

Efficacy of Magnetic Resonance urography in detecting crossing renal vessels in children with ureteropelvic junction obstruction



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INTRODUCTION: *An aberrant or accessory crossing renal vessel (CV) leading to the lower pole of the kidney is the most common extrinsic cause of uretero pelvic obstruction (UPJ) obstruction in a child and young adolescent. There is still controversy regarding their functional significance in obstruction. Preoperative identification of such vessels may influence surgical management.*

OBJECTIVE: *First aim is to determine the value of magnetic resonance (MR) urography in detecting crossing vessels in children with UPJ obstruction, comparing the data with postoperative findings and the second one is to evaluate morphologic and functional parameters in these hydronephrotic kidneys.*

MATERIALS AND METHODS: *Between June 2009 and December 2012 we retrospectively reviewed MR urography records of one hundred and nine children with unilateral hydronephrosis at the University Children's Hospital. 68 (62.4%) were male and 41 (37.6%) were female, median age was 6.5 ± 5.7 . Of the total number of patients, 30 (27%) underwent pyeloplasty, while 79 (72.5%) did not. The age at surgery ranged from 0.3 to 18 years (median 6.6 years). The indication for surgery was based on standard criteria (obstructed renal transit time with or without altered renal function of $vDRF < 40\%$), and did not depend on the presence or absence of a crossing vessel. Consensus reviews of the MR urography studies were compared with surgical findings.*

RESULTS: *A crossing vessel (CV) was found upon surgery in 9 (33%) of 30 kidneys. On MRU, there was no crossing vessel in 21 kidneys, confirmed at surgery in 18. A crossing vessel was detected with MRU in 9 kidneys and confirmed at surgery in 6. Thus, the sensitivity of MRU was 66.7%, the specificity was 85.7%, the positive predictive value was 66.7%, the negative predictive value was 85.7% and the accuracy was 80%. There was no statistically significant difference in the detection of crossing vessels between MR urography and surgery ($p = 0.004$ and $p < 0.01$ respectively). Overall, MRU and surgery showed good agreement ($\kappa = 0.524$).*

CONCLUSION: *Based on our results we suggest that MR urography is a reliable and safe diagnostic tool to determine crossing vessels in selected children with UPJ obstruction. Thus, MRU can substitute for other imaging modalities and provide detailed information about the morphology and function of the affected kidney*

KEY WORDS: Children, Crossing renal vessels, Hydronephrosis, Ureteropelvic function obstruction

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Introduction

Unilateral hydronephrosis in a child or young adolescent is most likely due to ureteropelvic junction (UPJ) obstruction, which in turn may be attributable to intrinsic or extrinsic factors. A muscular defect causing

impaired peristalsis and urine drainage is the most common intrinsic cause. In contrast, an aberrant or accessory vascular branch leading to the lower pole of the kidney and crossing anteriorly to the UPJ or upper ureter is the most common extrinsic cause of UPJ obstruction. However, a crossing vessel as the cause or aggravating factor of the obstruction is controversial. Nowadays, hydronephrosis is frequently a prenatal diagnosis, and is followed up postnatally by sonography. Thus, detection of crossing vessels at the UPJ can be important as an indicator of the duration of follow-up required for conservatively managed hydronephrosis. In older symptomatic patients, mainly older children, a crossing vessel is considered a more frequent cause of obstruction. Finally, in both adult patients and older children, advances in endourological techniques and laparoscopic repair have increased the need for detailed pre-operative imaging. This work aims to determine the value of magnetic resonance (MR) urography in detecting crossing vessels in children with UPJ obstruction, and to evaluate morphologic and functional parameters in these hydronephrotic kidneys.

Materials and Methods

PATIENTS

Between June 2009 and December 2012 we retrospectively reviewed MR urography records of children with unilateral hydronephrosis at the University Children's Hospital. Children with unilateral UPJ obstruction were included in the study and those who showed the presence of any other anomaly of the urinary tract (including duplex systems, horseshoe and ectopic kidneys) were excluded from the study. Parental informed consent was obtained and the diagnostic procedure and the study were approved by the Ethics Committee of the University Children's Hospital. One hundred and nine children were included in the study, 68 (62.4%) were male and 41 (37.6%) were female. The mean age of participants was 6.5 ± 5.7 years (range 0.3–18). In children under 6 years of age, the procedure was performed under analgesia/sedation, in accordance with the protocol of the Anaesthesiology Ward of the University Children's Hospital. Of the total number of patients, 30 (27%) underwent pyeloplasty, while 79 (72.5%) did not. The age at surgery ranged from 0.3 to 18 years (mean age 6.6 years). The indication for surgery was based on standard criteria (obstructed renal transit time with or without altered renal function of $vDRF < 40\%$), and did not depend on the presence or absence of a crossing vessel.

