

# MR urography in pediatric uropathies with dilated urinary tracts

Murat Kocaoğlu, Ahmet Turan Ilica, Nail Bulakbaşı, Atilla Ergin, Bahri Üstünsöz, Tuba Sanal, Cem Tayfun, İbrahim Somuncu

## PURPOSE

To determine the diagnostic value of magnetic resonance (MR) urography in children with urinary tract dilatation.

## MATERIALS AND METHODS

Twenty-five children between the ages of 4 months and 13 years (19 males and 6 females, mean age 6.5 years) were evaluated with T2 weighted and contrast-enhanced T1 weighted MR sequences. Results were compared with findings obtained with ultrasonography (n=25), intravenous urography (n=18), Tc99m-DTPA scintigraphy (n=16), and/or micturating cystourethrography (n=13).

## RESULTS

MR urography provided a superior imaging of urinary system dilatation, the site and the etiology of obstruction, and both regular and complicated kidney duplication than did conventional imaging methods. MR urography that used T2 weighted sequences was able to demonstrate 29 of 32 (90.6%) abnormal renal collecting systems. Fourteen of 21 (66.7%) normal systems were revealed by heavily T2 weighted images. Forty-six of 51 (90.2%) renal collecting systems could be shown by T1 weighted sequences. With this sequence, however, five collecting systems (9.8%) could not be shown secondary to poor renal function and/or dilution of contrast agent within the dilated urinary tract.

## CONCLUSION

In children, MR urography may replace conventional urological methods.

**Key words:** • kidney • magnetic resonance imaging • pediatrics • urinary tract

Many techniques such as ultrasonography, intravenous urography (IVU), micturating cystourethrography (MCUG), and radio-nuclide scintigraphy are used in assessing obstructive uropathy in children. However, in uropathy, it is not always possible to reach a diagnosis with a single imaging method. Additional examinations, on the other hand, result in cost increases and time loss. Magnetic resonance (MR) urography has become a popular imaging method in recent years due to the fact that it has been successfully used as a problem solver for various other pathological conditions (1-8).

MR urography has been used to investigate the urinary system since the pioneering study of Hennig et al. on heavily T2 weighted sequences in 1986 (9). In the years that followed, major developments were accomplished in MR urography due to new sequences. Intravenous (IV) contrast enhanced T1 weighted MR urography techniques were added to the non-enhanced T2 weighted techniques. These two methods used in an integrative fashion and/or independently, on various occasions, have complemented each other. As a result of these developments, MR urography began to be used in adults and also in children for various indications (1, 2, 6, 10-15). In this study, the role of MR urography in the evaluation of uropathy accompanied with dilation of the collecting system was assessed. Most of these uropathies were secondary to congenital anomalies.

## Materials and methods

### Patients

Twenty-five patients between the ages of 4 months and 13 years (19 males and 6 females, mean age 6.5 years) were investigated with MR urography between December 2001 and October 2004 for suspected urinary system pathology. All 25 patients' urinary systems were found to be dilated. Based on their previous laboratory and imaging findings, they had initial diagnoses of uropathy, which led to the dilation of their urinary systems, primary being ureteropelvic (UP) and ureterovesical (UV) narrowing. These patients were additionally examined with MR urography. In patients with vesicoureteral reflux, MR urography was conducted to reveal suspected UV and UP obstruction that is associated with vesicoureteral reflux. Before the MR examinations, ultrasonography was conducted on all patients, whereas 13 patients also underwent MCUG, 16 patients had Tc99m-DTPA scintigraphy, and 18 patients had IVU. In addition, two patients, for whom IVU was conducted, also underwent antegrade pyelography.

### MR imaging technique

Patients were hydrated with saline infusion, which began 30 minutes before the start of the MR examination, in order to prevent dehydration. Of the 9 children under the age of 5 years, 5 were intravenously sedated

From the Departments of Radiology (M.K. ✉ [kocaoglumurat@yahoo.com](mailto:kocaoglumurat@yahoo.com), A.T.I., N.B., B.Ü., T.S., C.T., I.S.), and Anaesthesiology and Reanimation (A.E.), Gülhane Military Academy of Medicine, Ankara, Turkey.

Received 3 May 2005; revision requested 16 June 2005; revision received 28 June 2005; accepted 4 July 2005.

and 4 were sedated orally. Midazolam was used for the intravenous sedation. Effectiveness of the oral sedation was ensured with a cardiac cocktail of midazolam and atropine. While sedated, the patients were monitored by electrocardiography, pulse oximetry, and blood pressure measurements. Elastic tapes and supports were used to prevent patient movements.

MR studies were conducted with two different 1.5 T MR scanners (Intera Nova, Philips Medical Systems, Best, the Netherlands, and Vision Plus, Siemens, Erlangen, Germany). Head and body coils were used depending on the size of the patients. MR imaging began with localizing sequences and continued with single slice heavily T2 weighted and multislice heavily T2 weighted images. Intravenous furosemide (0.3 mg/kg) was administered to dilate the collecting system by increasing glomerular filtration and to reduce the T2\* effect of intravenously administered Gd-DTPA. Two minutes after the diuretic

injection, 0.1 mmol/kg of Gd-DTPA was given intravenously. Patients were examined in the coronal plane during the next 20 minutes (at 15 seconds, 1, 3, 5, 10, 15, and 20 minutes) using three-dimensional gradient-echo (3D-GRE) T1 weighted sequences. Additional imaging of kidneys was performed to assess the renal parenchyma using GRE T1 weighted and turbo spin echo (TSE) T2 weighted sequences. MR sequences and the assessment protocols that we used with both scanners are shown in Tables 1 and 2.

