Ureteral peristalsis with 3D spiral data reconstructed at 4 frames per second

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Target audience: Clinicians and scientists interested in the urinary system.

Purpose: Functional evaluation of the renal collecting system and ureters is routinely assessed by X-ray fluoroscopy or invasive catheterization procedures. Here, we aim to develop a non-invasive technique to image flow down the ureters at high temporal resolution to capture ureteral peristalsis. In this work, we take advantage of the rapid blood clearance of gadoxetate contrast agent 20 minutes post-injection to image at maximal ureter to tissue contrast. This is imaged with a high spatial resolution 3D spiral acquisition reconstructed at high temporal frame rate using TRACER.

Methods: In 40 patients undergoing abdominal MRI with gadoxetate disodium from September 2011 to October 2012, ureters were imaged at 1.5T in the coronal plane using a 3D spiral fat-suppressed gradient echo sequence 20 minutes after the injection of 10cc of gadoxetate disodium contrast using the following parameters: TR=4.3-6.05ms; TE=0.53-0.8ms; flip angle=30°; 48 or 72 leaves, FOV=48cm; matrix=256x256, 320x320, or 512x512; slice thickness=4-6mm, bandwidth=±62.5kHz, spectrally selective fat saturation, partial slice encoding factor of 0.7. The angle between consecutive spiral interleaves was based on the golden ratio to enable flexible view sharing. 60 seconds of spiral data were continuously collected with 1 or 2 breath-holds. A MIP of 8 to12 coronal slices encompassing the pelvicalyceal system was obtained at ~4 frames per second using TRACER [1], which is a constrained reconstruction technique that produces a full 3D stack of images for every nTR where n is the number of slice encodes. Pulse wave frequency and rate propagation were analyzed by applying region of interest analysis (Functool, GE AW4.2 workstation) to the renal collecting system and along the ureter. Time/intensity plots showed peaks corresponding to each peristaltic wave, which were shifted in time according to location along the ureter. From these data, the peristalsis wave frequency and velocity were calculated.

Results: Out of 40 patients, ureteral peristalsis was seen in 26. The peristalsis wave frequency ranged from 0.9 to 4.5 contractions/min and the peristalsis wave velocity ranged from 24 to 136 mm/sec, which corresponds to the values reported in the literature (1 to 5 contraction/minute[2]). The reasons for non-visualization of peristalsis may be due to dehydration (e.g. fasting before the scan), insufficiently long data sampling or motion artifacts (e.g. respiratory) obscuring the images.

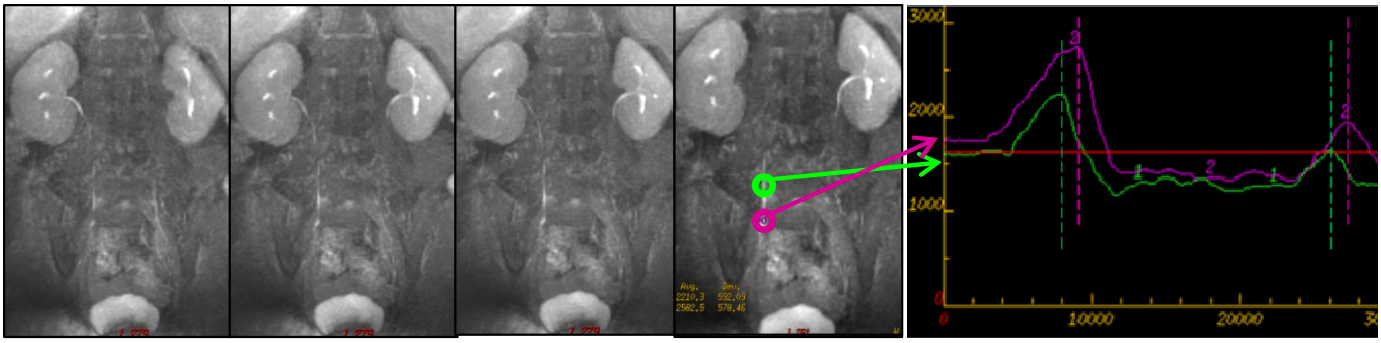

Fig. 1. Selected MIP timepoints at 0 ms, 4991 ms, 5642 ms and 7812 ms show ureteral peristalsis. A Graph of the signal intensity at 2 points along the right ureter shows peaks corresponding to peristalsis wave. The wave velocity can be calculated from the distance between points divided by the time shift between peaks

Discussion/Conclusion: 3D coronal spiral MR reconstructed at 4 frames per second 20 minutes post-gadoxetate captures ureteral peristalsis. Pulse wave frequency and rate propagation down the ureters can be easily calculated to analyze clinical impact of urinary disease. Although gadoxetate disodium is more commonly used for liver imaging, it is well suited for this application because of the low dose and the rapid hepatocyte uptake and clearance from blood. With traditional extracellular agents, there is greater background tissue and blood enhancement at 20 minutes, which obscures the ureters. Conventional 3D dynamic imaging post-gadolinium is not able to visualize bolus transit down the ureters with sufficient spatial and temporal resolution. This problem is overcome here by using a constrained image reconstruction that requires very few spiral leaves in order to obtain an updated frame. We anticipate this may be useful for characterization of urinary disorders including obstruction (e.g. kidney stone or stricture), megaloureter, reflux nephropathy and renal transplant dysfunction.

References:

[1] Xu B et al MRM. 2012 Mar 22. doi: 10.1002/mrm.24253. [2] Boyarsky S et al. Annu. Rev. Med. 1969.20:383-394