MAGNETIC RESONANCE IMAGING PROCEDURE

The children were positioned supine on the imaging table of the Achieva 1.5-T MRI unit (Philips Healthcare,

Amsterdam, Netherlands). Scout images were acquired to determine the position of the kidneys. Following IV hydration and bladder catheterization, pre- and post-contrast MR imaging of the abdomen and pelvis was performed. Lasix (1 mg/kg, maximum 20 mg) was administered IV prior to starting scanning (approximately 15 min before contrast injection). MR images were acquired as per a previously described method¹. Pre-contrast sequences: Localizer 2D FLASH, 2D T2 TSE fat sat ax high resolution, 2D T2 TSE fat sat cor, 3D T2 TSE fat sat cor with MIP reconstruction (3D urogram), 3D T1 GRE fat sat cor. Post-contrast sequences after IV administration of Gd-DTPA (0.1 mmol/kg, 0.20 ml/s), 15 min dynamic 3D T1 GRE fat sat cor (54 continuous acquisitions with progressive delays). After the completion of dynamic 3D T1W sequences, data were transferred to a workstation for post-processing and analysis of the specified parameters using the CHOP-fMRU software package (Children's Hospital of Philadelphia)².

Pyelocaliceal and ureter anatomy was analysed using high resolution T2W sequences and post-contrast, dynamic T1W sequences. Furthermore, dynamic T1W sequences provided visualisation of the renal arteries immediately following contrast administration. Differential renal function (vDRF) was determined by the total volume of kidney parenchyma enhanced following contrast application.

The following morphological parameters were evaluated using MR urography:

1. Degree of hydronephrosis (SFU grading system)
2. Pelvic type: intrarenal, extrarenal, large extrarenal
3. Crossing vessel (CV) - cause of luminal ureteral transition at the UPJ.

The following functional parameters were evaluated using MR urography:

1. Renal transit time (RTT)
2. Volumetric differential renal function (vDRF)

The degree of hydronephrosis was classified in accordance with the criteria proposed by the Association of Foetal Urologists SFU³. RTT is the time for contrast agent to reach the ureter below the level of the lower pole of the kidney (< 4 min = non-obstructed, 4–8 min = equivocal, > 8 min = obstructed). vDRF = split renal function based on the parenchymal volume (Vp). Based on renal transit times, the patients were classified as having obstructed, equivocal or non-obstructed kidneys^{1,4,5}.

Statistical analysis was performed using SPSS software (IBM Corp., Armonk, NY, USA). The sensitivity and specificity of magnetic resonance urography (MRU) in detecting crossing renal vessels were calculated. The agreement between the MRU and surgery was calculated using kappa (κ) statistics. Statistical significance was defined as a p value of $p < 0.05$.

Results

A crossing vessel was found upon surgery in 9 (33%) of 30 kidneys. The correlation between MRU and surgical data is described in Table I

On MRU, there was no crossing vessel in 21 kidneys, which was confirmed at surgery in 18. A crossing ves-

sel was detected with MRU in 9 kidneys and confirmed at surgery in 6. Thus, the sensitivity of MRU was 66.7%, the specificity was 85.7%, the positive predictive value was 66.7%, the negative predictive value was 85.7% and the accuracy was 80%.

There was no statistically significant difference in the detection of crossing vessels between MR urography and surgery ($p = 0.004$ and $p < 0.01$ respectively). Overall, MRU and surgery showed good agreement ($\kappa = 0.524$). Crossing vessels were noted in 18 (16.5%) kidneys in the patient cohort (109 patients) with UPJ obstruction (Table II).

