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Magnetic Resonance Urography in Patients with Non-Contributory Intravenous Urography

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Abstract: *Magnetic Resonance Urography (MRU) is increaingly replacing Intravenous Urography (IVU) which has been the traditional modality for uro-imaging. However, the effectiveness and advantages of this new and costly modality need to be proven before defining its place in the uro-radiological armamentarium. We conducted a prospective study to assess the role of MRU in 100 consecutive cases where IVU was inconclusive or contra-indicated. As 4 patients had solitary functioning kidney, a total of 196 renal units were evaluated. In all the cases the results of IVU and MRU were cross-checked for accuracy by multi- modality imaging or surgical feedback. The Sensitivity, Specificity and the Predictive Value of a positive and negative MRU were calculated. Since the study was conducted in cases where IVU was non-contributory , MRU was evaluated as a stand-alone test. We found that with the exception of diagnosing stone disease in non-obstructed renal units, MRU is an excellent modality for evaluating the renal system. It can be successfully used to image paediatric and pregnant cases. It can rapidly demonstrate the pelvi- calyceal system even in renal units with deranged excretion. It can be used in emergency settings on unprepared patients. Its efficacy is reduced in non-dilated renal units.*

I. Introduction

Intravenous Urography (IVU) has been the initial imaging technique of choice for diagnosis of various urological disorders, ever since it was first performed in 1923 at Mayo Clinic by Osborne et al.[1-5] However, it has limitations related to low spatial resolution, radiation exposure and toxicity & allergy related to contrast . [4&6] It is not very effective in diagnosis of small and/ or radio-lucent lower ureteric calculi due to overlying bowel and bony shadows. [7] It has low sensitivity and specificity in diagnosis of parenchymal or extra-renal/extra-ureteric masses and diagnostic quality depends on adequacy of bowel preparation and fasting. [4] Therefore, use of IVU has decreased, more so due to the advent of newer cross-sectional imaging techniques. However, it has remained in general use because of its low cost, availability, and ready acceptance by urologists . [5&8] Ultrasonography (USG), though safe from the complications associated with radiation and contrast, does not give any information of the renal function. It is also not a very good tool for identifying distal Ureteric pathologies. Computed Axial Tomography (CT), though the current gold standard in diagnosing urolithiasis, is fraught with the drawbacks of radiation exposure and contrast toxicity.[2-4] Magnetic Resonance Urography (MRU), introduced by Hennig *et al* in 1986, is emerging as a safe alternative. [11&12] In this technique MRI technology is used to create high resolution heavily- T_2 weighted coronal images of the urinary tract that resemble a traditional IVU without the use of contrast agents or ionizing radiation. Here urine serves as intrinsic contrast medium. It is a rapid, safe and non- invasive method which allows visualization of the entire urinary tract and renal parenchyma as well as surrounding extra renal/ peri-ureteric tissues. It is of good diagnostic value in virtually all kinds of urinary tract disorders in adult as well as paediatric patients.[1,9&10] Several studies (Klein L T *et al*, Regan F *et al*, Shokeir AA *et al etc*) have shown that MRU is an imaging modality which can determine the degree of dilatation and location of obstruction in the renal collecting system. It is one of the best modalities in identifying non- calcareous cause of obstruction. [2,4&9] However, MRU is an emerging and costly modality and the experience of radiologists is also limited. Its place in uroradiological imaging needs to be precisely defined. [1,5&13] Being mindful of these unanswered questions we conducted a prospective study to evaluate the role of MRU in cases where IVU could not be performed or was inconclusive.

II. Material and methods

The study was a prospective study carried out from April 2013 to Dec 2016, on patients attending ESI Hospital Basaidarapur or Northern Railway Central Hospital, Delhi. These patients fulfilled at least one of the following criterion--

1. Inconclusive IVU, including poorly/non-visualized kidney or dilated PCS without obvious cause.
2. Patients of renal pathologies who were not suitable to undergo IVU –

a. Radiation constraints - paediatric cases and pregnancy
b. Contrast constraints - renal dysfunction and/ or hypersensitivity .

The study was conducted on 100 cases without any selection bias.

Patients underwent IVU wherever indicated and permissible using non- ionic contrast. Standard Imaging protocol was used. MR Urography was performed after IVU in those patients whose IVU reports were inconclusive and without preceding IVU in patients where IVU was contra- indicated or inadvisable. In all these cases, except in pregnancy, a plain skiagram of the KUB region was done prior to MRU.

