4 and 5 min (arrows) in the same infant presented in figure 1A with clinical and laboratory presentation compatible with acute pyelonephritis. The DRF of each kidney is also 50% according to the DMSA scan. (The left kidney is bigger than the right on USG.) We think that this equality in DRF is false; this may have resulted from the kidneys being different in size, with the left kidney appearing larger than the right on USG.

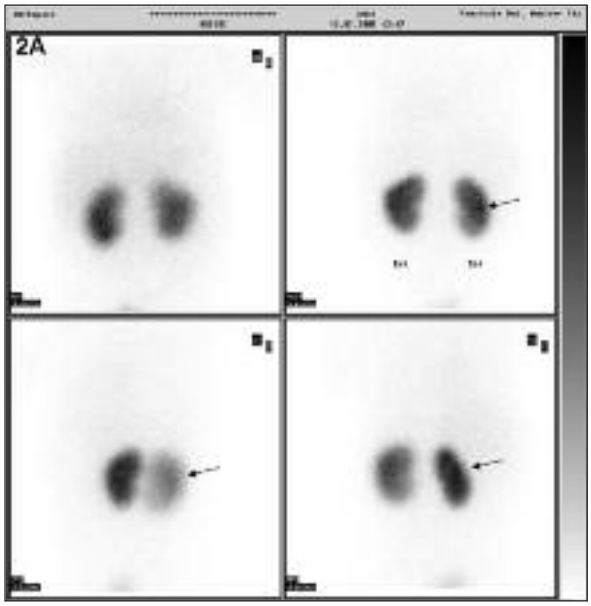

FIGURE 2A: The DMSA scan in an infant with acute pyelonephritis shows a parenchymal defect and slightly decreased uptake in the right kidney. DRF for left and right kidneys are 53% and 47%, respectively.

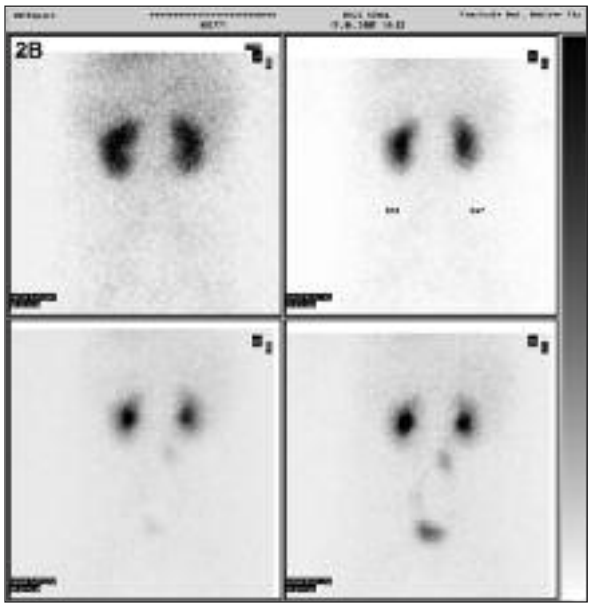

FIGURE 2B: Normal parenchymal uptake in the right and left kidneys are observed on the dynamic MAG3 study at 2, 3, 4 and 5 min in the same infant in Figure 2A. The DRFs of left and right kidneys are 53% and 47%, respectively.

mal (four left kidneys and one right kidney). However, there was a good correlation between two scintigraphic studies for detecting right and left renal parenchymal lesions (Kappa= 0.700).

DISCUSSION

Technetium-99m DMSA is currently considered the best agent for renal imaging in clinical situations such as acute pyelonephritis or chronic reflux nephropathy in children.[1,3,4,9-11] However, DMSA requires a waiting period of at least 3 hr after injection, an acquisition time of no less than 30 min and effective immobilization or sedation of the patient.[1,4] Besides, in pediatric patients, there is a need to reduce the radiation exposure as much as possible. The Tc-99m MAG3 is an ideal agent for dynamic renal scans because it exhibits high plasma protein binding (90%) and a high renal extraction fraction (40%), with 70% of the isotope being in the bladder at 30 min.[1,7,12] The radiation exposure from MAG3 (whole body dose, 0.25 mGy/MBq) is less than that of DMSA (WB dose 1.60 mGy/MBq).[5] MAG3 is therefore a suitable agent for use whenever drainage of the kidney requires investigation.[7,8,13] A substantial contrast (appropriate for assessment of parenchymal data) between the renal parenchyma and the background is obtained during the early (4-5 min) period after radiopharmaceutical injection. Published studies reported variable results, when the simple summed MAG3 image was compared to DMSA for the detection of renal parenchymal defects.[1,4,5,7,9,14] The greatest advantage of MAG3 is the short duration of the test (5

TABLE 2: Comparison of MAG3 to DMSA images for 29 left kidneys.

	Tc-99m MAG3 (60-300 sec image)	
Tc-99m DMSA	**Normal**	**Abnormal**
Normal	8	4
Abnormal	0	17

Sensitivity=100%, Specificity= 66%, Accuracy= 86% for Tc-99m MAG3 study.

TABLE 3: Comparison of MAG3 to DMSA images for 29 right kidneys.

	Tc-99m MAG3 (60-300 sec image)	
Tc-99m DMSA	**Normal**	**Abnormal**
Normal	8	1
Abnormal	3	17

Sensitivity= 95%, Specificity= 89%, Accuracy= 86% for Tc-99m MAG3 study.