There were 4 girls and 14 boys, with a mean age of 6.89 (range 0.3-18 years). Based on the renal transit time, there were seven kidneys in the obstructed group, 9 in the non-obstructed and only two in the equivocal. The mean SFU grade of hydronephrosis in the CV group was 4.3 (range 1-5); these kidneys were almost twice as likely to have an extrarenal ($n = 12$) as an intrarenal ($n = 6$) pelvis and the mean vDRF was 39%.(range

Table I - Correlation between magnetic resonance urography (MRU) and surgical findings. N = 30 kidney.

MRI	Surgery		
	CV+	CV- 3	Total
CV+	6	3	9
CV-	3	18	21
Total	9	21	30

Legend: CV: crossing vessel; +present; -absent.

Table III - Comparison of operated versus nonoperated patients in the crossing vessel present (CV+) group.

	CV+ operated	CV+ nonoperated
Age (years)	Mean 7.67 (min 0.3-max 18)	Mean 6.1 (min 0.3-max 15)
SFU grade hydronephrosis	Mean 4.88 (min1-max5)	Mean 3.5 (min1-max5)
Renal Transit Time (RTT)	7 obstructed, 1 equivocal, 1 non-obstructed	8 non-obstructed, 1 equivocal
Volumetric Differential Renal Function (vDRF)	Mean 30.84% (min 6.06%- max 51.76%)	Mean 49% (min 31.25-max 64.80)

TABLE II - Clinical characteristics of the crossing vessel present (CV+) group.

Patient	Gender (male, female)	Age (years)	SFU grade hydronephrosis	Pelvis type	Renal Transit Time (RTT)	volumetric Differential Renal Function (vDRF)	Operated
1	m	0.3	3	ER	Non-obstructed	-	-
2	m	0.4	5	IR	Equivocal	42.96	-
3	m	15	4	ER	Non-obstructed	-	-
4	m	5	5	IR	Non-obstructed	31.25	-
5	m	0.8	1	IR	Non-obstructed	44.84	-
6	m	0.3	5	ER	Obstructed	28.57	+
7	f	0.3	5	LER	Obstructed	36.27	+
8	m	3	5	IR	Non-obstructed	39.64	+
9	f	11	5	ER	Equivocal	43.59	+
10	f	14.5	5	LER	Obstructed	51.76	+
11	m	18	5	LER	Obstructed	20.21	+
12	m	1	5	LER	Obstructed	30.77	+
13	m	3	5	LER	Obstructed	6.06	+
14	m	15	3	IR	Non-obstructed	64.80	-
15	m	2.5	4	ER	Non-obstructed	57.03	-
16	m	4	2	ER	Non-obstructed	57.49	-
17	m	12	5	ER	Non-obstructed	45.84	-
18	f	18	4	IR	Obstructed	20.72	+
	14 males, 4 females	Mean 6.5 (min 0.3-max18)	Mean 4.3 (min1-max 5)	7 ER, 5 LER, 6 IR	9 non-obstructed, 7 obstructed, 2 equivocal	Mean 39% (min 6%-max 64.8%)	9 operated, 9 nonoperated

6.06%-64.80%) Nine children from the CV group were operated on; all seven renal units from the obstructed group, one from the equivocal and one from the nonobstructed groups.

Comparing the results from the CV operated versus CV nonoperated group of kidneys (Table III), children from the operated group were older (mean age 7.6 years, range 0.3-18) than in the nonoperated group of children (mean age 6.1 years, range 0.3-15). Furthermore, the mean SFU grade of hydronephrosis in the operated group was 4.88 (range 1-5), compared with mean 3.5 (range 1-5) in the nonoperated group. Based on the renal transit time in the operated group there were 7 kidneys with an obstructed RTT, one renal unit with equivocal RTT, and only one with a nonobstructed RTT. This is in contrast to their nonoperated counterparts, where most of the children had a nonobstructed RTT (n = 8), and only one had an equivocal transit time. Additionally, the vDRF was also different between groups; the mean vDRF in the operated CV group was 30.23%(range 6.06%-51.67%) while most kidneys in the nonoperated group had preserved renal function with a mean vDRF of 49%(range 31.25%-64.80%)

