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FLUID DYNAMICAL ASSESSMENT OF LOWER URINARY TRACT: EXPLORATORY RESEARCH TO OBSERVE VORTICITY IN PROSTATIC URETHRA AFTER TRANSURETHRAL ENUCLEATION USING COLOR DOPPER ULTRASONOGRAPHY

Hypothesis / aims of study

In 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. Although pressure flow study is main observative method to assess voiding mechanism in lower urinary tract, there are few studies to understand lower urinary tract (LUT) in the aspect of fluid dynamics. Although urine flow velocity was assessed by ultrasonography (US) (1), especially power Doppler US, fluid dynamical assessment including direction and vorticity of urine flow in urinary bladder and urethra has nat investigated yet.(1-3)

In patients with voiding dysfunction induced by benign prostatic hyperplasia (BPH), vorticity may be interrupted by compression or deformity of urethra by prostatic adenoma. Indeed, a flatten-shape duct is not ideal to pass fluid making vorticity whereas a round-shape duct can keep enough space to make vorticity. Althoug fluid dynamics may be important to understand pathology of BPH patients, there are no clinical method to assess fluid dynamics including vorticity passing urethra. Therefore, to establish methodology is one of the most important problems to assess LUT in the aspect of fluid dynamic. On the other hand, color Doppere ultrasonography (CDUS) is common clinical modality to evaluate fluid dynamics in blood circulation. Herein, we attempted to observe fluid dynamical characteristics of urine flow in male urethra using CDUS. As the first step of fluid dynamical assessment of LUT, urine flow was observed using CDUS in the prostatic urethra with enough space for flow direction observation, just after transurethral surgery for BPH. The aim of this study is development of method to evaluate urine flow in the aspect of fluid dynamics, especially flow direction and vorticity.

Study design, materials and methods

A patient who was diagnosed as BPH was enroled in this study. Under general anesthesia, Holmium Laser Enucleation of the prostate (HoLEP) was parformed. Digital ulgrasoographic diagnostic system (HIVISION Preirus, HITACH, Tokyo, Japan) was used in this study. Fine Flow mode (high flame rate and high resolution of color imaging mode) was set up to detect direction of fluid flow as CDUS. Just after HoLEP, prostatic bleeding was coagulated using bipolar resect scope. Micro bubbles are fulled in urinary bladder for a while. **(Fig. 1A, B, C)** The top of external cylinder was placed on urethral sphincter to make the urinary bladder empty, and transabdominal ultrasonogaphy was done to observe direction of fuid flow saggitally. **(Fig. 1D)** The results were recorded in the hard-disc-drive in the US system as movie, and were analysed dynamically. All of the above procedures was done under general anesthesia in lithotomy position.

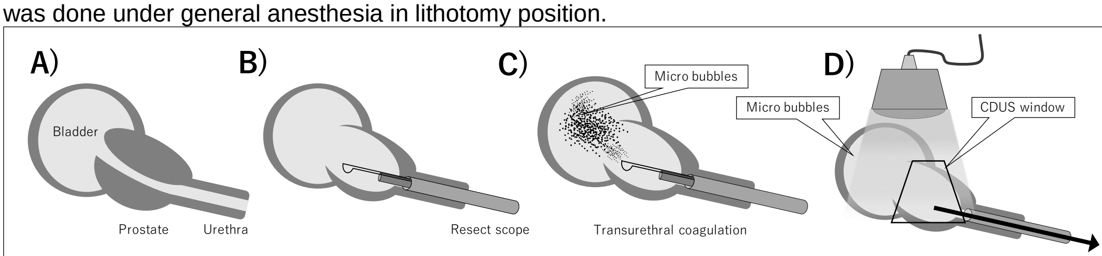

Fig. 1 Schema of methodology in this study. A) Lowere urinary tract before HoLEP. B) Resect scope was placed on the urethral sphincter just after HoLEP. C) Transurethal coagulation generates micro bubbles in the urinary bladder. D) After removal of the internal cylinder of resect scope, fluid flow in prostatic urethra can be observed using CDUS. Micro bubbles assist to see fluid flow in urinary bladder outside of CDUS.

Results

After transurethral coagulation, micro bublles diffused in urinary bladder. **(Fig. 2A, B)** After removal of internal cylinder placing urethral sphyincter, micro bubbles started to make flow from all direction to bladder neck. **(Fig. 2C)** And, Doppler signals were revealed in prostatic urethra under ultrasonography with CDUS. Moreover, the Doppler signals in the prostatic urethra, red and blue signals made clear contrast alternately. **(Fig. 2D)** During the voiding, the contrast of blue and red signals remained at the end of voiding. **(Fig. 2E, F)**

