Drainage-related ultrasonography (DRUS): a novel technique for discriminating obstructive and nonobstructive hydroureters in children

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Abstract

Background Despite advances in urologic imaging, the paucity of an optimal technique that accurately clarifies obstructive and nonobstructive hydroureter exists.

Objective This study was conducted to introduce a novel and modified ultrasonographic technique, known as drainage-related ultrasonography (DRUS), discriminating obstructive and nonobstructive, nonrefluxing hydroureter.

Materials and methods A total of 358 children (mean age, 3.7 years) with 418 nonrefluxing hydroureter were included. These children were composed of two groups of obstructive nonrefluxing (141 children with 157 dilated ureters) and nonobstructive, nonrefluxing (217 children with 261 hydroureter). The definite diagnosis regarding the

subtype of hydroureter was derived from appropriate investigation. The maximum diameter of the dilated ureter, which was observed on ultrasonography, was recorded before and after 3 h of catheterization, as $D1$ and $D2$, respectively. To assess the D ratio, a formula was developed, that is, $[(D1 - D2)/D1] \times 100$. Values were recorded and cutoff points were set to discriminate between subtypes.

Results Obstructive versus nonobstructive subtypes of nonrefluxing hydroureter were clarified with 78.5 % sensitivity and 83.4 % specificity, by setting a cutoff point of 22 % for the D ratio. Regardless of the cutoff point assigned to the reduction in D ($D2$ compared with $D1$), DRUS revealed 93.9 % sensitivity, 80.6 % specificity, 63.2 % positive predictive value, and 97.4 % negative predictive value in discriminating upper from lower obstruction.

Conclusion DRUS affords favorable results in terms of differentiating between obstructive and nonobstructive, nonrefluxing hydroureter, as well as between upper and lower obstruction in obstructive cases. It has the potential to become an efficient imaging modality in the diagnostic algorithm of hydroureter.

Keywords Urinary tract obstruction · Hydroureter · Technetium-99 m DTPA · Radioisotope renography · Urinary bladder · Drainage

Sommario

Background Nonostante i progressi nella diagnostica per immagini urologica, vi è la mancanza di una tecnica ottimale che definisca con precisione l'idrouretere ostruttivo e non-ostruttivo.

Obiettivi Questo studio è stato condotto per introdurre una nuova e modificata tecnica ecografica (US), conosciuta

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come drenaggio correlato all'ecografia (DRUS), per discriminare l'idrouretere ostruttivo da quello non-ostruttivo.

Materiali e metodi Un totale di 358 bambini (età media: 3,7 anni) con 418 idroureteri senza reflussi sono stati inclusi nello studio. Questi bambini sono stati divisi in due gruppi, con forme ostruttive, senza reflusso (141 bambini con 157 ureteri dilatati) e con forme non-ostruttive, senza reflusso (217 bambini con 261 idroureteri). La diagnosi definitiva riguardo il sottotipo di idrouretere è stata fatta con indagini appropriate. Il diametro massimo dell'uretere dilatato misurato con ecografia, è stato registrato prima e tre ore dopo la cateterizzazione, rispettivamente come *D1* e *D2*. Per valutare il rapporto *D*, è stata sviluppata una formula $[(D1 - D2)/D1] \times 100$. I valori sono stati registrati e sono stati fissati punti di cut-off per discriminare tra i sottotipi.

Risultati Le forme ostruttive vs non-ostruttive di idrouretere, senza reflussi, presentavano il 78,5 % di sensibilità e il 83,4 % di specificità, con punto di cut-off del 22 % per il rapporto *D*. Indipendentemente dal punto di cut-off assegnata al rapporto *D* (*D2* rispetto a *D1*), il DRUS ha rivelato 93,9 % di sensibilità, 80,6 % di specificità, 63,2 % e 97,4 % PPV NPV nel differenziare ostruzioni alte da quelle basse.

Conclusioni Il DRUS comporta risultati favorevoli nella diagnosi differenziale tra forme ostruttive e non-ostruttive senza reflusso. Ha le potenzialità per diventare una modalità di imaging efficace negli algoritmi diagnostici dell'idrouretere.