Discussion

As a cause of obstruction, crossing vessels are present in 11-49% of kidneys with UPJ obstruction⁶⁻⁹. If crossing vessels are present they are usually located anterior to the UPJ, whereas posteriorly crossing vessels are less commonly found. Different authors define these vessels as “anomalous”, “aberrant” or “crossing”. It appears that they aggravate rather than initiate UPJ obstruction, because intrinsic pathological changes are nearly always found in the ureter. Most children with unilateral UPJ present in 2 distinct groups: the younger group, asymptomatic with prenatally diagnosed hydronephrosis, and the older group of children, often symptomatic and incidentally diagnosed. Traditionally, increased hydronephrosis on ultrasound examination combined with static or dynamic scintigraphy and pronounced split renal function (more than 10%), are indications for pyeloplasty. Additionally, some surgeons operate earlier, to prevent renal damage at a later stage. The literature suggests that around 25% of children with prenatally diagnosed hydronephrosis caused by UPJ obstruction require surgery^{10,11}.

Patients which do not require surgical management are followed up with ultrasound and scintigraphy, and recently even with MR urography. In our study, the incidence of crossing vessel as a cause of UPJ obstruction was 16.5% in the whole group of unselected children and 30% in the operated group. Previous studies reported similar results. Rooks and Lebowitz⁶ evaluated 201 children operated on for UPJ obstruction, and they found crossing vessel as the obstructive factor in 49% of 100 symptomatic patients with hydronephrosis, but

