Evaluation of stress urinary incontinence by computer-aided vector-based perineal ultrasound

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Abstract

Background. In this study, we compared the differences in dynamic changes of the bladder neck between women with and without urodynamic stress incontinence by computer-aided vector-based perineal ultrasound. Methods. The function and morphology of the lower urinary tract were assessed in 48 women with or without urodynamic stress incontinence by urodynamic study and computer-aided vector-based perineal ultrasound. Results. Patients in the urodynamic stress incontinence group had a significantly higher parity and higher prevalence of funneling of the bladder neck than participants in the control group (p<0.05). After adjusting for parity, women with a corrected bladder neck movement ≥10 mm were 9.0 times more at risk of having urodynamic stress incontinence than women with a corrected bladder neck movement <10 mm (p<0.05). If we used corrected bladder neck movement ≥10 mm as the cut-off point for diagnosis of urodynamic stress incontinence, the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were 77.8%, 66.7%, 87.5%, 50%, and 75%, respectively. Conclusions. The increase in corrected bladder neck movement is associated with functional impairment of urethral closure. Computer-aided vector-based perineal ultrasound is valuable in assessing anatomic change of the bladder neck, but it is not a sensitive tool for predicting urodynamic stress incontinence.

Key words: Urodynamic stress incontinence, computer-aided vector-based perineal ultrasound, urodynamic study, bladder neck movement

Abbreviations: USI: urodynamic stress incontinence, SUI: stress urinary incontinence, ICS: International Continence Society

Stress urinary incontinence (SUI) is caused by defects in pelvic support that lead to increased mobility of the urethra and bladder neck. Adequately defining the anatomic and functional defects in women with SUI prior to surgical repair is essential (1). Ultrasonographic studies of patients with SUI can provide quantitative measurements and qualitative descriptions of the lower urinary tract (2).

Perineal ultrasound has been used as an alternative to conventional radiological techniques to assess the dynamic changes of the urethrovesical junction and proximal urethra for two decades (3–8). Simple tracking of bladder neck movement on the screen may not be accurate. The pressure of the perineal tissues against the probe during a Valsalva maneuver or cough moves the probe relative to the pubic bone so that directly measuring on-screen motion may not reflect the true movement of the bladder neck. Therefore, Reddy et al. described using a vector-based analysis of bladder neck movement to cope with probe movements relative to the symphysis pubis in order to quantify the amount of probe-symphysis displacement (8).

Although the vector method allows corrected bladder neck movement after correcting probe-symphysis displacement to be defined on the screen...
with few measurements, the process is cumbersome. We propose the computer-aided evaluation model based on the method by Reddy et al. (8), which can be concise and easy-to-use. To our knowledge, no other study has scientifically evaluated SUI by computer-aided vector-based perineal ultrasound. An exploration of computer-aided vector-based perineal ultrasound in the evaluation of SUI was therefore thought to be of importance. In this respect, the purpose of this study was to compare the differences in dynamic changes of the bladder neck between women with and without urodynamic stress incontinence (USI) by computer-aided vector-based perineal ultrasound.

Materials and methods

Subjects

Forty-eight subjects were randomly enrolled among women with lower urinary tract symptoms (frequency, nocturia, urgency, or urinary incontinence) for at least 3 months. All presented for urogynecologic consultation and underwent functional evaluation of the lower urinary tract by urodynamic study together with morphologic assessment of the lower urinary tract by ultrasonography (including computer-aided vector-based perineal ultrasound in the evaluation of the bladder neck movement) in our department. The random samples were generated by computer. Subjects with USI diagnosed by urodynamic study and those with normal bladder function revealed by urodynamic study (as control group) were included. Women who met any of the following criteria were excluded: 1. those who had undergone anti-incontinence surgery; 2. those who had symptoms of hematuria, recurrent dysuria, or infection on urine culture; 3. those who had 2 or more diagnostic entities by urodynamic study. This study was approved by our institutional review board, and written informed consent was obtained from all of the women that participated in this study.

Computer-aided vector-based perineal ultrasonography

With patients in a supine position with a comfortably full bladder, perineal ultrasonographic cystourethrography was performed using a Toshiba Capasee II (Toshiba Medical Systems Co, Ltd, Tokyo, Japan) and a 3.5-MHz convex probe. The morphologic characteristics of the lower urinary tract were evaluated at rest and during a maximal Valsalva maneuver. These included measurement of the bladder neck position and observation of the development of funneling of the bladder neck. The position of the bladder neck was measured from the distance of the bladder neck to the lower border of the pubic symphysis and the angle between the bladder neck–symphyseal line and the midline of the pubic symphysis was measured. When a sonography was performed, an analog video signal was transmitted from the VCR output of the scanner to a digital handycam (Sony, Tokyo, Japan). The data were then analyzed by the proposed computer-aided evaluation model based on the method by Reddy et al. (8) with the examiner blinded to continence status.

