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Impact of magnetic resonance urography and ultrasonography on diagnosis and management of hydronephrosis and megaureter in paediatric patients

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ABSTRACT

Background: (1) To evaluate the diagnostic value of magnetic resonance urography (MRU) in comparison with ultrasonography (US) to determine the extent of upper urinary tract dilation and (2) to evaluate the impact of MRU on therapy management. **Materials and Methods:** From January 2005 to December 2010, paediatric patients with hydronephrosis or megaureter who underwent MRU in addition to standard work-up imaging were included. Data were retrospectively collected and analysed in comparison with the data obtained from results by US. **Results:** Forty-five patients with upper urinary tract dilatation were included into the study. Twenty-six patients (58%) had a hydronephrosis and 19 patients (42%) presented with a megaureter. Diagnosis was established in all patients by multimodulary imaging work-up including micturating cysto-urethrography, MAG3 renography, US and MRU and could be confirmed in all patients who underwent surgery ($n = 28$). Hydronephrosis was detected in 26 of 26 patients by US (100% sensitivity) and in 25 of 26 patients (96%) by MRU (Not significant (n.s.)). Megaureter was detected in 17 of 19 patients (sensitivity 89%) by US and in 18 of 19 patients (sensitivity 95%) by MRU (n.s.). In all 45 patients, MRU had no impact on surgical or conservative management of hydronephrosis or megaureter. **Conclusion:** In our experience, MRU was not superior to US in detecting hydronephrosis or megaureter and had no impact on the surgical or conservative management of upper urinary tract dilation.

Key words: Children, hydronephrosis, magnetic resonance urography, megaureter, ultrasonography

INTRODUCTION

The incidence of newborn children with abnormalities of the urinary tract is about 0.76%.[1] Despite of a high rate of spontaneous regression of upper urinary tract dilation, surgery is frequently the only curative treatment option in patients with ureteropelvic junction obstruction or obstructive megaureter. Patients with a primary obstructive megaureter require surgical intervention in more than 20%.[2] More than 40% of newborns with hydronephrosis may need pyeloplasty.[3] Therefore, an extensive work-up is mandatory in order to select the patients who require surgery or benefit from a conservative treatment with closed monitoring. Standard modalities of imaging work-up include ultrasonography (US), micturating cysto-urethrography (MCUG) and ^{99m}Tc-MAG3 diuretic renography (MAG3).

Magnetic resonance imaging was introduced in paediatric urology in 1986, followed by Magnetic resonance urography (MRU) in 1999.[4,5] MRU is a highly advanced imaging modality of the urinary tract in children. It provides detailed morphological information by acquisition of images with high contrast and spatial resolution in any orthogonal plane.[6] MR urography showed a high correlation with surgical findings in patients with hydronephrosis and obstruction of the mid and lower ureter.[7-9]

A limiting factor in widespread routine implementation of MRU in paediatric patients is the requirement of sedation for most infants and young children to eliminate motion artefacts.[10] MRU requires a preparation time up to 45 min including intravenous access, hydration and sedation. The examination itself can take up to 1 hour.[11] The most commonly used drug for conscious sedation of neonates and small children is chloral hydrate. Unfortunately, it has the disadvantage of having an ineffective sedation in approximately

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15% of cases.[6] In case of ineffective sedation or non-compliance of older children, it might be necessary to perform the examination under general anaesthesia.

MRU was introduced at our centre in January 2005. A total of 45 patients with upper urinary tract dilation underwent MRU after conventional work-up. The primary aim of this study was to compare MR urography and US with respect to the correct diagnosis of upper urinary tract dilation. Furthermore, we investigated whether findings obtained by MRU resulted in a change of therapy management.

MATERIALS AND METHODS

From January 2005 to December 2010, 45 patients with upper urinary tract dilation (hydronephrosis or megaureter) underwent MR urography and were included in this observational study. The patients were not enrolled consecutively. Data were collected retrospectively by review of medical records. Parental or legal guardian informed consent for the MRU was obtained for all patients. Performing the MRU was approved by our local ethical committee.