Introduction

Hydroureter is characterized as a dilated ureter with a diameter greater than 6 mm. It comprises 8–23 % of cases with hydronephrosis detected on prenatal ultrasonography (US) [1]. A variety of etiologies can cause hydroureter, including a primary defect in the development of distal ureter and ureterovesical junction, or can occur secondary to other disorders such as ectopic ureter, neurogenic bladder, and diabetes insipidus [2].

A precise clarification of the subtype is of utmost importance because the therapeutic approach to each subgroup is different [1]. Spontaneous resolution is observed in a significant proportion of primary nonrefluxing non-obstructive hydroureter, whereas secondary obstructive and/or refluxing hydroureter requires correction of the underlying etiology [3]. The development of urologic imaging has had a great influence on the diagnosis and treatment of urological disorders [3]; however, US remains the initial diagnostic modality in suspected urinary abnormalities. It provides useful details of the renal parenchyma,

collecting system, and bladder; in addition, it can discriminate the causes of hydronephrosis, such as suggesting ureteropelvic junction obstruction (UPJO) based on the presence or absence of a dilated ureter [4]. The most crucial aim of imaging is to detect ureters requiring surgical intervention. Nonetheless, an optimal modality remains to be unveiled [5]. Because US does not provide objective, reproducible parameters of function and obstruction, other diagnostic modalities, including diuretic renal scintigraphy (diuretic renography), are mandatory to evaluate for obstruction in hydroureter [6].

The authors hypothesize that response to free bladder drainage in terms of ureteral diameter may help categorize hydroureter. This study aimed to introduce a novel US-based imaging modality that assists in discriminating between obstructive and nonobstructive hydroureter.

Materials and methods

Between April 2000 and February 2012, a total of 358 children with 418 hydroureter (dilated ureters with largest diameter ≥ 6 mm after urination) diagnosed through ultrasonographic examination by an expert pediatric radiologist were studied. A novel modification in routine US examination of the urinary tract with measurement analysis of the anterior–posterior pelvic diameter (APPD) and ureteric diameters (UD), before and after a 3-h free bladder drainage, has been used and regarded as drainage-related ultrasonography (DRUS). Children with hydroureter in whom voiding cystourethrogram (VCUG) established no vesicoureteral reflux (VUR) were included.

Those who had undergone surgical repair or had transient hydroureter, which relieved after repeated measurements, were excluded. In addition, children who were not compliant with the study and participants with incomplete records were not included. Patients were divided into two groups, obstructive hydroureter ($n = 157$) and nonobstructive hydroureter ($n = 261$), according to the findings on the technetium-99 m diethylenetriamine pentaacetic acid (^{99m}Tc -DTPA) study. No treatment or reconstructive surgical intervention was performed before enrollment. All parents were provided with detailed description, and written consent was obtained from all parents or caregivers. All participants received care according to the 2008 World Medical Association Declaration of Helsinki. This study was approved by an appropriate institutional board review.

Data acquisition

Routine US evaluation of urinary tract was performed for all participants to obtain information regarding the urinary collecting system, bladder, and kidneys. Subsequently,

VCUG was performed before enrollment to rule out VUR and to obtain information regarding the urinary tract [7]. Diuretic renography with ^{99m}Tc -DTPA was performed, and delay in clearance was regarded as an obstructive pattern. A half-time ($T_{1/2}$) of >20 min with no response to diuretics was regarded as obstruction. Parents were instructed to fully hydrate children before the procedure.

Baseline metabolic panel, complete blood count, urine analysis, and urine culture were obtained. Further specific investigations were requested for a minority of patients to establish the diagnosis. The definite diagnosis was established based on findings from the combination of assessments performed by an experienced pediatric urologist and pediatric radiologist accompanied by counseling with an expert pediatrician. DTPA was considered the gold standard to compare and interpret the results obtained by the DRUS technique.