In our study Only T 2 –weighted Static –Fluid technique was used and T 1 –weighted excretory MR Urography was not performed. The protocol for this was as follows-

- HASTE Sequence applied in – Axial plane, Coronal plane and Sagittal plane, covering from diaphragm till bladder base
- Thick Sagittal MRCP Sequence (RARE) applied in - Oblique & Sagittal plane for both kidneys
- Thin slice HASTE (FS) MRCP Sequence in – Sagittal plane for each kidney & Coronal plane for KUB
- Thin Axial T1 and TSE T2 at the level of obstruction

Multi-planar imaging was performed using a 1.5 T MR System. Heavily T2-weighted turbo spin echo sequences were applied. Thin axial T1 and TSE T2 sequences were performed in multiple planes at the level of obstruction.

III. Observation And Results

The study group consisted of 100 cases. Of these, 4 patients had a solitary functioning kidney. Thus, a total of 196 renal units were evaluated. The patients were grouped on the basis of diagnosis and the indication of performing MR Urography. (Tables 1 & 2) Evaluation was done on the basis of individual renal units.(Table 3)

In all the cases the results of IVU and MRU were cross-checked for accuracy by multi- modality imaging or surgical feedback. Incomplete or incorrect diagnosis was considered as an inaccurate result. In one case of lower ureteric calculus, IVU gave the diagnosis on a delayed film after 24 hours and was recorded as correct. However, MRU was able to give the same diagnosis within half an hour. All the results were tabulated and the Sensitivity, Specificity and the Predictive Value of a positive and negative MRU were calculated. [Table 4] Since the study was conducted in cases where IVU was non-contributory we applied Chi Square test for the evaluation of MRU as a standalone test. [Table 5] The results clearly demonstrate that with the exception of diagnosing stone disease in non-obstructed renal units, T 2-weighted Static Fluid MR Urography is a good modality for evaluating the renal system. It can be successfully used to image paediatric and pregnant cases. It can rapidly demonstrate the pelvi- calyceal system in renal units with deranged excretion of contrast. It can be safely used in cases which have contrast associated morbidity. It gives significantly accurate results in congenital abnormalities, Neoplastic and inflammatory diseases and in dilated systems with urolithiasis. However, the significance has not been clearly brought out in some of the sub-groups of patients studied, probably due to small sample size-

- Non-dilated renal units with, Neoplastic or inflammatory diseases and with congenital defects associated with urolithiasis.
- Dilated systems with infective pathologies and with congenital defects associated with urolithiasis.

IV. Discussion

Radiological investigations of the urinary tract have long been an integral part of urological diagnostic work-up. Historically plain abdominal skiagram, Intra-Venous Urography (IVU) and Retrograde Pyelography (RGP) have been used. Newer advances in radiology have added USG, CT, MRI, Isotope studies and percutaneous or endoluminal interventions under image guidance. These have contributed to improved and safe diagnosis of a variety of urological disorders. Physician preference and availability often dictate the order or choice of procedure. However, close co-operation between the Urologist and radiologist always benefits the patient by expediting the work-up and minimizing the cost.

MRU has been constantly evolving and developing as an important diagnostic tool in uro-radiology. This is especially relevant in the context of minimizing contrast associated morbidity and radiation exposure. Moreover, imaging of poorly functioning renal moieties is also possible by this modality. Last, but not the least, is its easy acceptability by the urologists as it can give IVP like urogram pictures [1,2,4,5 &7-14]

It captures data which can yield excellent 3-dimensional images. It is more accurate in differentiating intrinsic and extrinsic causes of obstruction and provides additional information of parenchymal and/ or extra-renal masses. This can be performed even in emergency settings on unprepared patients. Newer imaging sequences with short acquisition times have lower susceptibility to artefacts including bowel and respiratory motion and allow imaging of sequential sections with even better image quality.

In dilated/ obstructed systems, static fluid MRU is extremely useful and both RARE and HASTE sequence give good result. With the two combined, as is usually done in the newer protocols the results are even better. This is because the large amount of water generates a good signal to noise ratio.[2,8 &11-17] The urographic effect is independent of the renal excretory function, so it can even be used to visualize the grossly obstructed urinary tract of a quiescent kidney.[2,12,15,16&18] This aspect is obviously an important advantage of static- fluid MR urography compared with conventional IVP. However, this also implies that static fluid MRU is unable to give any information about the functional status of the renal unit being evaluated. Static- fluid MR urography can be safely performed in children and during pregnancy. [19]

