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# Comparison of $^{99m}$Tc-DMSA, $^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3 Renal Scintigraphy in the Calculation of Relative Renal Function

## Rölatif Renal Fonksiyonunun Hesaplanmasında $^{99m}$Tc-DMSA, $^{99m}$Tc-DTPA ve $^{99m}$Tc-MAG3 Renal Sintigrafilerinin Karşılaştırılması

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**What's known on the subject? and What does the study add?**

Renal scintigraphies are frequently used tests to evaluate kidney parenchyma and collecting system. The relative renal function value can be calculated for both kidneys in each of these tests. This study shows whether there is a significant difference in the relative renal function calculation by comparing static renal scintigraphy (with DMSA) and the two most commonly applied dynamic renal scintigraphy (with DTPA and MAG3).

## Abstract

**Objective:** The aim of this study was to compare Tc-$^{99m}$ dimercaptosuccinic acid ($^{99m}$Tc-DMSA) renal cortical scintigraphy and Tc-$^{99m}$ diethylene triamine pentaacetic acid ($^{99m}$Tc-DTPA) and Tc-$^{99m}$ mercaptoacetyltriglycine ($^{99m}$Tc-MAG3) dynamic renal scintigraphy in the evaluation of relative renal function (RRF).

**Materials and Methods:** Forty seven patients with renal cortical scintigraphy (with $^{99m}$Tc-DMSA) and dynamic renal scintigraphy (with $^{99m}$Tc-DTPA or $^{99m}$Tc-MAG3) were included in this retrospective study. RRF obtained from $^{99m}$Tc-DMSA, $^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3 scintigraphies, clinical and demographic data were statistically analyzed.

**Results:** There was a high correlation between $^{99m}$Tc-DMSA renal cortical scintigraphy and dynamic renal scintigraphy ($^{99m}$Tc-DTPA or $^{99m}$Tc-MAG3) in terms of RRF evaluation (r=0.981, p<0.001 and r=0.918, p=<0.001, respectively). While the Bland Altman plot showed an average difference of 3.30 between RRFs measured by $^{99m}$Tc-DMSA and by $^{99m}$Tc-DTPA, the difference between that with $^{99m}$Tc-DMSA and $^{99m}$Tc-MAG3 was 0.08.

**Conclusion:** In conclusion, this study showed a high level of compliance between $^{99m}$Tc-DMSA renal scintigraphy and dynamic renal scintigraphy ($^{99m}$Tc or $^{99m}$Tc-MAG3) in the evaluation of RRF. Time loss, radiation exposed to the patients and economic losses are minimized with the use of a single method suitable for the purpose.

**Keywords:** Relative renal function, $^{99m}$Tc-DMSA renal cortical scintigraphy, Dynamic renal scintigraphy

## Öz

**Amaç:** Bu çalışmanın amacı Tc-$^{99m}$ dimerkaptosüksinikasit ($^{99m}$Tc-DMSA) böbrek kortikal sintigrafisi ile Tc-99m dietilentriaminpentaasetik asit (99mTc-DTPA) ve Tc-$^{99m}$ merkaptoasetiltriglisin ($^{99m}$Tc-MAG3) ile dinamik böbrek sintigrafilerini rölatif böbrek fonksiyonu hesaplanması (RBF) yönünden karşılaştırmaktır.

**Gereç ve Yöntem:** Bu retrospektif çalışmaya; bölümümüzde çeşitli tanılar ile böbrek kortikal sintigrafisi ($^{99m}$Tc-DMSA ile) ve dinamik böbrek sintigrafisi ($^{99m}$Tc-DTPA veya $^{99m}$Tc-MAG3 ile) uygulanmış 47 hasta dahil edildi. $^{99m}$Tc-DMSA, $^{99m}$Tc-DTPA ve $^{99m}$Tc-MAG3 sintigrafilerinden elde edilen RBF değerleri ile klinik ve demografik veriler istatistiksel olarak analiz edildi.