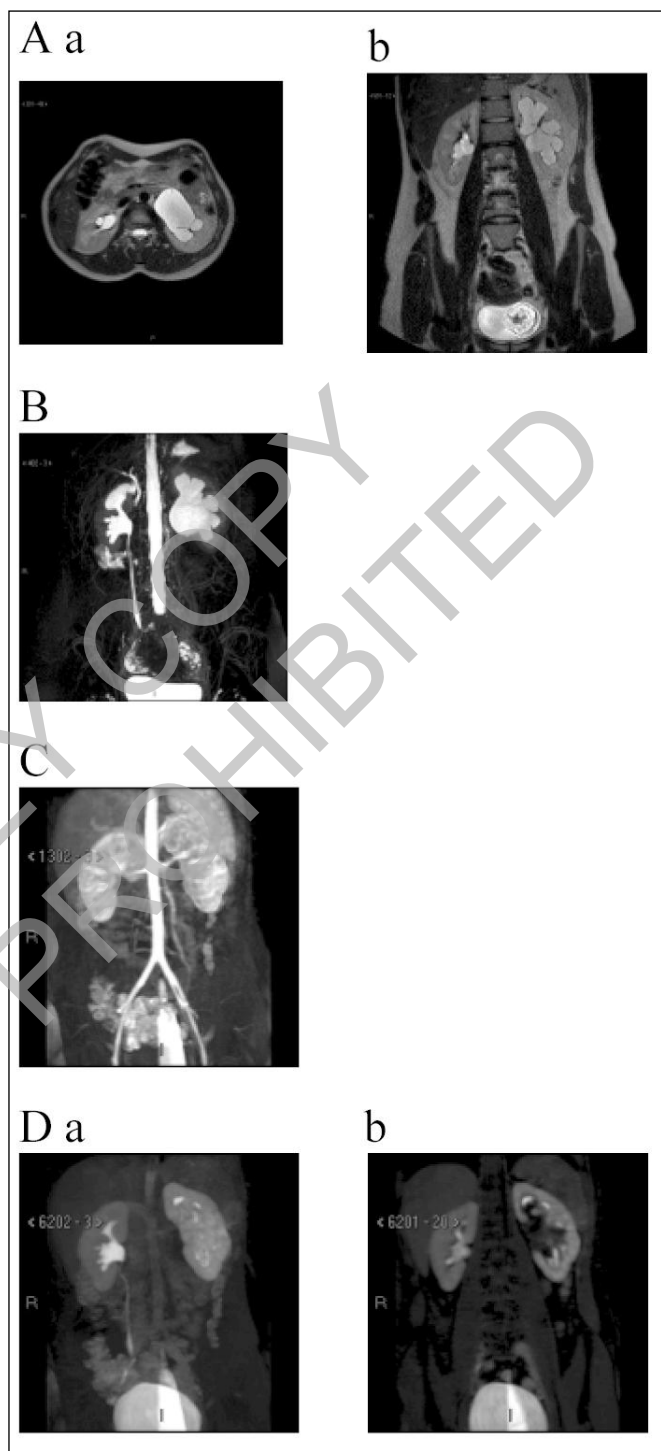


Fig. 1: MRU images of an 18-year-old girl with obstruction of the ureteropelvic junction (UPJ) caused by a crossing vessel. A. Axial (a) and coronal (b) high resolution T2W urograms show marked hydronephrosis of the left kidney with a large extrarenal pelvis and hyperintense kidney parenchyma. B. Maximum-intensity-projection image generated from the 3D T2W of the same patient without visualization of the left ureter. C. Arterial phase of the dynamic post-contrast T1W shows aberrant lower pole artery crossing marked dilated renal pelvis as a cause of obstruction. D. Dynamic post-contrast maximum-intensity-projection images of the same patient with changed functional parameters: prolonged CTT and RTT (after 8 minutes no visualization of the left ureter). Volumetric DRF calculation (vDRF) R:L = 50:40.

only in 11% of 101 patients with hydronephrosis detected by prenatal ultrasound. Our results are also supported by previous study from Lopez et al.¹² in a cohort of 84 kidneys with UPJ obstruction who underwent surgery, and found a crossing vessel in 24 (28.5%) kidneys and no crossing vessel in 60 (71.4%) kidneys. Although it is well known that the incidence of crossing vessels increases with age, the aetiological relationship between crossing renal vessels (CV) and UPJ obstruction remains controversial, with opinion divided over whether CV are incidental, aggravating or causative factors. Based on renal transit time, crossing vessels were identified in all categories in our study. Almost all of the children in the operated group (which were older) showed an obstructed pattern (8 obstructed and 1 equivocal). This is in contrast to the nonoperated CV group of children (8 non-obstructed and 1 equivocal) which almost all had normal, non-obstructed renal transit time. Although the pathophysiology of crossing vessels as a source of UPJ obstruction in children is still unclear, our results suggest that the obstructed pattern of the hydronephrotic kidney in the older group of children is probably a consequence of the exacerbating role of CV associated with obstruction (Fig 1). Minimal or mild intrinsic stenosis alone, which is common in young infants, would be insufficient to produce urinary obstruction later in life. Furthermore, most of the kidneys from this group had poor renal function (30% vDRF), while in the nonoperated group they had mostly preserved renal function (49% vDRF), suggesting that these kidneys may suffer decompensation when there is abnormal vascular configuration at the UPJ later in life. Evaluating the degree of hydronephrosis, we found significant differences between these two groups. Although some authors have suggested that pelvic dilation acts as a capacitor and protects renal parenchyma from increased pressure¹³ our results imply that the high degree of hydronephrosis has a strong correlation with prolonged RTT and large pelvic dilatation which, in our study, occurred mostly in the obstructed group of operated hydronephrotic kidneys. These kidneys most frequently presented with poor differential renal function (Fig. 2). Open pyeloplasty is the gold standard for the correction of UPJ obstruction and is performed in our Institution. However, in adults and in some older children endopyelotomy and laparoscopic pyeloplasty already present as an alternative to open surgery¹⁴. Several authors have reported their experience in paediatric patients and in the future we will probably see increased use of these less invasive surgical techniques, except in neonates and young children. Thus, the need for pre-operative imaging for detecting vessels crossing at the UPJ will increase^{15,16}. Several imaging procedures have been proposed to evaluate crossing vessels at the UPJ. Contrast-enhanced CT examination is a popular technique owing to its relatively noninvasive nature, rapid image acquisition and excellent spatial resolution. A number of studies have

