Ann Nucl Med (2015) 29:816–824
DOI 10.1007/s12149-015-1009-z

ORIGINAL ARTICLE

Correction of differential renal function for asymmetric renal area ratio in unilateral hydronephrosis

Gul Ege Aktaş[1] · Ali Sarıkaya[1]

Received: 27 April 2015 / Accepted: 20 July 2015 / Published online: 31 July 2015

Abstract

Objective Children with unilateral hydronephrosis are followed up with anteroposterior pelvic diameter (APD), hydronephrosis grade, mercaptoacetyltriglycine (MAG-3) drainage pattern and differential renal function (DRF). Indeterminate drainage preserved DRF in higher grades of hydronephrosis, in some situations, complicating the decision-making process. Due to an asymmetric renal area ratio, falsely negative DRF estimations can result in missed optimal surgery times. This study was designed to assess whether correcting the DRF estimation according to kidney area could reflect the clinical situation of a hydronephrotic kidney better than a classical DRF calculation, concurrently with the hydronephrosis grade, APD and MAG-3 drainage pattern.

Materials and methods We reviewed the MAG-3, dimercaptosuccinic acid (DMSA) scans and ultrasonography (US) of 23 children (6 girls, 17 boys, mean age: 29 ± 50 months) with unilateral hydronephrosis. MAG-3 and DMSA scans were performed within 3 months (mean 25.4 ± 30.7 days). The closest US findings (mean 41.5 ± 28.2 days) were used. DMSA DRF estimations were obtained using the geometric mean method. Secondary calculations were performed to correct the counts (the total counts divided by the number of pixels in ROI) according to kidney area. The renogram patterns of patients were evaluated and separated into subgroups. The visual assessment of DMSA scans was noted and the hydronephrotic kidney was classified in comparison to the normal contralateral kidney's uptake. The correlations of the DRF values of classical and area-corrected methods with MAG-3 renogram patterns, the visual classification of DMSA scan, the hydronephrosis grade and the APD were assessed.

Results DRF estimations of two methods were statistically different (p: 0.001). The categories of 12 hydronephrotic kidneys were changed. There were no correlations between classical DRF estimations and the hydronephrosis grade, APD, visual classification of the DMSA scan and uptake evaluation. The DRF distributions according to MAG-3 drainage patterns were not different. Area-corrected DRF estimations correlated with all: with an increasing hydronephrosis grade and APD, DRF estimations decreased and MAG-3 drainage patterns worsened. A decrease in DRF (<45 %) was determined when APD was ≥10 mm. When APD was ≥26 mm, a reduction of DRF below 40 % was determined.

Conclusion Our results suggest that correcting DRF estimation for asymmetric renal area ratio in unilateral hydronephrosis can be more robust than the classical method, especially for higher grades of hydronephrotic kidneys, under equivocal circumstances.

Keywords Hydronephrosis · DRF · DMSA · MAG-3 · Supranormal function · UPJ · Pelvic diameter

Introduction

When following up children with unilateral hydronephrosis, decision of optimal time to have surgery is based on a number of factors: anteroposterior pelvic diameter (APD), the grade of hydronephrosis [according to the Society of Fetal Urology (SFU)], the drainage pattern of diuretic renography, the initial differential renal function (DRF)

✉ Gul Ege Aktaş
dr.gulege@yahoo.com

[1] Department of Nuclear Medicine, Trakya University Medical Faculty, Edirne, Turkey

and DRF deterioration. However, it remains difficult to choose the optimal time for surgery due to variability in DRF estimations and the discordance of these estimations with the degree of the kidney damage and obstruction. An initially low DRF and a fall in DRF are very critical for decision making because the desired outcome of intervention is to maintain DRF or avoid deterioration of kidney functions [1, 2]. So, the robustness of the technique used in DRF calculations is very important. There are still some problems when estimating DRF in hydronephrotic kidneys, such as supranormal function, overestimation due to kidney size and the disparity between the visual and quantitative estimations of the kidney. These falsely negative results of DRF estimations can cause patients to miss their optimal surgery time.

In children with unilateral hydronephrosis MAG-3 diuretic renography's one of the aspects is calculation of the DRF and the second is assessment of drainage. It is known that drainage patterns do not usually correlate well with DRF deterioration and complete obstruction, especially in hydronephrotic kidneys with a high grade, so the major defining point of a renogram is the DRF estimation. However, a DMSA scan provides better information due to its high-quality signal. The morphological and functional (DRF) information obtained from DMSA scans are more reliable than dynamic tracers [2, 3]. The aim of this study is to offer a different kind of DRF calculation method that takes asymmetric kidney size into account and to compare it to the classical method of DRF estimation. APD, the SFU grade of hydronephrosis and MAG-3 drainage patterns are the important factors when making surgery decisions. We evaluated the correlations and relationships between these factors and the two methods for DRF estimation.