**Bulgular:** RBF değerlendirme açısından $^{99m}$Tc-DMSA statik böbrek sintigrafisi ile dinamik böbrek sintigrafileri ($^{99m}$Tc-MAG3 veya $^{99m}$Tc-DTPA ile) arasında yüksek düzeyde korelasyon bulundu (r=0,981, p<0,001; r=0,918, p=<0,001). $^{99m}$Tc-DMSA ve $^{99m}$Tc-DTPA ile ölçülen RBF (%) arasındaki Bland Altman grafiği, 3,30'luk ortalama fark gösterirken, $^{99m}$Tc-DMSA ve $^{99m}$Tc-MAG3'ün Bland Altman grafiği 0,08'lik ortalama fark gösterdi.

**Sonuç:** Sonuç olarak bu çalışma RBF değerlendirme açısından $^{99m}$Tc-DMSA böbrek sintigrafisi ile dinamik böbrek sintigrafileri ($^{99m}$Tc-MAG3 veya $^{99m}$Tc-DTPA ile) arasında yüksek düzeyde uyum olduğunu göstermiştir. Amaca uygun tek yöntem kullanımı ile hastanın maruz kaldığı radyasyon, zaman kaybı ve ekonomik kayıplar en aza indirilmiş olur.

**Anahtar Kelimeler:** Rölatif böbrek fonksiyonu, 99mTc-DMSA renal kortikal sintigrafisi, Dinamik renal sintigrafi

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## Introduction

Relative renal function (RRF) refers to the relative contribution rate of each kidney to total renal function. This rate is particularly important in patients with unilateral renal disorders and obstructive uropathies, as well as in terms of monitoring functional losses during follow-up. Kidneys with a RF value below 10% are unlikely to recover and nephrectomy is commonly recommended (1,2). In addition, it is known that RRF, calculated by scintigraphy, is a useful parameter in order to show whether the kidney function is improved or not from the early period of pyeloplasty (3). Likewise, it is used in the evaluation of the kidney donor's renal function and to choose less functioning kidney. Therefore, radioisotopic RRF evaluation is a recommended test for the preoperative evaluation of potential renal donors (4).

Although recent studies on the calculation of RRF with computed tomography and magnetic resonance imaging have been published (5,6), the most commonly used method is scintigraphic imaging. Among these, Tc-$^{99m}$ dimercaptosuccinic acid ($^{99m}$Tc-DMSA) renal cortical scintigraphy is the most sensitive method to demonstrate parenchymal injury due to pyelonephritis and to collect data on RRF (7). $^{99m}$Tc-DMSA is a radiopharmaceutical that binds to the proximal tubular cells in the renal cortex at a rate of 40-65% at 2 hours after the injection and allows visualization of the cortex (8). RRF can also be calculated by dynamic renal scintigraphies performed with Tc-$^{99m}$ mercaptoacetyltriglycine ($^{99m}$Tc-MAG3) and Tc-$^{99m}$ diethylene triamine pentaacetic acid ($^{99m}$Tc-DTPA). $^{99m}$Tc-DTPA is the only radiopharmaceutical that is filtered by the glomerulus and can be used both for imaging the kidney and measuring the glomerular filtration rate. $^{99m}$Tc-MAG3 is highly protein bound and the extraction rate is 40-50%. This ratio is more than twice that of $^{99m}$Tc-DTPA. Therefore, $^{99m}$Tc-MAG3 is preferred over $^{99m}$Tc-DTPA in patients with suspected obstruction and renal dysfunction (9). There is no consensus on the interchangeability of these tests in the calculation of RRF.

The aim of this study was to compare $^{99m}$Tc-DMSA scintigraphy and $^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3 scintigraphy in the evaluation of RRF.