Hydronephrosis was defined as a maximum anterior-posterior diameter of the renal pelvis ≥ 5 mm.[12] A distal ureter >5 mm in diameter was defined as megaureter.[13] Standard work up included ultrasonography, MCUG and diuretic renography using ^{99m}Tc-MAG3. In addition some patients underwent diagnostic cystoscopy to exclude lower urinary tract obstruction. A MRU was obtained after completion of the conventional workup. The decision about diagnostic and therapeutic management was made individually at an interdisciplinary conference with pediatric surgeons, nephrologists and radiologists analog to Guidelines of the European Society of Pediatric Urology (ESPU).[14] Each MRU examination was performed, interpreted and documented by a board-certified paediatric radiologist with experience in reading paediatric MRU. Each ultrasound was performed and documented by a board certified paediatric surgeon specialized in paediatric urology.

The main endpoints of this study were (1) to assess whether MRU is superior to ultrasonography for diagnosis of hydronephrosis or megaureter and (2) to evaluate the impact of MRU on therapy management.

MRU was performed at a clinical 1.5 T MR scanner (Magnetom Symphony, SIEMENS Medical Systems, Erlangen, Germany). Patients were placed in supine position and two flexible 4-channel body coils were placed around the patient for signal detection. In neonates and small children, MRU was performed with free breathing using conscious sedation with chloral hydrate. In older children, the examination was either performed with breath hold or under general anaesthesia with breath hold, if the child was non-compliant. After a T1-weighted (T1w) gradient-echo localizer in 3 orthogonal planes, a T2-weighted (T2w) Half Fourier Acquisition Single Shot Turbo Spin Echo (HASTE) sequence with fat saturation (30 slices, slice thickness 3 mm, TR/TE 500/35 ms, turbo factor 114, acquisition time (TA) :15 min) was acquired in axial plane for the visualization of the kidney and the ureters. Subsequently, a slightly angulated T2-weighted TrueFISP sequence was applied for static visualization of the urinary tract. Imaging parameters were TR/TE 6.25/3.18 ms, 25 slices, slice thickness 2.5 mm, matrix size 256 × 185, and the acquisition time was 0:15 min. In addition, high resolution T2w Turbo Spin-Echo images (TR/TE 5450/136, 27 slices, slice thickness 3 mm, matrix size 512 × 256, TA 4:35) were acquired in axial plane. For dynamic nephrography and urography, a 3D T1w TurboFLASH sequence (TR/TE 2.96/1.18 ms, matrix size 384 × 384) was used. In-plane resolution was 1.5 mm isotropic and the acquisition time was 0:25 sec. The image plane with 20 mm slice thickness was slightly angulated and positioned according to the longest cranio-caudal diameter of the kidneys and the course of the ureter. After a native scan, a bolus-injection of 0.05 mmol Gd-DTPA/kg body weight was administered at a flow rate of 0.5 mL/s followed by a 10 ml saline injection at a flow rate of 1.0 mL/s. Images were routinely acquired 1, 6, 9, 11 and 13 minutes after contrast injection, respectively. If deemed necessary by the performing radiologist additional images were acquired in five minutes intervals up to 60 minutes after contrast injection. Finally, a 3D T1w TurboFLASH sequence with the same imaging parameters were acquired in the axial plane.