Materials and methods

We reviewed the MAG-3, DMSA scans and renal US of 23 children: 6 girls and 17 boys, aged between 2 months and 16 years (mean age 29.1 ± 50.2 months) with unilateral persistent hydronephrosis (grade 1–4) and a normal contralateral unit. All children were evaluated with a MAG-3 dynamic renogram, DMSA scan within 3 months (mean 25.4 ± 30.7 days) and the closest US findings (mean 41.5 ± 28.2 days) were used in evaluation (Table 1).

Dynamic renography was obtained after an intravenous injection of 7.4 MBq/kg Tc-99 m MAG-3, with a minimum dose of 15 MBq and a maximum dose of 100 MBq. Images were acquired at 2 s/frame for 24 frames, 15 s/frame for 16 frames and 30 s/frame for 40 frames (64 × 64 matrix) with a dual-headed E-Cam gamma camera (Siemens, Erlangen, Germany) equipped with a low-energy all-purpose parallel-hole collimator. The energy setting was chosen photopeak at 140 keV with a 20 % symmetric window.

Intravenous diuretic administration (furosemide dose: 1 mg/kg for patients younger than 1 year old and 0.5 mg/kg for others) was performed at the end of the 20-min renogram phase if required. A diuretic renogram was obtained for an additional 20 min at 1 min/frame. A bean-shaped region of interest (ROI) was drawn manually over the kidneys to exclude the collecting system and a perirenal C-type region of the background was used for background subtraction. Quantitative parameters were derived using the area under curve method. The raw data were visually assessed by two experienced nuclear medicine physicians, in agreement. The renogram patterns of patients were evaluated retrospectively and separated into four subgroups according to the excretion phase findings: kidneys with normal drainage were classified as pattern 1, those with pelvicalyceal stasis and a complete response to diuretic administration were notified as pattern 2, those with a partial response to diuretic administration were classified as pattern 3 and those with no response were classified as pattern 4.

DMSA scan was performed, on the same scanner with MAG-3 scan, at 2–4 h after intravenous injection of 1.85 MBq/kg Tc-99 m DMSA. Anterior, posterior and right and left posterior oblique planar images were obtained with a low-energy high-resolution collimator and the energy setting photopeaked at 140 keV with a 20 % symmetric window.

The DRFs of hydronephrotic and contralateral normal kidneys were calculated using the geometric mean method: the square root of each kidney's background-subtracted ROI counts in the anterior × posterior views was used as defined in the equation in Fig. 1a. A second calculation was performed to correct the activity of each kidney according to its area, by dividing the counts of the kidneys by the number of pixels in each kidney's ROI. These corrected counts were used in the geometric mean calculation, as defined in the equation in Fig. 1b.

Visual assessments of DMSA scans were performed by two experienced nuclear medicine physicians in agreement and the hydronephrotic kidney was classified as (compared to the normal contralateral kidney): 1: normal, 2: slightly decreased DMSA uptake or 3: decreased DMSA uptake.

The correlations of the DRF values of classical and area-corrected methods with visual classification of the DMSA scan, SFU hydronephrosis grade, APD and the distribution of DRF estimations obtained with classical and corrected methods according to MAG-3 renogram patterns were assessed.

DRF values of <45 % were accepted as abnormal, those from 45 to 55 % were considered normal and those of >55 % were defined as supranormal. The supranormal and

Table 1 Patient population and DRF estimations with classical and area correction method

Patient no	Age (month)	Gender	HN side	HN grade	APD (mm)	% DRFHN mean: 52.3 ± 4.2*	% DRFcHN mean: 43.1 ± 4.7*
1[a]	17	M	L	1	8	56	52
2	2	M	L	1	9	53	51
3[b]	7	M	L	2	10	52	44
4[a]	16	M	L	2	12	56	49
5[b]	48	F	L	2	12	52	44
6	36	F	L	2	12	55	45
7	24	M	L	2	13	49	45
8	6	F	L	2	14	54	46
9[a]	4	M	L	2	14	58	47
10[a/b]	2	M	L	3	16	58	43
11	18	M	R	2	16	54	46
12[b]	8	M	L	3	16	53	43
13[b]	48	M	L	2	16	50	44
14[b]	3	M	L	3	17	55	42
15[b]	3	M	L	3	17	45	40
16	12	F	L	2	18	48	45
17[b]	2	M	R	3	20	53	44
18[c]	6	M	L	3	26	46	35
19[c]	48	M	L	3	27	53	36
20[b]	3	M	L	3	30	55	43
21[c]	8	M	L	3	33	42	37
22[a/c]	4	F	L	4	38	58	36
23[c]	192	F	R	4	49	49	35

HN hydronephrosis, *M* male, *F* female, *R* right, *L* left, *APD* anterior–posterior pelvic diameter, *DRFHN* DRF of hydronephrotic kidney with classical method, *DRFcHN* corrected DRF of hydronephrotic kidney

* DRF estimations of classical and area-corrected methods were significantly different $p = 0.000$