Correction of bladder neck position

The perineal ultrasonographic cystourethrography obtains views of the bladder, urethra, and pubic bone. The central axis of the pubic symphysis (pubic axis) was determined to correctly position the bladder neck. The pubic axis is defined by the pubic point (denoted PP) and the mid-pubic point (the middle point of the pubic symphysis, denoted MP) and then set as a line with 0° for future angle measurement. In general, a physician can easily identify a bladder, urethra, and pubic bone on a sonographic image by the shape and contrast of internal echoes, but the computer cannot easily locate the tissues. However, if a physician has already identified the tissues, a computer can use the positions to measure some beneficial information. In this study, a physician first extracted six reference points, i.e. PP_R, PP_S, MP_R, MP_S, BN_R, and BN_S, and then the computer evaluated the bladder neck movement based on these six positions. The PP_R and PP_S are the pubic points at rest and stress, respectively. The MP_R and MP_S denote, respectively, the mid-pubic points at rest and stress; and BN_R and BN_S denote the bladder neck positions at rest and stress, respectively. Figure 1 illustrates six manually selected reference points in a perineal ultrasound image.

Probe movement effects shifting of the pubic axis between the resting and stressing perineal ultrasound images. The relationships among the symphysis pubis, the location of the bladder neck and the bladder at rest and during a maximal Valsalva maneuver (at stress) are shown in Figure 2. The shifts in pubic axis can be obtained by measuring the pubic point movement (PP). The two reference points PP_R and PP_S can be utilized to obtain PP. On-screen bladder neck movement vector (BN), called uncorrected bladder neck vector, may not reflect the true movement of the bladder neck. The two vectors PP and BN were identically tracked and assigned both magnitude and angle relative to pubic
axis. Thus, the corrected bladder neck movement vector ($\overrightarrow{BN}$) was estimated using the difference between $\overrightarrow{PP}$ and $\overrightarrow{BN}$, such that

\[
\overrightarrow{BN'} = \overrightarrow{BN} - \overrightarrow{PP}
\]  

The $\overrightarrow{BN'}$ is measured as the final real movement of the bladder neck after being corrected by the probe motion. Figure 3 illustrates the proposed computer-aided evaluation model. In this program, only six reference points in a perineal ultrasound image were manually selected by physician.

**Urodynamic assessments**

The urodynamic assessment of each subject comprised a 20-min pad test, uroflowmetry of spontan-
neous voiding, both filling (with a rate of 60 ml H₂O/min) and voiding cystometry, and stress urethral pressure profile with 250 ml of distilled water in the bladder. The 20-min pad test was used to determine the quantity of urine leakage (9). USI was diagnosed according to the definition recommended by the International Continence Society (ICS) (10). A Dantec six-channel urodynamic monitor with computer analysis (Menuet, Tonsbakken, Skovlunde, Denmark) was used in this study.

### Statistical analysis

Student’s t-test was used for normally distributed continuous variables. When the data did not conform to the above assumption, nonparametric methods of statistical inference were used. When the assumption of the chi-square test was violated (i.e. when >1 cell had an expected count of <1, or >20% of the cells had an expected count of <5), Fisher’s exact test was used. A multivariate logistic regression model and odds ratios (with 95% confidence intervals) were used to assess the independent prognostic value of the cystourethrographic variables for USI. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were defined according to the values used by Sackett et al. (11). All statistical tests were two-sided. A p value less than 0.05 was considered statistically significant. The data were analyzed by the Statistical Package for Social Sciences (SPSS for Windows, release 8.0, SPSS Inc, Chicago, IL, USA). Sensitivity, specificity, PPV, NPV, and accuracy were calculated using Microsoft Excel 2000.

### Results

Table I shows demographic and cystourethrographic data of patients and participants in the USI and control groups. The two groups did not differ significantly in age, body mass index, menopause, resting bladder neck angle, resting bladder neck distance, or straining bladder neck distance. However, participants in the control group had a

<table>
<thead>
<tr>
<th>Value</th>
<th>Control (n = 12)</th>
<th>USI (n = 36)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>47.0 ± 8.5</td>
<td>52.1 ± 9.8</td>
<td>0.115</td>
</tr>
<tr>
<td>Paritya</td>
<td>1.3 ± 1.0</td>
<td>3.1 ± 1.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>21.6 ± 2.3</td>
<td>23.2 ± 2.5</td>
<td>0.058</td>
</tr>
<tr>
<td>Menopause (%)b</td>
<td>33.3</td>
<td>47.2</td>
<td>0.401</td>
</tr>
</tbody>
</table>