In undilated systems, the efficacy of static MRU has been less than that in dilated systems. This is because portions of the undilated ureter are either not visualized or their visualization is impaired by bowel/ motion artefacts. [19] To achieve sufficient visualization of the unobstructed urinary tract on T2-weighted MR urograms substantial hydration is necessary and intravenous Furosemide is used at relatively high doses. [16&20] Rothpearl et al suggested combining a Furosemide injection with external ureteral compression to induce urinary stasis and improve the distension of the collecting system. [17] However, the application of Furosemide at intravenous doses larger than 10 mg and the use of an inconvenient compression device can impede the patient's cooperation during the examination. [9]

Abdominal water collections such as intestinal or intra-peritoneal fluid, bile, cysts and lymphoceles can superimpose on parts of the urinary tract on MIP images. [15&20] This is eliminated effectively by vector-of-interest (VOI) editing but this can be a time-consuming post-processing procedure. [9 & 20]

Several studies have demonstrated that on MR urography stones are identified as typical filling defects. Most stones present as round or branched signal voids inside the un-enhanced or contrast-enhanced urine. [2,4, 15,18 & 21-23] Hypo intense filling defects are non specific and it may be difficult to distinguish a small calculus from a blood clot, a polyp or a surgical clip. [13] Since, stones cast no shadow on MRU; they are seen as negative filling defects just as in IVU. Therefore, it is essential to compare with a plain skiagram of the KUB region wherever permissible. It should be emphasized that filling defects are best found when reviewing the source images of each MR urographic sequence. Even large stones may become obscured on MIP images. [13] In acute stone colic, a peri-renal stranding is often visible on T2-weighted MR urograms. [24] In a study by Jung et al., excretory MR Urography with 3D-GRE sequences demonstrated a sensitivity of 90% in 72 patients with ureterolithiasis in comparison with 68% obtained with IVP. [23] Sudah et al. reported a sensitivity and specificity of up to 100% for the detection of stones in 26 patients with acute flank pain with the use of excretory MR urography. However, with static fluid MR urography alone the sensitivity was less than 60%. [14] Consequently, MR urography is not the primary modality but. It provides valuable information about the anatomy and variations of the collecting system that might determine the passage of the stone with or without lithotripsy or during endourologic removal. [13 & 22]) T2-weighted static fluid MR urography may also be used for the diagnosis of urolithiasis in pregnant women. Hence, as on date, MR urography, though better than IVU is inferior to Helical CT in diagnosing acute urolithiasis. [25] It is an alternative to CT to avoid repetitive radiation exposure and/ or contrast morbidity in patients with chronic Urolithiasis. It is also of use in evaluating the renal units of potential transplant donors. [10]

Congenital anomalies of the urinary tract are a frequent finding and often cause urologic symptoms. T2-weighted static- fluid MR urography is useful for the visualization of anomalies associated with a marked increase in fluid such as megaureters, Ureterocoeles, stenosis of the ureteropelvic or Vesico-ureteric junctions, dilated ectopic ureters and cystic kidney diseases. [9,15 &17] This is especially relevant as a large proportion of these cases are in paediatric age group.

The commonest intrinsic tumor in the upper urinary tract is transitional cell carcinoma (TCC). [26] However, more frequent is an extrinsic affection of the pelvicalices and ureters due to causes like retroperitoneal lymph node metastases/ fibrosis, postoperative haematoma, scarring after radio-therapy, etc. MR imaging provides a good opportunity to combine MR urography with standard pulse sequences in the axial or coronal plane. Conventional MR pulse sequences display the size of a tumor and the signal morphology of its matrix, whereas MRU demonstrates the extent of the affected urinary tract.

Typical urographic signs for extrinsic retroperitoneal compression of the ureters are displacement and concentric stricture with gradual tapering of the ureteral wall or abrupt reduction in calibre without a filling defect. [15 & 21] TCC often appears as a sessile filling defect with irregular exophytic or smooth polypoid configuration. [26] TCC in the ureter leads to a characteristic cup shaped dilatation of the pre-stenotic ureteral segment – 'The goblet sign'. [13 &27] MR also gave good information about renal vein or IVC involvement.