[a] Cases with supranormal DRF estimates with classical method

[b] Cases that changed category as 40≤ DRF <45 % with corrected method

[c] Cases that changed category as DRF <40 % with corrected method

(a)

$$DRFH = \frac{\sqrt{AH \times PH}}{\sqrt{AH \times PH} + \sqrt{AN \times PN}} \times 100$$

(b)

$$correctedDRFH = \frac{\sqrt{\frac{AH}{AHp} \times \frac{PH}{PHp}}}{\sqrt{\frac{AH}{AHp} \times \frac{PH}{PHp}} + \sqrt{\frac{AN}{ANp} \times \frac{PN}{PNp}}} \times 100$$

Fig. 1 **a**, **b** Equations for calculation of DRF with classical and area-corrected method. *DRF* differential renal function of hydronephrotic kidney, *AH* anterior counts of hydronephrotic kidney, *AN* anterior counts of normal kidney, *PH* posterior counts of hydronephrotic kidney, *PN* posterior counts of normal kidney, *AHp* total pixels in anterior region of interest of hydronephrotic kidney, *PHp* total pixels in posterior region of interest of hydronephrotic kidney, *ANp* total pixels in anterior region of interest of normal kidney, *PNp* total pixels in posterior region of interest of normal kidney

discordant DRF estimates with category changes obtained using the two methods were further analyzed.

Exclusion criteria

Patients with bilateral hydronephrosis, vesicoureteral reflux, duplex kidneys, posterior urethral valves, neurogenic bladders, solitary kidneys, previous urological surgeries or other urologic anomalies were excluded.

Ethics

This retrospective study was approved by the Scientific Ethics Committee of Trakya University Medical Faculty Hospital.

Statistic

Differences of means and distributions were tested using *T* test and ANOVA. The distribution of estimations according to nonparametric patterns was tested using a Kruskal–Wallis test. Correlations between DRF estimations and other clinical parameters were investigated using Spearman's rho. A p value of ≤ 0.05 was set as statistically significant. Statistic evaluations of this study were done together with the TU Medical Faculty Department of Biostatistics.

Results

Evaluations of 23 hydronephrotic and 23 contralateral normal kidneys were performed with MAG-3, DMSA and US. The APD of hydronephrotic kidneys was between 8 mm and 49 mm (mean: 19.2 ± 10.1). Two kidneys received a grade of 1 according to the SFU grading system, 9 received a grade of 2, 10 received a grade of 3 and 2 received a grade of 4. DRF estimations obtained using the classical method and the corrected method were significantly different (Table 1).

Four hydronephrotic kidneys' drainage patterns were normal (pattern 1). Five kidneys showed total response to diuretic administration (pattern 2). Partial response was observed in 9 kidneys (pattern 3), and in 5 the pelvic retention did not show any reduction with diuretic administration (pattern 4).

According to the visual evaluation: 6 hydronephrotic kidneys were normal (class 1), DMSA uptake was slightly reduced in 8 kidneys (class 2) and significantly reduced in 9 kidneys (class 3). All the contralateral kidneys were normal according to the visual evaluation.

There were no correlations between classical DRF estimations and hydronephrosis grades, APDs or visual evaluations of DMSA scans. Also there was no difference in distribution of DRF estimations according to MAG-3 renogram patterns. However, the DRF estimations obtained with the corrected method correlated with all of these. The most powerful correlation was seen between visual evaluations of DMSA scans and corrected DRF estimations. There was a significant inverse correlation between corrected DRF estimations and the hydronephrosis grade and APD. With an increased hydronephrosis grade and APD, DRF estimations decreased. Also, DRF estimations obtained with the corrected method had significantly different distributions according to the MAG-3 renogram patterns: when MAG-3 drainage patterns worsened, DRF estimations decreased, especially in Pattern 4 (Table 2, Table 3; Figs. 2a, b, 3a, b, 4a, b).

Table 2 Correlations between DRF estimations and hydronephrosis grade, APD, visual evaluation of DMSA scan of hydronephrotic kidneys

DRF	Grade	APD	HNv
HN	−0.226	−0.269	−0.347
p	0.300	0.215	0.105
HNc	−0.675	−0.745	−0.873
p	0.000*	0.000*	0.000*

HN DRF of hydronephrotic kidney, *HNc* corrected DRF of hydronephrotic kidney, *Grade* hydronephrosis grade, *APD* anterior–posterior pelvic diameter, *HNv* visual evaluation of hydronephrotic kidney

* $p < 0.05$

Table 3 Distribution of DRF estimations according to MAG-3 renogram patterns

DRF	MAG-3				
	1 ($n = 4$)	2 ($n = 5$)	3 ($n = 9$)	4 ($n = 5$)	*p*
HN	55 (53–58)	52 (49–56)	52 (45–58)	55 (42–58)	0.300
HNc	49 (46–52)	44 (35–49)	44 (35–46)	37 (36–43)	0.010*