#### Anatomic assessment

<table>
<thead>
<tr>
<th>Resting bladder neck position</th>
<th>Angle (°)</th>
<th>Distance (mm)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>90.2 ± 12.7</td>
<td>24.6 ± 4.4</td>
<td>0.167</td>
</tr>
<tr>
<td>Straining bladder neck position</td>
<td>Angle (°)</td>
<td>Distance (mm)</td>
<td>p value</td>
</tr>
<tr>
<td>Angle</td>
<td>108.8 ± 19.3</td>
<td>20.6 ± 6.0</td>
<td>0.001</td>
</tr>
<tr>
<td>Rotational angle of bladder neck (°)</td>
<td>Uncorrected</td>
<td>Corrected</td>
<td>p value</td>
</tr>
<tr>
<td>Angle</td>
<td>18.4 ± 17.6</td>
<td>15.5 ± 12.1</td>
<td>0.004</td>
</tr>
<tr>
<td>Bladder neck movement (mm)</td>
<td>Uncorrected</td>
<td>Corrected</td>
<td>p value</td>
</tr>
<tr>
<td>Angle</td>
<td>8.9 ± 5.8</td>
<td>7.7 ± 4.9</td>
<td>0.002</td>
</tr>
<tr>
<td>Funneling (%)d</td>
<td>0</td>
<td>50</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Values are mean ± SD; statistical analysis with Student’s t test.

aStatistical analysis with Mann–Whitney test.
bStatistical analysis with chi-square test.
cRotational angle of bladder neck (bladder neck angle during strain–bladder neck angle at rest).
dStatistical analysis with Fisher’s exact test.
significantly lower parity and lower prevalence of funneling of the bladder neck than patients in the USI group (p < 0.001 and p = 0.002, respectively). Straining bladder neck angle was bigger in the USI group than in the control group (p = 0.001). Rotational angle of bladder neck (uncorrected and corrected) was bigger in the USI group than in the control group (p = 0.004 and p = 0.001, respectively). Bladder neck movement (uncorrected and corrected) was higher in the USI group than in the control group (p = 0.024 and p = 0.001, respectively).

Women with a corrected rotational angle of bladder neck ≥ 30° were 4.7 times (95% confidence interval: 1.1–20.5) more at risk for being diagnosed with USI than women with a corrected rotational angle of bladder neck < 30° (p < 0.05). Women with a corrected bladder neck movement ≥ 10 mm were 7.0 times (95% confidence interval: 1.7–29.4) more at risk for being diagnosed with USI than women with a corrected bladder neck movement < 10 mm (p < 0.05).

After adjusting for the potential confounding factor (parity), the multivariate logistic regression model showed that the corrected bladder neck movement significantly affected the prevalence of USI in all subjects. That is, women with a corrected bladder neck movement ≥ 10 mm were 9.0 times (95% confidence interval: 1.3–62.9) more at risk of having USI than women with a corrected bladder neck movement < 10 mm (p < 0.05). If we used corrected bladder neck movement ≥ 10 mm as the cut-off point for diagnosis of USI, the sensitivity, specificity, PPV, NPV, and accuracy were 77.8%, 66.7%, 87.5%, 50%, and 75%, respectively.

**Discussion**

Perineal ultrasound scanning is a well-established way of obtaining images of the lower urinary tract, and being a dynamic investigation it can aid in the tracking of bladder neck motion (4,12,13). Although at present there is no general consensus on how bladder neck movement should influence treatment, we believe that efforts to improve quantification of this parameter are worthy of attention (8).

Several methods and parameters have been proposed for the quantitative analysis of the lower urinary tract on ultrasonography. In this study, we measured the motility of the bladder neck by computer-aided vector-based perineal ultrasound using two parameters, the bladder neck–symphysis distance and the rotational angle of the urethrovesical junction, which are appropriate to describe both direction and distance of bladder neck movement seen during real-time scanning (12,14).

Serial reports have indicated that the morphological features of USI are change in urethral angles, funneling of the bladder neck, and location of the urethrovesical junction being at the most dependent point of the lower urinary tract (12,15–18). Our study also supported those findings. Moreover, our results showed that corrected bladder neck movement significantly affected the prevalence of USI in the subjects after adjustment for parity. The lower urinary tract overlays the anterior vaginal wall in such a way that anatomic defects of the anterior vaginal wall may result in hypermobility of the bladder neck or funneling of the bladder neck. The defects suggest lax anterior zone structures (pubourethral ligament, hammock) (18).

Previous studies on anatomical evaluation of bladder neck in USI patients by different probes have yielded conflicting results (7,14,20). The possible reason for the discrepancies found in different studies was that those studies failed to take into account probe movement relative to the symphysis pubis. This computer-aided vector-based perineal ultrasound, which copes with probe movements relative to the symphysis pubis, can calculate corrected bladder neck movement after correcting probe-symphysis displacement. Finally, the present study shows that the increase in corrected bladder neck movement is associated with functional impairment of urethral closure. Computer-aided vector-based perineal ultrasound is valuable in assessing anatomic change of the bladder neck, but it is not a sensitive tool for predicting USI.

In conclusion, the results of our study suggest that the increase in corrected bladder neck movement is associated with functional impairment of urethral closure. Further studies of tension-free vaginal tape operation to correct USI might provide new information on the anatomic background underlying the anterior vaginal wall in women.

**References**