## Materials and Methods

### Patient Preparation

A total of 47 patients, who underwent renal cortical (with $^{99m}$Tc-DMSA) and dynamic renal scintigraphy ($^{99m}$Tc-DTPA or $^{99m}$Tc-MAG3) for several reasons between 2015 and 2019, were included in this retrospective study. Twenty-eight patients underwent $^{99m}$Tc-DMSA and $^{99m}$Tc-DTPA renal scintigraphy and 19 patients underwent $^{99m}$Tc-DMSA and $^{99m}$Tc-MAG-3 renal scintigraphy. Inclusion criterion was a time interval of less than one month between static and dynamic renal scintigraphy. Single kidney and horseshoe kidney patients were excluded from the study.

### Dynamic and Static Renal Scintigraphy

$^{99m}$Tc-DMSA scintigraphy imaging was performed two hours after the injection (recommended dose according to age and weight is 1-5 mCi) in the supine position using a dual head gamma-camera (E-CAM, Siemens, Germany) with low-energy parallel-hole collimator. RRF (%) was calculated by using manually drawn regions of interests (ROIs) around the kidney for the right and left kidneys and for background activity extraction (Figure 1A).

Dynamic renal scintigraphy was performed just after injection (recommended doses according to age and weight is between 1-5 mCi) in the supine position using a dual head gamma-camera (E-CAM, Siemens, Germany) with low-energy all-purpose parallel-hole collimator. Routine diuretic injection was performed at 15 min in dynamic renal scintigraphy. RRF (%) rates were calculated by using manually drawn ROIs around the kidney for the right and left kidneys and for background activity extraction (Figure 1B). RRF was measured on a composite image (2-3 min after the injection).

### Statistical Analysis

Continuous variables are reported as mean ± standard deviation, whereas categorical variables are presented as absolute numbers. Spearman's correlation coefficient was used for correlation analysis. A p value of less than 0.05 was considered statistically significant. All analyses were performed using the SPSS software (version 20.0). The Bland-Altman analysis was used with R software to assess the degree of agreement between RRF values.

## Results

A total of 47 patients (18 male, 29 female) with the mean age of 18.21±19.83 (1-68 years) were included in the study. Renal scintigraphy was performed in 22 (46.8%) patients due to infection, in 12 (25.5%) due to

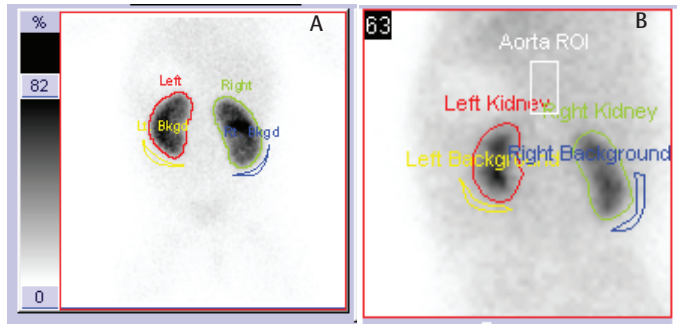


**Figure 1.** Regions of interest drawn in $^{99m}$Tc-DMSA (A) and dynamic renal scintigraphy (B)

hydronephrosis and 13 (27.7) for other diagnoses.

The correlation between 99mTc-DMSA and dynamic scintigraphy ($^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3) was significantly high (p=0.934). The correlation between $^{99m}$Tc-DMSA and $^{99mTc}$-MAG3 was higher than the correlation between $^{99m}$Tc-DMSA and $^{99m}$Tc-DTPA (Table 1, Figure 2).

Bland Altman plot between RRFs (%) measured using $^{99m}$Tc-DMSA and $^{99m}$Tc-DTPA showed a mean difference of 3.30 [95% confidence interval (CI) = (5.72; 0.88)]. The limit of agreement ranged from 14.28 to -7.67.

On the other hand, Bland Altman plot for between RRFs (%), measured by $^{99m}$Tc-DMSA and $^{99m}$Tc-MAG3 showed a mean difference of 0.08 [95% confidence interval (CI) = (1.92; -1.75)]. The limit of agreement ranged from 8.61 to -8.44 (Figure 3).