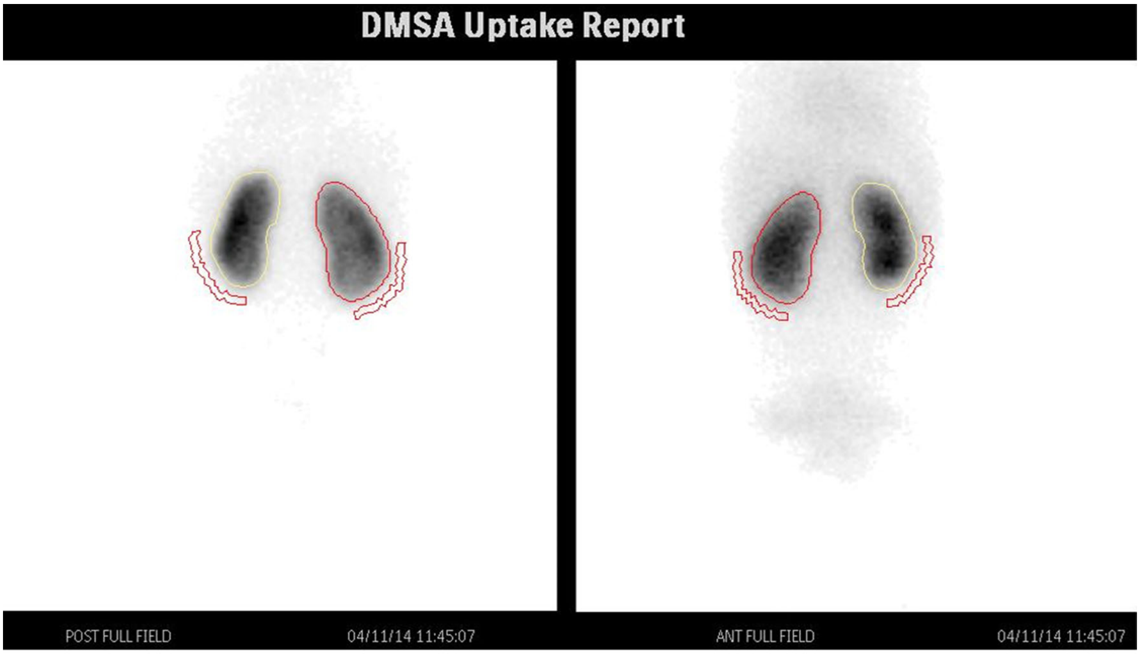
Median (min–max)

HN DRF of hydronephrotic kidney, *HNc* corrected DRF of hydronephrotic kidney

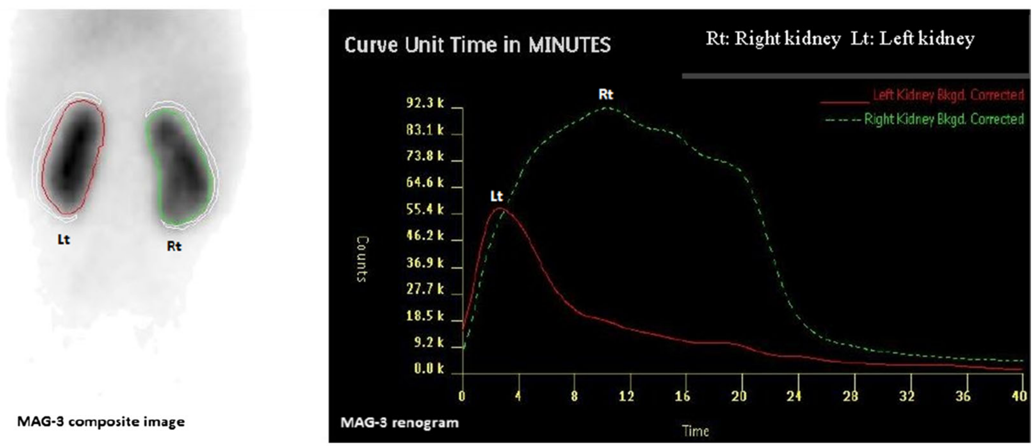
* Kruskal–Wallis test, $p < 0.05$

There was no relationship between DRF estimations obtained with classical method and APD (Table 4). However, there was a relationship between APD and the corrected DRF estimations: a decrease in DRF (<45 %) occurred when APD was ≥10 mm. More importantly, when APD was ≥26 mm, DRF was reduced below 40 % (Table 5).