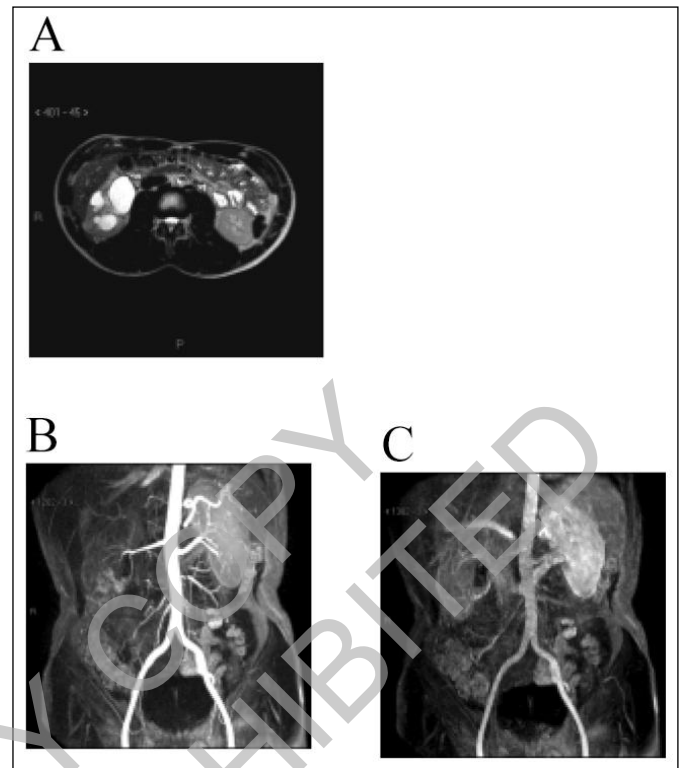


Fig. 2: MRU images of a 17-year-old boy with a crossing vessel as the cause of ureteropelvic junction (UPJ) obstruction and a poorly functioning right kidney. A. Axial view in high resolution T2W shows hypointensive kidney parenchyma on the right with marked hydronephrosis. B. and C. Dynamic series acquired during arterial phase shows aberrant lower pole artery crossing marked dilated renal pelvis as a cause of obstruction. vDRF indicates obstructed RTT with loss of function of the right kidney, R:L = 20:80.

demonstrated sensitivities and specificities for CV detection in excess of 90%^{17,18}. However, the radiation dosage associated with CT is considerable, and this is of particular concern in the evaluation of children. Furthermore, there has been limited experience in the preoperative imaging of children in the evaluation of CV. Non-contrast-enhanced colour Doppler ultrasonography has been evaluated, but appears to have poor specificity and to be highly operator-dependent¹⁹. Thus, MR urography is well suited to this purpose. Because of the high temporal and spatial resolution of MR urography, images obtained immediately after the administration of a contrast agent reliably delineate the renal arteries. In support of this, McDaniel et al. identified CRV in 14 of 61 obstructed kidneys in their systematic evaluation of MR urography in unselected children with UPJ obstruction⁴. In our institution, open pyeloplasty is the only procedure used for surgical treatment of UPJ obstruction. As a result, we can document the reliability of MRU by comparing MRU and intra-operative findings. At surgery, we found a crossing vessel in 9 of 30 renal units, which

is concordant with the literature. We demonstrated satisfactory correlation between the MRU and surgical results. For the whole study we showed that MRU had a sensitivity of 66.7%, a specificity of 85.7%, a positive predictive value of 66.7%, a negative predictive value of 85.7% and an accuracy of 80%. We encountered six errors of diagnosis in 30 renal units, three of which were false positives. These false positive results occurred in 3 infants (two 0.3 years of age, and the third 1 years old). All of them had impaired renal function (vDRF < 40%), and an obstructed renal transit time. All of these factors suggest that the primary causes of obstruction are of an intrinsic nature, and that CV may only be an aggravating factor later in life. This also explains the low sensitivity rate. Our study has several limitations. Firstly, it was not focused solely on detecting crossing vessels associated with UPJ obstruction. For this study we evaluated MR urography examinations retrospectively following surgery, and in addition to CV we also evaluated important morphologic and functional parameters associated with hydronephrotic kidneys. The purpose of our study was to show retrospectively the potential role of MR urography as a diagnostic tool in detecting crossing renal vessel in nonselected patients, and to evaluate renal morphologic and functional parameters. Second, our study cohort was relatively small and nonselected, therefore our results need to be validated by further studies with a larger series of selected, symptomatic patients. Third, for study purposes we used the standard MR urography protocol which contains the "static T2W and dynamic post-contrast T1W sequences", which are different from the protocol used in conventional contrast enhanced MR angiography (MRA) in previous reports²⁰. Finally, the need for sedation in children age < 6 years of age and the cost of MR examination are drawbacks in the use of MRU for detecting crossing renal vessels. However, the main goal of this study was to show the accuracy of the MR imaging technique in demonstrating the presence of crossing vessels in children and to highlight their role in kidney obstruction.

Conclusion

In conclusion, based on our results we suggest that MR urography is a reliable and safe diagnostic tool to determine crossing vessels in selected children with UPJ obstruction. Thus, MRU can substitute for other imaging modalities and provide detailed information about the morphology and function of the affected kidney.

