#398 Fluid dynamical assessment of lower urinary tract: exploratory research to observe vorticity in male lower urinary tract using color Dopper ultrasonography

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OBJECTIVES

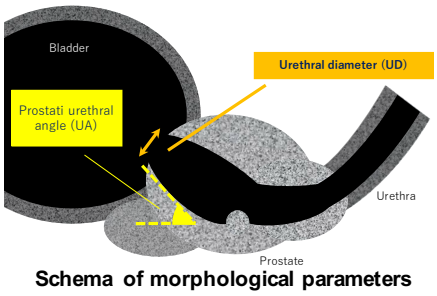
We can find vorticity, when we evacuate bathtub of water. Like that, fluid with high Reynolds number, Newton's law of resistance is important to define resistance of fluid passing in a duct. To reduce flow resistance of fluid with high verocity, vorticity can be created, such as narrow duct. Then, vorticity is key physical phenomenon for fluid dynamics when fluid passes a narrow duct like urethra. However, there are few studies to understand urinary micturition in the aspect of fluid dynamics. On the other hand, novel technologies of color Doppler ultrasonography (CDUS), such as fine-flow (FF) mode and vector flow mapping (VFM), were developed to detect flow direction. FF mode can be used for sensitive detection of fluid flow with high flame rate. VFM is an echocardiographic technology which enables visualization of the intraventricular flow velocity vector. Herein, we attempted to evaluate vorticity and direction of urine flow in lower urinary tract using FF mode and VFM.

METHODS

We conducted a 2-step study, FF mode for urethra and VFM for urinary bladder, to evaluate vorticity and urine flow direction in lower urinary tract.

FF mode for urethra

Fist, prostate cancer patients were enrolled in FF mode observation to evaluate urethral function before radical prostatectomy. Transrectal ultrasonography (TRUS) was done for visual evaluation of urethral sphincter and urine flow using FF mode CDUS. The patients were put on the fluoroscopic tilting table for passive postural change from spine to standing position, and passed urine under TRUS. And, vorticity formation was evaluated. Volticity was defined as alternation of red and blue signals in prostatic urethra. The enrolled patients who can void in this procedure were divided into 2 groups: vorticity group and non-vorticity group. Prostatic urethral angulation (PUA) and urethral diameter (UD) were measured during micturition.



Schema of morphological parameters

VFM for urinary bladder

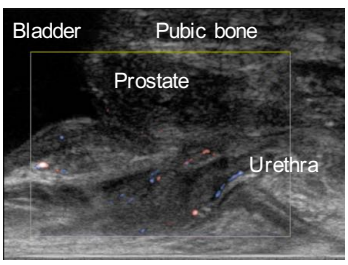
Second, a healthy volunteer was enrolled in VFM observation to evaluate urine flow in urinary bladder under urine micturition in standing position. Transabdominal ultrasonography (TAUS) was done for challenge of visualization of urine flow direction and vorticity formation in urinary bladder.

RESULTS

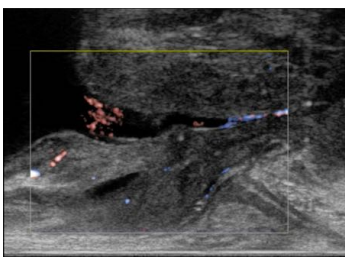
Fifteen patients were enrolled in the first experiment. Thirteen patients can void in this setup, and TRUS can detect opening of urethra and urine flow. And, FF mode can clearly demonstrate alternation of red and blue Doppler signals in 4 patients. Representative images were shown in Fig. 1A, B, and C. The arrow indicates bladder neck opening at the beginning of urine micturition. And, arrow heads indicate alternation of Doppler signals. Urethral morphological parameters, UD and PUA, were measured and compared between vorticity group and non-vorticity group. (Fig.1D)

Fig.1 Fine-Flow mode CDUS (Transrectal ultrasonography, sagittal)

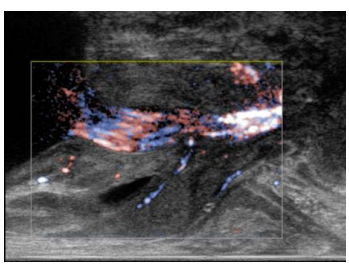
A) Before voiding



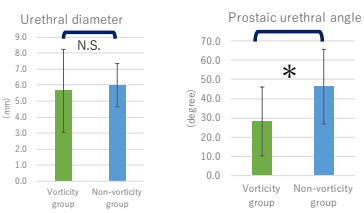
B) Beginning of voiding



C) Peak flow of voiding



D) Comparison of urethral morphology



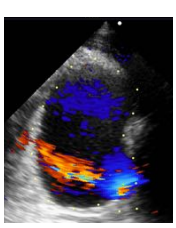
The images were obtained by HITACH, Preirus ®

Second, one volunteer was enrolled in the VFM observation. Urine flow direction and vorticity formation was dynamically demonstrated in this setup. (Fig.2A, B, C, D).

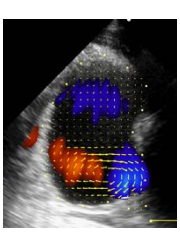
Fig. 2 Vector Flow mapping (Transabdominal ultrasonography, sagittal)

A) B mode

B) Normal CDUS

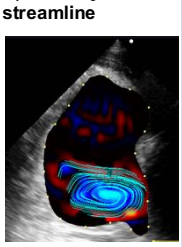


C) Vector Flow



Arrows indicate stream direction and velocity.

D) Vorticity & streamline



Blue: clockwise rotation
Red: anticlockwise rotation
Blue-lines indicate streamlines (direction).

The images were obtained by HITACH, LISENDO880 ®

CONCLUSIONS

Interpretation of results

Vorticity of spontaneous urine micturition in prostatic urethra can be detected in some patinets using CDUS. Vorticity may be associated with urethral morphology, such as UA. Vorticity in urnary bladder can be also observed using VFM. However, the enrolled patients are not health volunteer, and nor LUTS patients. The role of vorticty has been still mysterious yet. Moreover, VFM is developed for evaluation of hart function. The adaptation of VFM to lower urinary tract should be considered carefully.

Conclusion

The results of this study indicates that CDUS can demonstrate vorticity formation during urine micturition in prostatic urethra. And, CDUS with VFM mode may be able to visualize the direction and vorticity of urine flow in urinary bladder. Thus, CDUS with the noble technology can be a method for fluid dynamical assessment of urine flow in prostatic urethra and urinary bladder.