Upon the completion of the above mentioned examinations, multislice heavily T2 weighted and 3D-GRE-T1 weighted images were converted by a maximum intensity projection (MIP) technique to images that were similar to conventional urographic images.

#### Evaluation of MR images

MR urography was conducted within 2-7 days after other imaging examinations. This method was used to de-

termine the presence or the absence of dilation in the urinary system, to find the etiology of the dilation and its location, to ascertain the number of collecting systems and the opening of the ureters if there was more than one collecting system, to define the contours of the bladder, and to know whether or not there was posterior urethral dilation. These findings were compared with other imaging techniques and surgical results. Pelvicalyceal enlargement was graded as three degrees of severity: low, mild, and severe. In cases in which the pelvicalyceal system, ureter, UP, and UV junctions could be delineated, it was assumed that the whole urinary system was viewed. Due to the presence of large numbers of dynamic series, the assessment was performed on our diagnostic workstation instead of using hardcopies. All patients were also examined by ultrasonography. Ultrasonographic examinations were conducted using 3.5-5 MHz convex and 5-12 MHz lin-

**Table 1.** MR urography sequences used in Siemens Vision Plus MR scanner

Sequence	TR/TE (msec)	Slice thickness (mm)	Number of slices	Acquisition time (sec)	Number of excitations	Flip angle (°)
T2-HASTE (single slice)	2800/1100.0	50-80	1	7	1	90
T2-HASTE (multislice)	11.9/95.0	4	20	11	1	90
3D GRE T1*	4.6/1.8	1-1.5	60	10	1	30
TRUFI 2D	4.8/2.3	5	15-20	8	1	70
FL2D 80	144.4/4.1	4	15	15	1	80
TSE FS T2	4500/99	5	10-15	120	2	

TR: repetition time, TE: echo time, HASTE: half Fourier single shot turbo spin echo, 3D: three-dimensional, GRE: gradient recalled echo, TRUFI: true fast imaging with steady-state precession, TSE: turbo spin echo

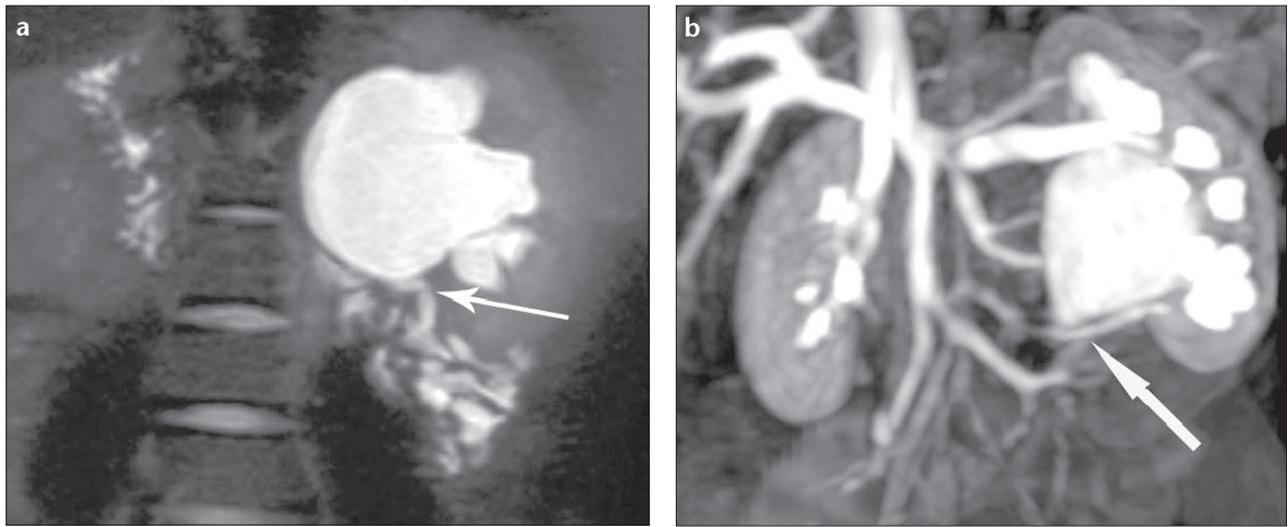
\*MR urography and MR angiography sequence

**Table 2.** MR urography sequences used in Philips Gyroscan Intera MR scanner

Sequence	TR/TE (msec)	Slice thickness (mm)	Number of slices	Acquisition time (sec)	Number of excitations	Flip angle (°)
Single shot TSE	8000/900	65-80	1	8	1	90
3D T2 TSE	1800/650	1.6	20	180	1	90
T1 FFE 3D*	4.7/1.4	1.0	60	12	1	40
B-TFE	6.0/3.0	8.4	15-20	15	1	90
T2 TSE	1600/100	4	10-15	80	2	
T1 FFE	209/4.6	7	15	20	1	80

