Magnetic resonance urography vs computed tomography urography in urothelial malignancy diagnosis

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Purpose

To evaluate by a direct comparison the diagnostic accuracy in urothelial malignancy detection of Magnetic Resonance Urography (MRU) and Computed Tomography Urography (CTU).
Methods and Materials

Thirty patients with urothelial malignancy, suspected on the presence of haematuria, were evaluated with both computed tomography urography (CTU) and magnetic resonance urography (MRU) within one week. There were 22 men and 8 women (age range 41-86 years; mean age 65±14 years; median age 66 years). Informed consent was obtained for each patient after the nature of the procedure had been fully explained. We selected cooperative patients with no contraindication to MR imaging.

All CT urography studies were performed on a 64-slice MDCT system. No preliminary patient preparation was required except for emptying of the bladder immediately before entering the CT suite. CTU was performed after injection of 0.1 mg/kg of furosemide, with a single nephro-urographic phase obtained 90 s after the end of the injection of a split bolus of contrast material (400 mgI/kg, 7 minutes of pause, 200 mgI/kg).

Data were obtained with the following parameters: collimation 64x0.5 mm, pitch 0.828, 120 kV, automatic current modulation based on the scout image with dedicated software, standard smooth reconstruction kernel with accepted standard deviation (SD) of 12.5.

MRU was performed with a 1.5 T system and a surface phased array coil (Sense-body) after administration of negative oral contrast material to eliminate T2 signal intensity of the fluid within the bowel. We performed a static fluid 3D MR urography (breath triggered TSE T2 weighted sequence: TR 1375 ms; TE 650 ms; flip angle 90°, matrix 344x275, 1 mm slices) and an excretory MR urography after 10 minutes from diuretic (0.1 mg/kg of furosemide) and gadolinium contrast material (0.05 mmol/kg) injection (breath hold T1-weighted 3D gradient-recalled echo sequence: TR 4.2 ms; TE 1.27 ms, flip angle 30°, matrix 300x204, 1.5 mm slices; breath hold T1-weighted 3D GRE: TR 5.1 ms; TE 2.5 ms, flip angle 10°; matrix 208x168, 2 mm slices). In the waiting time dynamic sequences had been performed focusing on the probable site of disease, if recognisable in static fluid images.

All examinations were stored digitally.

Image analysis

Image evaluation was performed separately by two radiologists with 3 and 6 years’ experience in genitourinary imaging.

For each examination the reviewers evaluated upper, medium and lower calices, pelvis, and ureter on each side and bladder, assessing the overall quality of visualization of each portions on a six-point scale from 0 (complete absence of visualization) to 5 (excellent image quality), using a modified version of the classification proposed by Kelsey Fry [1].
After evaluation of image quality the reviewers were asked to assign independently a confidence level in diagnosis of urothelial malignancy according to a five-grade scale (1, definitely absent; 2, probably absent; 3, indeterminate; 4, probably present; 5, definitely present). Scores 1-2 indicated negative results (absence of disease); scores 4-5, positive results (presence of disease). Score 3 indicated that presence or absence of urothelial malignancy could not be determined.

The reviewers evaluated calyces of the upper, middle and low group, renal pelvis, lombar, sacral and pelvic ureter on each side and bladder. CT and MR window settings were used according to experience and practice of the reader.

Statistical analysis

Comparison of CTU and MRU image quality in the different portions of the excretory system was done using the Wilcoxon matched pairs test and Friedman statistic with Dunn’s multiple comparison test. In MRU evaluation, the best score for each segment between static fluid and excretory MR urography was used.

Receiver-operator characteristic (ROC) curve analysis was employed to assess the overall confidence of diagnosis of urothelial malignancy using the response from the five-grade scale [2]. The areas under the curve were calculated using a dedicated software. p<0.05 was considered to indicate a statistically significant difference.

Diagnosis of malignancy was considered as positive (score 4-5); negative (score 1-2) and indeterminate (score 3). Patient history, made up of further exams, cystoscopies and histological specimens, was considered as reference to evaluate CT and MR data.