With ALARA philosophy being the guideline of the day, a modality without ionizing radiation (USG or MR) should always be preferred over those with radiation. This becomes more relevant in cases which are at increased risk to radiation exposure- children, young adults and during pregnancy. [28] The diagnosis of ureteral calculi is particularly problematic in pregnant patients. [29] USG would probably be the study of first choice. However, the typical hydronephrosis due to pregnancy can make diagnosis of a superimposed obstructing ureteral calculus difficult. Borthne et al have heralded MRU as a gold standard in paediatric imaging. Today, in many departments, urography in children is being exclusively done by MR imaging. [1 & 30]

Since the static fluid MRU uses urine as an intrinsic contrast medium, it does not depend upon the kidney to excrete any dye. Hence, no ionic/ non-ionic contrast needs to be given as is needed in IVU. Therefore MRU can be conveniently used to image even non/poorly functioning kidneys. Two special indications of MRU include imaging of the post transplant kidney and in cases of radical cystectomy with Ileal conduit / neobladder. [13, 22, 31 & 32]

Table 1 : Distribution of renal units by diagnosis

	DIAGNOSIS	CASES/ (RENAL MOIETIES)		
		Dilated	Non-Dilated	Total
1	Congenital Malformations	26	10	36
2	Congenital Malformations with calculus disease	6	0	6
3	Calculus disease	46	8	54
4	Infection	6	6	12
5	Neoplasm	12	2	14
6	Normal	12	62	74
	TOTAL	108	88	196

Table 2: Case distribution by – age & indications of performing MRU

	Distribution of Cases in various age groups						
	0-5	5-15	15-25	25-40	40-60	>60	Total
Contrast Hypersensitivity					4		4
Renal Failure		2		4	16	2	24
Inconclusive IVU		2	2	14	24	8	50
Paediatric age	6	12					18
Pregnancy			2	2			4
Total	6	16	4	20	44	10	100

Table 3 : MRU results in renal moieties - by diagnosis and dilatation

DIAGNOSIS	RENAL UNITS Total (Dilated + Non-dilated)	RESULT OF MRU	
		CORRECT	INCORRECT
Congenital Malformations	36 (26+10)	36 (26+10)	NIL (0+0)
Congenital Malformations with calculus disease	6 (6+0)	6 (6+0)	NIL (0+0)
Calculus disease	54 (46+8)	48 (46+2)	6 (0+6)
Infection	12 (6+6)	12 (6+6)	NIL (0+0)
Neoplasm	14 (12+2)	14 (12+2)	NIL (0+0)
Normal	74 (12+62)	74 (12+62)	NIL (0+0)
TOTAL	**196 (108+88)**	**190 (108+82)**	**6 (0+6)**

Table 4 : Efficacy of MR Urography *in* various clinical settings

DIAGNOSIS	SPECIFICITY	SENSITIVITY	PREDICTIVE VALUE OF	
			POSITIVE TEST	NEGATIVE TEST
RENAL UNITS - ALL	100%	95%	100%	93%
OBSTRUCTED	100%	100%	100%	100%
NON-OBSTRUCTED	100%	77%	100%	91%
CALCAREOUS RENAL UNITS - ALL	100%	90%	100%	96%
OBSTRUCTED	100%	100%	100%	100%
NON-OBSTRUCTED	100%	57%	100%	92%
NON-CALCAREOUS RENAL UNITS - ALL	100%	100%	100%	100%
OBSTRUCTED	100%	100%	100%	100%
NON-OBSTRUCTED	100%	100%	100%	100%
RENAL UNITS IN CASES WEHERE IVU WAS NOT FEASIBLE				
RADIATION CONCERNS - PAEDIATRIC &PREGNANCY	100%	92%	100%	91%
CONTRAST CONCERNS - RENAL DERANGEMENT & CONTRAST ALLERGY	100%	92%	100%	50%

Table 5 : Significance of results of MR Urography

DIAGNOSIS	DILATED SYSTEMS	NON - DILATED SYSTEMS	TOTAL
NORMAL MOIETIES	0.01<P<0.02	P<0.001	**P<0.001**
INFECTED/ INFLAMATORY MOIETIES	0.05<P<0.1	0.05<P<0.1	**0.01<P<0.02**
NEOPLASTIC MOIETIES	0.01<P<0.02	0.3<P<0.5	**0.005<P<0.01**
MOIETIES with CALCULI	P<0.001	0.3<P<0.5	**P<0.001**
CONGENITALLY MALFORMED MOIETIES	P<0.001	0.02<P<0.05	**P<0.001**

CONGENITALLY MALFORMED MOIETIES with CALCULI	0.05<P<0.1	NA	**0.05<P<0.1**
ALL CALCAREOUS MOIETIES	P<0.001	0.3<P<0.5	**P<0.001**
ALL NON-CALCAREOUS MOIETIES	P<0.001	P<0.001	**P<0.001**
TOTAL MOIETIES	P<0.001	P<0.001	**P<0.001**