Drainage-related ultrasonography

Images were acquired through a multistep procedure. The US evaluation of upper urinary tract and bladder was performed to measure the diameters of renal parenchymal cortex, renal pelvis, and ureters as well as to observe the bladder appearance. The same measurements were repeated after voiding in a comfortable room to rule out transient hydroureter for toilet-trained participants. Children in whom hydroureter resolved after voiding (or neonates after emptying the bladder) were excluded from the study. Parenchymal thickness was measured as the sum of the length of medulla and renal cortex. Ureteral and renal pelvis diameters were measured on longitudinal images. Subsequently, an appropriate-sized Nelaton (straight) catheter with respect to patient's age was inserted into the bladder. The largest diameter of the hydroureter was recorded as $D1$. The largest diameter of ureter was measured although there was no peristalsis wave. The severity of hydroureter was graded I if $6\text{ mm} < D1 < 10\text{ mm}$, II if $10\text{ mm} \leq D1 \leq 15$, and III if $D1 > 15\text{ mm}$. All participants were under the supervision of an experienced pediatric radiologist and pediatric urologist; no restriction on drinks and food was given. In contrast to diuretic renography, no medication such as diuretics was administered. A 6- to 8-F feeding tube or Nelaton catheter was used for bladder-free drainage. During the 3-h catheterization, infants were seated on the lap of their mothers with the bag being secured to their body. Toddlers could walk around during the study. After catheterization, the abovementioned measurements were repeated, and the largest diameter of ureter after catheterization was recorded as $D2$. Changes in the diameter ($|D1 - D2|$) of the hydroureter were calculated and divided by the largest diameter, which was measured immediately after catheterization ($D1$). Because

ureteral diameter varies depending on age, gender, and body mass index, we estimated calculating the ratio of $(|D1 - D2|)/D1$, which enabled us to standardize alterations in the ureteral diameter individually. Moreover, the standardized change in ureteral diameter was regarded as the D ratio. A single experienced radiologist who was blind to previous medical results at the time of the procedure performed ultrasound examinations for all participants. DRUS was performed using a US unit (Siemens model Ultrasound, Siemens Medical Solutions, USA) equipped with a linear array transducer with 4–9 MHz or a curved array transducer with a 1- to 4-MHz emission frequency (based on the child's age). VCUG was performed at the beginning of the study before the DRUS procedure. All participants received a prophylactic dose of antibiotics (cephalexin, 15 mg/kg/night) before catheterization as the routine of our center to avoid urosepsis.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences software (SPSS, version 16; Chicago, Illinois, USA). Categorical variables were compared using the Chi-square test. Continuous variables were expressed as mean $\pm$ SD and compared using the Student t test. The Kolmogorov–Smirnov test was used to assess the normality of continuous variables. Diameters measured by US were expressed in millimeters. The receiver operating characteristic (ROC) curve was drawn to determine the cutoff value for the D ratio to discriminate between obstructive and nonobstructive cases of nonrefluxing hydroureter. The area under the curve, the positive predictive value (PPV), the negative predictive value (NPV), and the sensitivity and specificity of the test were determined. In this study, ^{99m}Tc -DTPA was considered as the gold standard for the detection of obstruction.

Results

Overall findings

A total of 88 girls and 270 boys with mean age of 3.7 ± 3.2 years (range, 1 month to 13 years) were included in this study. From 418 hydroureter units, 203 (48.5 %) involved the left ureter, 95 (22.7 %) were right sided, and 120 (28.8 %) dilated ureters were bilateral. The mean kidney parenchymal thickness was 9.0 ± 6.4 mm with significantly higher values on the left renal units compared with the right side (9.8 ± 8.3 vs. 8.6 ± 3.4 mm, $p = 0.024$), as expected. The mean APPD of all renal units was 18.0 ± 14.1 mm, with significant higher values on the left side (18.8 ± 14.0 vs. 16.1 ± 14.7 mm, $p = 0.001$).