References

1. Grattan-Smith JD, Perez-Brayfield MR, Jones RA, et al.: *MR imaging of kidneys: Functional evaluation using F-15 perfusion imaging*. *Pediatric Radiol*, 2003; 33:293-304.

2. Khrichenko D, Darge K: *Functional analysis in MR urography made simple*. *Pediatr Radiol*, 2010; 40:182-99.
3. Fernbach SK, Maizels M, Conway JJ: *Ultrasound grading of hydronephrosis: Introduction to the system used by the Society for Fetal Urology*. *Pediatr Radiol*, 1993; 23:478-80.
4. McDaniel BB, Jones RA, Scherz H, et al.: *Dynamic contrast-enhanced MR urography in the evaluation of pediatric hydronephrosis: part 2, anatomical and functional assessment of ureteropelvic junction obstruction*. *AJR*, 2005; 185:1608-614.
5. Grattan-Smith JD, Little SB, Jones RA: *MR urography in children: how we do it*. *Pediatr Radiol*, 2008; 38:3-17.
6. Rooks VJ, Lebowitz RL: *Extrinsic ureteropelvic junction obstruction from a crossing renal vessel: Demography and imaging*. *Pediatr Radiol*, 2001; 31:120-24.
7. Sampaio FJB: *Vascular anatomy at the ureteropelvic junction*. *Urol Clin North Am*, 1998; 25:251-58.
8. Gupta M, Smith AD: *Crossing vessels: Endourologic implications*. *Urol Clin North Am*, 1998; 25:289-93.
9. Hoffer FA, Lebowitz RL: *Intermittent hydronephrosis: A unique feature of ureteropelvic junction obstruction caused by a crossing renal vessel*. *Radiology*, 1985; 156:655-58.
10. Josephson S: *Antenatally detected, unilateral dilatation of the renal pelvis: a critical review. 1. Postnatal non-operative treatment 20 years on - is it safe?* *Scand J Urol Nephrol*, 2002; 36:243-50.
11. Ulman I, Jayanthi VR, Koff SA: *The long-term followup of newborns with severe unilateral hydronephrosis initially treated nonoperatively*. *J Urol*, 2000; 164:1101-105.
12. Lopez C, Ash S, Veyrac C, et al.: *Lower pole pedicle in a series of 84 pyelo-ureteral junction obstruction syndromes surgically treated in children*. *Prog Urol*, 2000; 10:638-43.
13. Park JM, Bloom DA: *The pathophysiology of UPJ obstruction: Current concepts*. *Urol Clin North Am*, 1998; 25:161-69.
14. Godbole P, Mushataq I, Wilcox DT, et al.: *Laparoscopic transposition of lower pole vessels-the vascular hitch: An alternative for pelvi-ureteric junction obstruction in children*. *J Laparoendoscop Adv Surg Tech* 2005; 15:209.
15. Figenshau RS, Clayman RV: *Endourologic options for management of ureteropelvic junction obstruction in the pediatric patients*. *Urol Clin North Am*, 1998; 25:199-209.
16. Tan HL: *Laparoscopic Anderson-Hynes dismembered pyeloplasty in children*. *J Urol*, 1999; 162:1045-47.
17. Khaira HS, Platt JF, Cohan RH, et al.: *Helical computed tomography for identification of crossing vessels in ureteropelvic junction obstruction-comparison with operative findings*. *Urology*, 2003; 62(1): 35-39.
18. El-Nahas AR, Abou-El-Ghar M, Shoma AM, et al.: *Role of multiphase helical computed tomography in planning surgical treatment for pelvi-ureteric junction obstruction*. *BJU Int*, 2004; 94: 582-87.
19. Veyrac C, Baud C, Lopez, et al.: *The value of colour Doppler ultrasonography for identification of crossing vessels in children with pelvi-ureteric junction obstruction*. *Pediatr Radiol*, 2003; 33:745-751.
20. Calder AD, Hiorns MP, Abhyankar A, et al.: *Contrast-enhanced magnetic resonance angiography for the detection of crossing renal vessels in children with symptomatic ureteropelvic junction obstruction: comparison with operative findings*. *Pediatr Radiol*, 2007; 37:356-61.