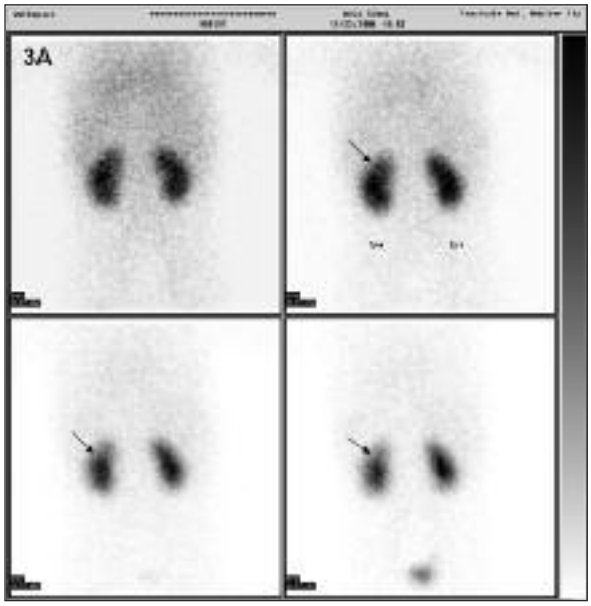

FIGURE 3A Parenchymal defect in the left upper pole is detected on a dynamic MAG3 study of an infant with normal DMSA scan. We think that this defect in the left kidney is false and that it has resulted from the projection of the 11th rib.

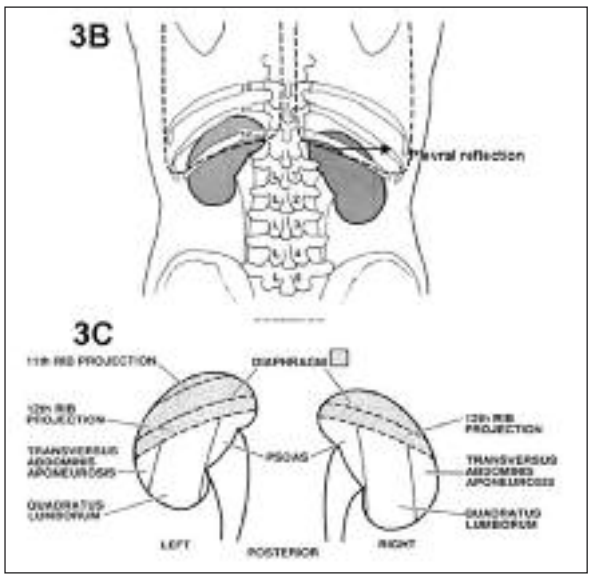

FIGURE 3B, C: The attenuation of the 11th left rib projection and diaphragm.

min for parenchymal imaging), which requires no waiting period after injection. Immobilization is easier in this short period and sedation is not necessary for infants.[1,4]

Our study showed that Tc-99m MAG3 dynamic imaging had a similar sensitivity (95-100%) to DMSA scintigraphy for renal cortical lesions in infants. Some patients had only MAG3 abnormalities, resulting in a lower specificity (66-89%) for MAG3 compared with DMSA when the latter was considered the gold standard test. The main disadvantages of the Tc-99m-MAG3 images are the use of only posterior projections that may be an important drawback in patients with abnormal kidney positions and lower image counts and larger pixel size because of dynamic-acquisition. Most of the MAG3 renal cortical abnormalities were observed in the left upper pole of the kidney (Figure 3A). The explanation for this is probably related to the attenuation by the projection of the 11th left rib and the diaphragm (pars lumbalis diafragmatis) because of the higher relative location of the left kidney (Figure 3B, 3C).[15] The correlation between results regarding the exact site of the focal abnormality revealed more abnormalities on functional MAG3 image than on the DMSA scan. This finding is probably related to the summed images of Tc-99m MAG3 being noisy, resulting in a high false positive rate and giving a low specificity. However, renography may provide interesting and valuable information regarding the transit parameters. We suggest that combining the transit parameters with the renal imaging data in one single study is a major advantage of MAG3 renography without extra burden to the infant.

In this homogenous group, the results showed a high correlation ($r= 0.99$; $p\leq 0.01$) between the DRF measured by MAG3 and DMSA. We have demonstrated that the Tc-99m MAG3 is also an ideal agent to assess DRF in infants since it delivers almost identical information about the renal parenchymal function to the DMSA scan. Additionally, it provides more information about perfusion, excretion and pelvic drainage. Moreover, the radiation exposure rate is significantly lower in MAG3 scanning than that of DMSA.[1,5,7,12,16,17] This experiment supports the possibility that MAG3 scintigraphy may be a safe, fast and accurate technique for the evaluation of renal cortical defects, especially in infants.[1,5,7]

CONCLUSION

Our results showed that in routine clinical practice, a Tc-99m MAG3 scan would provide accurate DRF and that most of parenchymal lesions detected

on DMSA scans could be identified on MAG3 parenchymal scans in infants with normal kidney position. The greatest advantage of this technique is that it allows the completion of the study within 5 min after injection; it also has the advantage of a smaller radiation dose in infants. However, because of the low specificity of Tc-99m MAG3 cortical analysis, Tc-99m DMSA scintigraphy is required for the definitive diagnosis and management of renal cortical lesions.

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