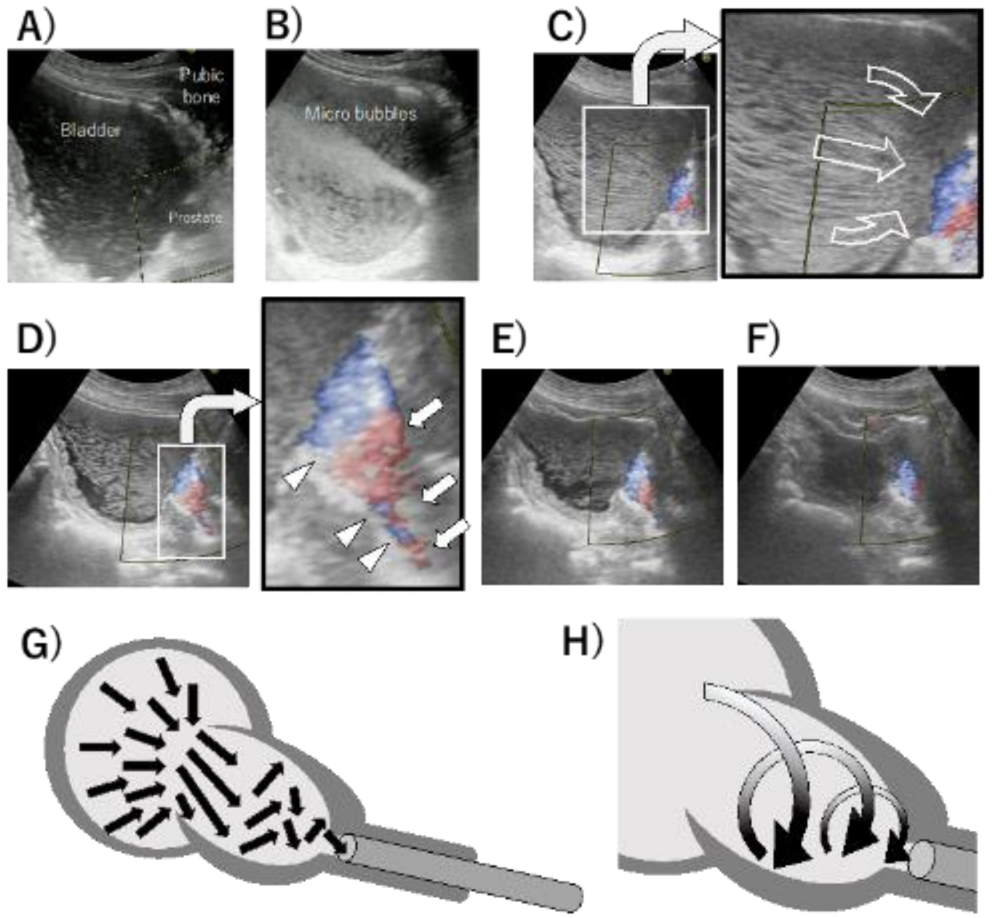

Fig. 2 US images and schemas of the result in this study. A) US image before HoLEP. B) Trans urethral coagulation generated micro bubbles in urinary bladder. C) At the begining of voiding, Doppler signals can be detected in the prostatic urethra after HoLEP. The flow of micro bubbles helps to see direction of urine in the urinary bladder. Fluid flow concentrated from all direction to the bladder neck. D) Blue signals can be seen in the proximal side of prostatic urethra, and red signals can be seen in the distal side of prostatic urethra. Alternation of blue (arrow head) and red (arrow) was detected clearly. E) The contrast of blue and red signals continued during voiding. F) Image just after voiding. The fluid in the urinary bladder was voided completely without residual urine. G) Schema of the results of this study. H) Interpretation of the obtained findings in the CDUS. Vorticity mignt be created in the prostatic urethra.

Interpretation of results

Using transabdominal CDUS, the directions of urine flow in the prostatic urethra were successfully observed in this method. The red and blue Doppler signals showed clear contrast in prostatic urethra alternately. These findings indicted that urine flow in the prostatic urethra is vorticity to reduce the flow resistance. **(Fig. 2G, H)** This phenomenon is rational in the aspect of fluid dynamics. Micro bubbles generated by transurethral coagulation assisted to see urine flow in the urinary bladder outside of CDUS windows. This method is helpful to conduct fluid dynamical assessment in LUT widely. This is the first report to assess urine flow in the aspect of fluid dynamics using CDUS, and to observe vorticity in prostatic urethra just after HoLEP. Indeed, there are many limitations, such as general anesthesia, position, and condition just after surgery. However, possibility of fluid dynamical assessment was shown in these results. In the aspect of fluid dynamics, vorticity can be a new parameter to understand normal and abnormal urine flow.

Concluding message

The results of this study indicates that CDUS can be a method to observe direction and vorticity of urine flow in urethra.

References

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Disclosures

Funding: None **Clinical Trial:** Yes **Public Registry:** No **RCT:** No **Subjects:** HUMAN **Ethics not Req'd:** This is a retrospective observational study. **Helsinki:** Yes **Informed Consent:** No