TR: repetition time, TE: echo time, FFE: fast field echo, TSE: turbo spin echo

\*MR urography and MR angiography sequence



**Figure 1. a, b.** A five-year-old patient presenting with colic pain. **a.** In the coronal T2-HASTE MR image, pelvicalyceal dilation at left, indentation at the proximal part of the left ureter (*arrow*), and angulation of the ureteric part proximal to that point is seen. **b.** An accessory renal artery that compressed the left ureteropelvic junction is seen on coronal MIP MR urography image (*arrow*).

ear transducers, depending on the size of each patient. Renal dimensions and the dilation of the collecting systems were recorded. Micturating cystourethrography was performed on 13 patients. An X-ray film was taken before the bladders were filled. Any reflux to the retrovesical segments of the ureters was evaluated with oblique films during the retrograde filling of the bladders. On male children, the miction was conducted on oblique position to view the urethra. Vesicoureteral reflux was graded as I-V. IVU was performed on 18 patients and it began with the plain abdominal views. During these examinations, additional abdominal films were taken 5, 15, 30, and 60 minutes after the intravenous injection of the non-ionic contrast media. Radio-nuclide studies were conducted using Tc-99m DTPA to reveal the presence of the obstruction and/or the urinary stasis, and to see if diuretics had corrected them.

## Results

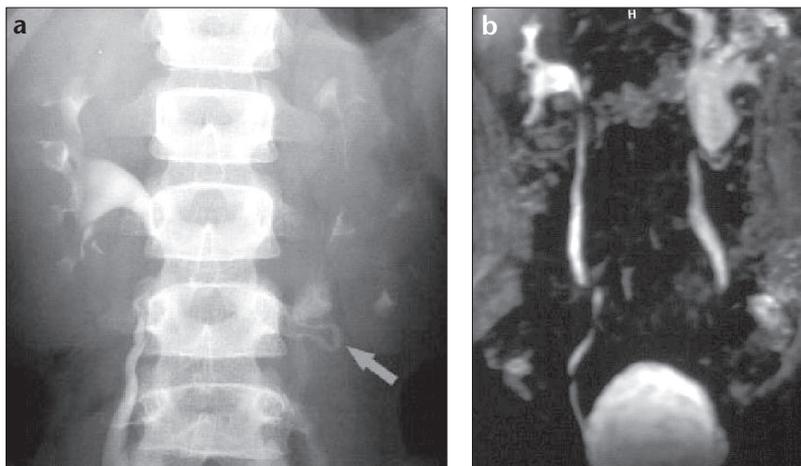
The examinations were successfully completed on the patients who were intravenously sedated. One patient that was orally sedated woke up during the examination and IV contrast-enhanced investigation could not be performed. MR urography images were diagnostically sufficient in all patients. The demographic characteristics of our patients, the results of MR urography, the results of other investigative techniques, and surgical results

are presented in Table 3. A total of 53 collecting systems in 25 patients were examined. One patient had a bilateral and two patients had unilaterally duplicated collecting systems. One case was found to have a solitary kidney. IVU and/or ultrasonography had identified pelvicalyceal and/or urethral dilation in 32 out of the 53 systems investigated. The remaining 21 systems had normal caliber. Urethral dilation was not identified in any of the cases. Nine systems could not be shown with IVU due to extreme abdominal gas distension, impaired renal function, and dilution of the contrast media in dilated collecting systems. Twenty-nine (90.6%) out of 32 pathological systems were shown with MR urography, which used T2 weighted sequences. Fourteen (66.7%) of the 21 normal systems could be identified by heavily T2 weighted images. With T1 weighted sequences 46 (90.2%) of the 51 systems could be shown. The remaining 5 systems could not be viewed due to insufficient function and/or dilution of the contrast media in dilated systems. However, T2 weighted sequences could show these 5 systems; therefore, the urinary systems of all the patients could be imaged by combining T1 weighted and T2 weighted sequences. The patients were assessed and placed in 4 groups according to the dilation of the collecting system. These groups were as follows; pelvicalyceal dilation due to ureteropelvic junction obstruction,

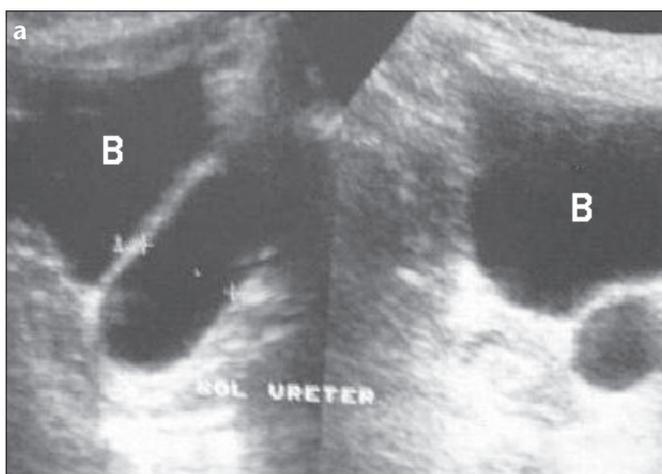
dilation caused by ureterovesical narrowing and/or distal ureteral obstruction, dilation caused by vesicoureteral reflux, and ureter with ectopic insertion.