DRF estimations were categorized into groups, ≥45, 40–45 and <40 %, because of the clinical importance of these subgroups. All the DRF estimations were >40 % with the classical method, and there were 5 supranormal functions. These 5 supranormal estimations belonged to children that were under 2 years of age, 3 of whom were under 1 year of age. None of the DRF estimations of these kidneys were supranormal with the corrected method: 3 were normal, 1 had a DRF of 40–45 % and the other had a DRF of <40 %. In addition, 12 hydronephrotic kidneys' DRF categories changed with the corrected method: of the 11 kidneys that were considered normal, 8 were estimated as 40–45 % and 3 were estimated as <40 %. The remaining kidney had a DRF of 40–45 % with the classical method and a DRF of <40 % with the corrected method (Table 6). When we examined this discordant data, common parameters emerged, including higher hydronephrosis grade and larger APD (cases with supranormal function and cases categorized as 40–45 or <40 % are marked in



(a)



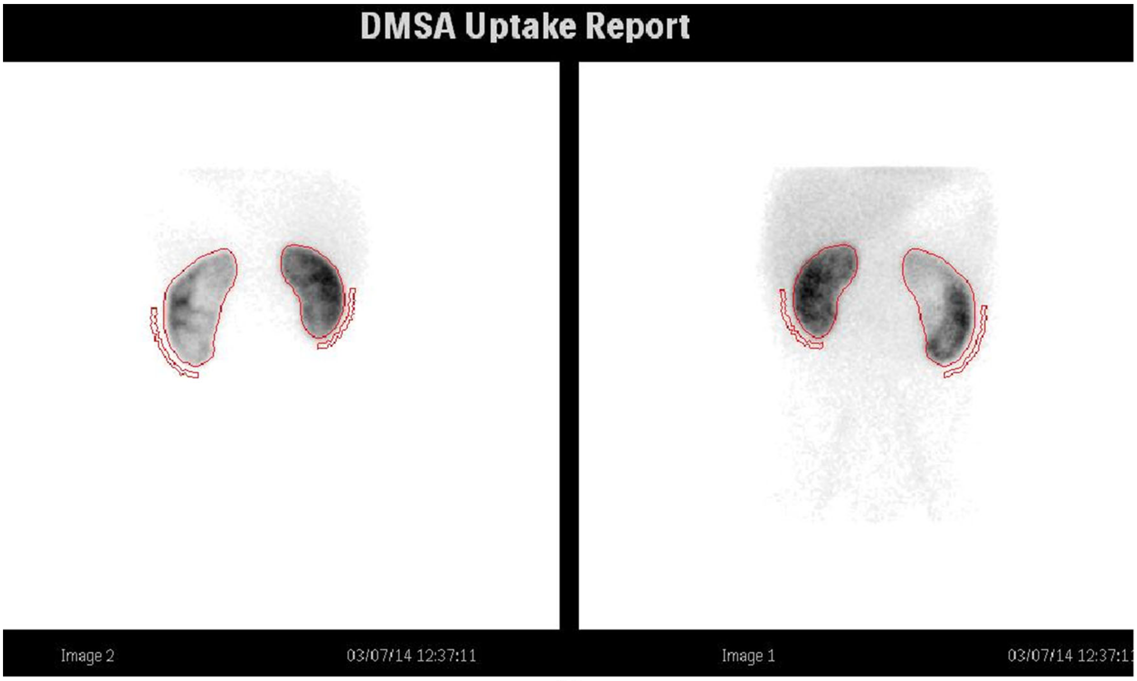
(b)

Fig. 2 **a**, **b** DMSA scan and MAG-3 renogram of a case with grade 2 hydronephrosis. DMSA scan of 18-month-old boy with grade 2 right hydronephrosis. Bean-shaped ROIs were drawn around the kidneys and sub-renal c-type ROIs were used in background correction (**a**). The MAG-3 renogram of the same patient; 1–3 min summed image with ROIs of kidneys and backgrounds on *left* and time activity curve showing excretion pattern on *right* (**b**). There was complete response to diuretic administration in MAG-3 renogram. DRF of hydronephrotic kidney with the classical method was determined as 54 % and it was calculated as 46 % with the area-corrected method

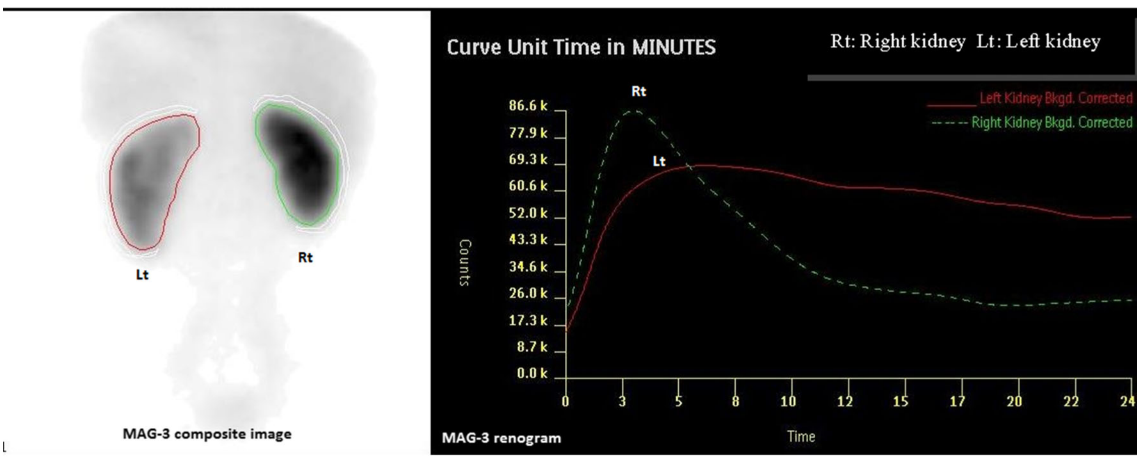
Table 1 with "superscripted letters a, b and c", respectively).