Post-processing was performed with vendors software (Syngo Vers. Xy, SIEMENS, Erlangen, Germany). Contrast-enhanced images were reformatted to obtain thick slice Maximum Intensity Projections (MIP) in different planes with a slice thickness of 20 mm. Degree of hydronephrosis was described analog to the postnatal grading system established by the Society for Fetal Urology.[15] This grading system has been used to classify the degree of post natal hydronephrosis since 1990. It is already being used and published in pediatric urology research.[16-18] At Grade 0, there is no hydronephrosis. At Grade 1, there is a slight separation of the central renal

echo complex. Grade 2, hydronephrosis is present when only a few calices are identified in addition to a further dilated renal pelvis. At Grade 3, the renal pelvis is dilated and there are fluid filled calices throughout the kidney. Grade 4, hydronephrosis has a similar appearance as Grade 3 plus parenchymal thinning [Figures 1a-c]. The degree of megaureter was described using Pfister-Hendren's classification.[19] A mild megaureter is characterized by minimally ureter dilation and a normal pyelocalyceal system. A moderate megaureter has some caliectasis and greater ureterectasis throughout. A severe megaureter shows significant hydronephrosis and a uniform ureteral dilation [Figure 1 d-f].

Statistical analysis

Sensitivity, specificity, accuracy, Positive predictive value (PPV) and negative predictive value (NPV) were calculated for US and MRU regarding diagnosis of hydronephrosis or megaureter. The two-tailed Fisher Exact test was used for comparison of Sensitivity between US and MRU. *P* value less than 0.05 indicated statistical significance. The statistical analysis was performed using the Predictive Analytics Software18 (PASW) software.

RESULTS

During a 6-year study period, 45 paediatric patients with upper urinary tract dilation were included in the study. The median age was 6 months (range 0 -189 months [=15 years]), with a gender distribution of 31 boys (69%) and 14 (31%) girls. Twenty-six patients had a hydronephrosis and 19 patients had a megaureter. Differential diagnoses of hydronephrosis were Uretero-pelvic junction obstruction (UPJO) (n = 18), Vesicoureteral reflux (VUR) (n = 5) and post-operative long term renal pelvis dilation without reflux or obstruction (n = 3). Differential diagnoses of megaureter included non-refluxing/ non-obstructed (n = 9), obstructed (n = 7) and refluxing (n = 3). Thirty-four patients (76%) had a primary form of hydronephrosis or megaureter and in 11 patients (24%) it was secondary to other conditions. The diagnosis was assured in all patients by cysto-urethrography and MAG3 renography. Of the 45 patients, 27 underwent a diagnostic urethro-cystoscopy to exclude lower urinary tract obstruction. Twenty-eight patients (62%) underwent surgery with curative intention and 17 patients (38%) were conservatively treated. Of the 28 surgically treated patients, 11 underwent a pyeloplasty, 6 patients had a Ureterocystoneostomy (UCN), 4 had a cutaneous ureterostomy, 2 patients a ureterolysis and one each had a combined UCN right and cutaneous ureterostomy left, a suprapubic catheter, cystoscopic incision of ureterocele, endoscopic deflux injection and endoscopic placement of double J ureteral stent, respectively. We also imaged 3 patients with suspicious diagnosis of hydronephrosis but proved to have an ampullary type of renal pelvis.

Hydronephrosis was detected in 26/26 patients by ultrasonography (100% sensitivity) and in 25/26

