4D Transperineal Ultrasound for the Diagnosis and Classification of Stress Urinary Incontinence in Postmenopausal Women

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ABSTRACT

Objective: To explore 4D transperineal ultrasound (TPUS) parameters distinguishing urethral hypermobility (UH) and intrinsic sphincter deficiency (ISD) in stress urinary incontinence (SUI).

Study Design: Observational study.

Place and Duration of the Study: The Second Affiliated Hospital of Soochow University, China, from January 2018 to January 2022.

Methodology: According to valsalva leak point pressure (VLPP), postmenopausal SUI women were divided into UH and ISD groups, and healthy women were set as control group. Medical data and ultrasound parameters were analysed for their diagnostic values on SUI.

Results: In women with SUI, body mass index, parity, urethral funnel formation rate, bladder neck descent (BND), retrovesical angle (RVA) under the maximum valsalva manoeuver (MVM), urethral rotation angle (URA) and levator hiatus area (LHA) were higher, but bladder neck internal angle (BIA), urethral length (UL) at rest and UL under MVM were smaller than those in control ($p<0.05$). In the UH group, BIA, BND, and UL under MVM were higher, but ICIQ-SF score and urethral funnel formation rate were smaller than those in the ISD group, and Cystocele Green's type differed significantly ($p<0.05$). Smaller BIA, shorter UL under MVM, and higher ICIQ-SF score were more likely to diagnose ISD, while Cystocele Green's type II were likely to diagnose UH ($p<0.05$). The area under receiver operator characteristic curve of the logistic regression model was 0.864 with 90.6% sensitivity and 71.9% specificity. VLPP was positively correlated with BIA and UL under MVM but negatively correlated with the ICIQ-SF score.

Conclusion: Parameters of 4D TPUS can differentiate UH and ISD in SUI.

Key Words: *Stress urinary incontinence, Transperineal ultrasound, Valsalva leak point pressure, Urethral hypermobility, Intrinsic sphincter deficiency*.

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INTRODUCTION

Stress urinary incontinence (SUI) is more common in postmenopausal women impacting their quality of life. The treatment for these women depends on the clinical types of SUI, which include urethral hypermobility (UH) and intrinsic sphincter deficiency (ISD).[1,2] Urodynamics (UDs) is currently used for UH and ISD classification, and valsalva leak point pressure (VLPP) is a reproducible urodynamic parameter.[3,4] With the development of imaging, ultrasound can obtain a good soft tissue contrast comparable to magnetic resonance imaging (MRI), and is used to measure and visualise the changes of the bladder neck and urethra following the valsalva manoeuver.

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In recent years, 4D transperineal ultrasound (TPUS), a kind of pelvic floor ultrasound, has been widely used in urogynaecology to assess pelvic floor dysfunction. Compared to MRI, TPUS is more cost-effective for anatomical evaluation. In SUI diagnosis, there is a good correlation between UDs and TPUS.[5] However, few literature report the role of TPUS in clinical types of SUI. Therefore, the aim of this study was to explore valuable parameters of 4D TPUS to distinguish UH and ISD in postmenopausal women with SUI.

METHODOLOGY

The study was approved by the ethics committee and review board of the Hospital and conducted ethically in accordance with World Medical Association Declaration of Helsinki. A total of 96 postmenopausal women with SUI in the Urology Department, The Second Affiliated Hospital of Soochow University, Suzhou, China, from January 2018 to January 2022, were enrolled as SUI group. The inclusion criteria were SUI confirmed by ultrasound examination and interview, and postmenopausal age of 45-65 years. Thirty healthy postmenopausal women without SUI or pelvic organ prolapse were served as

control group (n=30). Participants with overactive bladder, urinary tract infections, pelvic tumour, history of pelvic surgery, neurological disorders, and ineligible valsalva manoeuver were excluded. All the participants completed a standard questionnaire on admission to obtain information about age, body mass index (BMI), parity, gynaecological surgery, and international consultation on incontinence questionnaire-short form (ICIQ-SF) score, which was a credible measure of severity and the impact of urinary incontinence on the quality of life in women.