Weighted kappa statistics were calculated to assess interreader agreement in diagnostic confidence. Agreement was graded as poor (kappa value <0.20), moderate (#0.20 and <0.40), fair (#0.40 and <0.60), good (#0.60 and <0.80) and very good (0.8-1).
Results

No adverse events occurred in our series during the administration of both iodinated and gadolinium-based contrast agents, but in two patients MR exam has not been completed for incoming of claustrophobia, and, for this reason, only static-fluid MRU was disposable. One patient had been previously treated with left kidney and ureter removal, two patient had a cistectomy.

For assessing the overall quality of visualization, 323 portions had been evaluated (upper, medium, lower calyces, pelvis and ureter on each side and bladder); 439 regions had been evaluated to assess the overall diagnostic confidence (calyces of the upper, middle and low group, renal pelvis, lombar, sacral and pelvic ureter on each side and bladder): 414 were negative and 25 positive (8 in calyces, 4 in renal pelvis, 7 in ureter and 6 in bladder).

Assessment of image quality is summarized in Table in Fig.1 on page 7.

Both CTU and MRU presented a good image quality, permitting the recognition of subtle structure, like calyx and papilla, and anatomical abnormalities (Fig.2 on page 7, Fig.3 on page 8, Fig.4 on page 9). The average image quality grade was statistically significant (p<0.05) better for CT images than for MR images for both readers. A very good inter-reader agreement was found for both CTU and MRU (weighted kappa value=0.87 and 0.95). When the different excretory portions were considered, subjective image quality of MRU was significantly lower than image quality of CTU at the level of calyces. In other tracts the difference was not statistically significant, partly because of little number of patients in the study. MRU image quality was mostly affected by the presence of motion and breathing artifacts in poorly cooperative patients (Fig.5 on page 10).

ROC curve analysis was employed to assess the overall diagnostic confidence of urothelial malignancy at CTU and MRU. Results are summarized in Fig.6 on page 11 and in Table in Fig.7 on page 12. Inter-reader agreement was very good for both imaging modalities (weighted kappa value of 0.86 for CTU and 0.83 for MRU). For both readers, the diagnostic performance of MRU is inferior than that of CTU (area under ROC curve: 0.896±0.0492 and 0.7929±0.0738 for MRU; 0.9963±0.0034 and 0.9826±0.0147 for CTU for reader 1 and for reader 2, respectively). A good inter-reader agreement was found for both CTU and MRU (weighted kappa value=0.67 and 0.66).

MRU diagnostic confidence was most of all affected by the presence of indeterminate segments, in particular at calyceal level. Motion and breathing artifacts in MR may hamper urinary tract visualization, with the possibility of missing lesions, while also in poorly cooperative patients we obtained good quality in CT imaging (Fig.5 on page 10).
Even in case of good quality exams, considerable limitations of MRU are both a lower spatial resolution than CT (Fig.8 on page 12), and the insensitivity to calcifications, with consequent poor diagnostic confidence in differentiating a stone from a neoplastic filling defect (Fig.9 on page 13). Furthermore the panoramic capabilities of CT allowed diagnosis of both wall thickening malignancy and filling defects, while static fluid and excretory MRU offer only lumen depiction (Fig.10 on page 14).

Evaluating only the 9 patients of our series with obstructed and non excreting kidney, better overall image quality shifts from CT to MR in a statistically significant way (p<0.05) for both readers. Data are summarized in Table presented in Fig.11 on page 15. Considering the different excretory portions subjective image quality of MRU was significantly lower than image quality of CTU at the level of calyces.