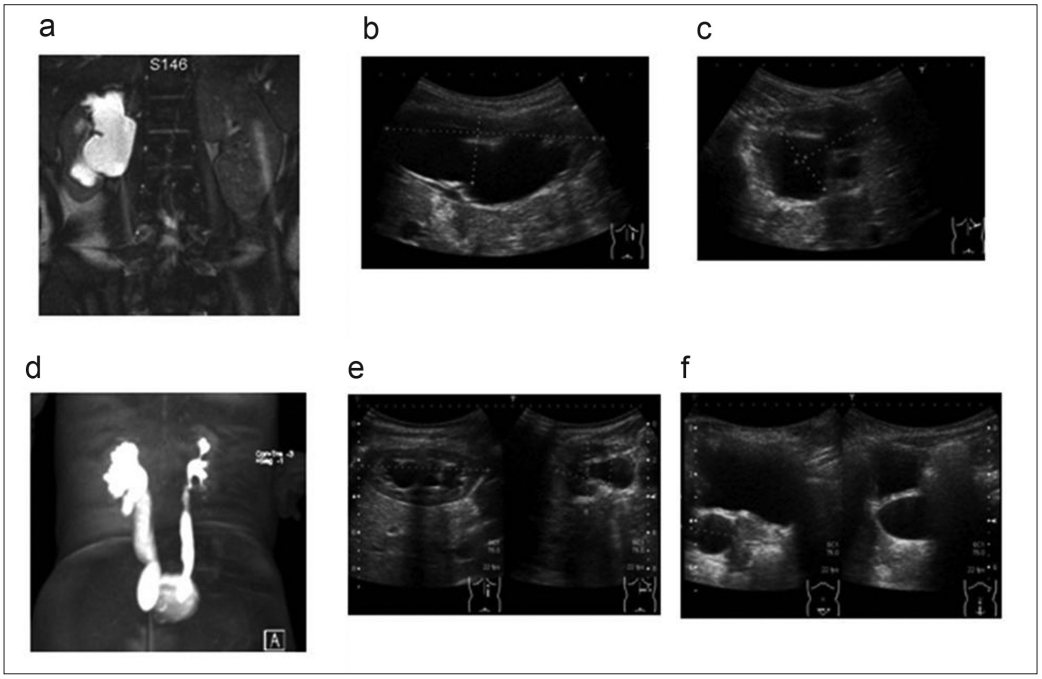


Figure 1: The figure panel shows a hydronephrosis Grade 4 (a, b, c) and a patient with a right giant megaureter (d, e, f) a: coronal MRU of right renal pelvis b: coronal US of right renal pelvis c: axial US of right renal pelvis d: maximum intensity projection MRU of right giant megaureter e: coronal and axial US of right renal pelvis f: coronal and axial US of bladder with right distal ureter

patients (96%) by MR urography (n.s.). There was no difference of more than one degree of hydronephrosis between US and MRU. An ampullary type of renal pelvis was detected by MR urography in 3 of 3 patients (specificity 100%) but was missed by US in all of these 3 patients (specificity 0%). NPV of US and MRU were 0% vs. 75% respectively in this non-pathological condition. PPV and accuracy of US and MRU were similar.

Megaureter was detected in 17 of 19 patients (sensitivity 89%) by US and in 18 of 19 patients (sensitivity 95%) by MRU (P = n.s.). In 2 patients with megaureter, a dilated renal pelvis was described by US but the dilated ureter was missed. In 1 patient, MRU described dilation of renal pelvis but missed the dilated ureter. There was no difference of more than one degree of megaureter classification between US and MRU. Because of no true negative patients imaged by MRU, which are only suspicious for megaureter, specificity, PPV, NPV, and accuracy were not calculated.

Twenty-eight of 45 patients (62%) received surgical treatment, whereas 17 patients (38%) underwent conservative therapy [Table 1]. Decision for surgery was based on MAG3 renography findings in 71% (n = 20). Six patients (21%) underwent surgery because of VUR detected by MCUG. One patient with a megaureter deteriorated and became obstructed due to kinking of the ureter and one patient with a nonrefluxing, nonobstructed megaureter developed an acute, severe pyelonephritis. Both patients received a cutaneous ureterostomy. Decision for conservative therapy (n = 17) was based on a combination of MAG3 renography and MCUG in 59% (n = 10), on MAG3 renography alone in 29% (n = 5) and on MCUG alone in 12% (n = 2). In all 45 patients, MRU had no impact on surgical or conservative management of hydronephrosis or megaureter.