Table 1 Overall findings in the four categories of nonrefluxing hydroureter

Variable	Obstructive nonrefluxing	Nonobstructive nonrefluxing	<i>p</i> Value
<i>Mean ± SD</i>			
Number (%)			
Participants	141 children with 157 ureteral unit	217 children with 261 ureteral units	ND
Age	4.0 ± 2.6	3.6 ± 2.3	0.102
Female	31 (22.0 %)	57 (26.3 %)	0.381
Male	110 (78.0 %)	160 (73.7 %)	
Kidney length	79.9 ± 20.6	81.2 ± 21.3	0.541
Parenchymal thickness	9.1 ± 5.2	9.4 ± 4.6	0.539
AP diameter	18.2 ± 13.8	17.9 ± 13.2	0.825
Hydroureter grade			
I	52 (33.1 %)	82 (31.4 %)	0.431
II	76 (48.4 %)	129 (49.4 %)	
III	29 (18.5 %)	50 (19.2 %)	

Age has been expressed in years. Kidney and urinary tract measurements have been expressed in millimeter

ND not determine

The mean ureteral diameter before catheterization was 12.8 ± 5.6 mm (range, 6–37 mm). Table 1 demonstrates the demographics and measurements implicated in the *D* ratio calculation.

Diameter changes through DRUS

No increase in ureteral diameter or aggravated hydronephrosis was observed after catheterization and after

performing DRUS. Kidney diameters did not change through DRUS. However, APPD in 23 patients with non-obstructive, nonrefluxing hydroureter decreased by 6.4 ± 3.7 mm. The mean reduction in ureteral diameter was 4.3 ± 4.6 mm (range, 0–18). Ureteral diameter decreased in 49/157 (31.2 %) and 183/261 (70.1 %) of ureters in categories of obstructive nonrefluxing and non-obstructive, nonrefluxing hydroureter, respectively. Figures 1 and 2 show UD changes in a child with nonobstructive, nonrefluxing dilated ureters.

Classification of hydroureter into obstructive and nonobstructive groups

The *D* ratio provided by DRUS was used to categorize hydroureter into obstructive versus nonobstructive subtypes. By setting a cutoff of 22 %, the sensitivity, specificity, PPV, and NPV of the test were 78.5, 83.4, 92.3, and 71.1 %, respectively (Fig. 3), for differentiating between obstructive and nonobstructive hydroureter.

DRUS may discriminate upper obstruction from lower obstruction

As noted, 49 ureteral units (33 patients) with the diagnosis of obstructive nonrefluxing MGU showed decreased diameter through the DRUS procedure ($D2 < D1$). Of them, 31 ureteral units were in children with posterior urethral valve (categorized as lower obstructive uropathy), and 18 ureteral units were in children with upper obstructive uropathy. MGU patients with UPJO (35 hydroureter) and ureterovesical junction obstruction (40 hydroureter) (also categorized as upper obstructive MGUs) had no

Fig. 1 DRUS in a boy with secondary nonrefluxing, nonobstructive hydroureter that was well hydrated before procedure similar to all other participants. **a** Start of DRUS with a unilateral right

nonobstructed hydroureter. **b** At the end of DRUS with dramatic decrease, more than 40 %, in nonobstructed ureter diameter

Fig. 2 $D1$ in bilateral hydronephrosis of a girl with ureterovesical junction obstruction was 15.8 mm on the left side and 16.9 mm on the right side, and at the end of DRUS, $D2$ was not changed. RU right ureter, LU left ureter; After Cath, at the end of DRUS when $D2$ was measured

Fig. 3 ROC curves of the D ratio (blue curves) to categorize nonrefluxing hydronephrosis. The area under the curve was 0.875 ($p < 0.001$) for the D ratio to discriminate obstructive from nonobstructive hydronephrosis

response to DRUS, with no significant change in diameter ($D1 - D2$). Therefore, only 18 children with upper urinary tract obstruction had decreased $D2$ (19.3 %), whereas 93.3 % of children with lower urinary tract obstruction responded to DRUS with decreased $D2$ ($p < 0.05$). Accordingly, regardless of the cutoff point assigned to the reduction in D ($D2$ compared with $D1$), DRUS has 93.9 % sensitivity, 80.6 % specificity, 63.2 % PPV, and 97.4 % NPV in discriminating upper from lower obstruction.

