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URINE FLOW DYNAMICS SIMULATION OF MALE URETHRA USING DEFORMABLE MODEL

Hypothesis / aims of study

Voiding dysfunction is one of the major symptoms deteriorating patients' Quality of Life (QOL) among aged male. Deformation of intraluminal cavity at the prostatic urethra caused by bladder outlet obstruction (BOO) or benign prostatic hyperplasia (BPH) has been considered to be related to voiding dysfunction, however, influence of the deformation on turbulence of the urine flow still remains uncertain. In the previous study, we performed urine flow dynamics simulation in the virtual urethra processed from cystourethroscopic video, and found computed pressure loss of urine stream through the urethra showed close relationship with clinical parameters [1]. We try to create another experimental system analyzing urine flow dynamics simulation using phantom models of the prostatic urethra to validate results of previous results in the virtual urethral models.

Study design, materials and methods

We designed a urethra model using 3D CAD software following the previous method [2]. The model is composed of the proximal urethra, which is thought to be deformed in various ways according to disease status. The urethral model was configured by poly-vinyl alcohol (PVA) cryogel, which is often used as an ultrasound phantom as its similarity to the human tissues, placed in a box, and aqueous gelatin solution was poured to the box to cover the model (Fig. 1). The box was connected to the tube that was attached to the syringe that was pushed by linear motor (Fig. 2). The lumen of the model was closed by negative pressure applied with syringe to imitate urethra, then was passively dilate by urine flow. Ultrasonography was performed during injection of the fluid into the intraluminal cavity of the model, and images of motion of the intraluminal cavity were captured.
The images were processed using MATLAB® to obtain contours of the urethra model. Because of its characteristic that ultrasound image have, Chan-Vese segmentation method [3] was applied to segment the urethra from the acquired images canceling speckle noises of ultrasound image. Labeling method was used to the segmented images to separate inner and outer contours of the urethra model. This procedure was applied to the time series of the images.

Results

The urethral model had adequate softness enough to be deformed with the dynamic pressure of the flow. Ultrasonographic images were obtained with the model set in the experimental system. The inner and outer contours of the urethra model was obtained sequentially showing deforming motion under dynamic pressure of the stream (Fig. 3).

Interpretation of results

Created urethral model and experimental system was indicated to be able to simulate urine flow in terms of passive dilation of the urethra by flow pressure. As for the image processing method, the phantom model, experimental model and Chan-Vese segmentation processing method were suggested to be adequate for observing urethral motion during urination. Coupled analysis and observation of urine stream are planning using the phantom in comparing with results of the results of virtual models.

Concluding message

We constructed the urine flow experimental system of the urethral model as a preliminary phase of developing novel diagnosing method for micturition disorder. The experimental system should be evaluated further to fortify simulation results on the virtual urethral simulation.

Fig. 1 The model covered with gelatin solution

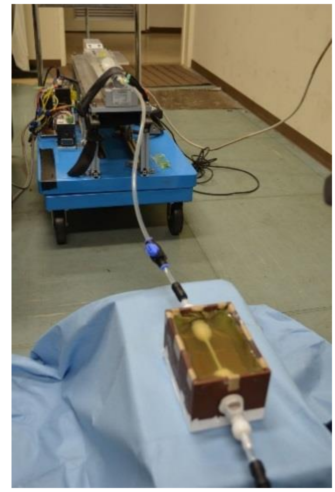

Fig. 2 Experimental set up

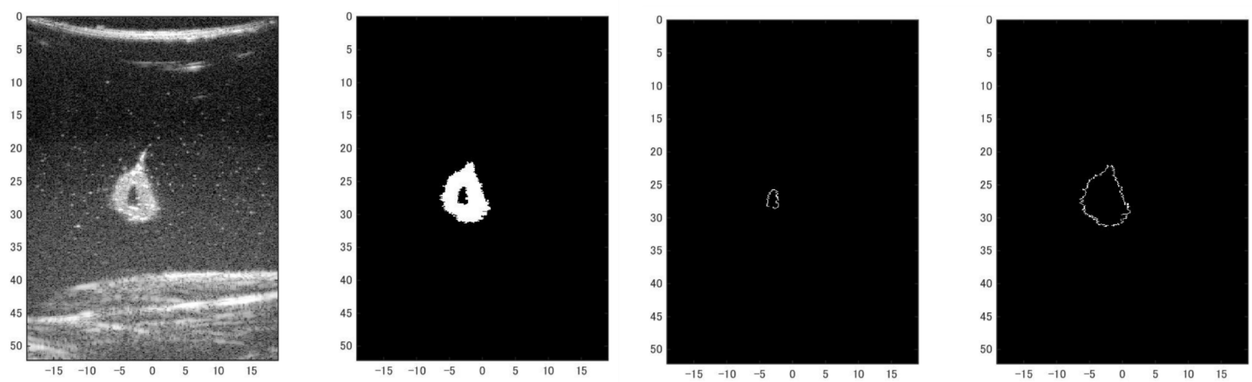

Fig. 3 Obtained image, segmented area, inner and outer contours of the urethra model (from left to the right)

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Disclosures

Funding: This work was supported by JSPS KAKENHI Grant Numbers 70302544, 15K20913. **Clinical Trial:** No **Subjects:** NONE