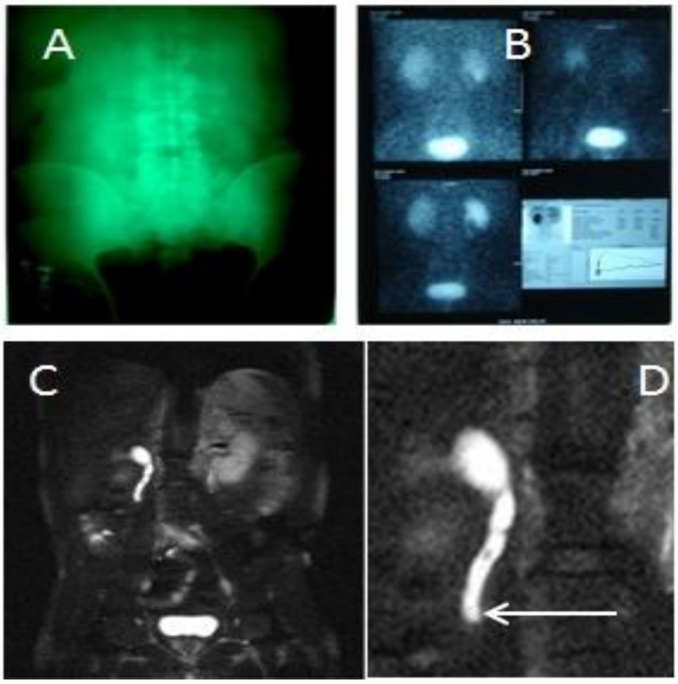

Fig. 1 – **A :** X-ray KUB with 2 radio opaque shadows on either side of lumber spine. **B:** DTPA scan showing right sided obstruction. **C** : MRU diagnosed right sided calculus disease in a dilated system but missed the stone in the non-dilated left system. **D:** enlarged view of **C** with arrow depicting meniscus sign. IVU not possible due to deranged KFT.

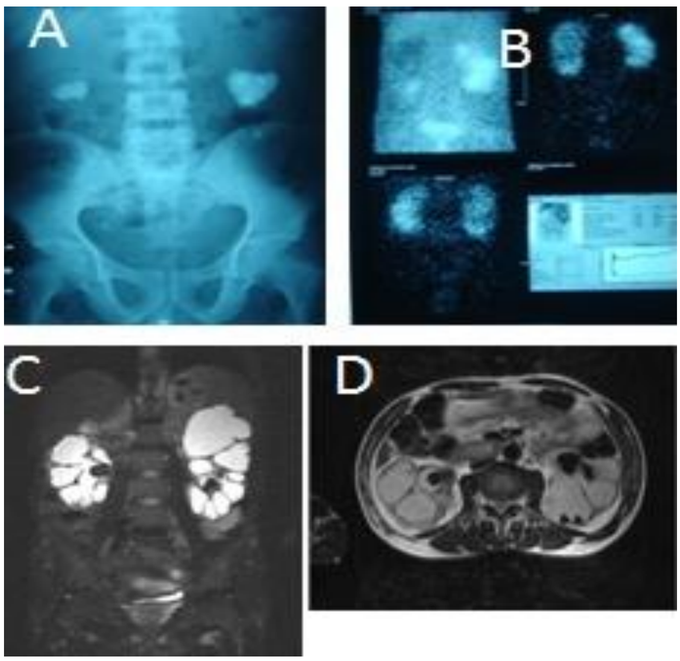

Fig. 2 – **A :** X-ray KUB with 2 radio opaque shadows on either side of lumber spine. **B:** DTPA scan showing bilateral sided obstruction. **C & D** : MRU diagnosed bilateral renal pelvic calculus disease with gross hydronephrosis. stones are seen as negative shadows. IVU not possible due to deranged KFT.

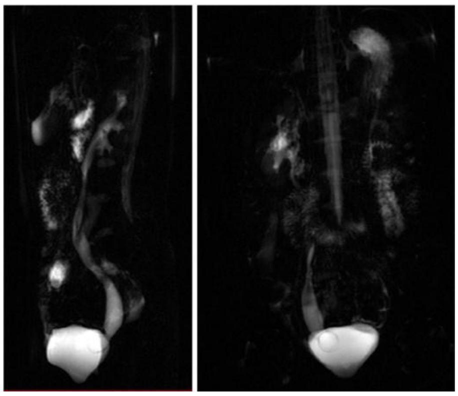

Fig. 3 – MRU picture of ureterocoele. IVU avoided due to paediatric age group.