Discussion

Studies describing the means of clarification between obstructive and nonobstructive hydronephrosis are sparse. This study was conducted to differentiate these subtypes, by applying a modified US examination designated as DRUS. The procedure was carried out on obstructive and nonobstructive, nonrefluxing hydronephrosis, and 3-h free drainage was confirmed as the most appropriate time course for APP and UD changes.

In this study, a formula was developed as $[(D1 - D2)/D1] \times 100$ in which $D1$ referred to the largest diameter of the ureter, immediately after the insertion of an appropriately-sized bladder catheter, and $D2$ presented the same value after 3 h of catheterization. By setting a cutoff value of 22 %, a sensitivity of 78.5 % and specificity of 83.4 % were achieved in terms of differentiating between obstructive and nonobstructive dilated ureters. This cutoff value was chosen because it was associated with the highest sensitivity and specificity. Hence, the authors propose DRUS as an effective diagnostic modality, which holds the potential to be added to the diagnostic algorithm of nonrefluxing hydronephrosis (Fig. 4). In addition, it may relieve high pressure in bladder and improve bladder-free drainage in subjects with urine overproduction or dysfunctional voiding. It is possible that the free drainage provided by DRUS improves urine flow and reduces pressure of bladder in nonobstructive uropathies associated with hydronephrosis. This hypothesis needs further investigations.

Obstructive uropathies such as posterior urethral valve may lead to increased residual urine volume and bladder pressure and higher maximum detrusor pressure and detrusor overactivity [8]. Relief of obstruction improves bladder

Fig. 4 Diagnostic algorithm of hydronephrosis and the place of DRUS according to this study. DRUS can help the discrimination of obstructive nonrefluxing from nonobstructive, nonrefluxing hydronephrosis with the cutoff value of 22 % for the *D* ratio

function and also treats refluxing hydronephrosis in these patients [8]. No effect on bladder function has been reported in patients with the level of obstruction beyond the bladder such as UPJO. Interestingly, we found that DRUS may discriminate upper from lower urinary tract obstructions. *D2* was decreased in 93.3 % of children with lower urinary tract obstruction, whereas the corresponding figure was only 19.3 % in children with upper urinary tract obstruction.

In this study, transient hydronephrosis was easily detected by the comparison between diameters on US before and after voiding; thereafter, the DRUS technique was carried out on those with true hydronephrosis with no changes after micturition. All patients underwent diuretic renography as the mainstay technique for detection of obstruction and observation of renal function [9]. Radiological modalities are routinely used for the detection of obstruction, including diuretic renography [9] and intravenous urography (IVU) [10]. However, they are not without shortcomings; despite the ability of diuretic renography in distinguishing different degrees of obstruction, limitations in terms of function, application, and comprehensiveness are present. Moreover, it is an invasive procedure that exposes the child to ionizing radiation and results in a high proportion of false-positive or indeterminate findings [11]. In diuretic renography, the kidney's ability in responding to diuretic-induced volume change is assessed to discriminate nonobstructive and obstructive hydronephrosis. However, some limitations to its application have been described in the literature. Chen et al. [12] indicated that obstruction is not reliably diagnosed without including an observation period. Moreover, Homsy et al. [13] reported that the validity of diagnosis is reduced because of the ongoing physiological changes in children. Hence, its reliability is challenged. In addition, an accurate estimation of the

differential renal function or drainage could not be obtained in the presence of significant hydronephrosis [14].

Despite various studies conducted to set an optimal diagnostic modality, diuretic renography remains the mainstay diagnostic imaging for obstructive uropathy. Also, some authors have suggested IVU as an alternative [10]. Diagnostic modalities such as Doppler US, gadolinium magnetic resonance imaging, and contrast-enhanced computerized tomography have been previously used, some of which expose the child to radiation, which is associated with long-term consequences. Vittori et al. [14] compared two renographic procedures to determine a more accurate technique in differentiating between nonobstructive and obstructive dilation.

