165

Arif M[1], Idzenga T[2], L. de Korte C[2], van Mastrigt R[1]
1. *Sector Furore, Department of Urology, Erasmus Medical Center, Rotterdam, Netherlands,* ***2.*** *Medical UltraSound Imaging Center, Department of Radiology, Radboud University Nijmegen, Nijmegen, Netherlands*

DECORRELATION OF ULTRASOUND RF-SIGNALS FOR A NON-INVASIVE DIAGNOSIS OF BLADDER OUTLET OBSTRUCTION

Hypothesis / aims of study

Bladder Outlet Obstruction (BOO) is common in elderly men and often caused by Benign Prostatic Enlargement (BPE). Lower Urinary Tract Symptoms (LUTS) such as a weak urinary stream, dribbling and frequent voiding are mostly the result of BOO and have a significant negative impact on the patient's quality of life. Currently, a urodynamic pressure-flow study is the standard procedure for a differential diagnosis of the cause of LUTS. The invasive nature of the standard diagnostic method makes it patient unfriendly and may cause pain and acute urinary tract infections. A variety of non-invasive and more patient friendly methods have been proposed to diagnose BOO in patients with LUTS. However, as yet these methods cannot adequately replace the standard invasive diagnostic method.

Time-domain correlation methods have been used for estimating blood flow velocity in arteries using IntraVascular UltraSound (IVUS) catheters. The basic principle behind these correlation methods is that when a group of randomly distributed scattering particles move across an ultrasound beam, the correlation between received Radio Frequency (RF) signals decreases (de-correlate) as a function of time. The rate of decorrelation between subsequent RF- signals is a function of flow velocity. In the case of an obstruction in an artery or in the urethra, the cross-sectional area decreases which results in an increased flow velocity and a high decorrelation rate. In [1] it has been shown that a single value for the cross-sectional area could accommodate both unobstructed and obstructed flow. Therefore, bladder outlet obstruction cannot be diagnosed from an ultrasound image of the urethral cross-sectional area alone. However, the turbulence created by the obstruction may also affect the decorrelation rate. Therefore, the decorrelation method may provide a new non-invasive approach to diagnose BOO. To test this hypothesis, we did an experimental study to relate decorrelation information to the degree of obstruction of urethral models.

Study design, materials and methods

A soft tissue mimicking urethral model representing the lower urinary tract of a male was made from a 10% aqueous solution of Polyvinyl Alcohol (PVA) cryogel. To create different degrees of obstruction two flexible PVA rings (modelling the prostate) were placed around the model urethra, which was placed in a water filled container to prevent evaporation. To generate flow through the model one end was connected to a water column generating the bladder pressure. The other end was connected to an outflow tube draining into a fluid filled expansion barrel through a rotating disk flow meter (Disa Electronic, Denmark). The fluid from the barrel was pumped back into the water column through a roller pump (Verder B.V. The Netherlands). For different water column pressures (i.e. bladder pressures) the pressure drop (p1-p2) over the model urethra and the corresponding flow rate (Q) were recorded with and without rings. The measured pressure drop values and the corresponding flow rate values were plotted in a pressure-flow plot to define the different degrees of obstruction.

An ultrasound system (BK-Medical, Pro Focus UltraView 2202) with a custom designed RF-interface was used to acquire RF data. Silica gel particles of size 15µm-40µm (Sigma-Aldrich, USA) were added to the water circulating through the model to simulate urine and generate ultrasound reflections. To get maximum decorrelation the probe was positioned parallel to the flow direction with ultrasound beam orthogonal to the flow. We acquired 10 subsequent RF-data frames at a Pulse Repetition Frequency (PRF) of 11.4 kHz. Each frame consisted of 144 adjacent RF-signals. We calculated the correlation coefficients between the first and subsequent nine RF-data frames (i.e. 1 with 2, 1 with 3, etc.) for all 144 RF-signals to make correlation images. In each correlation image, we selected a Region of Interest (ROI) in which we calculated the mean correlation coefficient values for three degrees of obstruction. The decorrelation curve was obtained by plotting the resulting mean cross-correlation coefficient value as a function of the time interval between the frames. The decorrelation slope [2] was calculated for each decorrelation curve by taking the decrease in correlation during the time interval between two subsequent RF-signals (87µs). The decorrelation slope in urethral models was studied at three different ultrasound transducer positions: at the obstruction and at 2cm and 4cm downstream of it. The calculated decorrelation slope values were plotted at the different degrees of obstruction.

Results

Figure (A) shows the pressure-flow plots of the urethral models for the three degrees of obstruction. The two straight lines represents the categorization of the pressure-flow data into: unobstructed, equivocal and obstructed according to the Bladder Outlet Obstruction Index (BOOI) [3]. The decorrelation slope for each of the three obstruction at three different positions are shown in Figure (B).