## Discussion

**Table 1. Correlation of RRF values between $^{99m}$Tc-DMSA and $^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3 scintigraphies**

| | $^{99m}$Tc-DTPA right | $^{99m}$Tc-DTPA left | $^{99m}$Tc-MAG3 right | $^{99m}$Tc-MAG3 left |
|---|---|---|---|---|
| $^{99m}$Tc-DMSA left | - | r=0.918 p<0.001 | - | r=0.981 p<0.001 |
| $^{99m}$Tc-DMSA right | r=0.918 p<0.001 | - | r=0.981 p<0.001 | - |

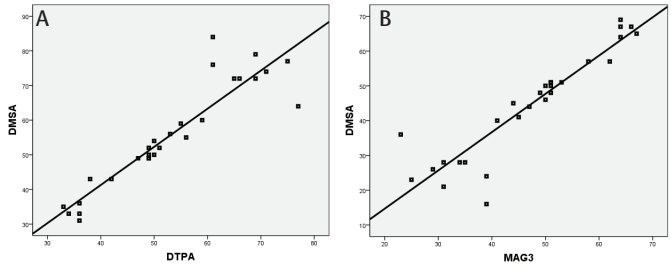


**Figure 2.** Correlation of RRF values measured by $^{99m}$Tc-DMSA, $^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3 scintigraphy

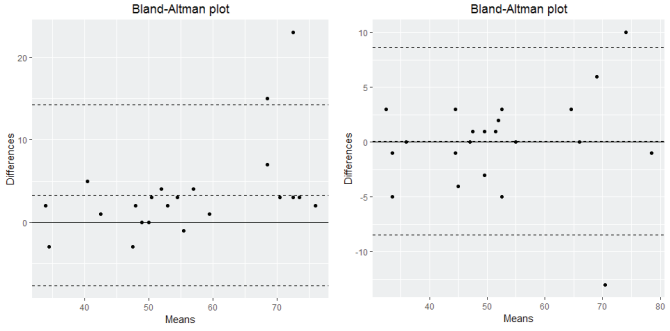


**Figure 3.** Bland-Altman plots between RRFs (%), measured by $^{99m}$Tc-DMSA and $^{99m}$Tc-DTPA (A), measured by the $^{99m}$Tc-DMSA and 99mTc-MAG3 (B)

In this study, measurements of RRF obtained by $^{99m}$Tc-DMSA, $^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3 renal scintigraphy were found to be highly compatible with each other. The agreement between $^{99m}$Tc-DMSA and $^{99m}$Tc-MAG3 measurements was much better than with $^{99m}$Tc-DTPA.

RRF is an important parameter used for determination and monitoring of changes in renal function. Scintigraphy methods are often used to evaluate relative function. $^{99m}$Tc-DMSA scintigraphy allows the imaging of renal cortical structure and thus it is a recommended test for evaluating infection and RRF (10). In their study, Momina et al. (11) compared RRF calculated with $^{99m}$Tc-DMSA and $^{99m}$Tc-DTPA scintigraphy and found a positive correlation between the two methods (r=0.996, p<0.001). In a similar study, Yalcin et al. (12) compared RRF values calculated by $^{99m}$Tc-DTPA with those calculated by $^{99m}$Tc-DMSA and reported that $^{99m}$Tc-DTPA was also a good method for calculating RRF.

There are different diuretic administration protocols. Some of those are F + 20, F-15 and F-0 protocols. In a study comparing $^{99m}$Tc-DTPA and DMSA scintigraphy in terms of RRF; F +10 diuretic application in DTPA scintigraphy provided more compatible results compared to F0 protocol (13). In our study, diuretic injection was performed in all the dynamic studies at 15 min.