The injection of furosemide 15 min (F-15) before radioisotope injection and a new procedure called F + 10SP (Seated Position) were compared, and the study revealed that only F + 10SP could differentiate between a normal and nonobstructive dilated ureter in adults, but not in children. In addition, Rowe et al. [6] developed fluorescence imaging to obtain dynamic images of the urine flow and ureteral peristalsis; they concluded that fluorescence imaging would be a potential modality for the diagnosis of UPJO, but its ability in differentiating obstructive from nonobstructive hydronephrosis was not indicated. MRU and computed tomography urography (CTU) possess a diagnostic superiority over conventional modalities [15]. Mithusami et al. [10] investigated the role of MRU in the evaluation of obstructive uropathy. Despite its benefits in providing detailed information on morphological features, the administration of gadolinium exposes the child to possible nephrogenic systemic fibrosis when given to patients with acute kidney injury or chronic kidney disease [16]. CTU exposes the child to radiation, which exceeds the dose applied in IVU in some occasions; on the

Table 2 Comparison of available imaging modalities for discriminating obstructive from nonobstructive uropathy with DRUS

Imaging diagnostic modality	Advantages	Disadvantages
Intravenous urography	1. Mainstay of diagnosis of obstruction	1. Contrast reaction 2. Radiation exposure
Diuretic renal scintigraphy	1. Gold standard modality	1. Invasive 2. Ionizing radiation exposure 3. High proportion of false-positive and indeterminate findings
Magnetic resonance urography	1. Highly sensitive in detecting hydronephrosis and hydroureter 2. No radiation exposure	1. Expensive 2. Invasive 3. Require sedation or even general anesthesia 4. Takes up to one and a half hours 5. Considerable stress factor for the child
Computed tomography urography	1. Promising in evaluating hydronephrosis	1. Radiation exposure 2. Contrast reaction 3. Not routinely used in the pediatric population
Whitaker test; a urodynamic study combined with antegrade pyelography	1. Discrimination of obstructive from nonobstructive uropathy 2. Delineation of the level of obstruction	1. Invasive 2. Need to perform nephrostomy 3. Ionizing radiation 4. Contrast reaction 5. It can cause complication
Color doppler ultrasonography	1. Noninvasive 2. Sufficient discriminative power	1. Its ability in determining obstruction at the UVJ level is yet to be defined
Drainage-related ultrasonography (DRUS)	1. Transportable 2. Easy to handle 3. Non-expensive 4. Repetitive 5. Highly sensitive 6. No need for contrast agent 7. No side effect	1. Fails to differentiate between secondary obstructive and nonobstructive hydroureter 2. The ability to discriminate obstructive from nonobstructive uropathy has not been assessed in non-hydroureter or refluxing ureters 3. Invasive 4. Three hours are taken

other hand, the application of CTU has been limited to adult patients [15]. De Bessa et al. [17] explored the efficacy of color Doppler sonography in discriminating between obstructive and nonobstructive hydronephrosis in children and indicated that a relative jet frequency less than 25 % could be a good indicator of obstruction in severe unilateral hydronephrosis. Nevertheless, its value as an independent predictor of obstruction is yet to be defined; moreover, the study was investigated to merely determine obstruction at proximal ureter and not the distal ureter that is observed in obstructed hydroureter. In addition, compared with DRUS, it poses higher costs to the patient. Table 2 summarizes multiple imaging modalities applied to distinguish obstructive uropathy from nonobstructive cases in comparison with DRUS.

We showed that DRUS is beneficial in determining the presence of obstruction in nonrefluxing hydroureter by

applying a *D* ratio of 22 % as the cutoff. This diagnostic modality poses no beverage or food restriction to the child, and contrary to standard diuretic renography, no medication such as diuretics are administered. All children were well hydrated with drinking water before DRUS, with the amount proportionate to a child's status. A disadvantage of DRUS compared with renal scintigraphy is the lack of differential function data. In addition, repeated catheterization is recognized as the only invasiveness of this diagnostic procedure. Remarkably, to minimize catheterization and preserve its comprehensiveness, the authors performed VCUG at the end of DRUS and omitted the free bladder drainage phase of diuretic renogram during the recent decade.