*Pelvicalyceal dilation caused by urethro-pelvic junction obstruction:* Upon examination of the 13 renal systems of 10 patients (3 cases were examined bilaterally) with MR urographic images, various degrees of pelvicalyceal dilatation, compatible with ultrasonographic grading, were identified. In two of these patients, MR urography showed the narrowing of the ureteropelvic junction and the angulation of the proximal part of the ureter. These findings were typical for vascular compression and were proved by IVU. However, vascular compression could not be shown by color Doppler ultrasonography in these patients (Figure 1). The ureters of two cases whose collecting system dilation continued after pyeloplasty could not be seen in IVU, however these were clearly shown with MR urography. In one case, MR urography demonstrated the non-dynamic twisted segment of the proximal ureter and subsequent functional obstruction. This finding was compatible with the IVU finding and the above-mentioned segment was excised (Figure 2).

*Dilation caused by urethrovesical narrowing and/or distal urethral obstruction:* Upon examination of the 8 collecting systems of 6 patients (2 cases were examined bilaterally) with ultrasonog-



**Figure 2. a, b.** An eight-year-old female patient had a pelvicalyceal expansion of the left kidney, which was identified with ultrasonography. **a.** In intravenous urography, a twisted segment (*arrow*) is seen at the proximal part of the left ureter. The calyces and infundibuli of the left side are thin. **b.** Coronal MIP MR urography image is analogous to the intravenous urography; the collecting system of the right kidney is normal and there is a twisted segment at the left ureteropelvic junction. The passage of the contrast media to both ureters is evident.



**Figure 3. a-c.** A four-month-old male patient in whom ureteropelvic ectasia was seen in prenatal ultrasonography. **a.** Dilatation of the lower end of the left ureter at the level of the bladder (*B*) is seen on the ultrasonographic image at transverse plane. **b.** Dilatation of the left pelvicalyceal system can be seen on the intravenous urography. The contrast passage to the left ureter cannot be seen. **c.** On the coronal MIP MR urography image, the left pelvicalyceal system and the ureter are dilated and the renal parenchyma is thinned.

raphy and/or IVU, ureteral dilatation and/or pelvicalyceal dilatation was noted. The IVU that was conducted on one case for post-natal follow-up of prenatally identified unilateral ureteropelvic ectasia did not have a diagnostic quality due to the presence of severe intestinal air. In this case, however, the ureteropelvic ectasia could be identified ultrasonographically, whereas the MR urography identified a dilated ureter along its entire length and a narrow ureterovesical junction. The patient was operated on after an initial diagnosis of ureterovesical obstruction (Figure 3). In another child with a prenatal ultrasonographic diagnosis of pelvicalyceal dilatation, MR urography that was performed for a suspected ureteropelvic narrowing revealed an ureterovesical narrowing (Figure 4). The distal ureter could not be demonstrated with IVU in a patient who had undergone radiotherapy due to embryonic rhabdomyosarcoma of the bladder, although unilateral ureteropelvic dilatation was ultrasonographically identified. In this case, an antegrade pyelography was conducted and the ureter was shown with similar radiological characteristics as those obtained with MR urography. Axial MR images showed the retroperitoneal soft tissue lesion that led to the above-mentioned obstruction. In that case, the operative diagnosis was compatible with retroperitoneal fibrosis (Figure 5).

*Dilatation caused by vesicoureteral reflux:* In that group there were 5 patients with a total of 7 collecting systems. With MCUG, vesicoureteral reflux of grade II-IV, and ureteral and/or pelvicalyceal dilations of varying severity were identified. MR urography identified dilated systems that were the indirect sign of the reflux.

*Ectopically inserted ureters:* MR urography revealed ectopic ureters in 4 systems of 4 patients, and these observations were surgically confirmed. In two of these patients, ectopic ureters were opened to the neck of the bladder and this could only be seen with MR urography (Figure 6). A female child had urinary dripping, was thought to have an ectopically inserted ureter, and was therefore examined with MR urography. A unilateral collecting system duplication and vaginal insertion were identified. The IVU of this patient could not show the distal part of the dilated ectopic system. She was

