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Idzenga T[1], Farag F[2], Heesakkers J[2], Feitz W[2], de Korte C[1]

1. Dept. of Radiology, Radboud University Nijmegen Medical Center, Nijmegen, The Netherlands, 2. Dept. of Urology, Radboud University Nijmegen Medical Center, Nijmegen, The Netherlands

NONINVASIVE MEASUREMENT OF DETRUSOR MUSCLE CONTRACTION USING RADIOFREQUENCY ULTRASOUND STRAIN IMAGING

Hypothesis / aims of study

The function of the urinary bladder is to store urine at low pressure, then to expel urine until complete emptying is achieved. This requires coordination between detrusor muscle contraction and urethral outlet complex relaxation. Disturbances in this coordination lead to voiding dysfunctions such as bladder outlet obstruction (BOO). BOO is characterized by increase in detrusor pressure with decreased urinary flow rate during voiding. Pressure flow study (PFS) is the current standard diagnostic test for BOO. It studies the relation between bladder contractility force and the urine flow output of this force. To perform a PFS, trans-urethral and rectal pressure sensitive catheters are mandatory to quantify detrusor pressure by subtracting the abdominal pressure from the intra-vesical pressure. The invasive nature of PFS can lead to potential morbidities such as urinary tract infections, discomfort and pain. Furthermore, it only measures the result of the detrusor contraction and not the function of the detrusor itself. Therefore, there is an apparent necessity for developing a non-invasive diagnostic technique to quantify detrusor muscle contractility. Such a non-invasive method could make diagnostic procedures more patient friendly.

With radiofrequency (RF) ultrasound it is possible to estimate deformation in biological tissues [1]. This deformation can be either passive by applying an external compression, or active in case of contracting muscle. This technique has been applied in dynamic monitoring of local skeletal muscle strain during contraction [2]. In the current study we applied RF ultrasound to measure deformation of the detrusor muscle during the voiding phase. This may give a clue to the mechanisms of the generated force in relation to detrusor muscle structural and dynamic properties, under physiologic and under disease conditions.

Study design, materials and methods

The patient population consisted of 20 male patients suffering from LUTS/BPH (all subjects signed an informed consent). RF ultrasound data were acquired during the onset of voiding using a SONOS 7500 ultrasound system (Philips Medical Systems, Bothell, USA) equipped with a linear array transducer, 11-3L, fc = 7.5 MHz. The transducer was placed transversal above the pubic bone. In each patient ~20 seconds of data was acquired and stored for offline analysis. In all subjects, at the start of an increase in detrusor pressure the RF ultrasound data were acquired prospectively at a frame rate of 2 Hz (2 patients) and 5 Hz (18 patients) and stored for offline analysis. The urinary flow rate and intravesical pressure were recorded using standard urodynamic equipment (MMS Medical Measurement Systems, Enschede, The Netherlands).

Displacement and strain in the detrusor muscle during voiding was estimated from the RF ultrasound data using a coarse-to-fine strain estimation algorithm [3]. Strain estimation was corrected for detrusor movements during voiding using a tracking algorithm. On the first B-mode image of the acquired time-series a Region-Of-Interest (ROI) was drawn and the mean axial strain (i.e. strain in the direction of the ultrasound beam) in this ROI was calculated.

Results

In 8 patients RF ultrasound data was acquired during a part of the voiding cycle where there was an increase in detrusor pressure and urinary flow. In 5 out the 8 patients the axial strain showed a significantly positive correlation with the detrusor pressure (Spearman = 0.52 – 0.81, $p<.05$). Only one of these patients showed a negative correlation (Spearman = -0.61, $p<.05$) and two patients showed a weak non-significant correlation (Spearman = -0.18 ($p = .07$) and -0.20 ($p = .08$)).

In 5 patients RF ultrasound data was acquired during an isovolumetric contraction (i.e. an increase in detrusor pressure without urinary flow). In all 5 patients the axial strain showed a significantly positive correlation with the detrusor pressure (Spearman = 0.70 – 0.99, $p<.05$). An example of strain in the detrusor during an isovolumetric contraction is shown in Figure 1.

In 7 patients tracking of the bladder wall during voiding failed, either by out-of-plane motion of the bladder wall or erroneous acquisition.

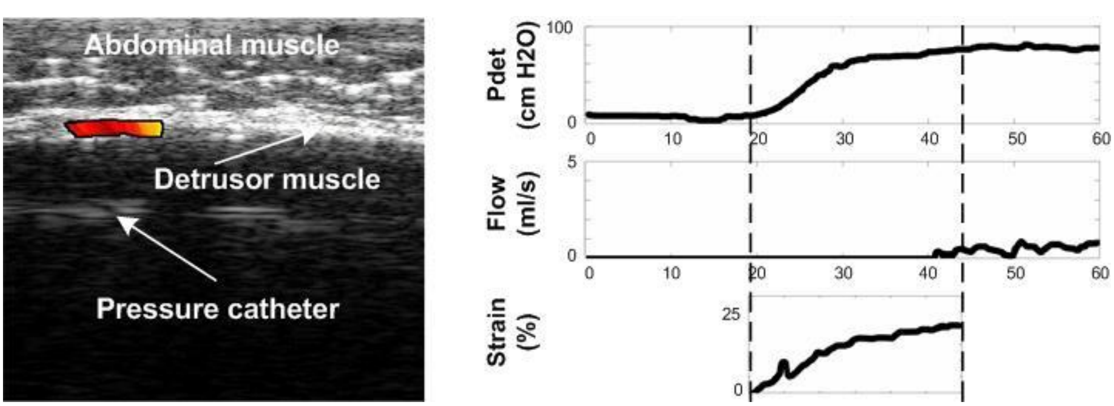

Figure 1: Example of axial strain in the detrusor muscle in a patient with an isovolumetric contraction of the detrusor muscle. The axial strain increases with an increase in detrusor pressure without any change in bladder volume.

Interpretation of results

Strain in the bladder wall was significantly correlated with the detrusor pressure in 10 out of the 13 successfully acquired ultrasound data. The presented values of strain were cumulated with respect to the first acquired ultrasound image; an increase in axial strain therefore, indicates “thickening” of the detrusor muscle during voiding. Whereas a decrease indicates “thinning” of the detrusor muscle with respect to a previous muscle status. In all the patients with an isovolumetric contraction an increase in strain in the detrusor muscle was observed simultaneous with an increase in detrusor pressure. This measurement indicates that the thickening of the detrusor muscle is indeed caused by contraction of the muscle.

Concluding message

In a symptomatic patient population with LUTS we have shown that strain in the detrusor (estimated using radiofrequency ultrasound imaging) correlates positively with the detrusor pressure. This suggests that ultrasound strain imaging could possibly be used to detect detrusor muscle activity for the diagnosis and classification of LUTS.

References

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Disclosures

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