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ORIGINAL RESEARCH

# Utility of Shear Wave Elastography Combined with Transperineal Pelvic Floor Ultrasound in Evaluating Pelvic Floor Function After Hysterectomy

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**Purpose:** To study the utility of Shear Wave Elastic (SWE) combined with transperineal ultrasound in evaluating pelvic floor function after hysterectomy.

**Patients and Methods:** Sixty patients who underwent hysterectomy at our hospital between April 2018 and January 2023 were enrolled as the study group, and another 60 volunteers without hysterectomy were selected as the control group. General conditions, Ultrasonic parameters and related factors of pelvic floor dysfunction were collected and compared between the two groups.

**Results:** Ultrasonic diameters, including distance between bladder neck and pubic symphysis, the posterior angle of vesicourethra, the anterior-posterior diameter of levator hiatus and bladder neck mobility, were all different between patients with or without hysterectomy during Valsalva ($P < 0.05$). For SWE examination, elasticity of left and right levator ani muscle (LAM) at rest, the difference in elasticity of left and right levator ani muscle at rest and during Valsalva were statistically different between the two groups ($P<0.001$). The incidence of cystocele and uterine/vault prolapse in study group was significantly higher than control group ($P < 0.05$). The evaluation efficiency of transperineal ultrasound plus SWE was better than that of transperineal ultrasound only.

**Conclusion:** Pelvic floor dysfunction is more likely to occur in patients with hysterectomy, especially cystocele and uterine/vault prolapse. The decreased elasticity of levator ani muscle may be one of the factors.

**Keywords:** transperineal ultrasound, shear wave elastography, hysterectomy, pelvic floor function

## Introduction

Hysterectomy, the most commonly performed surgical procedure for various benign and malignant uterine disorders, is frequently linked to several postoperative complications, with pelvic floor dysfunction (PFD) being a particularly prevalent and enduring outcome.[1] Given the increasing number of women undergoing total hysterectomy for diverse medical indications, the growing incidence of pelvic floor dysfunction (PFD) has become a significant issue in female healthcare.

The role of hysterectomy as a risk factor for post-hysterectomy pelvic organ prolapse (POP) has been discussed for many years, but there is still no consensus.[2] The prevalence of PFD has been found to be higher than in the general population.[3] It is reported that hysterectomy is an independent risk factor for PFD,[4–6] with research indicating that approximately 47% of patients develop PFD following the procedure, highlighting the considerable effect of uterine removal on the structural and functional integrity of the pelvic support system.

However, it remains unknown how a hysterectomy affects the structure and function of the pelvic floor, and there are relatively few studies related to this. Accurately assessing pelvic floor function following total hysterectomy can offer



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valuable guidance to clinicians in selecting appropriate rehabilitation strategies. In recent years, transperineal ultrasound has been increasingly utilized in the assessment of pelvic floor function. Also, as an emerging ultrasound technique, shear wave elastography (SWE) enables the evaluation of tissue elasticity, providing insights into the supportive function of pelvic floor muscles.[7] In this study, transperineal ultrasound combined with shear wave elastography (SWE) was applied in postoperative pelvic floor evaluation of patients who underwent total hysterectomy, enabling multi-angle observation and diagnosis of pelvic floor structure, functional assessment of the pelvic floor, and provision of an anatomical basis for the clinical selection of appropriate interventions.

## Materials and Methods

Patients admitted from April 2018 to January 2023 were selected according to the following criteria:

Inclusion criteria: (1) Total hysterectomy for various reasons; (2) Those aged 18–80 years; (3) BMI≤28kg/m$^2$; (4) A history of at least one vaginal delivery; (5) Preoperative clinical pelvic floor evaluation was normal; (6) All patients and (or) Family members were informed of the purpose and method of the experiment, and signed informed consent.

Exclusion criteria: (1) BMI > 28kg/m$^2$; (2) Age > 80 years old; (3) Patients with severe cardiopulmonary and other important organ dysfunction; (4) Combined with other diseases that cause increased abdominal pressure, such as constipation, cough, etc.; (5) Patients with a history of chemoradiotherapy; (6) Patients with severe pelvic adhesion; (7) history of the other pelvic surgeries; (8) Inability to cooperate with Valsalva isokinetic authors; (9) The number of pregnancies ≥3; (10) A history of macrosomia or double (multiple) births; (11) Incomplete clinical data.

The patients were told to breathe calmly, the bladder lithotomy position was taken, and the bladder was emptied (bladder residual urine volume<50mL). Transperineal ultrasound was performed firstly by using a Voluson E8/E10 Expert system (GE Healthcare Ultrasound, Milwaukee, WI, USA) with a RAB6-D and RIC5-9 transducer under supervision of a total of 3 senior sonographer. The operators blinded against all clinical and ultrasound data. Imaging was performed in dorsal lithotomy position with the hips flexed and slightly abducted or in the standing position. Automatic image acquisition took about 3–5 seconds, and the main transducer axis was oriented in the mid-sagittal plane. The acquisition angle was set at the transducer maximum of 70° Volumes were acquired at rest and during Valsalva, after the efficacy of both maneuvers had been ascertained by 2D imaging in the mid-sagittal plane.[5] The horizontal line at the posterior and lower margin of pubic symphysis was set as the reference line, and the distance between bladder neck and pubic symphysis was recorded, and the distance between external cervical orifice and pubic symphysis was recorded, and the distance between anorectal junction and pubic symphysis was recorded, and the Angle between the proximal end of urethra and the midline of human body was recorded. Urethral bevel (Angle between the back wall of the bladder and the middle line of the human body), anterior and posterior diameter of the anal levator hiatus (distance between the medial margin of the pubic symphysis and the medial margin of the anal levator), bladder neck movement (difference between the bladder neck-pubic symphysis distance between resting and Valsalva states), and urethral rotation (difference between urethral bevel between resting and Valsalva states).

