Simultaneous Anterior-Posterior Dynamic Renal Scintigraphy for the Evaluation of Congenital Abnormal Kidneys

Konjenital Anomalili Böbreklerin Dinamik Böbrek Sintigrafisi ile Değerlendirilmesinde Eş Zamanlı Ön-Arka Görüntülemenin Rolü

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ABSTRACT Objective: To describe the potential benefits of simultaneous anterior-posterior dynamic renal scintigraphy (DRS) in congenital abnormal kidneys (CAK). **Material and Methods:** Simultaneous anterior-posterior projection DRS with 99mTc diethylene triamine pentaacetic acid (DTPA) by a dual-headed gamma camera was performed in 13 CAK patients. Dynamic renal functions were evaluated visually; anterior-posterior renograms were obtained. Differential renal functions (DRF) were calculated in 7 patients using geometric means. Eight patients had dimercaptosuccinic acid (DMSA) cortical renal scintigraphy (CRS). Hypoactive areas on CRS were counted and compared with DRS on the basis whether they displayed "fill-in" with 99mTc DTPA. DRFs of DRS and CRS were compared. **Results:** CAK types were pelvic-horseshoe-fused triple-cross ectopic kidneys. The best visual dynamic renal function evaluation in the anteriorly located kidneys/kidney parts were obtained from the anterior images. Renograms of all the anteriorly located CAK obtained from the anterior acquisition displayed renal functions better than the posterior renograms. Twenty two out of 27 regions showing decreased DMSA uptake from the anterior projection showed "fill-in" with 99mTc DTPA on anterior views of the DRS. Sixteen of 20 posterior hypoactive regions displayed "fill-in" on posterior projection DRS images. Five regions with decreased DMSA uptake from the anterior projection and four from the posterior did not show "fill-in" pattern on either projection in DRS. DRF of DRS were in concordance with the DRF of CRS. **Conclusions:** Simultaneous anterior-posterior projection DRS in CAK can assess dynamic functions of the anteriorly/posteriorly located kidneys of a patient in a single scintigraphic study, gives the oppurtunity of calculating DRF with geometric mean counts, and helps to differentiate parenchymal damage from dilated collecting systems.

Key Words: Technetium Tc 99m DTPA, radionuclide imaging; kidney; kidney pelvis

ÖZET Amaç: Bu çalışmada, konjenital anomalili böbreklerde (KAB) dinamik böbrek sintigrafisinin (DBS) eş zamanlı olarak ön-arka pozisyondan yapılmasının potansiyel yararlarını araştırmak ve tariflemek amaçlandı. **Gereç ve Yöntemler:** On üç KAB hastasının Tc-99m "dietilen triamin pentaasetik asit"(DTPA) DBS çekimleri eş zamanlı ön-arka görüntüleme için çift-başlı gama kamera kullanılarak gerçekleştirildi. Dinamik böbrek fonksiyonları görsel ve ön-arka sintigrafik bilgilerden oluşturulan böbrek zaman-aktivite eğrileriyle (BZAE) değerlendirildi. Yedi hastada her böbreğin hastadaki toplam böbrek fonksiyonuna katkısı [diferansiyel böbrek fonksiyonu (DBF)] ön, arka sintigrafik bilgilerin geometrik ortalamasıyla hesaplandı. Sekiz hastanın kortikal "dimercaptosuccinic acid" (DMSA) böbrek sintigrafisi (KBS) mevcuttu. Bu hastalarda KBS'deki hipoaktif alanların sayısı bulundu; KBS'deki hipoaktif alanların DBS'de Tc-99m DTPA ile dolup dolmadığı değerlendirildi. DBS'den ve KBS'den elde edilmiş DBF birbirleriyle karşılaştırıldı. **Bulgular:** Hastalarda saptanan KAB tipleri şöyle idi: Pelvik, at nalı, birleşmiş üçlü, kros-ektopik böbrekler. Vücudun ön kısmında yerleşmiş böbrek/böbrek bölgelerinin sintigrafik olarak en iyi dinamik böbrek fonksiyonu değerlendirmesi eş zamanlı DBS'nin ön poz görüntülerinden sağlandı. Öne yerleşimli KAB'lere ait böbrek fonksiyonlarını ön pozdan elde edilmiş sintigrafik bilgilerden sağlanan BZAE arka pozdan sağlanan BZAE'den iyi gösterdi. Anterior pozda KBS'de 27 hipoaktif alan vardı; bunların 22'sinin DBS'de Tc-99m DTPA ile dolduğu saptandı. Posterior pozda ise KBS'deki 20 hipoaktif alanın 16'sının DBS'de dolduğu görüldü (böbrek içi toplayıcı sistem). KBS'de önden beş, arkadan dört adet saptanan hipoaktif alanlar DBS'de Tc-99m DTPA ile hiç bir pozda dolmadı (parankim hasarı). DBS, KBS'den sağlanan DBF'ler birbirleriyle uyumluydu. **Sonuç:** Eş zamanlı ön-arka DBS görüntülemesi KAB'de dinamik böbrek fonksiyonlarının tek sintigrafik çalışmayla değerlendirilmesini sağlamakta, DBS'de DBF'nin ön-arka geometrik ortalamasının alınarak hesaplanmasına olanak tanımakta, KBS'de saptanan hipoaktif alanların parankim hasarı/dilate toplayıcı sistem ayırıcı tanısında yardımcı olmaktadır.

