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A CORRELATION-BASED ULTRASOUND METHOD FOR THE DIAGNOSIS OF BLADDER OUTLET OBSTRUCTION

Hypothesis / aims of study

Lower Urinary Tract Symptoms (LUTS) such as weak stream, dribbling and frequent voiding are common symptoms in elderly men. These LUTS can be the result of Bladder Outlet Obstruction (BOO) and have a significant negative impact on the patient's quality of life. A urodynamic pressure flow study is currently the standard procedure for the diagnosis of BOO. However, due to the invasive nature of the method, it is patient unfriendly and may cause pain and acute urinary tract infections. Therefore, a new simple non-invasive method to diagnose BOO is needed.

In the field of cardiology, IntraVascular UltraSound (IVUS) is used to diagnose atheromatous plaque that leads to stenosis of the artery. Assessment of blood flow velocity by using a time-domain correlation-based method has been used to evaluate the functional status of a diseased artery. This technique calculates the change in correlation coefficients among a series of radiofrequency (RF) echo signals to form a decorrelation curve that reflects the degree of change in subsequent RF echo signals. RF echo signals are the raw signals containing the high frequency information on which the echogram is based. A high correlation indicates little movement of the particles in the fluid, hence a low velocity. Therefore, by calculating the change in the correlation coefficients of two RF echo signals as a function of time, the flow velocity can be estimated [1]. In this study, our aim was to differentiate between an obstructed and an unobstructed urethral phantom by using correlation-based processing for flow estimation.

Study design, materials and methods

A 10% aqueous solution of Polyvinyl Alcohol (PVA) cryogel was used to make a soft, tissue mimicking phantom representing the lower urinary tract of a male. The internal and external diameters of the phantom were 7mm and 16mm respectively. To create an obstruction in the phantom a flexible PVA ring (7mm- 29 mm) was placed around the urethra. The PVA phantom was placed in a water filled container. One end of the phantom was connected to a centrifugal water pump generating the bladder pressure and the other end to a turbine flow meter. The flow meter drained into a fluid filled expansion barrel that also functioned as the supply for the centrifugal pump. To generate ultrasound reflections, Silica gel particles (15µm-40µm) were added to the water. An ultrasound machine (Philips Medical Systems, IE-33) with a linear array transducer (Philips Medical Systems, L11-3) perpendicular to the particle flow was used to acquire RF ultrasound data. For each line of the ultrasound image, 10 consecutive signals were transmitted and acquired at a Pulse Repetition Frequency (PRF) of ~13.7 kHz. This procedure was repeated for all image lines. We calculated normalized cross-correlation coefficients between the first and the remaining 9 consecutive signals (i.e. 1 with 2, 1 with 3, etc.) and repeated that for all the lines to make correlation images. At the location of the obstruction, we selected a Region-of-Interest (ROI, see Figure A) and B)) and calculated the mean cross-correlation coefficient in that region. Because the correlation coefficients were not normally distributed, we applied the Fisher Z-transform [2] before calculating the mean cross-correlation coefficients. The resulting mean cross-correlation coefficient value for each pair of correlation images was plotted as a function of the time interval. The correlation images were acquired in an obstructed (with PVA ring resembling the prostate) and a non-obstructed phantom (without ring) at flow rate values of 5ml/s, 10 ml/s and 20ml/s, respectively.

Results

An example of the cross-correlation coefficients distribution for lines acquired with a 0.36ms interval (signal 1 and 6) for the non-obstructed and the obstructed phantom at a flow rate of 5 ml/s is shown in Figure A) and B). In both cases the mean correlation coefficient deceased with increasing time difference between acquiring the signals as shown in Figure C). For the obstructed phantom the mean cross-correlation coefficient value decreased faster than for the non-obstructed phantom. A similar pattern was found for the flow rates 10 ml/s and 20 ml/s with increasing decorrelation rate for increasing flow rates.

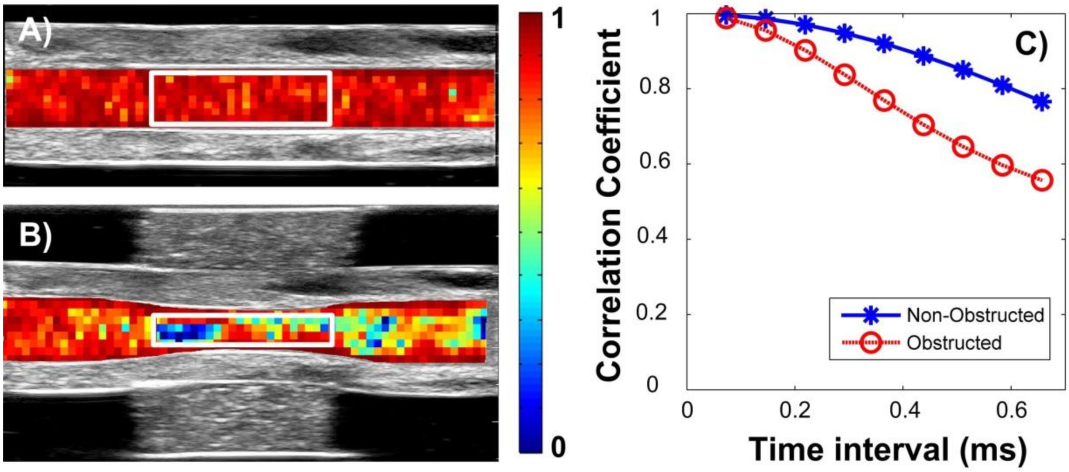

Figure: A) B-Mode image of non-obstructed and B) obstructed urethral phantom with correlation coefficients distribution at 5ml/s. C) Mean decorrelation curve as a function of time interval at 5ml/s.

Interpretation of results

In the obstructed urethral phantom the cross-sectional area was decreased in the obstructed region which resulted in an increased flow velocity in that region. Accordingly Figure C) shows a faster 'decorrelation' in the obstructed region. Therefore, it seems possible to develop a correlation based ultrasound method for diagnosing BOO.

Other authors [3] have used ultrasonography to diagnose BOO on the basis of flow velocity. They calculated the ratio between velocities measured at two locations, the external sphincter and the sphincteric urethra. However, they used color Doppler ultrasound. Using that method the measurement of a Doppler frequency shift at higher flow velocities (e.g. at flow rate= 10ml/s and cross-sectional diameter= 3 mm, velocity= 141 cm/s) such as in the obstructed urethra is not possible due to the aliasing effect. The correlation-method we have used does not determine the Doppler frequency or phase shift but compares two subsequently acquired signals and the effect of the positional change of fluid particles in relation to time. Therefore, we hypothesize that with this method the higher flow velocities in the obstructed urethra can be measured.

Concluding message

In this study, we applied a correlation-based method to raw RF ultrasound measurements on obstructed and non-obstructed urethral phantoms at different flow rate values. The results showed that the decorrelation curves for the obstructed urethral phantom decreased more rapidly than those of the non-obstructed urethral phantom. We therefore conclude that decorrelating ultrasound data can be a new potential technique to noninvasively diagnose BOO.

References

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Disclosures

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