In a study by Aktas and Inanir (14) comparing $^{99m}$Tc-DMSA and $^{99m}$Tc-MAG3, it was found that RRF estimations with both methods showed significant correlation with good reproducibility in children with hydronephrosis. In a study by Othman et al. (15) comparing $^{99m}$Tc-DMSA and $^{99m}$Tc-MAG3 to evaluate renal cortex and RRF; it was reported that $^{99m}$Tc-MAG3 scintigraphy provided adequate imaging for renal cortex evaluation and RRF. Ritchie et al. (16) reported that there was no significant difference between $^{99m}$Tc-DMSA and $^{99m}$Tc-MAG scintigraphy in terms of RRF and cortical evaluation. As a result, if the RRF is normal and there is no evidence of scar in the renal cortex on $^{99m}$Tc-MAG3 scintigraphy, $^{99m}$Tc-DMSA scintigraphy is not necessary.

In our study, we compared $^{99m}$Tc-DMSA with $^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3 to calculate RRF. We found a high correlation between $^{99m}$Tc-DMSA and dynamic scintigraphies. However, the correlation between $^{99m}$Tc-DMSA and $^{99m}$Tc-MAG3 was a little better than with $^{99m}$Tc-DTPA. In addition, in the Bland Altman analysis, the mean difference value of $^{99m}$Tc-DMSA with 99mTc-MAG3 was very low. In a similar study, Dostbil et al. (17) reported that the RRF calculated by $^{99m}$Tc-DMSA, $^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3 were compatible with each other and any of these techniques could be used. In their study of rabbits with unilateral ureteral obstruction, Lee et al. (18) compared renal function measurements obtained using $^{99m}$Tc-DMSA with

that by $^{99m}$Tc-MAG3, and $^{99m}$Tc-DTPA and found no significant difference. They concluded that $^{99m}$Tc-MAG3, and $^{99m}$Tc-DTPA could be used in place of the static image of $^{99m}$Tc-DMSA.

A study performed with $^{99m}$Tc-DMSA, $^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3 in newborns and children showed that the kidney was the highest radiation-absorbed organ in the body and the radiation dose was the highest in $^{99m}$Tc-DMSA, and least in $^{99m}$Tc-MAG3 (19). In a study by Marcia et al. (20) the total radiation dose absorbed to the kidney was 0.00466 and 0.00339 mGy.MBq$^{-1}$ in renal scintigraphy with $^{99m}$Tc-DTPA and $^{99m}$Tc-MAG3, respectively. Total absorbed radiation dose to the kidney in dynamic renal scintigraphy consists of the radiopharmaceutical activity in the kidney and in the bladder. In $^{99m}$Tc-DMSA scintigraphy, the absorbed dose to the kidney was 0.17881 mGy.MBq$^{-1}$. Total absorbed radiation dose to the kidney in DMSA renal scintigraphy consists of the radiopharmaceutical activity in the kidney, bladder, spleen and liver. According to these results, the lowest radiation dose was determined in $^{99m}$Tc-MAG3 study.

## Conclusion

In conclusion, this study suggests that there is a high level of correlation between $^{99m}$Tc-DMSA renal scintigraphy and dynamic renal scintigraphy ($^{99m}$Tc-MAG3 and $^{99m}$Tc-DTPA) in terms of RRF evaluation. For this reason, any of these tests (the most appropriate for the clinical purpose) can be selected in the RRF evaluation. In this way, radiation, time loss and economic losses are minimized by a single measurement method.

### Ethics

**Ethic Committee Approval:** This study was supported by Gaziosmanpaşa University Research Fund (project number: 19-KAEK-109).

**Informed Consent:** This was not necessary for retrospective study.

**Peer-review:** Externally peer-reviewed.

### Authorship Contributions

Concept: F.D., Design: F.D., M.D., Data Collection or Processing: F.D., M.D., Analysis or Interpretation: F.D., M.D., Literature Search: F.D., M.D., Writing: F.D., M.D.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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