**Table 3.** Demographic features, imaging findings and surgical diagnoses of the patients

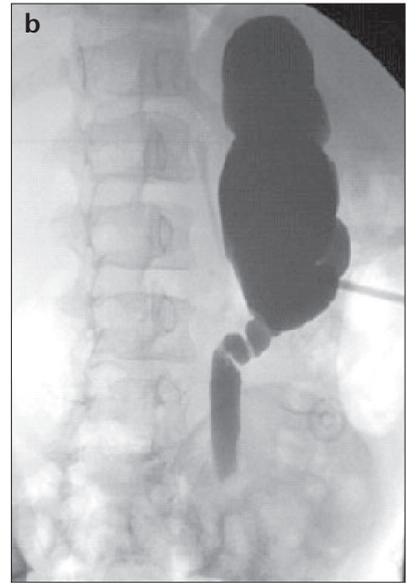
Age/Gender	Ultrasonography	MCUG	IVU	Tc-99m scintigraphy	MR urography	Surgical diagnosis
5/F	Collecting system duplication at the right	N	Collecting system duplication at the right, the distal part of the upper collecting system (-)	-	Ectopic right ureteric insertion to vagina, upper zone is dysplastic	Right upper pole ureter is ectopically inserted to vagina
9/M	Bilateral UPCD, trabeculated bladder	Bilateral grade V VUR	Dilated collecting system, nondiagnostic	-	Bilateral UPCD, trabeculated bladder	-
8/M	Left PCD	-	Left PCD	PCD responding to diuretics at left	Vascular compression at left UPJ, PCD	Accessory renal artery compression to left UPJ
4/M	Left UPCD	N	Nondiagnostic, gaseous distention	UPCD responding to diuretics at left	Left ureterovesical obstruction, left UPCD	Left UV obstruction
2/F	Left PCD	N	-	Nonfunctioning left kidney	Left PCD obstruction	Left UP obstruction
13/M	Left PCD	-	Left PCD	Left kidney function and excretion is impaired	Left PCD	Left UP obstruction
10/M	Right PCD	-	Right extrarenal pelvis?	PC stasis responding to diuretics	Right extrarenal pelvis	-
14/M	Distally dilated right ureter	Grade V VUR at right	Kidney excretion is impaired, nondiagnostic	Renal functions are diminished, partial response to diuretics at right	Right UPCD	Right VUR
9/M*	Solitary right kidney	N	Ureter that opens to the seminal vesicle	PCE with total response to diuretics, ureteral stasis	Ureter that opens to the seminal vesicle	Ureter that opens to the seminal vesicle
6/F	N	Grade II VUR at left	-	-	Left kidney atrophy and dilated ureter	-
8/F	Ureterocele	Grade II VUR at left	N	Left PC stasis with total response to diuretics	Ureterocele	Ureterocele +VUR
7/M	Bilateral PCD	-	Right PCD, no excretion at right	Right PC stasis responding to diuretics, no excretion at left	Bilateral obstructive PCD	Bilateral UV obstruction
7/M	Right UPCD	Grade IV VUR at right	Nondiagnostic, gaseous distention	Stasis responding to diuretics at right	Right duplicated collecting system, right PCD	Right duplicated collecting system and VUR
4/ M	Bilateral PCD	-	-	Bilateral stasis responding to diuretics	Bilateral PCD	-
9/F	Right PCD	-	-	PCD responding to diuretics	Right PCD	-
5/M	Left PCD	-	Left PCD obstruction	Left PCD unresponsive to diuretics	Accessory artery compression at UPJ	Accessory artery compression at left UPJ
9/M	Bilateral PCD	-	Bilateral PCD	PCD with partial response to diuretics	Bilateral PCD	-
8/M	Left UPCD	-	Left PCD, ureter (-)	Left PCD with partial response to diuretics	Passage from UPF (+), UPCD	-
11/M*	Left UPCD	-	Ureteral passage (-)	-	UPCD, obstruction at the distal part of the ureter	Retroperitoneal fibrosis
8/M	Left PCD	N	Distal part of the left ureter (-)	-	Ectopic ureteral insertion to bladder neck	Ectopic ureteral insertion to bladder neck
8/F	Left PCD	-	-	-	Twisting at the proximal part of the left ureter	Adynamic ureteral segment and ureteral twisting
11 mo/M	Hypertrophic left kidney	Grade IV VUR at left	-	-	Left UPCD, right atrophic kidney, dilated right ureter	Left VUR, right atrophic kidney and dilated ureter
8/M	Right UPCD, ureter stone at its lower end	-	Right UPCD, stone at the lower end	-	Right UPCD	Stone at the lower end of the right ureter
10 mo/M	Left PCD	Left grade IV VUR	-	-	Left UPCD, UV obstruction	Left UV obstruction
4/M	Dilated duplicated collecting system	Grade III VUR of the left upper system	-	Stasis responding to diuretics at left	Bilateral duplicated collecting system, upper pole ureter of the left side inserts to the bladder neck	Ectopic ureteral opening to the bladder neck at the left side, VUR

MCUG: micturating cystourethrography, IVU: intravenous urography, UPCD: ureteropelvic dilation, VUR: vesicoureteral reflux, PCD: pelvicalyceal dilation, PC: pelvicalyceal, UP: ureteropelvic, UPJ: ureteropelvic junction, UV: ureterovesical.

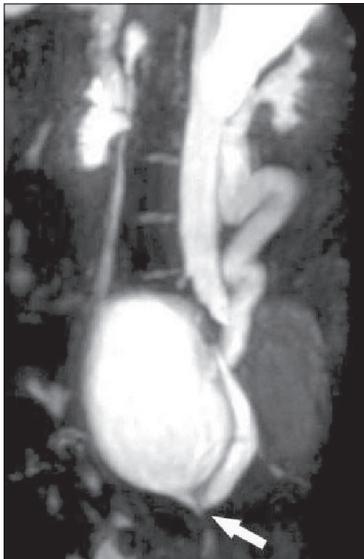
\*Antegrade pyelography was performed.