UDs examination was performed to measure VLPP, according to the 2002 International Continence Society standardisation document.[6] Patients were divided into UH group (n=64) with VLPP >60 cm H_2O, and ISD group (n=32) with VLPP ≤60 cm H_2O.[7,8]

4D TPUS was performed using the voluson E10 ultrasound instrument and a 5-8MHz RIC5-9-D transvaginal volume probe (GE Medical Systems, Australia). TPUS parameters were analysed using 4D view16.0 analysis software (GE Medical Systems) with intelligent measurement function and collected according to AIUM/IUGA practice parameter.[9] Urethral length (UL) was a curved distance from the bladder neck to the external urethral opening. Bladder neck internal angle (BIA) was the angle of bilateral bladder inner wall of bladder neck at rest. Bladder neck descent (BND) was the difference between bladder neck position at rest and under the maximum valsalva manoeuver (MVM). Retrovesical angle (RVA) was the angle between the posterior bladder wall and proximal urethra. Urethral rotation angle (URA) was the rotation angle of proximal urethra under MVM. Levator hiatus area (LHA) was the area in axial plane measured by 4D mode under MVM. Urethral funnelling was distinct funnel-shaped opening at the proximal urethra under MVM.[10] Cystocele Green's type is the traditional radiological classification of cystoceles based on BND, RVA, and URA.[11] All ultrasound data were collected at rest and under MVM three times by doctors who had been trained and qualified for pelvic floor ultrasound, and the operation of parameter measurements usually cost less than 5 minutes.

Statistical analysis was performed using R Project software. Shapiro-Wilk test was employed to test data normality, normally distributed continuous data were expressed as mean ± standard deviation and analysed by t-test, however, non-normally distributed data were expressed as median and interquartile ranges, and compared by Mann-Whitney U test. The categorical data were expressed as percentages or counts, and analysed by chi-square test or Fisher's exact test. The variables with significant difference were included in logistics regression model. The receiver operating characteristic (ROC) curve was then performed to assess the prediction value of these variables to differentiate UH and ISD in postmenopausal SUI women using UDs diagnosis as reference standard. Correlation analysis was performed using Pearson correlation. The value of $p < 0.05$ was considered statistically significant.

RESULTS

There was no significant difference in age, RVA at rest between the SUI group and control group ($p > 0.05$). The BMI, parity number, urethral funnel formation rate, BND, RVA under MVM, URA and LHA in SUI group were higher than those in control group ($p < 0.05$). However, BIA, UL at rest and under MVM in the SUI group were significantly lower than those in the control group ($p < 0.05$, Table I).

Table I: Comparison of characteristics between the SUI group and control group.

Group	SUI (n=96)	Normal (n=30)	p-value
[1]Age (year)	55.0 (49.0-63.2)	55.5 (52.0-60.5)	0.722
[1]BMI (Kg/m^2)	24.0 (22.0-26.0)	23.0 (21.0-25.0)	0.044
[1]Parity number (n)	2.00 (1.00-2.00)	1.00 (1.00-2.00)	0.029
[1]ICIQ-SF	15.0 (14.0-18.0)	-	-
[1]VLPP (cmH_2O)	90.0 (55.8-120)	-	-
[2]Urethral funnel formation (n, %)	70 (72.9%)	3 (10.0%)	<0.001
[1]BIA (°)	124 (103-142)	138 (124-154)	0.010
[1]BND (mm)	26.0 (20.0-31.2)	18.0 (16.0-19.8)	<0.001
[1]RVA at rest (°)	123 (116-134)	121 (114-125)	0.157
[3]RVA under MVM (°)	154±18.5	131±20.4	<0.001
[3]URA (°)	46.5±15.3	32.9±15.1	<0.001
[3]UL at rest (mm)	34.3±3.10	35.9±3.50	0.032
[1]UL under MVM (mm)	30.5 (28.0-33.0)	34.0 (32.0-36.0)	<0.001
[1]LHA (cm^2)	20.5 (18.0-23.0)	17.0 (16.0-18.0)	<0.001