Table 1: Clinicopathological characteristics of patients

Characteristics	No. of Patients	%
Total number of patients	45	100
Age, months		-
Median	6	
Range	0 - 189	-
Gender		
Male	31	69
Female	14	31
Upper urinary tract dilation		
Hydronephrosis	26	58
Megaureter	19	42
Localisation hydronephrosis		
Right	9	35
Left	16	61
Both sides	1	4
Localisation megaureter		
Right	6	32
Left	11	58
Both sides	2	10
Differential diagnoses hydronephrosis		
UPJO	18	69
VUR	5	19
Postoperative long term dilation	3	12
Differential diagnoses megaureter		
Nonrefluxing, nonobstructed	9	47
Obstructed	7	37
Refluxing	3	16
Duplicated collecting system		
Double ureter	2	4
Bifid ureter	3	7
Diagnostic intervention		
Urethrocystoscopy	21	47
None	24	53
Diagnosis confirmed by		
Surgical findings	28	62
Multimodulary imaging work-up	17	38

DISCUSSION

In this study, we investigated magnetic resonance urography in comparison with ultrasound for the evaluation of upper urinary tract dilation in paediatric patients. Each diagnosis was proven either by intraoperative findings or multimodulary imaging work-up. MRU was not superior to ultrasonography for the diagnosis of upper urinary tract dilation in children. Both imaging modalities are highly sensitive in detecting hydronephrosis and megaureter with no statistical difference. We also found that in our institution performing a MRU had no impact on the therapeutic management of surgically or conservatively treated patients.

The development of MRU has offered a high sensitive diagnostic tool in the evaluation of the paediatric genitourinary tract. Several studies have evaluated the role of MR urography in patients with hydronephrosis and megaureter.[7-9,20,21] All these studies showed a high sensitivity of MRU in terms of correct evaluation of upper urinary tract dilation. However, most of these studies evaluated MRU alone without comparing to ultrasonography. Here, for the first time, we present a direct comparison between MR urography and hhigh resolution ultrasonography in the evaluation of pediatric patients with upper urinary tract dilation.

In this study US detected each hydronephrosis [Table 2]. MRU had a sensitivity of 96%. The one patient who was interpreted by MRU as normal (Grade 0) had only a minimal dilation of the renal pelvis (hydronephrosis Grade 1) as imaged by US. There was a

Table 2: Diagnosis of upper urinary tract dilation by ultrasonography and magnetic resonance urography

	Hydronephrosis		*P**	Megaureter		*P**
	US	MRU		US	MRU	
Sensitivity	100% (26/26)	96% (25/26)	1,0	89% (17/19)	95% (18/19)	0,1
Specificity	0% (0/3)	100% (3/3)	-	-	-	-
PPV	90%	100%	-	-	-	-
NPV	0%	75%	-	-	-	-
Accuracy	90%	97%	-	-	-	-

*, comparison of US and MRU by Fisher Exact test (two-tailed), -, not calculated, PPV, positive predictive value, NPV, negative predictive value, US: Ultrasonography, MRU: Magnetic resonance urography

time difference of 24 hours between both examinations. The patient had a VUR as underlying pathology. It is known that patients with VUR might show a diversity of renal pelvis dilation due to different pressure caused by different bladder filling. It could be assumed that at the time of the MRU the pressure was low with no impact on the upper urinary tract. Keeping these variations of pressure and filling status of the upper urinary tract in mind, we defined differences of one Grade between MRU and US in terms of hydronephrosis or megaureter grading as not significant [Tables 3 and 4].

Specificity was calculated in patients with hydronephrosis. Three patients with suspicious diagnosis of hydronephrosis at initial presentation but proven as ampullary type of renal pelvis served as negative control. MRU detected all 3 patients as true negative (specificity 100%) whereas US interpreted these non-pathological conditions as hydronephrosis Grade 1 (specificity 0%). Despite of a statistical significant difference the informative value would be low. Considering the small number of negative control patients and the low false positive US grading, there is no possibility for a valid answer regarding specificity of MRU and US in children with hydronephrosis. Because there were no patients who were only suspicious for megaureter but proven as normal, specificity of MRU and US was not calculated.