The importance of the precise clarification of the subtype of hydroureter is highlighted by the fact that the treatment approach toward different subclasses differs significantly. The management of postnatal hydronephrosis is directed by

the presence or absence of obstruction. Nonobstructed and nonrefluxing hydroureter often shows gradual resolution, whereas obstructive refluxing cases require intervention [1]. The mainstay of treatment of hydroureter is removing the underlying etiology; hence, a variety of consecutive diagnostic modalities are required to establish the diagnosis. The evaluation of the urinary tract by US is the initial step; this valuable study provides useful information regarding the site of pathology. The current study revealed that with catheterization and diameter measurement of ureters as part of the DRUS procedure, findings achieved from US can be strengthened. Indications for surgery are grades IV and V hydronephrosis, a UD greater than 15.0 mm, and poor drainage curve during diuretic renography [18], all of which could be easily detected on DRUS. DRUS has the appeal of being a cost-effective and safe modality with no radiation exposure. It is readily available, especially in developing countries. It is safe, inexpensive, and radiation free, and most importantly, it can discriminate between two obstructive and nonobstructive dilated ureters. The diagnosis of the underlying cause of a dilated ureter would be achieved with a step-by-step algorithm, with respect to the presence or absence of VUR and obstruction. In addition, the authors propose it as a potential screening modality before performing diuretic renography. However, more studies should be performed to prove this hypothesis. In addition, attempts to determine the efficacy of US in VUR grading and in refluxing hydroureter continue, and the response to DRUS expressed as the *D* ratio can be evaluated in future studies. Noteworthy, as it cannot distinguish primary and secondary forms of obstructive megaureter, it seems unlikely that it could replace VCUG or DMSA scan in clinical practice, and further studies with larger populations are required in this regard. Limitations of this study bear mention; it is associated with some degrees of operator dependence that could be overcome by the standardization of the technique. Further evolution of DRUS is recognized to fulfill the need for a gold standard and to achieve a central role in the diagnosis and classification of hydroureter. Because a computerized program was not used to obtain diameter measurements, inaccuracy might have occurred. On the basis of the way the ureter was “sectioned” and because of its tortuosity, the ureter may have had a skewed diameter measurement, leading to data misinterpretation. In addition, a larger sample seems necessary to validate the validity of the *D* ratio, before this technique could be applied to clinical practice.

Conclusion

On the basis of this study, DRUS affords favorable results in terms of differentiating between obstructive and non-obstructive hydroureter. It may be recommended as a

satisfactory diagnostic technique, which can be routinely carried out during diagnostic work-ups performed on children with hydroureter. It may offer the opportunity to avoid more invasive and expensive modalities such as standard diuretic renography. Finally, DRUS has the potential to become an important and efficient imaging modality in the diagnostic algorithm of hydroureter. Nonetheless, larger studies are mandated before applying it in clinical practice.

Conflict of interest Abdol-Mohammad Kajbafzadeh, Mehrzad Mehdizadeh, Zahra Aryan, Maryam Ebadi, Shadi Abdar Esfahani, Laleh Montaser-Kouhsari, Azadeh Elmi, Saman Shafaat Talab, Zhina Sadeghi declare no conflict of interest.

Human and Animal Studies The study was conducted in accordance with all institutional and national guidelines for the care and use of laboratory animals.

Informed Consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. All patients provided written informed consent to enrolment in the study and to the inclusion in this article of information that could potentially lead to their identification.