[1]Data are presented as mean and interquartile ranges and compared by Mann-Whitney U-test; [2]Data are presented as counts and percentages and compared by chi-square test or Fisher's exact test; [3]Data are presented as mean ± standard deviation and compared by t-test. SUI: Stress urinary incontinence, BMI: Body mass index, ICIQ-SF: International Consultation on Incontinence Questionnaire-Short Form, VLPP: Valsalva leak point pressure, BIA: Bladder neck internal angle, BND: Bladder neck descent, RVA: Retrovesical angle, MVM: Maximum Valsalva manoeuver, URA: Urethral rotation angle, UL: Urethral length, LHA: Levator hiatus area.

Table II: Comparison of characteristics between the UH group and ISD group.

Group	UH (n=64)	ISD (n=32)	p-value
[1]Age (year)	54.0 (49.0-62.2)	56.0 (50.8-65.0)	0.348
[2]BMI (Kg/m^2)	24.0±2.64	24.3±2.84	0.569
[1]Parity number (n)	2.00 (1.00-2.00)	1.50 (1.00-2.00)	0.204
[1]ICIQ-SF	15.0 (13.8-17.0)	17.0 (15.0-18.0)	<0.001
[3]Urethral funnel formation (n, %)	38 (59.4%)	32 (100%)	<0.001
[2]BIA (°)	128±23.1	113±23.2	0.005
[1]BND (mm)	27.5 (23.0-32.0)	24.5 (18.8-27.2)	0.021
[1]RVA at rest (°)	122 (114-128)	124 (119-141)	0.146
[2]RVA under MVM (°)	152±18.5	158±18.3	0.149
[2]URA (°)	48.2±13.3	43.2±18.5	0.181
[2]UL at rest (mm)	34.4±3.18	34.2±2.96	0.705
[1]UL under MVM (mm)	31.0 (30.0-33.0)	29.5 (25.0-31.0)	0.002
[1]LHA (cm^2)	21.0 (18.0-23.0)	20.0 (16.8-23.0)	0.370
[3]Cystocele Green's type:			0.030
0	10 (15.6%)	14 (43.8%)	
I	14 (21.9%)	5 (15.6%)	
II	35 (54.7%)	11 (34.4%)	
III	5 (7.81%)	2 (6.25%)	

[1]Data are presented as mean and interquartile ranges, and compared by Mann-Whitney U-test; [2]Data are presented as mean± standard deviation and compared by t-test; [3]Data are presented as counts and percentages, and compared by chi-square test or Fisher's exact test. UH: Urethral hypermobility, ISD: Intrinsic sphincter deficiency, BMI: Body mass index, ICIQ-SF: International Consultation on Incontinence Questionnaire-Short Form, BIA: Bladder neck internal angle, BND: Bladder neck descent, RVA: Retrovesical angle, MVM: Maximum valsalva manoeuver, URA: Urethral rotation angle, UL: Urethral length, LHA: Levator hiatus area.

As previously mentioned, 96 SUI women were divided into UH group (n=64) and ISD group (n=32). There was no significant difference in age, BMI, parity number, RVA at rest and under MVM, URA, UL at rest, and the LHA between the two groups ($p > 0.05$). The BIA, BND, and UL under MVM in UH group were significantly higher than those in ISD group ($p < 0.05$). However, the ICIQ-SF score, urethral funnel formation rate in UH group were significantly lower than those in ISD group ($p < 0.05$). Moreover, there was a significant difference in Cystocele Green's type between the two groups ($p < 0.05$, Table II).