Discussion

Uretheropelvic junction obstruction (UPJO) is the most common cause of hydronephrosis. The majority of cases are transient or ultimately resolve during conservative management or follow-up. For this reason, differentiating between dilatation from real obstructions and a close follow-up is very important for those who need surgery before they lose DRF. Depending on the clinical problems and experience of particular departments, children with persistent hydronephrosis are evaluated with MAG-3 renograms and/or DMSA scans. The timing of and decision to undergo surgery depend upon multiple factors: progressive dilatation of APD, high hydronephrosis grade, initially deteriorated DRF or decreased DRF by follow-up, recurrent urinary infections and flank pain [1, 2, 4].



(a)



(b)

Fig. 3 **a**, **b** DMSA scan and MAG-3 renogram of a case with grade 3 hydronephrosis. DMSA scan of 9-year-old boy with grade 3 left hydronephrosis. Bean-shaped ROIs were drawn around the kidneys and sub-renal c-type ROIs were used in background correction (**a**). The MAG-3 renogram of the same patient; 1–3 min summed image with ROIs of kidneys and backgrounds on *left* and time activity curve showing excretion pattern on *right* (**b**). There was partial response to diuretic administration in MAG-3 renogram. DRF of hydronephrotic kidney with the classical method was determined as 46 % and it was calculated as 35 % with the area-corrected method

In MAG-3 diuretic renography's one of the aspects is calculation of the DRF and the second is assessment of drainage. Inanir et al. suggest that the preferred radiopharmaceutical for DRF estimation in unilateral hydronephrosis should be DMSA [5]. Despite the fact that DMSA studies require minimal background corrections, the chosen technique might still be unsatisfactory in some cases [6]. Problems estimating DRF in hydronephrotic kidneys has been reported [2, 3, 7–9]. Supranormal and overestimated functions with DMSA have been reported by Capolichio et al. who used the geometric mean method [7]. The main problems reported in previous studies include background activity, kidney depth, the reservoir effect and a asymmetric kidney size.

Overestimated and supranormal DRF estimations obtained using the classical methods, especially cases with a higher hydronephrosis grade and in children younger than 2 years of age reported in the literature were concordant

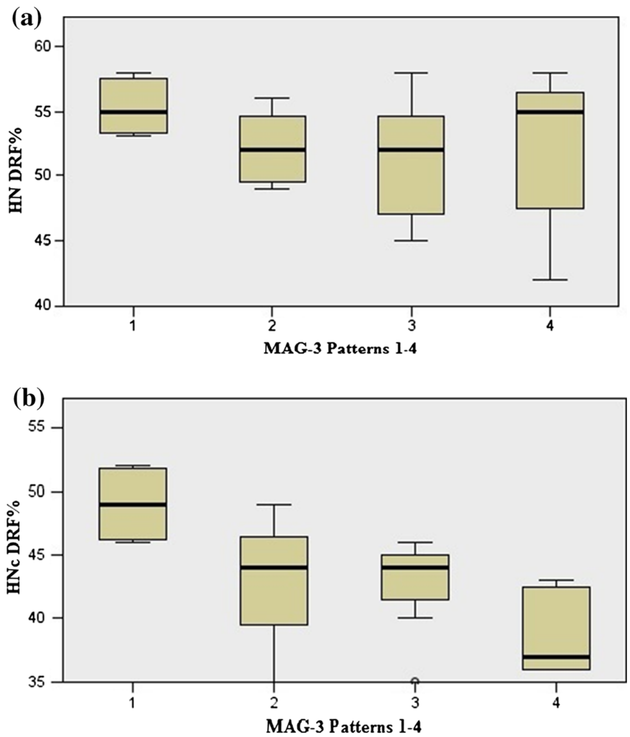


Fig. 4 **a** DRF distribution of classical method according to MAG-3 renogram patterns. *HN DRF %* DRF of hydronephrotic kidney with classical method, *MAG-3 patterns 1–4* MAG-3 renogram patterns (1–4). **b** DRF distribution of corrected method according to MAG-3 renogram patterns. *HNc DRF %* DRF of hydronephrotic kidney with corrected method, *MAG-3 patterns 1–4* MAG-3 renogram patterns (1–4)

Table 4 The relationship between classical DRF and AP diameter

% DRF	APD (mm)			n	p
	Minimum	Maximum	Mean ± std		
40–45	17	33	25 ± 11.3	1	0.416
≥45	8	49	18.7 ± 10.1	22	
Total	8	49	19.2 ± 10.1	23	

AP anterior–posterior pelvic diameter

Table 5 The relationship between area-corrected DRF and AP diameter

% DRF	APD (mm)			n	p
	Minimum	Maximum	Mean ± std		
<40	26	49	34.6 ± 9.3	5	0.000
40–45	10	30	16.4 ± 5.1	9	
≥45	8	16	12.1 ± 3.1	9	
Total	8	49	19.2 ± 10.1	23	