References

1. Anheuser P, Kranz J, Steffens J et al (2013) Primary megaureter]. *Der Urologe Ausg A* 52(1):33
2. Anderson CB, Tanaka ST, Pope JC et al (2012) Acute pain crisis as a presentation of primary megaureter in children. *J Pediatr Urol* 8(3):254–257. doi:10.1016/j.jpurol.2011.05.012
3. Bueschen AJ, Lockhart ME (2011) Evolution of urological imaging. *Int J Urol* 18(2):102–112. doi:10.1111/j.1442-2042.2010.02677.x
4. Campbell MF, Wein AJ, Kavoussi LR. *Campbell-Walsh Urology*. WB Saunders; 2007
5. Riccabona M (2010) Obstructive diseases of the urinary tract in children: lessons from the last 15 years. *Pediatr Radiol* 40(6):947–955. doi:10.1007/s00247-010-1590-1
6. Rowe CK, Franco FB, Barbosa JA et al (2012) A novel method of evaluating ureteropelvic junction obstruction: dynamic near infrared fluorescence imaging compared to standard modalities to assess urinary obstruction in a swine model. *J Urol* 188(5):1978–1985. doi:10.1016/j.juro.2012.07.002
7. Lebowitz RL, Olbing H, Parkkulainen KV et al (1985) International system of radiographic grading of vesicoureteric reflux. *International Reflux Study in Children. Pediatr Radiol* 15(2):105–109
8. Tourchi A, Kajbafzadeh AM, Aryan Z et al (2014) The management of vesicoureteral reflux in the setting of posterior urethral valve with emphasis on bladder function and renal outcome: a single center cohort study. *Urology* 83(1):199–205. doi:10.1016/j.urology.2013.07.033
9. Garcia-Aparicio L, Rodo J, Krauel L et al (2012) High pressure balloon dilation of the ureterovesical junction—first line approach to treat primary obstructive megaureter? *J Urol* 187(5):1834–1838. doi:10.1016/j.juro.2011.12.098
10. Muthusami P, Bhuvaneshwari V, Elangovan S et al (2013) The role of static magnetic resonance urography in the evaluation of obstructive uropathy. *Urology* 81(3):623–627

11. Penna FJ, Chow JS, Minnillo BJ et al (2011) Identifying ureteropelvic junction obstruction by fluorescence imaging: a comparative study of imaging modalities to assess renal function and degree of obstruction in a mouse model. *J Urol* 185(6):2405–2413
12. Chen SY, Su YT, Wu CY (2010) Nonobstructive dilation of urinary tract and later development of obstruction: report of one case. *Pediatr Neonatol* 51(6):353–355. doi:[10.1016/S1875-9572\(10\)60068-X](https://doi.org/10.1016/S1875-9572(10)60068-X)
13. Homsy YL, Mehta PH, Huot D et al (1988) Intermittent hydronephrosis: a diagnostic challenge. *J Urol* 140(5 Pt 2):1222–1226
14. Vittori M, D'Addessi A, Pinto F et al (2011) (99 m)Tc-MAG3 diuretic renography in assessment of obstructive uropathy. The new test F+10SP: a step ahead in the differential diagnosis. *Urologia* 78(3):221–226. doi:[10.5301/RU.2011.8633](https://doi.org/10.5301/RU.2011.8633)
15. Silverman SG, Leyendecker JR, Amis ES Jr (2009) What is the current role of CT urography and MR urography in the evaluation of the urinary tract? *Radiology* 250(2):309–323. doi:[10.1148/radiol.2502080534](https://doi.org/10.1148/radiol.2502080534)
16. Lin SP, Brown JJ (2007) MR contrast agents: physical and pharmacologic basics. *J Magn Reson Imaging* 25(5):884–899. doi:[10.1002/jmri.20955](https://doi.org/10.1002/jmri.20955)
17. de Bessa J Jr., Denes FT, Chammas MC et al (2008) Diagnostic accuracy of color Doppler sonographic study of the ureteric jets in evaluation of hydronephrosis. *J Pediatr Urol* 4(2):113–117. doi:[10.1016/j.jpuro.2007.10.013](https://doi.org/10.1016/j.jpuro.2007.10.013)
18. Arena S, Magno C, Montalto AS et al (2012) Long-term follow-up of neonatally diagnosed primary megaureter: rate and predictors of spontaneous resolution. *Scand J Urol Nephrol* 46(3):201–207. doi:[10.3109/00365599.2012.662695](https://doi.org/10.3109/00365599.2012.662695)