**Figure 4.** A ten-month-old male patient was clinically followed-up for an initial diagnosis of ureteropelvic junction obstruction. Coronal MIP MR urography image reveals a twisted and dilated left urethra, and ureteropelvic junction obstruction.



**Figure 5. a, b.** An eleven-year-old male patient who underwent radiotherapy due to bladder rhabdomyosarcoma and presented with left flank pain. **a.** There is evident dilation of the left pelvicalyceal structures and the proximal 2/3 of the ureter in coronal 2D-TRUF1 MR sequence. **b.** Antegrade pyelography reveals total obstruction at the distal part of the left ureter. A mass lesion that may have caused the obstruction was identified on the source images. Biopsy of that mass revealed retroperitoneal fibrosis.



**Figure 6.** A four-year-old male patient presented with recurrent urinary infections. Coronal multislice heavily T2-weighted (3D-T2-SPIR-TSE) MR image shows bilateral duplicated collecting systems and the insertion of the ureter that drains the upper part of the left kidney to the bladder neck (*arrow*).



**Figure 7. a, b.** A nine-year-old male patient was operated for anorectal malformation and solitary kidney on the right. Ultrasonography has revealed a dilated collecting system. **a.** In the coronal MIP MR urography image, the distal ureter is seen inserting into the seminal vesicle (*arrow*). **b.** The antegrade pyelography that was performed to treat pyonephrosis demonstrates a mildly expanded ureter and its opening to the seminal vesicle (*arrow*).

operated on and an ureteroureterostomy was performed. The fourth patient had an anorectal malformation and a solitary kidney. He presented with urinary infection and was found to have ureteropelviccaliectasis at right. As the

micturating cystourethrography was normal, an MR urography was scheduled. It revealed a ureter that opened to the seminal vesicle. However, the connection between the seminal vesicle and the bladder could only be found with antegrade urography (Figure 7).

## Discussion

Imaging of the urinary system plays an important role in the radiological examination of children. The widespread use of obstetric ultrasonography has led to the identification of congenital abnormalities in the prenatal stage and has also significantly increased the

number of radiological examinations in pediatric age groups. The morphology of urinary abnormalities must be identified to be able to distinguish between the congenital urinary system abnormalities that require surgical treatment and those that do not. Various imaging techniques are used in the diagnosis of these pathologies, which are mostly of an obstructive nature. IVU, used in the morphological assessment of the collecting system, also provides indirect information about renal function. Its disadvantages are the presence of ionizing radiation and the need for iodinated contrast media. Ultrasonography provides information about the kidneys and the morphology of the bladder, and it can reveal dilated systems, but it does not provide information about the function and cannot fully demonstrate the ureters. Micturating cystourethrography, the gold-standard technique in the assessment of vesicoureteral reflux, is capable of showing the urethra and reflux, if it is present. Its invasive nature and use of ionizing radiation are its disadvantages. With the development of multi-detector technology, computed tomography (CT) has gained a more important role in imaging renal tumors, trauma, and urolithiasis. In addition to that, CT angiography may also permit non-invasive evaluation of renal vascular structures. The use of ionizing radiation and iodinated contrast media are disadvantages of CT. Nuclear scintigraphy supplies information about renal function, and is a very sensitive technique for viewing renal scars; however, the spatial resolution is low and the technique also requires ionizing radiation (5, 12, 14-16).

MR urography is a non-invasive examination method that does not entail ionizing radiation and does not require iodinated contrast media. It may be used in poorly functioning or nonfunctioning kidneys. These characteristics have made MR urography a technique of interest in cases involving children in whom extensive urinary studies are performed (11, 17, 18). MR urography is primarily accomplished by two groups of sequences: T2 weighted and T1 weighted. In the first group of sequences, heavily T2 weighted sequences are used with patients in whom static fluids can be viewed. This technique is independent of function, does not require the use of contrast media,

and is especially successful in imaging dilated systems. In collecting systems that are not dilated, successful results can be obtained by inducing dilation with diuretic administration. With the development of faster sequences, the GRE-T1 weighted sequences provided the opportunity for fast examinations. It is possible to assess the parenchyma and collecting system by using diuretics and Gd-DTPA. In this technique, the diuretic given before the contrast media reduces the T2\* effect that is caused by Gd-DTPA, and it will ensure the acquisition of optimal images by dilating the collecting system. Although we have administered the diuretics 2 minutes before the injection of contrast media, there are studies that recommend administration of gadolinium 15 minutes after diuretic administration to achieve maximal diuretic effect (19). It is possible to obtain IVU-like images by employing MIP method on multislice heavily T2 weighted and contrast enhanced T1 weighted series. Furthermore, images that are taken in the arterial and the venous phase of the contrast enhancement allow identification of the vascular abnormalities by MR urography (4, 7, 17).