APD anterior–posterior pelvic diameter

Table 6 Discrepancy between classical and corrected DRF estimations

%HNc DRF	%HN DRF				
	≥45	40–45	<40	SPN	Total
≥45	6			3	9
40–45	8			1	9
<40	3	1		1	5
SPN					
Total	17	1		5	23

%HN DRF DRF estimation of hydronephrotic kidney with classical method, *%HNc DRF* DRF estimation of hydronephrotic kidney with corrected method, *SPN* supranormal

with the findings in our study [7, 8, 10]. Five supranormal functions with left hydronephrosis were found using the classical geometric mean method in this study. These children were all under 2 years old and 3 were under 1 year old. However, none of these were supranormal according to the corrected method.

An important pitfall of the classical method is that higher DRFs have been reported in kidneys with a higher hydronephrosis grade [7, 8, 10, 11]. Diuretic administration and/or late 24-h imaging did not lead to a significant change in DRF estimations compared to the second hour [9]. While maximum tubular DMSA uptake occurred, the amount that exceeded the maximum tubular uptake participated mostly in intravascular and extracellular background activity [12]. Inanir et al. suggest that a higher DRF reported in larger hydronephrotic kidneys is related to higher intrarenal vascular background activity. They determined that these kidneys had a higher renal area ratio (number of pixels within the ROI of the hydronephrotic kidney divided by that of the normal contralateral kidney) [5]. Our results are concordant with the suggestion that when DRF calculations were corrected according to the kidney area, by dividing the total counts to the number of pixels in the kidney's ROI, there was a clinically meaningful decrease in DRF of kidneys with a high hydronephrosis grade.

In some cases, there is discordancy between visual and quantitative DRF estimations. Piepsz et al. suggest that this is because there is no direct correlation between parenchymal thinning in US and split renal function; parenchymal thinning is related to the degree of distention of the collecting system. The thickness decreases while the surface increases, so the total function may be preserved [2]. Considered in another way, parenchymal damage and DRF deterioration should be related to prolonged pelvic distention and increasing pressure. Konda et al. suggested that renal cortical damage on DMSA image or diminished uptake in visual evaluation is a more robust criterium for surgical intervention. They performed surgery in infants with normal DRF when there was renal cortical damage on the DMSA image and confirmed that these kidneys had parenchymal damage and thinning with intraoperative findings. Also, they found a DRF of >53 % in 11 kidneys including 7 and 4 kidneys with grade 3 and 4 hydronephrosis, respectively. There was no significant difference between the DRF estimations of kidneys with normal visual evaluation and mild, moderate damaged kidneys which was also a clinically discordant finding [13]. We suggest that area-corrected DRF estimation can be helpful in these kinds of equivocal circumstances. While the classical DRF estimations and visual evaluations did not correlate well, the most powerful correlation was found between the visual evaluations of DMSA scans and the corrected DRF estimations in our study.

Usually, the drainage patterns of dynamic renograms do not correlate well with DRF deterioration. While there was no correlation between MAG-3 drainage patterns and classical DRF estimations, we determined an important clinical correlation between the drainage patterns and corrected DRF estimations. With an increased hydronephrosis grade and APD, DRF estimations decreased and MAG-3 drainage patterns worsened. This finding is supported by Ross et al. who found that deterioration in renal drainage was observed prior to loss of DRF for kidneys with hydronephrosis grade 3 or 4 [14]. Surgery decision was based on worsening drainage patterns on the renogram and/or the deterioration of DRF, according to Ross et al's algorithm. While in most cases, followed-up without surgery with initially preserved DRF, they observed that in kidneys with persistent hydronephrosis and worsening drainage patterns, a fall in DRF $\geq$10 % was observed and late surgical intervention was performed in most cases [14].

The predictive value of APD is also an important issue. The authors use the values of APD to determine which patients require close follow-up. An APD 15–30 mm is an indication for close follow-up [2]. Longpre et al. concluded that kidneys with an initially larger APD and grade 4 hydronephrosis are associated with a lower likelihood of resolution. They predicted that the mean APD in resolved cases was <10 mm [1]. Burgu et al. suggested that DRF is preserved ($\geq$40 %) when APD is <20 mm [15]. Our results were also concordant with the results of these studies. We determined a significant inverse correlation between the corrected DRF estimations and hydronephrosis grade and APD. There was a relationship between APD and corrected DRF estimations: there was a decrease in DRF (<45 %) when APD was $\geq$10 mm. More importantly, when APD was $\geq$26 mm, DRF was reduced below 40 %.