Multivariate logistic regression analyses showed that smaller BIA (OR 0.97, 95% CI 0.95-0.99, p = 0.005), shorter UL under MVM (OR 0.83, 95% CI 0.74-0.94, p <0.001), and higher ICIQ-SF score (OR 1.45, 95% CI 1.16-1.81, p = 0.009) were more likely to diagnose ISD, while Cystocele Green's type II (OR 0.23, 95% CI 0.08-0.66, p = 0.002) were more likely to diagnose UH.

The optimal threshold for logistic regression model was 0.239, which had the best prediction probability. Meanwhile, the area under ROC curve of the logistic regression model was 0.864 (95% CI 0.791-0.937), with sensitivity of 90.6%, specificity of 71.9%, positive predictive value of 61.7%, and negative predictive value of 93.9% (Figure 1A). SUI Patients were ranked according to the predictive probability magnitude of model, and score classification plot was shown in Figure 1B. It was found that most patients could be diagnosed with ISD when their value in the model was more than 0.239.

Further correlation analysis found that VLPP was positively correlated with BIA (r=0.244, p=0.020) and UL under MVM (r=0.284, p=0.005), and negatively correlated with ICIQ-SF score (r=-0.395, p<0.001), and BND (r=-0.263, p=0.010).

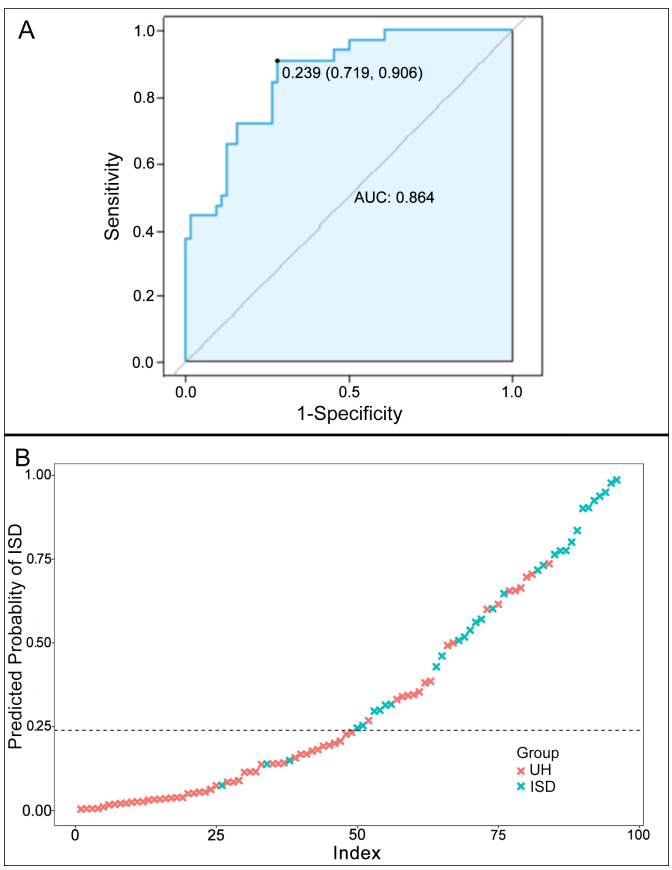

Figure 1: ROC curve and score classification for logistic regression model to differentiate UH from ISD in SUI patients. (A) ROC curve of logistic regression model; (B) Score classification of SUI patients based on the predicted probability magnitude of the model.
UH: Urethral hypermobility, ISD: Intrinsic sphincter deficiency, SUI: Stress urinary incontinence.

DISCUSSION

UDs is often used by urologists for preoperative evaluation of SUI types, but it is invasive and costly. TUPS is increasingly applied in the diagnostic evaluation of female pelvic floor dysfunction because of low cost and easy accessibility.[10] Moreover, 4D TPUS possesses the capacity of real-time dynamic imaging. This retrospective study indicated valuable ultrasound parameters to distinguish UH and ISD.