Anahtar Kelimeler: Tc-99m DTPA; dinamik böbrek sintigrafisi; böbrek, pelvik böbrek

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The value of radionuclide study in evaluating the patient with suspected disease of the genitourinary tract has increased with technical advances.

DRS is mainly used to assess the dynamic renal functions as perfusion, radioactivity concentration and excretion and gives the opportunity to calculate some valuable semiquantitative parameters such as DRF, glomerular filtration rate (GFR), effective renal plasma flow (ERPF) etc.[1,2] Since native kidneys are normally retroperitoneal organs, DRS is routinely performed from posterior projection except in renal transplant patients. The renal transplant scan is similar to the standard study except that anterior images of the iliac fossa, rather than the usual posterior images are taken. Similarly, it is sometimes difficult to evaluate the functions of CAK with only posterior imaging since their locations and rotations may differ from normal in the abdominopelvic region.

At present, Tc-99m "DMSA CRS" is the most reliable examination when compared to other imaging modalities such as ultrasonography and intravenous pyleography for the detection of renal cortical lesions (acute pyelonephritis/chronic renal scarring) used in the diagnosis of renal infarcts, horseshoe kidney, multicystic dysplastic kidney, ectopic kidney and it also provides calculation of the DRF.[1-9] Routinely, DMSA CRS should include at least a posterior view, acquired for a minimum of 200.000 counts or 5 min with high-resolution parallel hole collimator and both posterior oblique views. However, it is essential to obtain an anterior view to evaluate CAK and renal transplants.

Sometimes hypoactive areas on DMSA CRS are challenging and discrimination between acute pyelonephritis/renal scarring and dilated collecting systems inside the kidneys can not always be made definitely only by DMSA CRS. Moreover, ultrasonography is sometimes not appropriate for this evaluation, especially if the kidney is mallocated or malrotated and if the patient is overweight. In these situations, DRS is usually warranted to see whether these hypoactive areas show "fill-in" with radiotracer due to dilated collecting systems or not. It is also difficult to make this interpretation with only posterior DRS imaging in CAK.

Under the scope of these issues, the aim of this study was to describe the potential benefits of simultaneous anterior-posterior DRS obtained by dual-headed gamma camera in CAK.

MATERIAL AND METHODS

Simultaneous anterior-posterior projection DRS was obtained in 13 patients (6 female, 7 male, age range= 0.5-68 years; mean= 13.4 median= 8) with CAK who were referred to the nuclear medicine Department for the assessment of individual renal functions. In this study, no additional intervention other than routine scintigraphic procedures was performed on the patients, considering the Helsinki Declaration.