APD and SFU grading are used to assess antenatal and postnatal persistent hydronephrosis together with dynamic renogram patterns and DRF to decide the type of intervention. Conflicting results in the literature regarding how these criteria should be used complicates the decision-making progress. High-risk groups are important in follow-up and might be defined using all parameters in cooperation. However, it is common that these clinical findings do not correlate with DRF estimations and complete obstruction especially in high grades of hydronephrotic kidneys. Because the principle rational for intervention is maintaining DRF or avoiding deterioration of kidney function, falsely negative results of DRF estimations can result in missing the optimal surgery timing. There was no correlation between classical DRF estimations, hydronephrosis grade, APD, MAG-3 drainage pattern and visual evaluation of the DMSA scan in our study, so we offer a new approach, correcting the classical DRF estimation according to kidney area. DRF estimations with this corrected method correlated with all clinical findings: the most powerful correlation was determined between visual evaluation of the DMSA scan and corrected DRF estimation. We determined a significant inverse correlation between corrected DRF estimations and the grade of hydronephrosis and APD in our study. With the increasing grade of hydronephrosis and APD, MAG-3 drainage patterns worsened and DRF estimations decreased.

More studies are needed to further assess the prognostic contribution of area-corrected DRF estimation, not only for predicting need for surgical intervention but for also the recovery and preservation or improvement of DRF after surgery.

Conclusion

Our results suggest that correcting DRF estimation for the asymmetric renal area ratio in unilateral hydronephrosis can be more robust than the classical method, especially in higher grades of hydronephrotic kidneys, under equivocal circumstances.

References

1. Longpre M, Nguan A, MacNeily EA, Afshar K. Prediction of the outcome of antenatally diagnosed hydronephrosis: a multivariable analysis. J Pediatr Urol. 2012;8:135–9.
2. Piepsz A, Gordon I, Brock J, Koff S. Round table on management of renal pelvic dilatation in children. J Pediatr Urol. 2009;5:437–44.
3. Piepsz A, Colorinha P, Gordon I, Hahn K, Oliver P, Roca I. European Associations of Nuclear Medicine guidelines on c-99 m DMSA scintigraphy in children. Eur J Nucl Med. 2001;28(3):37–41.

4. Nguyen HT, Herndon CD, Cooper C, Gatti J, Kirsch A, Kokorowski P, et al. The Society for fetal Urology consensus statement on the evaluation and management of antenatal hydronephrosis. J Pediatr Urol. 2010;6:212–31.
5. Inanir S, Biyikli N, Noshary O, Caliskan B, Tugtepe H, Erdil TY, et al. Contradictory supranormal function in hydronephrotic kidneys: fact or artifact on pediatric MAG-3 renal scans. Clin Nucl Med. 2005;30:91–6.
6. Piepsz A, Blaufox MD, Gordon I, Granerus G, Majd M, O'Reilly P, et al. Consensus on renal cortical scintigraphy in children with urinary tract infection. Semin Nucl Med. 1999;29:160–74.
7. Capolicchio G, Jednak R, Dinh L, Salle JL, Brzezinski A, Houle AM. Supranormal renographic differential renal function in congenital hydronephrosis: fact, not artifact. J Urol. 1999;161:1290–4.
8. Aktas GE, Inanir S. Relative renal function with MAG-3 and DMSA in children with unilateral hydronephrosis. Ann Nucl Med. 2010;24:691–5.
9. Kabasakal L, Turkmen C, Ozmen O, Alan N, Onsel C, Uslu I. Is frusemide administration effective in improving the accuracy of determination of differential renal function by means of technetium-99 m DMSA in patients with hydronephrosis? Eur J Nucl Med. 2002;29:1433–7.
10. Gungor F, Anderson P, Gordon I. Effect of the size of regions of interest on estimation of differential renal function in children with congenital hydronephrosis. Nucl Med Commun. 2002;23:147–51.
11. Oh SJ, Moon DH, Kang W, Park YS, Park T, Kim KS. Supranormal differential renal function is real but may be pathological: assessment by Tc-99 m mercaptoacetylglycine renal scan of congenital unilateral hydronephrosis. J Urol. 2001;165:2300–4.
12. Evans K, Lythgoe MF, Anderson PJ, Smith T, Gordon I. Biokinetic behavior of technetium-99 m-DMSA in children. J Nucl Med. 1996;37:1331–5.
13. Konda R, Sakai K, Ota S, Abe Y, Hatakeyama T, Orikasa S. Ultrasound grade of hydronephrosis and severity of renal cortical damage on 99 m technetium dimercaptosuccinic acid renal scan in infants with unilateral hydronephrosis during followup and after pyeloplasty. J Urol. 2002;167:2159–63.
14. Ross SS, Kardos S, Krill A, Bourland J, Sprague B, Majd M, et al. Observation of infants with SFU grades 3–4 hydronephrosis: worsening drainage with serial diuresis renography indicates surgical intervention and helps prevent loss of renal function. J Pediatr Urol. 2011;7:266–71.
15. Burgu B, Aydoğdu O, Soygur T, Baker L, Snodgrass W, Wilcox D. When is it necessary to perform nuclear renogram in patients with a unilateral neonatal hydronephrosis? World J Urol. 2002;30:347–52.