Urinary incontinence is highly correlated with age, and a greater proportion of postmenopausal women are clinically diagnosed with SUI.[12] The population selected for this study was postmenopausal women to exclude the confounding factor of age. In this study, urethral funnel formation rate, BND, RVA under MVM, URA, and LHA in SUI women were significantly higher compared to the control group, which is similar to previous study,[13] and consistent with the consensus of Chinese experts.[14] A new parameter BIA, which has not been reported in previous literature, was investigated in this study. The BIA of SUI women was smaller than the control, and in ISD women it was smaller than UH women, in addition, BIA was negatively correlated with VLPP. A meta-analysis has showed that the dilation of bladder neck at rest is a strong characteristic sign of SUI.[15] It could be supposed that decreased BIA is related to the relaxation of supporting structures around urethra in SUI patients, and BIA can be smaller in ISD patients, which may reflect the lack of support force from urethral closed sphincter. Follow-up studies are needed to clarify this mechanism. UL measured by perineal ultrasound is an appropriate parameter to differentiate women with urinary incontinence, and a significant urethral elongation is found after valsalva manoeuver in SUI women.[15] However, those results showed that women with SUI had a shorter UL both at rest and under MVM, and the latter was meaningful to distinguish ISD and UH. ISD women with low VLPP may be associated with inadequate mucosal sealing and an impaired intrinsic proximal component of the bladder neck,[16] so, the proximal urethra closure fails when abdominal pressure increases, leading to urethral funnel formation and effective urethral shortening.

Cystocele was also classified by radiological Green classification. There is a moderate to good agreement between ultrasound and pelvic organ prolapse quantitation examination in the differentiation of cystocele.[11] In this study, the highest proportion of patients with Cystocele Green's type II in UH group was 54.7% with 35 cases, consistent with the previous study.[17] However, it was found that 14 (43.8%) cases in ISD women were free of cystocele, but were presented as urethral funnels. The defect in the urethral sphincter can lead to the decrease of urethral closure pressure and opening of internal urethral orifice at lower VLPP, even earlier than the BND. Meanwhile, the patients' valsalva movement may be stopped by sonographer to prevent urine outflow, causing the disappearance of cystocele in ISD patients. ICIQ-SF is easy to complete with a low rate of missing data (1.6% on average), so is often chosen as an indicator to assess the severity of urinary incontinence.[18] Moreover, ICIQ-SF score is reported to be significantly correlated with the

urodynamic parameters.[19] Multivariate logistic regression analysis found that the ICIQ-SF score was valuable to differentiate UH from ISD in SUI patients, and negatively correlated with VLPP.

However, there are still some deficiencies. Although qualified doctors, intelligent measurement function of ultrasound instrument, and referenced AIUM/IUGA practice parameters are helpful to improve the objectivity of measurement, the limitations of operation cannot be fully eliminated, which need to be further improved by operational optimisation studies. It can increase the diagnostic accuracy of ISD by the combination of maximum urethral closure pressure.[20] But the maximum pressure has not been collected from SUI patients, due to the uncomprehensive information of patients in this retrospective study. Moreover, it can be better to include more control groups, such as young women, to explore the role of BIA, which will be a direction in follow-up research.

CONCLUSION

In conclusion, 4D TPUS and its related parameters are valuable to differentiate UH and ISD in SUI, which thus, helps to guide the clinical selection of the treatment for postmenopausal women with SUI.

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ETHICAL APPROVAL:
This study was approved by the Ethics Committee and Review Board of the Second Hospital of Soochow University (No. JD-HG-2022-29) and conducted ethically in accordance with World Medical Association Declaration of Helsinki.

PATIENTS' CONSENT:
Patients consent is not required for this retrospectively designed study.

COMPETING INTEREST:
The author declared no competing interest.

AUTHORS' CONTRIBUTION:
XG, CD, SZ: Participated in the design, execution, analysis, and writing of the paper, and approved the final version of the manuscript to be published.
XG, CD: Contributed equally to this study.

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