Scintigraphic Protocol for Simultaneous Anterior-Posterior Projection Dynamic Renal Scintigraphy

1. Radiopharmaceutical agent: Tc-99m DTPA [37-370 MBq] was used as the radiopharmaceutical agent. Tc-99m DTPA was prepared in the following way: Tc-99m sodium pertechnetate was obtained from a generator (MON-TEK ^{99}Mo/Tc-99m generator, Monrol) and was labeled with a DTPA kit (Technescan DTPA, Mallinckrodt Medical) according to the manufacturer's recommendations.

2. The patients were hydrated orally with 300-500 mL water during the 30 minute-period prior to the study in order to obtain an adequate urinary function and they voided just before the beginning of the simultaneous anterior-posterior DRS.

3. The patients lied supine on the imaging table.

4. DRS was performed by a dual-headed gamma camera (Siemens, E-CAM, Erlangen, Germany) equipped with a high resolution, parallel hole collimator. Anterior-posterior projection with 180^{o} detector dual head configuration over the abdominopelvic region was used. Tc-99m DTPA was injected intravenously, followed by a rapid acquisition in dynamic mode. 60 x 1 second frames were acquired for kidney perfusion phase. After the perfusion phase, digital images were continued to be acquired (160 x 15 second frames; matrix= 64 x 64) for concentration and excretion phases and serial 2 minute condensed images were obtained by the help of the gamma camera computer software package for visual inspection.

5. Perfusion, concentration and excretion functions of each kidney both from the anterior and posterior projection views were interpreted visually.

6. Renograms, which are time-activity curves of the kidneys, were derived from computer-processed dynamic renal imaging using the selected kidney regions. Anterior renograms were obtained from the anterior projection data and posterior renograms were obtained from the posterior projection data.

7. Additionally DRF, which is percent right or left renal cortical radiopharmaceutical uptake, was calculated semiquantitatively in 7 patients using the following equation: DRF= Counts of one kidney-background/total counts of the kidneys-backgrounds. Regions of interests (ROIs) were drawn manually over each kidney both on the anterior and posterior images by the help of the computer software package and eventually geometric means from the 2nd minute mean uptake counts of each kidney was calculated from the anterior and posterior data. ROIs for backgrounds were also put on the lateral aspects of the kidneys. Geometric means were used for the equation.

Eight of the patients also had DMSA CRS within 1 month with simultaneous anterior-posterior DRS.

Scintigraphic protocol for DMSA Cortical Renal Scintigraphy

1. Radiopharmaceutical agent: Tc-99m DMSA (37-185 MBq) was used as the radiopharmaceutical agent. Tc-99m DMSA was prepared by labeling Tc-99m sodium pertechnetate obtained from the generator with a DMSA kit (Technescan DMSA, Mallinckrodt Medical) according to the manufacturer's recommendations.

2. Tc-99m DMSA was injected intravenously. Four hours after the injection of the radiopharmaceutical, static imaging was performed from the posterior, left posterior oblique, right posterior oblique and anterior projections (500 kcounts and 256 x 256 matrix for each projection) over the abdominopelvic region focusing on the kidneys by the dual-headed gamma camera (Siemens, E-CAM, Erlangen, Germany).

3. The posterior, left posterior oblique, right posterior oblique and anterior CRS images were interpreted visually.

Number of regions which showed decreased DMSA uptake were counted and were evaluated for "fill-in pattern" on simultaneous anterior-posterior DRS both from the anterior and posterior projection views. "Fill-in pattern" was defined as the radioactivity accumulation in the previously described hypoactive areas on DMSA CRS during the excretion phase of DRS.

DRFs from DMSA CRS were obtained in a similar way as described above in simultaneous anterior-posterior projection DRS

DRFs obtained from the DRS and DMSA CRS of each patient were compared with each other.

RESULTS

Types of CAK in the patients were as follows: Pelvic kidneys (PK) in 7 patients (1 patient had solitary kidney), horse shoe kidney (HK) in 3, fused triple kidneys (TK) in 1 and cross ectopic kidneys (CK) in 2 patients (Table 1).

The best visual interpretation of perfusion, concentration and excretion functions in all of the PK, CK and anteriorly positioned regions of HK and TK were obtained from the anterior images. The posteriorly located regions of HK, TK and all unilateral normal kidneys of PK patients were better assessed from the posterior views (Figure 1).

