Comparative study in assessing renal function with MR-urography from diuretic renogram.

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Aims and objectives

Renal function has been traditionally evaluated with nuclear medicine techniques such as the diuretic renogram, in order to give information about glomerular filtration, differential renal function or urinary tract anomalies.

The aim of our study is to introduce MR-urography as a new modality that is useful in this cases, delineating both anatomy and functionalism in a single test that does not use ionizing radiation.
Methods and materials

We evaluate hydronephrotic systems with MR-urography in 8 patients in our hospital in the first 9 months since we started with this technique (January 2013-September 2013).

2 patients were in pediatric ages, one of those without diuretic renogram.

The total patients included are 7, 6 males and 1 female, with suspicion diagnosis of pelviureteric junction obstruction (5 of them) and renal duplication (2 of them).

How do we prepare our patients?

Having patients void prior to entering the imager improves their comfort and prevents interruption of the study at an inopportune time.

It is described if no contraindications exist (eg, fluid restriction, congestive heart failure), to give to the patients 250 mL of normal saline solution intravenously at the start of imaging, to avoid bright bowel contents seen in T1- and T2-weighted sequences used for MR urography.

What does our MR urography protocol consist in?

We can divide it into two categories: static-fluid MR urography and excretory MR urography.

(a) Static-Fluid MR Urography:

Static-fluid MR urography treats the urinary tract as a static column of fluid, using T2-weighted sequences, similar to those used for T2-weighted MR cholangiopancreatography.

Breath-hold T2-weighted MR urograms can be obtained with either thick-slab single-shot fast spin-echo techniques or similar thin-section techniques.

The signal intensity of background tissues can be adjusted by modifying the echo time or using fat suppression.

Three-dimensional (3D) respiratory-triggered sequences can be used to obtain thin-section data sets that can then be postprocessed to create volume-rendered (VR) or maximum-intensity-projection (MIP) images of the entire urinary tract.
It is important to consider that static-fluid MR urography does not require the excretion of contrast material and is therefore useful for demonstrating the collecting system of an obstructed, poorly excreting kidney.

**Static part of our MR-urography protocol (Fig. 1 on page 6):**

*Image 1:* localization and orientation of scan plane encompassing the kidney, ureter and bladder, with the appropriate placement of the field of view (FOV) with the upper border just above the hemidiaphragms.

*Image 2:* T2 weighted sagittal images
*Image 3:* T2 weighted axial images with fat saturation
*Image 4:* T1 weighted coronal images
*Image 5:* T2 weighted coronal images with fat saturation

*Image 6:* 3D T2 fat saturation images. MIP reconstructions.

**(b) Excretory MR Urography:**

A gadolinium-based contrast agent is administered intravenously, and the collecting systems are imaged during the excretory phase (Dotarem 0.05 mmol/ml in order of 0.2ml/kg).

Diuretic administration can improve the quality of excretory MR urography by enhancing urine flow, resulting in dilution and uniform distribution of gadolinium-based contrast material throughout the urinary tract.

A relatively low dose of furosemide on the order of 0.1 mg/kg (ie, 5-10 mg for adults) is typically used for MR urography, giving an excellent image quality while permitting the patient to finish the examination without having to void and with no contraindications.

**Excretory part of our MR-urography protocol (Fig. 1 on page 6):**

*Imagen 7:* T1 fat saturation images. Pre-contrast.

*Images 8-11:* 3D T1 weighted gradient echo sequence with fat saturation (volumetric interpolated breath-hold examination) VIBE, corresponding to arterial, parenquimatous, calyceal and pelvic excretion and ureteric excretion,

*Image 12 and 13:* T1 weighted sagital images with fat saturation of each kidney.

*Image 14:* delayed T1 weighted coronal image with fat saturation

*Image 15:* MIP reconstructions.
After this, we evaluate the hydronephrotic systems analyzing both anatomic and functional information to determine whether obstruction is present, to evaluate its severity, and to identify its location and, if possible, its cause.

The anatomic information includes grading the hydronephrosis, identification of transition in caliber, evaluation of underlying causes such as kinks, strictures or crossing vessels and assessment of the quality of the renal parenchyma.

The functional evaluation includes calculation of the renal transit time (RTT) and CTT as well as DRF with both the volumetric (vDRF) and Patlak (pDRF) techniques.

The last part of our study is to compare the results we have obtained with diuretic renogram results.
Fig. 1: Images showing our MR urography protocol.

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Results

When evaluating or results we have to consider:

1. Anatomic evaluation:

We use both the T2-W and the delayed post-contrast images to define the pelvicalyceal and ureteric anatomy.

We grade the degree of hydronephrosis as mild, moderate or severe. Fig. 2 on page 10

Changes in ureteric caliber are useful indicators of the level of obstruction; such changes most commonly occur at the UPJ followed by the vesicoureteric junction and rarely the midureter.

UPJ obstruction can be idiopathic, associated with a neuromuscular defect at the UPJ Fig. 3 on page 10 , or associated with abnormalities such as aberrant lower pole vessels, kinks, adhesions or abnormal angulations.

The vascular phase of the dynamic contrast-enhanced series is used to identify crossing vessels associated with ureteric obstruction, such as in one of our cases Fig. 4 on page 11 .