Ultrasonography is traditionally the initial examination method in the imaging of dilated systems. It is assisted by MCUG, IVU, and scintigraphy in insufficiently examined cases (8, 14, 20). Obstetrical ultrasonographic examinations can show the dilations of fetal renal collecting systems. Dilations of the urinary system in the pediatric age group are generally due to urethropelvic strictures, vesicoureteral reflux, and posterior urethral valves. In such pathological conditions, ultrasonography proves to be a less expensive method of examination that does not require ionizing radiation. However, it cannot provide information about urinary excretion. Therefore, it necessitates complementary techniques such as scintigraphy and IVU (21, 22). Both IVU and MR urography/angiography are able to show the angulation at the ureteric part that is proximal to the compression, which is accepted to be typical of external vascular compression. It is possible to view the vascular structures that compress the ureteropelvic junction in pediatric patients with color Doppler ultrasonography and the findings obtained are compatible with intraoperative results (24). In our cases,

however, we were unable to show vascular compression. Very large cystic structures can be seen in cases with serious urinary dilation when performing ultrasonography; therefore, it may be difficult to evaluate these cases. Furthermore, if the midureteral segments are not dilated, they cannot be shown with ultrasonography. In either case, MR urography can provide diagnostic information.

High-grade urinary system dilations, which are caused by vesicoureteral reflux, may be indirectly shown. This is accomplished by the increased intensity of Gd-DTPA in the ureter at the advanced stage of the examination and by ureteropelvic dilatation. However, reflux cannot be shown directly because MR urography cannot be performed during urination (25).

Another group of pediatric pathologies that may pose difficulties in terms of conventional imaging methods are duplicated collecting systems. This pathology presents with subsequent complications. In duplicated collecting systems, obstruction, ectopic ureter, and ectopic ureterocele or vesicoureteral reflux may be seen in one of the systems (18, 25-27). If an obstruction is present, it is possible to identify this condition by ultrasonography during the prenatal or the postnatal period. However, if reflux or obstruction causes atrophy of one of the renal systems, it may not be possible to identify it with ultrasonography, or even with IVU or scintigraphy, as this condition impairs renal function. Furthermore, if an ectopic ureter exists, IVU is generally unsuccessful in showing the ectopic opening due to the nonfunctional system in which the ectopic ureter drains or the contrast solution passing through the dilated collecting system is diluted. MR urography, which utilizes heavily T2 weighted imaging may correctly show the ectopic opening of the ureter and the morphology of the collecting system, even in kidneys that have impaired functioning (18, 22). In two of our cases, it was possible to show the ureters that were ectopically opened, one to the bladder neck, one to the vagina, and the other to the seminal vesicle. In the last case, the relationship between the seminal vesicle and the bladder could only be seen after an antegrade urography was used.

The cost, access problems, and the need for anesthesia in some patients

are disadvantages of MR urography. However, the total cost of conventional techniques can often surpass the cost of the MR urography because usually more than one imaging technique is used in diagnosing uropathological problems. On the other hand, there is still a need for anesthesia for some children in scintigraphic examinations and the duration of this type of examination is generally longer than MR examinations. Some of the pathologies may only be seen with MR urography and therefore its advantages override its disadvantages (2, 6). Furthermore, it is also possible to quantitatively evaluate renal function with MR urography. Functional data, similar to the information that is gathered with scintigraphy, may be obtained by contrast enhanced dynamic MR urography. The response of the kidneys to the diuretic injection, and whether the dilation is obstructive or not can be determined by establishing time-signal intensity curves, and by adding structural sequences it may be possible to obtain morphological and functional information simultaneously (28-30). Rohrschneider et al. have combined the sequences that were targeted at the function and morphology in children with congenital dilation of the urinary system, and they have compared their results with postdiuretic scintigraphy (30). In their study, they have shown a significant correlation between dynamic MR urography and postdiuretic renal scintigraphy, in terms of renal functioning (30).

In conclusion, MR urography is a technique that can be used for all age groups. It provides information about renal function and allows the imaging of the collecting systems of under-functioning or nonfunctioning kidneys. It may also be used to evaluate double collecting systems with complex congenital pathologies.