Renograms of the all anteriorly located CAK obtained from the anterior acquisition displayed the renal functions better than the posterior renograms (Figure 2).

Eight patients also had recent DMSA CRS showing decreased Tc-99m DMSA uptake regions. There were 27 regions showing decreased DMSA uptake

TABLE 1: Types and number of CAK.

Types of CAK	Patient number
Pelvic kidneys	7 (solitary kidney in 1 patient)
Horse shoe kidneys	3
Fused triple kidneys	1
Cross ectopic kidneys	2

CAK: Congenital abnormal kidneys.

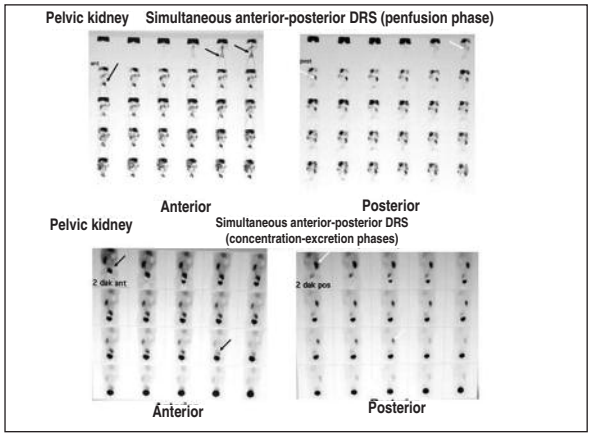

FIGURE 1: Simultaneous anterior-posterior DRS with Tc-99m DTPA of a patient with a pelvic kidney is displayed. Perfusion phase (1 sec images) on the top: Perfusion of the pelvic kidney is very well observed on the anterior projection images (black arrows) while the perfusion of this kidney can not be evaluated from the posterior projection views. Similarly, the perfusion of the other normal located-right kidney of the same patient is very well assessed from the posterior projection images (white arrows). Concentration and excretion phases (2 minute condensed images) on the bottom: From the anterior images, it is clearly identified that the pelvic kidney concentrates and excretes Tc-99m DTPA very well (black arrows). However, the posterior projection views can not define the concentration and excretion functions of the same pelvic kidney as good as the anterior projection images. White arrows show fine concentration and excretion functions in the normal located-right kidney of the same patient from the posterior projection views.

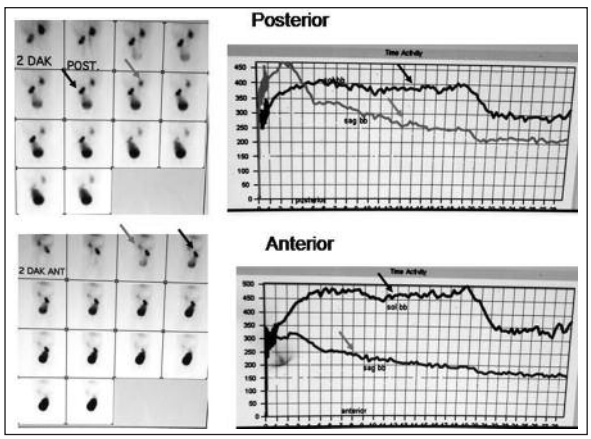

FIGURE 2: Top: Posterior dynamic views of simultaneous anterior-posterior DRS and posterior renograms of another patient with pelvic kidney. Bottom: Anterior views of simultaneous anterior-posterior dynamic renal scintiscraphy and anterior renograms. Gray arrows display the normal located right kidney and black arrows show the pelvic kidney. Anterior renogram of the pelvic kidney shows the renal functions better than the posterior renogram of this particular kidney. Similarly, posterior renogram of the normal located right kidney displays the kidney's renal function better than its anterior renogram.

from the anterior projection and 22 of them showed "fill-in" with Tc-99m DTPA on anterior views of the DRS. Twenty regions showed decreased DMSA uptake on DMSA CRS on posterior views and 16 of them displayed "fill-in" with Tc-99m DTPA on posterior projection images of the DRS. These regions were compatible with dilated collecting systems. Five regions with decreased DMSA uptake from the anterior projection and 4 from the posterior projection did not show "fill-in" pattern on either projection in simultaneous anterior-posterior DRS and they were consistent with parenchymal damage (Table 2). "Fill-in" pattern observed on anterior views could not be evaluated properly from posterior views. Similarly, "fill-in" pattern on posterior views could not be assessed clearly from anterior views (Figure 3-5).