One of our pediatric cases consisted in a megaureter. The diagnosis of primary megaureter is made when the ureter measures more than 7 mm in diameter and the ureteric insertion into the bladder is normally located. Primary megaureter is followed conservatively in the majority of patients with a high rate of spontaneous resolution.

Other entities can be evaluated such as ectopic ureteric insertion either in single systems or in combination with duplex systems, usually determined on the delayed post-contrast images or on the T2-W images in markedly dilated systems. Fig. 6 on page 13

MR urography can also demonstrate sinusal or cortical cysts (important pitfall to consider as it can mimic a dilated intrarenal collecting system in T1- or T2-weighted images obtained prior to the intravenous administration of contrast material). Fig. 7 on page 13

The quality of the renal parenchyma is assessed both on the high-resolution T2-W images and during the parenchymal phase of the nephrogram. We typically categorize
the renal parenchyma as normal, uropathic or decompensated. With MR urography, signs to suggest uropathy and permanent damage on the T2-W images include architectural disorganization with loss of the corticomedullary differentiation, small subcortical cysts and low cortical T2 signal intensity. The nephrogram in these cases usually shows dim and patchy contrast enhancement, reflecting damage to the microvasculature as well as glomeruli and tubules. Fig. 8 on page 14

In contrast to uropathic kidneys, the decompensated kidney typically shows increased signal intensity on T2-W images, reflecting edema as well as a delayed dense nephrogram. Fig. 9 on page 14

These two patterns have different prognostic implications: little improvement in renal function can be expected following pyeloplasty in uropathic kidneys, but significant improvement is seen in decompensated systems.

2. Functional evaluation:

This is where we compare our results with those in diuretic renogram (in our 6 cases with coded renal function).

Firstly it is important to understand the different concepts in renal function evaluation:

2.1. Renal transit time: the time it takes for the contrast agent to pass from the renal cortex to the ureter below the lower pole of the kidney.

If the transit time is less than 245 s, the system is considered nonobstructed. If the RTT is greater than 490 s the system is probably obstructed. RTT times between 245 s and 490 s are considered equivocal and are managed conservatively with close follow-up to ensure that renal function is stable.

When evaluating UPJ it is important to consider anatomy, as if the ureter inserts anteriorly into the UPJ, drainage into the ureter does not occur until the renal pelvis fills, whereas if the ureter inserts posteriorly, drainage into the ureter can occur earlier.

2.2. Calyceal transit time: the time it takes for the contrast agent to pass from the renal cortex to the collecting system. The CTT seems to be determined by both the GFR and tubular function. The CTT is most useful

when the contralateral kidney is normal and we can classify it as symmetric, delayed or rapid on the hydronephrotic side.
A delayed CTT suggests an acute decrease in GFR and an increase in reabsorption of urine by the renal tubules in response to increased intrapelvic pressure.

A rapid CTT is typically seen after successful pyeloplasty.

2.3. Differential renal function: in MR urography the DRF is calculated on the basis of enhancing renal volume (vDRF) and the Patlak number,

which is an index of the individual kidney GFR (pDRF). The vDRF represents the functioning renal mass above a user-defined threshold and is similar to values obtained with DMSA scans.

In compensated hydronephrotic systems there is a close correlation between the pDRF and the vDRF. Fig. 10 on page 15

In decompensated systems, there is a difference in the vDRF and pDRF, typically greater than 4%. The greater the difference between the pDRF and vDRF, the more severe the decompensation, using this measure to grade the severity of the obstruction. Fig. 11 on page 16

It is important when considering the vDRF and pDRF to assess the quality of the renal parenchyma to help estimate the recoverability of renal function.
Images for this section:

Fig. 2: Case of a severe right hydrenephrosis.

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Fig. 3: UPJ left obstruction, which resulted to be compensated in functional evaluation.

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Fig. 4: Pelvic ureteric junction obstruction caused by an anomalous drainage of left renal vein.

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Fig. 5: Megaureter in a 1 year old child. Sonographic suspicion is the first key in diagnosis.
**Fig. 6:** Incomplete duplex right system.

**Fig. 7:** Sinus cyst can mimic a dilated intrarenal collecting system in T2-weighted images before intravenous contrast administration. In postcontrast excretory phase images it has a low signal intensity vs urine (excretory system not seen in this image).
**Fig. 8:** Example of uropathic left kidney with delayed and patchy contrast enhancement.
Fig. 9: Example of decompensated left kidney.

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Fig. 10: Example of UPJ left obstruction with compensated hydronephrotic results.

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Fig. 11: Example of UPJ left obstruction with decompensated hydronephrotic results.

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Conclusion

Conclusions:

In our 6 cases with coded renal function we have demonstrated an agreement in results with severe obstruction and delayed functionalism in one case, compensated hydronephrosis in another case, two cases with functional anulation of one kidney and two other cases with normal functionalism demonstrated in both MR-urography and diuretic renogram.

It's important to take into account the additional morphologic information that MR-urography has given in two of our patients; one of them with an incomplete urinary tract duplication and an atypical cyst as well as a patient with important parenchymal atrophy with cortical thinning.

So we can conclude in a reliable demonstration of a correct correlation between renal functionalism obtained rather by MR-urography or by diuretic renogram, with the additional value of obtaining both anatomy and functionalism when using MR-urography. Fig. 12 on page 18
Fig. 12: Complete study showing an uropathic left kidney.

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References