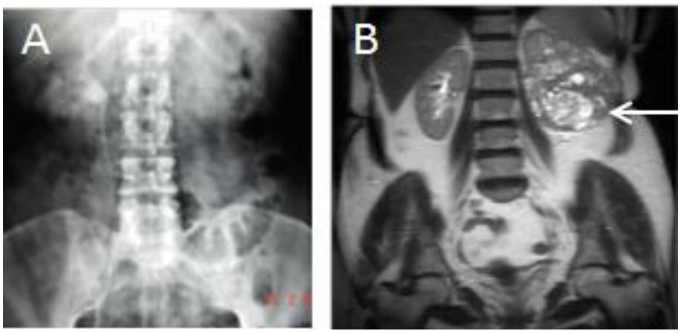

Fig. 4 – **A:** Non-visualized left kidney on IVU. **B:** MRU diagnosed inferior Polar mass which was subsequently proven to be renal cell carcinoma. MRU also gave information about involvement of local extra-renal tissues.

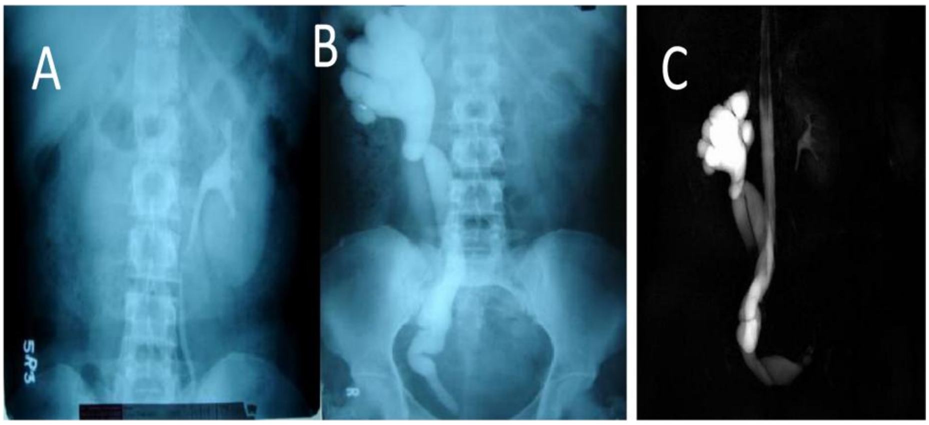

Fig. 5 – **A:** Non-visualized right kidney on IVU. **B:** Dilated right PCS and ureter till uretero-vesical junction on RGP. **C:** MRU diagnosed the same as well as gave additional information about duplication of the right ureter.

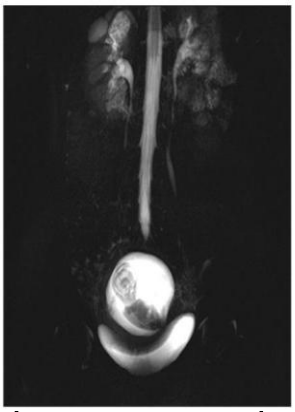

Fig. 6 Bilateral normal PCS in a case of pregnancy in a case of right ureteric colic due to suspected calculus on USG

V. Conclusion

Current status of MRU *vis a vis* IVU

Static fluid MR urography is, in most cases, is as good, if not superior to IVU. It gives equally good images of the pelvi-calyceal system and also gives extra information about renal parenchyma and extra-renal pathologies. [15 & 33] However, its limitations include inability to identify non-obstructing calculi and lack of information regarding the functional status of the kidney. Both of these shortcomings can be addressed by excretory MR Urography which uses gadolinium as a contrast agent. Use of plain skiagram of the KUB region, when permissible, is mandatory. As reported by Sudah et al, the diagnostic accuracy of combined static and excretory MRU approaches 100%. [14]

Last but not the least is the cost and availability considerations, especially in a third world country. IVU being a traditional modality is easily available throughout the country, whereas centres with facilities for MRU examination are limited. The radiologists are experienced in reporting and even the urologic Surgeons are adept in evaluating IVU films. However, when the cost of additional investigations in inconclusive IVU studies is loaded and the economics of contrast and radiation morbidity also considered, the cost of MRU does not seem prohibitive. [33] The expertise of radiologists is already rising and with newer and faster protocols, artifacts are decreasing day by day. Moreover, the acceptance of IVU like MIP images is higher among surgeons than the cross-sectional studies like USG/ CT.[1]