Eight patients also had DMSA CRS within 1 month with simultaneous anterior-posterior DRS

TABLE 2: Results in 8 patients who had both Tc-99m DMSA CRS and simultaneous anterior-posterior DRS.

Scintigraphy	Number of Regions	
	Anterior	Posterior
Decreased DMSA uptake	27	20
Positive "fill-in" pattern on DRS views	22	16
Negative "fill-in" pattern on DRS views	5	4

DMSA: Dimercaptosuccinic acid,
DRS: Dynamic renal sinticraphy.

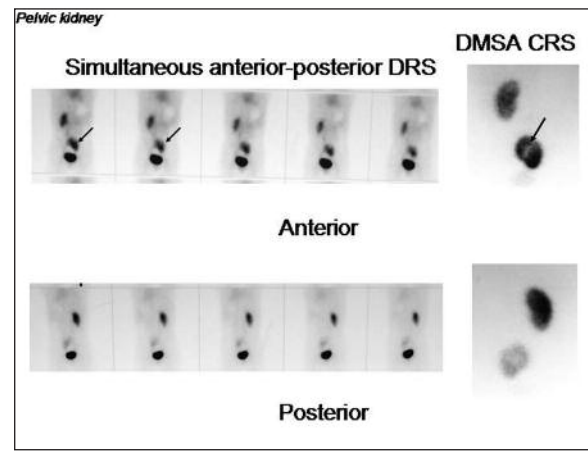

FIGURE 3: On the top row, a part of simultaneous anterior-posterior DRS and dimercaptosuccinic acid (DMSA) cortical renal scintiscraphy (CRS) images of the patient in Figure 1 are shown from the anterior projection. The hypoactive area in the middle of the pelvic kidney on DMSA CRS displays "fill-in" with Tc-99m DTPA on DRS (arrows) which was mostly compatible with the collecting system of the kidney. However, on posterior views at the bottom row neither DMSA CRS nor DRS indicate the same area clearly.

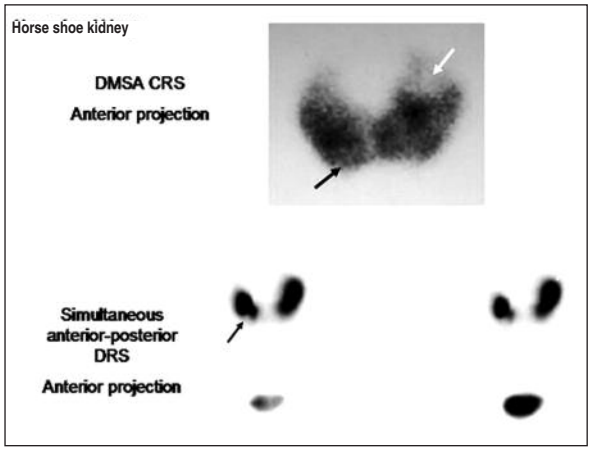

FIGURE 4: In a patient with a horse shoe kidney, anterior projection images show that the significant hypoactive area on dimercaptosuccinic acid cortical renal scinticraphy on the upper pole of the left component (white arrow) shows "fill-in" with Tc-99m diethylenetriamine pentaacetic acid (DTPA) on dynamic renal scinticraphy (DRS) and the relative hypoactive area on the lower pole of the right component does not display "fill-in" pattern (black arrows). The patient had a recent urinary tract infection with fewer and positive laboratory findings and the scintigraphic findings of the lower pole of the right component was most probably due to acute pyelonephritis in that region.

