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REAL-TIME FOUR-DIMENSIONAL ULTRASONOGRAPHY FOR MONITORING BLADDER MOTION AND SHAPE ANALYSIS DURING VOIDING

<u>Hypothesis / aims of study</u>

The abnormality of the bladder shape and/or urethral opening during voiding is related to voiding dysfunction. Video-urodynamics including voiding fluoroscopy or voiding ultrasonography have been used to evaluate dynamic anatomical voiding dysfunction (1-3). However, these conventional imaging modalities are able to demonstrate only two-dimensional images. Recently, the most notable improvements in advanced ultrasound (US) technologies have concerned the speed of acquiring imaging data, allowing the demonstration of dynamic changes of three-dimensional US images in an almost real-time manner. Four-dimensional US (or dynamic three-dimensional US) is a new technology that can show dynamic changes in 3D US imaging. 4D-US has the potential to record the dynamic anatomical movements of the lower urinary tract, such as bladder wall motion, changes of intravesical volume or diameter, or the opening and closing of the urethra or sphincter in a real-time manner during voiding. The aim of this study is to describe the initial applications of 4D US for the monitoring of dynamic change in bladder shape and volume during voiding.

<u>Study design, materials and methods</u>

Fifteen healthy male volunteers (controls) aged 28-42 years and 5 male patients with urinary disturbance aged 62-84 years were included in the study. 4D-US volume data sets of the bladder during voiding were obtained by trans-abdominal US using the Voluson 730 Expert (GE Medical Systems) with motorized transducer. All voiding was monitored by both 4D-US and uroflowmetry at the same time in the standing position. The bladder volumes during voiding could be acquired with a single automated sweep of the transducer. The spatial and temporal imaging information was subsequently combined to display dynamic images that can be extracted from the volume data sets. Acquisition lasted from 4 seconds to 13.3 seconds and was performed during voiding in the absence of abdominal pressure where possible. Changes of intravesical dimensions in the axial, coronal, and sagittal planes as well as intravesical volume were measured, and analyzed in comparison with uroflowmetry.

<u>Results</u>

Dynamic monitoring of the bladder motion and bladder shape analysis during voiding was feasible in all of the subjects. Multiplanar display and the volume rendering method described the dynamic 3D-shapes of the bladder motion during voiding, simultaneously visualized in the axial, coronal, and sagittal planes (Figure 1-2). The velocity of the change in bladder volume calculated by 4D-US data had a significant correlation with the maximum flow rate ($r=0.53$, $p=0.05$) and the average flow rate($r=0.70$, $p<0.01$) during the interval of 4D-US monitoring. Between the 3 kinds of intravesical diameter in the axial, coronal and sagittal planes, significantly the change of intravesical diameter in the coronal plane was most correlated with the change of the total intravesical volume ($r=0.796$, $p<0.01$). The changes in coronal diameter were substantially greater in patients with urinary disturbance, compared to those observed in the controls ($t=-3.05$, $p<0.01$)

Figure 1
Before voiding (at bladder vol.= 305 ml)

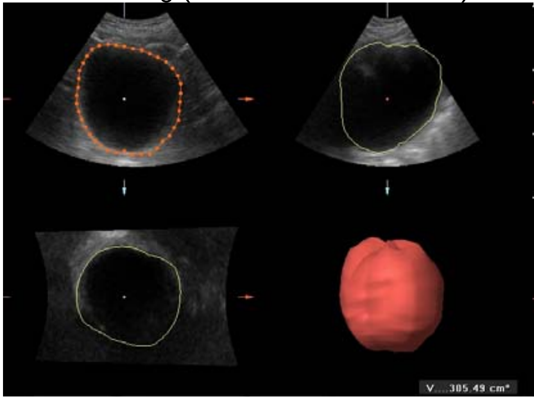
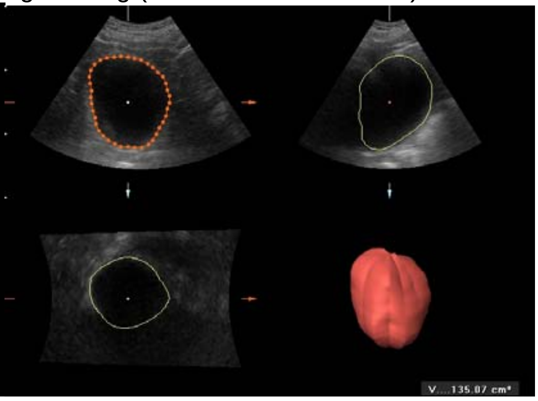


Figure 2
During Voiding (at bladder vol.=135 ml)



Interpretation of results

4D US for the monitoring of bladder motion and shape analysis is feasible and could be a novel imaging technique for the assessment of voiding. The velocity of the change in bladder volume was correlated with the maximum flow rate and the average flow rate. The velocity of changes in bladder volume and bladder diameters calculated from 4D-US data could be new parameters to evaluate voiding function. Diameter analysis in the craniocaudal axis may have an important impact on voiding dysfunction. 4D US offers the potential to provide non-invasive, repeatable, real-time dynamic imaging of the lower urinary tract anatomy during voiding without a radiation hazard as well as without the necessity of catheterization.

Concluding message

The monitoring of voiding using 4D-US was feasible in both healthy subjects and patients with urinary disturbance. 4D-US has the potential to simplify non-invasive three-dimensional visualization of the lower urinary tract and to improve the anatomical understanding of the voiding dysfunction.

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