Future directions in MRU

Different MR techniques can be combined to establish an all in one imaging modality for uro-radiological evaluation. Use of better and newer machines and protocols coupled with the use of negative oral contrast agents are likely to minimize artefacts and improve the diagnostic accuracy. [9 & 33] Artifacts arising from the bowel contents and movement often make visualization of the terminal ureteric pathologies difficult in undilated ureters. In our study of 196 renal units, all fallacies were of inability to diagnose non-obstructing ureteric calculi. It has been shown that bowel preparation is ineffective because use of laxatives, though reduces bowel content but increases bowel gas and motility and is therefore of no real benefit. [34] An alternative may be found in the use of negative oral contrast agents that eliminate signals from the GI tract. Hirohashi et al have demonstrated that the signal intensity in the gastrointestinal tract was almost completely eliminated with the use of a water- miscible oral positive contrast agent with ferric ammonium citrate as its active ingredient. [35]

The newer pulse sequences in MR urography are-

- FIESTA (Fast imaging using Steady state acquisition –GE)
- True – FISP (Fast imaging with Steady state precession –Siemens)
- Balanced Fast field Echo- Philips
- T1-weighted imaging using newer 3D-GRE sequences combined with gadolinium enhancement, have improved spatial resolution for resolving masses and vascular anatomy. eg; 3D volumetric interpolated breath-hold examination {VIBE}, T1-weighted fast acquisition multiple excitation {FAME}, or 3D T1-weighted high resolution isotropic volume examination {THRIVE}.
- T2-like imaging using breath-hold balanced echo true free-induction with steady-state precession (TFISP) may provide additional information for urographic evaluation of the collecting system.
- Acquisition of pre- and post-contrast 3D GRE images with subtraction may be useful for determining vascularity and tumor within a high-signal protein- or blood-containing renal lesion. Measurements of individual renal GFR and RBF, and simultaneous measurement of individual renal perfused and functional volumes on contrast MRU, coupled with the exquisite soft tissue contrast provided by the standard MR images can provide critical diagnostic information on structural diseases of the kidneys and collecting system, including congenital and acquired diseases, and also the full range of the causes of dysfunction in the transplanted kidney. [34]
- MR urography can provide useful assessment of obstructive uropathy and may predict information about which children are likely to benefit from surgery. It has the potential to identify parameters that indicate a significant obstruction as opposed to self- limited hydronephrosis. [36]

References

[1]. Kawashima A, Glockner JF, King Jr. BF ; CT Urography and MR Urography Radiologic Clinics of North America ; 2003; 41(5) : 945 – 961

[2]. Regan F, Bohlman ME, Khazan R, et al ; MR Urography using HASTE imaging in the assessment of Ureteric obstruction ; Am. J. Roentgenol. ; 1996; 167 : 1115 – 1120

[3]. Smith RC, Verga M, McCarthy S, Rosenfield AT ; Diagnosis of acute flank pain: value of Unenhanced Helical CT ; Am. J. Roentgenol.; 1996; 166 : 97-101

[4]. Shokeir AA, El- Diasty T, Eassa W, et al; Diagnosis of non calcareous hydronephrosis: role of magnetic resonance urography and non-contrast computed tomography ; Urology 2004 Feb;63(2):225-9

[5]. Locua G ; MR Urography in diagnosis of Urinary Tract Obstruction ; European Urology ; 1999; 35 : 102-108

[6]. Amis Jr E S; Epitaph of Urogram; Radiology 1999; 213 : 639-640.