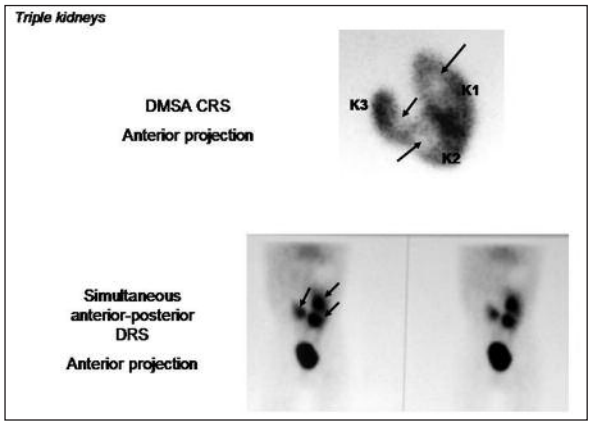

FIGURE 5: Anterior kidney images of the patient with triple kidneys clearly show the hypoactive areas on dimercaptosuccinic acid cortical renal scinticraphy and "fill-in" pattern on simultaneous anterior-posterior dynamic renal scinticraphy (arrows).

as we mentioned before. Among our patients whose DRFs were calculated on simultaneous anterior-posterior DRS by using geometric mean counts on the 2nd minute images, only 4 had calculated DRF on DMSA CRS. Unfortunately, it was impossible for us to calculate the DRF on DMSA CRS in the remaining 4 patients since these scintigraphic studies were performed in another institution. These results are listed in detail in Table 3. The obtained DRF values on simultaneous anterior-posterior DRS and DMSA CRS in each patient were comparable with each other.

DISCUSSION

It is especially important to evaluate the renal functions in patients with CAK since they are more predisposed to renal disorders such as obstructive uropathy, infection and vesicouretheral reflux because of the anatomical variations and different rotations and locations in such kidneys. Additionally, renal scars can lead to the later development of hypertension or even end-stage renal disease in a significant number of patients.[10,11] So it is essential to identify renal parenchymal disease properly especially in this particular group of patients. Tc-99m DMSA CRS is the gold standard for the detection of scars.[10] The most commonly encountered problem in the DMSA CRS interpretation is the hypoactive areas due to the dilated collecting systems mimicking parenchymal injury. Although history and some scintigraphic criteria like sharpness of kidney contours could be helpful in the differential diagnosis,[1,3] DRS is sometimes warranted as a complementary functional imaging modality to identify the nature of these kidney regions (renal parenchymal disease versus dilated collecting system), especially in CAK. However, it is usually difficult to evaluate the functions of anteriorly located or mallocated/malrotated kidneys or kidney regions with only posterior projection data on renal scintigraphic studies.

The counts coming from the anteriorly located kidneys were severely attenuated in the body during posterior imaging, making the proper evaluation of renal functions impossible. So, we performed simultaneous anterior-posterior projection DRS in 13 patients with CAK to assess the functions also from the anterior projection in addition to the routine posterior interpretation and we aimed to describe the potential benefits of simultaneous anterior-posterior DRS obtained by dual-headed gamma camera in CAK.

Dynamic renal functions of both the anteriorly and posteriorly located kidney tissue of CAK in our patient group were assessed properly with

simultaneous anterior-posterior DRS obtained by dual-headed gamma camera. In addition to visual evaluation, simultaneous dynamic renal study gave the opportunity to obtain both anterior and posterior renograms of the CAK and this helped to make an appropriate interpretation of the renal functions.

Existence or absence of "fill-in" pattern on DRS of the kidney regions showing decreased Tc-99m DMSA uptake on CRS were better evaluated by simultaneous anterior-posterior projection acquisition. Adding the results of simultaneous anterior-posterior DRS to the routine evaluation with DMSA CRS helped the clinician to decide on the type of the therapy and follow-up for these particular patients. Our results showed that DRS should be performed with simultaneous anterior-posterior acquisition in CAK to assess the dynamic renal functions of anteriorly and posteriorly located kidney tissue since these types of kidneys may cause difficulty in interpretation of DRS due to the variations in the depth of the renal tissue. For example, as a result of the associated malrotation, a significant proportion of the CKs display pelvicaliceal dysmorphism that simulates hydronephrosis and in some instances, an abnormal pelviureteral junction position or an aberrant vessel may interfere with pelvis-emptying to produce obstruction.[12] Investigators reported that renal scintigraphy was more accurate than sonography in identifying ectopic renal tissue and additionally the patient's obesity may hamper ultrasonography. Similarly, it is difficult to diagnose a HK by ultrasound, especially if the isthmus is not visible. Hydronephrosis, urolithiasis and infection are the three most common clinical complications of HK.[13] Renal maldevelopment may lead to quantitative and qualitative deficiencies in renal parenchyma. So, we again suggest to evaluate the dynamic renal functions of HK with simultaneous anterior-posterior DRS.

