Dynamic Magnetic Resonance Ureterography: Initial Experience with Contrast-Enhanced, Highly Time-Resolved Evaluation of Ureteral Peristalsis

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Purpose:

Abnormal ureteral peristalsis has been associated with acute and chronic obstruction, primary megaureter, vesicoureteral reflux, prior ureteral surgery, and abnormal ureteral implantation. Non-invasive techniques to evaluate ureteral peristalsis include Doppler sonography of ureteral jets and real-time ultrasound imaging of the ureters[1], time-activity curves of ureteral activity following renal scintigraphy[2], and dynamic fluoroscopy[3]. The aim of this study is to determine the feasibility of dynamic contrast-enhanced magnetic resonance ureterography using an undersampled spiral highly time-resolved 3D gradient echo sequence, TWIST, that relies on complete sampling of a defined central region of k-space and fractional sampling of the periphery with each acquisition.

Methods:

Imaging of ureteral peristalsis was performed in one healthy volunteer and three patients. All subjects signed informed consent approved by the IRB. Imaging in a healthy volunteer was performed after i.v. administration of 20 ml of Gd-DTPA prior to and after i.v. administration of 10 mg of furosemide. All patients were given i.v. Gd-DTPA (20-30 ml) as part of clinically indicated examinations. One of the three patients also received 10 mg of i.v. furosemide 10 minutes prior to imaging.

MR images were obtained at 1.5 T (Avanto, Siemens Medical Solutions) using TWIST, a novel data-sharing 3D gradient echo sequence utilizing spiral acquisition of k-space data originally designed for MR angiography. A standard coronal 3D gradient echo MR urogram was utilized to scout the ureters. Dynamic imaging of the ureters was performed for 110-120 seconds using an oblique sagittal 3D T1 TWIST sequence with the following parameters: TR/TE = 3.31/1.32 ms, FA = 25°, voxel size 1.4 x 1.3 x 6.0 mm, temporal resolution = 0.99s (partial matrix), iPAT = 3, central region A = 70%, sampling density B = 50% (TWIST, Siemens Medical Solutions). Images were reviewed by two board-certified radiologists on an independent workstation using *syngo* Software (Siemens Medical Solutions).

Results:

Seven ureters in four subjects were examined. Three ureters were examined without furosemide, two ureters were examined after iv administration of furosemide, and two ureters were examined before and after furosemide. In all cases, image quality was good. Ureteral peristalsis could be visualized in the renal pelvis and the proximal, mid, and distal ureter (Fig 1).

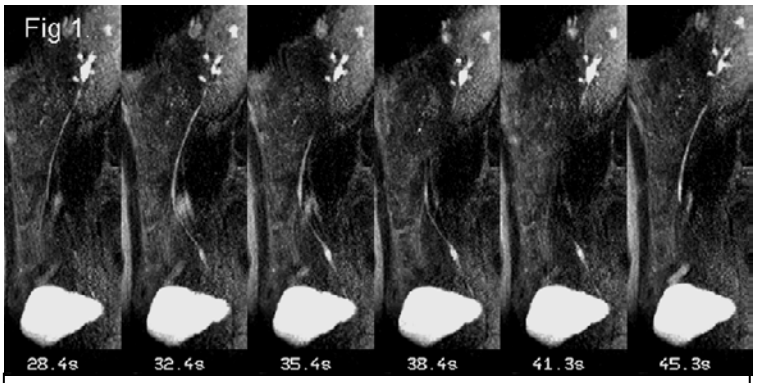

Fig. 1. TWIST ureterography. The pelvis is distended at 28.4s, followed by pelvic contraction at 32.4s, and propagation of the peristaltic wave through the proximal, mid, and distal ureter to the bladder over the next 12.9s. Initiation of a subsequent peristaltic contraction in the renal pelvis is demonstrated on the final image.

In one patient, a single ureter was imaged, and although the ureter was well-visualized, no peristaltic waves were visible; the patient had maintained a fasting state for approximately 12 hours before the examination. In a second patient, one ureter was visualized with no peristaltic waves, and the contralateral ureter demonstrated a single peristaltic wave during two minutes of imaging.

In the healthy volunteer, there was improved visualization and increased frequency of ureteral peristalsis after the administration of furosemide. Prior to furosemide administration, the peristaltic frequency was 2.75 min^{-1}; when imaging began 4 minutes after furosemide administration, peristaltic frequency was 3.75 min^{-1}. In the patient who received furosemide, imaging began 10 minutes after furosemide administration, and peristaltic frequency was 5.4 min^{-1}. Furosemide may have a mild effect on the velocity of peristalsis; in the healthy volunteer, peristaltic propagation from the renal pelvis to the bladder took an average of 15.9 s, but only 13.4 s after furosemide administration.

Conclusion:

TWIST, a novel time-resolved T1 3D gradient echo sequence, can clearly demonstrate ureteral peristalsis after the administration of gadopentetate dimeglumine. To our knowledge, this is the first report of a MRI method permitting quantitative evaluation of ureteral function. Further evaluation of normal and abnormal ureters may help to define normal ranges for peristaltic frequency and velocity. In the future, dynamic MR ureterography may aid in the diagnosis of a wide range of ureteral pathology including acute and chronic obstruction, primary megaureter, vesicoureteral reflux, and abnormal ureteral implantation.

References: 1) Keller MS, et al. J Urol. 1993. 149:553-5.; 2) Lewis CA, et al. Br J Urol. 1989. 63: 144-8.; 3) Durben G, et al. Invest Urol. 1980. 18:207-8.