## References

1. Karabacakoglu A, Karakose S, Ince O, Cobankara OE, Karalezli G. Diagnostic value of diuretic-enhanced excretory MR urography in patients with obstructive uropathy. *Eur J Radiol* 2004; 52:320-327.
2. Riccabona M. Pediatric MRU-its potential and its role in the diagnostic work-up of upper urinary tract dilatation in infants and children. *World J Urol* 2004; 22:79-87.
3. Borthne AS, Pierre-Jerome C, Gjesdal KI, Storaas T, Courivaud F, Eriksen M. Pediatric excretory MR urography: comparative study of enhanced and non-enhanced techniques. *Eur Radiol* 2003; 13:1423-1427.
4. Nolte-Ernsting CC, Staatz G, Tacke J, Gunther RW. MR urography today. *Abdom Imaging* 2003; 28:191-209.
5. Avni EF, Bali MA, Regnault M, Damry N, Degroot F, Metens T, Matos C. MR urography in children. *Eur J Radiol* 2002; 43:154-166.
6. Riccabona M, Simbrunner J, Ring E, Ruppert-Kohlmayr A, Ebner F, Fötter R. Feasibility of MR urography in neonates and infants with anomalies of the upper urinary tract. *Eur Radiol* 2002; 12:1442-1450.
7. Nolte-Ernsting CC, Adam GB, Gunther RW. MR urography: examination techniques and clinical applications. *Eur Radiol* 2001; 11:355-372.
8. Verswijvel GA, Oyen RH, Van Poppel HP, et al. Magnetic resonance imaging in the assessment of urologic disease: an all-in-one approach. *Eur Radiol* 2000; 10:1614-1619.
9. Hennig J, Nauwerth A, Friedburg H. RARE imaging: a fast imaging method for clinical MR. *Magn Reson Med* 1986; 3:823-833.
10. Zielonko J, Studniarek M, Markuszewski M. MR urography of obstructive uropathy: diagnostic value of the method in selected clinical groups. *Eur Radiol* 2003; 13:802-809.
11. Hughes J, Jan W, Goodie J, Lund R, Rankin S. MR urography: evaluation of different techniques in non-dilated tracts. *Clin Radiol* 2002; 57:989-994.
12. Leppert A, Nadalin S, Schirg E, Petersen C, Kardorff R, Galanski M, Fuchs J. Impact of magnetic resonance urography on preoperative diagnostic workup in children affected by hydronephrosis: should IVU be replaced? *J Pediatr Surg* 2002; 37:1441-1445.
13. Erdoğan B, Bozkurt M, Bakır Z. Üriner sistem obstrüksiyonlarında HASTE tekniğinin ve ekskretuar MR ürografinin tanı değeri. *Tani Girişim Radyol* 2004; 10:309-315.
14. Borthne A, Pierre-Jerome C, Nordshus T, Reiser T. MR urography in children: current status and future development. *Eur Radiol* 2000; 10:503-511.
15. Borthne A, Nordshus T, Reiser T, et al. MR urography: the future gold standard in pediatric urogenital imaging? *Pediatr Radiol* 1999; 29:694-701.
16. Roy C, Saussine C, Guth S, et al. MR urography in the evaluation of urinary tract obstruction. *Abdom Imaging* 1998; 23:27-34.
17. Nolte-Ernsting CC, Tacke J, Adam GB, et al. Diuretic-enhanced gadolinium excretory MR urography: comparison of conventional gradient-echo sequences and echoplanar imaging. *Eur Radiol* 2001; 11:18-27.
18. Engin G, Esen T, Rozanes I. MR urography findings of a duplicated ectopic ureter in an adult man. *Eur Radiol* 2000; 10:1253-1256.
19. Jones RA, Perez-Brayfield MR, Kirsch AJ, and Grattan-Smith JD. Renal transit time with MR urography in children. *Radiology* 2004; 233:41-50.
20. Cronan JJ. Contemporary concepts in imaging urinary tract obstruction. *Radiol Clin North Am* 1991; 29:527-542.
21. Riccabona M, Fritz G, Ring E. Potential applications of three-dimensional ultrasound in the pediatric urinary tract: pictorial demonstration based on preliminary results. *Eur Radiol* 2003; 13:2680-2687.
22. Riccabona M. Potential of modern sonographic techniques in paediatric uro-radiology. *Eur J Radiol* 2002; 43:110-121.
23. Barnewolt CE, Paltiel HJ, Lebowitz RL, Kirks DR. The genitourinary tract. In: Kirks DR, Griscom NT, eds. *Practical Pediatric Imaging*, 3rd ed. Philadelphia: Lippincott-Raven, 1998; 1042-1049.
24. Veyrac C, Baud C, Lopez C, Couture A, Saguintaah M, Averous M. The value of colour Doppler ultrasonography for identification of crossing vessels in children with pelvi-ureteric junction obstruction. *Pediatr Radiol* 2003; 33:745-751.
25. Avni FE, Nicaise N, Hall M, et al. The role of MR imaging for the assessment of complicated duplex kidneys in children: preliminary report. *Pediatr Radiol* 2001; 31:215-223.
26. Claudon M, Ben-Sira L, Lebowitz RL. Lower pole reflux in children: uro-radiologic appearances and pitfalls. *AJR Am J Roentgenol* 1999; 172:795-801.
27. Lebowitz RL, Avni FE. Misleading appearances in pediatric uro-radiology. *Pediatr Radiol* 1980; 10:15-31.
28. Rohrschneider WK, Hoffend J, Becker K, et al. Combined static-dynamic MR urography for the simultaneous evaluation of morphology and function in urinary tract obstruction. I. Evaluation of the normal status in an animal model. *Pediatr Radiol* 2000; 30:511-522.
29. Rohrschneider WK, Becker K, Hoffend J, et al. Combined static-dynamic MR urography for the simultaneous evaluation of morphology and function in urinary tract obstruction. II. Findings in experimentally induced ureteric stenosis. *Pediatr Radiol* 2000; 30:523-532.
30. Rohrschneider WK, Haufe S, Wiesel M, et al. Functional and morphologic evaluation of congenital urinary tract dilatation by using combined static-dynamic MR urography: findings in kidneys with a single collecting system. *Radiology* 2002; 224:683-694.