Although the number of the kidneys were limited, DRFs which were calculated both on simultaneous anterior-posterior DRS and DMSA CRS were well correlated in our study (Table 2). An important advantage of simultaneous anterior-posterior DRS was the calculation of DRF by using geometric mean counts on the 2nd minute images. With anteriorly located PKs, the pelvis forms a barrier between the radioactively labeled tracer and the gamma camera, reducing the amount of radiation detected on routine posterior imaging and this issue can also cause underestimation of the real function of the kidney.[14] One should be aware that attenuation due to the pelvic bone structure gives rise to a significant underestimation of the function in the ectopic kidney. The split function is unable to assess the quality of the individual kidney function on only posterior views in these types of kidneys. When deciding for a nephrectomy or partial nephrectomy, the surgeon may be interested in evaluating the function of the remaining moiety. DRF calculated with only the posterior data on DRS may underestimate the real split function of the CAK or kidney regions. DRF obtained with geometric mean counts on simultaneous anterior and

TABLE 3: A summary of DRFs which were calculated both on DMSA CRS and simultaneous anterior-posterior DRS.

				Differential Renal Functions (DRF) (%)			
Congenital abnormal kidneys (CAK)	**Tc-99m DMSA CRS**			**Tc-99m DTPA DRS**			
Pelvic kidney	Ectopic		Normal	Ectopic		Normal	
	33%		67%	33%		67%	
Pelvic kidney	Ectopic		Normal	Ectopic		Normal	
	30%		70%	34%		66%	
Triple kidneys	K1	K2	K3	K1	K2	K3	
	23%	34%	43%	21%	31%	48%	
Horse shoe kidney	Left		Right	Left		Right	
	54%		46%	55%		45%	

K: Kidney, DMSA CRS: Dimercaptosuccinic acid cortical renal scinticraphy, DRS: Dynamic renal scinticraphy.

TABLE 4: Advantages of simultaneous anterior-posterior DRS in CAK.

Obviates performing a second additional DRS from the anterior projection in this particular group of patients, leading to patient comfort and cost-effectiveness.
Functions of both the anteriorly and posteriorly located kidneys of a patient can be assessed in a single scintigraphic study.
Gives the oppurtunity to calculate the differential functions by using geometric mean counts.
Helps to differentiate renal scar and dilated collecting systems more confidently in abnormally located CAK showing decreased DMSA uptake.

CAK: Congenital abnormal kidneys, DRS: Dynamic renal sinticraphy, DMSA: Dimercaptosuccinic acid.

posterior images of DRS gives a more precise estimation of split renal function, in this particular group of kidneys.

Simultaneous anterior-posterior DRS also has the advantage of evaluating both the anteriorly and posteriorly located kidneys of a patient in a single scintigraphic study. This obviates a second study from the anterior projection leading to patient comfort and cost-effectiveness.

Advantages of simultaneous anterior-posterior DRS in CAK may be listed as in Table 4.

In conclusion, we suggest to perform simultaneous anterior-posterior projection DRS with a dual-headed gamma camera (if available) in patients with known CAK in order to give an optimum scintigraphic information. This obviates performing a second additional DRS from the anterior projection in this particular group of patients. Functions of both the anteriorly and posteriorly located kidneys of a patient can be assessed in a single scintigraphic study. It gives the opportunity to calculate the differential functions by using geometric mean counts. It helps to differentiate renal scar and dilated collecting systems more confidently in abnormally located congenital abnormal kidneys showing decreased Tc-99m DMSA uptake.

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