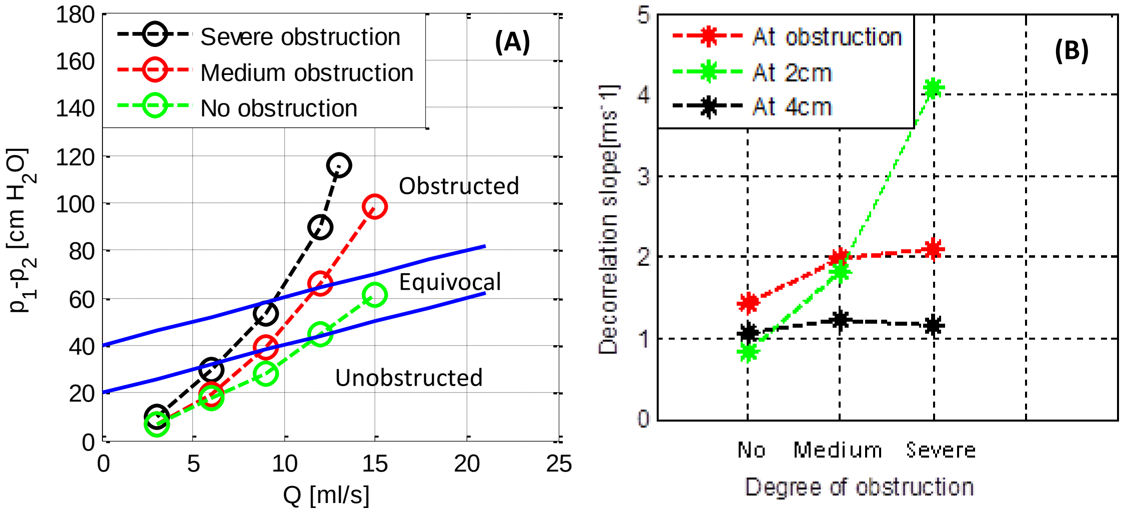

Figure: A) Pressure-flow plot to define the degree of obstruction of the three urethral models. B) The calculated decorrelation slope plotted for the three different models at flow rate of 12ml/s.

<u>Interpretation of results</u>

The pressure-flow plot (Figure A) demonstrates the degree of obstruction of the three different urethral models. We can see that with increasing flow rate the pressure drops increases smoothly for each urethral model. The plot also shows that the pressure-flow relation in our model is not in accordance with the linear relation assumed in the BOOI analysis model [3]. For that reason we have not used BOOI to characterize the degree of obstruction in our models. At a flow rate of 12ml/s we calculated the decorrelation slope in each urethral model at three different positions. In obstructed region and at 2cm downstream of the obstruction the decorrelation slope increases linearly by increasing degree of obstruction. However at 2cm downstream of the obstruction the decorrelation slope increased most with the degrees of obstruction. This is due to turbulence created by the obstruction. A higher degree of obstruction creates more turbulence and results in higher decorrelation slope. At 4cm downstream of the obstruction the flow becomes laminar again and the change in decorrelation slope is not very significant.

<u>Concluding message</u>

In this study, we applied a decorrelation method to RF ultrasound signals measured in urethral models with different degree of obstruction. The results show that the decorrelation slope increased strongly with the different degree of obstruction at 2cm downstream of the obstruction. At other measuring positions (in the obstruction and at 4cm downstram) the relation was weak. We conclude that the decorrelation of ultrasound images may be a new technique to noninvasively diagnose bladder outlet obstruction.

<u>References</u>

1. Van Straten M, Arif M, Van Mastrigt R, "Can bladder outlet obstruction be diagnosed from the urethral cross-sectional area estimated by ultrasound imaging?," Neurourol Urodyn, vol 31, issue 6, page 841-843, 2012.
2. W. Li, A. F. W. van der Steen, C. T. Lancée, I. Céspedes, and N. Bom, "Blood Flow Imaging and Volume Flow Quantitation With Intravascular Ultrasound," vol. 24, pp. 203-214, 1998.
3. D. Griffiths, K. Hofner, R. van Mastrigt, H. J. Rollema, A. Spangberg, and D. Gleason, "Standardization of terminology of lower urinary tract function: pressure-flow studies of voiding, urethral resistance, and urethral obstruction. International Continence Society Subcommittee on Standardization of Terminology of Pressure-Flow Studies," Neurourol Urodyn, vol. 16, pp. 1-18, 1997

<u>Disclosures</u>

Funding: This research is supported by the Dutch Technology Foundation STW (NIG 10896), applied science division of NWO and the Technology Program of the Ministry of Economic Affairs. **Clinical Trial:** No **Subjects:** NONE