CT urography, depending on contrast medium excretion, cannot depict urinary tract of obstructed patients, while dilated calyces and ureters are perfectly depicted by static-fluid MRU, permitting to recognize not only the precise site of obstruction, where dynamic sequences have to be focused, but also to exclude the presence of synchronous lesions (Fig.12 on page 16). The dimension of the sample in our series was too small for an effective comparison between CTU and MRU diagnostic confidence, since in both exams no error occurred.
<table>
<thead>
<tr>
<th></th>
<th>CTU Reader 1</th>
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<th>CTU Reader 2</th>
<th>MRU Reader 2</th>
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<td>Calices</td>
<td>4.29±1.38</td>
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<td>Ureter</td>
<td>3.76±1.70</td>
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<td>Bladder</td>
<td>3.60±1.97</td>
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<td>Whole</td>
<td>4.11±1.47</td>
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**Fig. 0:** Assessment of image quality

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Fig. 0: MIP view in the coronal plane: comparison between CTU (a) and MRU (b) in the same patient

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Fig. 0: volume rendering view on the coronal plane: comparison between MRU (a, b) and CTU (c, d)

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**Fig. 0:** Right ureteral duplication with ureterocele (arrow): comparison among static fluid MRU (a, b), CTU (c, d) and excretory MRU (e)

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**Fig. 0:** Old and poorly cooperative patient: MRU (a) shows the large mass occupying renal pelvis (arrow), but the presence of motion artifacts hides completely all calyceal groups; CTU (b) on the other hand permits a complete visualization of all structures and therefore permits to exclude synchronous localization of malignancy.

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Fig. 0: comparison of ROC curves

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<th>CTU Reader 2</th>
<th>MRU Reader 2</th>
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<td>True positive</td>
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<td>False negative</td>
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<td>7</td>
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</table>

Fig. 0: ROC curve statistics

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Fig. 0: The MRU image (a) doesn't show any irregularity in this patient, though CTU (b), thanks to higher spatial resolution, permits the identification of a little filling defect in a middle calyx (arrow).

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**Fig. 0:** MRU image of a good quality (a) shows clearly a filling defect (arrow) of unknown nature within a superior calyx, CTU (b) permits a high diagnostic confidence in differentiating this stone from a neoplastic filling defect

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**Fig. 0:** Static fluid MRU (a, b) and excretory MRU (b, e) don’t show any significant disease both in coronal (a, b) and in axial (d, e) images, while in CTU images (c, f) a bladder wall thickening is clearly visible (arrow)

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<table>
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<th>CTU Reader 2</th>
<th>MRU Reader 2</th>
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<td>Calyces</td>
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<td>Renal pelvis</td>
<td>3.38±1.81</td>
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<td>2.77±2.36</td>
<td>3.88±1.49</td>
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<td>Ureter</td>
<td>3.22±1.86</td>
<td>3.66±1.68</td>
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<tr>
<td>Bladder</td>
<td>3.88±0.78</td>
<td>3.88±0.33</td>
<td>3.44±1.59</td>
<td>4.11±0.60</td>
</tr>
<tr>
<td>Whole</td>
<td>3.74±1.58</td>
<td>4.19±1.20</td>
<td>3.14±2.05</td>
<td>4.16±1.22</td>
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</tbody>
</table>
**Fig. 0:** Assessment of visualization in hydronephrotic patients

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**Fig. 0:** CTU (a, b) in a patient with left obstructed and non excreting kidney doesn't show left excretory tract, but permits to suspect the presence of a tumor in the pelvic ureter (arrow). Static-fluid MRU (c) doesn't need excretory function and therefore depicts completely the dilated ureter and the solid mass within the pelvic tract; enhancement confirmed the nature of the filling defect in the dynamic imaging (e), while excretory MRU (d) gives no information of the left system.

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Conclusion

In our study MR urography allows a poorer depiction of the urinary tract, in particular of calyces, when compared to CT urography and shows a larger range of variability in image quality, even in these selected patients. Diagnostic confidence in recognition and in exclusion of urothelial tumor is significantly better for CT, mainly due to the presence of a lower number of indeterminate tract.

On the other hand static fluid MR urography allows the visualization of the excretory tract also in obstructed and poor functioning kidney, when CTU cannot depict urinary lumen.

In conclusion, there is a large potential for the use of MR urography in the imaging of the excretory system thanks to absence of ionizing radiation but, although further investigations are needed, our study shows that CTU is a more effective and reproducible imaging modality for detection of urothelial malignancy, while MRU has to be reserved to patient at low risk for malignancy and for the evaluation of obstructed patients.
References


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