[7]. Pollack HM; Some limitations and pitfalls of excretory urography; J Urol; 1976; 116(5): 537-543
[8]. Roy C, Saussine C, Guth S, et al; MR urography in the evaluation of urinary tract obstruction; Ab Im; 1998 (Jan); 23(1): 27-34
[9]. Klein L T, Frager D, Subramanium A, et al; Use of Magnetic Resonance Urography ; Urology ; 1998; 52: 602-608
[10]. Nolte-Ernsting CC; Staatz G; Tacke J; et al ; MR urography today **;** Ab Im ; 2003 (Mar-Apr); 28(2) : 191-209
[11]. Hennig J, Nauerth A, Friedburg H ; RARE imaging: a fast imaging method for clinical MR; Magn Reson Med ; 1986; 3:823-833
[12]. Friedburg HG, Hennig J, Frankenschmidt A; RARE-MR urography: imaging of the urinary tract with a new fast nontomographic MR technique ; Radiologe;1987; 27:45-47
[13]. Nolte-Ernsting CC, Adam GB, Gunther RW ; MR urography: examination techniques and clinical applications; Eur Radiol ; 2001; 11(3): 355-72**.**
[14]. Sudah M, Vanninen R, Partanen K, et al ; MR Urography in Evaluation of Acute Flank Pain: T2-Weighted Sequences and Gadolinium- Enhanced Three-Dimensional FLASH Compared with Urography ; Am. J. Roentgenol**. ;** 2001; 176: 105 – 112
[15]. Tang Y, Yamashita Y, Namimoto T. et al. ;The value of MR urography that uses HASTE sequences to reveal urinary tract disorders ; AJR ;1996 ; 167: 1497-1502
[16]. Nolte-Ernsting CCA, Tacke J, Staatz G, et al.; Comparison of gadolinium enhanced T1-weighted excretory MR urography and static fluid T2-weighted MR urography. 12th Eur. Congress of Radiology ECR 2000; Eur Radiol ; 2000; 10(Suppl-1): 212
[17]. Rothpearll A, Frager D, Subramaniam A, et al; MR urography: Technique and application ; Radiology ;1995; 194:125-130
[18]. Nolte-Ernsting CCA, Bucker A, Adam GB. et al.; Gadolinium enhanced Excretory MR urography after low-dose diuretic injection: comparison with conventional excretory urography ; Radiology ; 1998 ; 209; 147-157.
[19]. Roy C, Saussine C, Le BrasY, et al; Assesment of painful Ureterohydronephrosis during pregnancy by MR urography; Eur Radiol; 1996; 6:334-338
[20]. Hattery RR, King BF; Technique and application of MR Urography; Radiology;1995:194:25-27
[21]. Roy C, Saussine C, Jahn C, et al. ; Evaluation of RARE-MR urography in the assessment of ureterohydronephrosis; J Comput Assist Tomogr;1994;18:601-608.
[22]. Nolte-Ernsting CCA, Tacke J, Adam GB, et al.; Diuretic-enhanced gadolinium excretory MR urography: comparison of conventional gradient-Echo sequences and echo-planar imaging; Eur Radiol; 2001;11:18-27
[23]. Jung P, Brauers A, Nolte-Ernsting CCA, et al.; Magnetic resonance urography enhanced by gadolinium and diuretics: a comparison with conventional urography in diagnosing the cause of ureteric obstruction; BJU Int; 2000; 86: 960-965
[24]. Regan F, Petronis J, Bohlman M, et al.; Perirenal MR high signal- a new and sensitive indicator of acute ureteric obstruction; Clin Radiol; 997; 52: 445-450
[25]. Fielding JR, Silverman SG, Rubin GD; Helical CT of the urinary tract; AJR; 1999; 172: 1199-1206 .
[26]. Goldman SM, Gatewood OMB; Neoplasms of the renal collecting system. pelvis. and ureters; In: Pollack HM. ed. Clinical Urography; Philadelphia: WB Saunders. 1990:1292-1352.
[27]. Daniels RE III; The goblet sign; Radiology; 1999; 210:737-738.
[28]. Tamm EP, Silverman PM, Shuman WP; Evaluation of the Patient with Flank Pain and Possible Ureteral Calculus; Radiology 2003; 228:319–329.
[29]. Houshiar AM, Ercole CJ; Urinary calculi during pregnancy: when are they cause for concern? Postgrad Med; 1996; 100:131–138.
[30]. Borthne A, Nordshus T, Reiseter T, et al. ; MR urography: the future gold standard in paediatric urogenital imaging? ; Pediatr Radiol ; 1999;29:694-701.
[31]. Dorsarn J, Knopp MV, Carl S, et al.; Ureteral complications after kidney transplantation: evaluation with functional magnetic resonance urography; Transplant Proc; 1997; 29: 132-135.
[32]. Schubert RA, Gockentz S, Mentzel HJ, et al; Imaging in ureteral complications of renal transplantation: Value of static fluid MR urography; Eur Radiol; 2000; 10: 1152-1157.
[33]. Verawijvel GA, Oyen RH, Van Poppel HP, et al; Magnetic resonance imaging in the assessment of urological disease : an all- in-one approach; Eur Radiol; 2000; 10: 1614-1619.
[34]. Bobby Kalb, John R. Votaw, Khalil Salman, Puneet Sharma, Diego R. Martin; Magnetic Resonance Nephrourography: Current and Developing Techniques; Magn Reson Imaging Clin N Am 18 (2010) 29–42
[35]. Hirohashi S, Hirohashi R, Uchida H, ET AL; MR Cholangio-pancreatography and MR Urography: Improved Enhancement with a Negative Oral Contrast Agent; Radiology; 1997; 203:281-285
[36]. J.Damien Grattan-Smith, RichardA. Jones; MR Urography:Technique and Results for the Evaluation of Urinary Obstruction in the Pediatric Population; Magn Reson Imaging Clin N Am 16 (2008) 643–660.