This study showed a high MRU sensitivity in detecting upper urinary tract dilation. However, it has to be asked if such an extensive and invasive imaging tool is necessary to detect and describe hydronephrosis or megaureter. As mentioned before MRU might require sedation or even general anesthesia. The procedure with preparation and imaging takes up to one and a half hours and means a considerable stress factor for the child. As shown in our study using modern ultrasound techniques there is no difference of sensitivity between US and MRU. Standardized grading of hydronephrosis and megaureter have improved US reliability and generated comparable results.[15,22] Especially in neonates with hydronephrosis or megaureter imaging of the urinary tract on a regular base is of paramount

Table 3: Grading of hydronephrosis by US and MRU[15]

	Ultrasound				Total
	Grade 1	Grade 2	Grade 3	Grade 4	
MRU					
Grade 0	1	0	0	0	1
Grade 1	1	0	0	0	1
Grade 2	4	7	0	0	11
Grade 3	0	5	4	0	9
Grade 4	0	0	0	4	4
Total	6	12	4	4	26

Grade 0, central renal complex is closely apposed, no pathology, Grade 1, slight separation of the central renal complex, Grade 2, dilated renal pelvis, single or few calices are visualized, Grade 3, dilated renal pelvis, fluid filled calices throughout the kidney, Grade 4, as grade 3 with thinned renal parenchyma

Table 4: Severity of megaureter by US and MRU[19]

	Ultrasound				Total
	Mild	Moderate	Severe	WD	
MRU					
Mild	0	1	0	0	1
Moderate	0	4	0	2	6
Severe	0	2	9	0	11
WD	1	0	0	0	1
Total	1	7	9	2	19

Mild, normal pyelocalyceal system and normal or minimally dilated upper ureter, Moderate, some caliectasis and greater ureterectasis throughout, Severe, significant hydronephrosis with uniform ureteral dilatation, WD, wrong diagnosis: hydronephrosis instead of megaureter

importance to pick up deteriorating patients which may require surgery. Ultrasound which is transportable, easy to handle, non-invasive, non-expensive, repetitive and highly sensitive seems to be an ideal imaging tool.

The second main point of our study was to evaluate the impact of MRU on therapy management. Interestingly in this special group of patients with graded, defined diseases performing a MRU had no impact in none of the cases on the decision to perform a surgical or conservative therapy. It has to be mentioned, that only 5 out of 45 patients in our study had upper urinary tract dilation of a duplicated collecting system and this condition might be difficult to image by US. However, even in these challenging cases, MRU has not changed the therapeutic management.

In addition to morphologic data, MRU can provide detailed information about differential renal function and drainage as measured by MAG3 renography.[6,23,24] Avoiding exposure to ionizing radiation it might have the potential to replace MAG3 renography as gold standard investigation of patients suspected for ureter obstruction.[25] In our retrospective study the temporal resolution of the dynamic MRU sequence was not suited for a functional analysis. As a result, we could not use functional MRU data and therefore only morphologic data are presented in our study. Today with modified MR urography protocols and free downloadable post processing software the combination of morphologic and functional analysis is quite simple.[26,27]

MRU and US should be complementary and not competitive. Main indications of MRU are complex uropathies difficult to evaluate by US alone. In our retrospective study, MRU was also used in cases of simple dilation with a renal pelvis diameter between 5 and 12 mm and hydronephrosis grad 1-2. Today, with the background of our results, we would not prescribe an MR urography to a patient with this type of mild and uncomplicated urinary tract dilation.

In conclusion, we demonstrated that ultrasound with its high sensitivity and convenient handling seems to be the first imaging tool of choice in paediatric patients with upper urinary tract dilation. In our study, MRU had no impact on the therapeutic management. This complex imaging modality combining both morphological and functional analysis should be used in case of an ambiguous anatomic situation or to replace MAG3 renography and therefore to avoid radiation.

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