Ultrasound parameters such as bladder neck to pubic symphysis distance, external cervical orifice to pubic symphysis distance, anorectal junction to pubic symphysis distance, vesicourethral posterior Angle, urethral bevel, anterior-anterior-anterior-posterior diameter of anal levator hiatus, left and right elasticity of puborectal muscle were observed in the resting state, Valsalva state and anal retract state were recorded.

The SWE imaging mode was initiated once the levator ani muscle (LAM) was clearly visualized at rest, during contraction, and during maximal Valsalva maneuver. The acquired SWE image was then monitored for 5 seconds to ensure stability and complete color filling within the region of interest (ROI). Only images demonstrating high stability and quality—indicated by a motion-stability (M-STB) index of 4 or 5 green stars and a validity rate exceeding 90%—were retained for analysis. Next, three circular ROIs, each with a diameter of 5 mm, were symmetrically placed at the pubic ramus, the muscle belly, and the inferior portion of the pelvic floor muscles. Young's modulus values (in kPa) were automatically recorded for each ROI. All measurements were performed in triplicate, and the mean values were calculated to improve measurement accuracy.

To assess intra-observer and inter-observer repeatability, 10 women who underwent total hysterectomy were randomly selected and independently evaluated by three different operators. None of the operators were aware of each other's measurement results. Additionally, each operator measured the patients twice within a week to test for intra-observer repeatability.

General information of patients (age, gestational time, BMI) and related clinical diagnosis and treatment data (other examination indicators, clinical diagnosis and treatment results, and specialist examination results) were obtained. Clinical evaluation and diagnosis of anterior and posterior vaginal prolapse was performed by gynecologists who were blinded to the patient data.

Physical examinations of diagnosis on Pelvic organ prolapse are as follows: 1. Positioning: Lithotomy position, with the patient asked to perform a Valsalva maneuver or cough to accentuate prolapse. 2. Manual Palpation: Identify anterior vaginal wall bulge. A speculum may be used to isolate the anterior wall. 3. Staging: Use the Pelvic Organ Prolapse Quantification (POP-Q) system (Stage 0–IV) to measure descent relative to the hymen.

Sample size was calculated according to the formula as follows:

$$n = \frac{2[Z_{a/2}\sqrt{2pq} + Z_{\beta}\sqrt{p0q0 + p1q1}]^2}{(p0 - p1)^2}$$

According to the literatures,[1–3] the Incidence rate of the exposed group was 0.47, Non-exposed group was 0.13, we estimated α=0.05, β=0.1, power (test power) was 1-β=90%, then the sample size was at least 37. In consideration of 10% of lost to follow-up, the sample size would be 42.

SPSS21.0 software was used for statistical analysis. When the measurement data were in line with normal distribution, they were all expressed as mean ± standard deviation, and the two independent samples *T*-test was used for pairwise comparison. Multivariate analysis was used to eliminate confounding factors in the study. Kruskal–Wallis test was used in the event of abnormal distributions. α=0.05 was considered statistically significant.

For the studies using all the clinical data were approved by Medical Ethics Committee of Chongqing Health Center for Women and Children (Registration Number: (2023–011). All patients involved were approved and signed a written agreement. All patients related in this article were written informed consent to publish their case (including publication of images)

## Results

60 patients who meet the criteria were collected in study group; the other 60 patients admitted without total hysterectomy during the same period were selected as the control group. Surgical causes in the study group included multiple or large fibroids (n=43), severe adenomyopathy (n=9), endometrial polyps (n=2), dysfunctional uterine bleeding (n=4), and other causes (n=2). The rest of the general information was presented in Table 1

Table 2 showed Comparison of all ultrasonic diameters between study group and control group. The distance between bladder neck and pubic symphysis in Valsalva, the posterior angle of vesicourethra in rest and Valsalva, the anterior-posterior diameter of levator hiatus in Valsalva and bladder neck mobility were all different between two groups ($P < 0.05$). The incidence of prolapse of anterior and apical vaginal wall in study group was significant different compared to control group ($P < 0.05$). For SWE result, left and right sphincteric elasticity at rest, difference in sphincteric elasticity at rest and during contraction were statistically different (see Table 3).

**Table 1** Comparison of Baseline Data Between the Two Groups

| Baseline Data | Control Group (n=60) | Total Hysterectomy Group (n=60) | P value |
|---|---|---|---|
| **Age (years)** | 53.02±5.84 | 52.57±5.91 | 0.675 |
| **BMI (kg/m$^2$)** | 23.14±1.30 | 22.97±1.79 | 0.844 |
| **Gravidity** | 2.13±0.72 | 2.07±0.76 | 0.137 |
| **Parity** | 1.35±0.48 | 1.26±0.44 | 0.412 |

**Table 2** Comparison of Ultrasound Parameters Between the Two Groups

| Ultrasound Parameters | Control Group (n=60) | Total Hysterectomy Group (n=60) | $t/\chi^2$ | *P* |
|---|---|---|---|---|
| **Bladder neck-pubic symphysis distance (mm)** | | | | |
| At rest | 27.44±4.05 | 26.46±3.54 | 1.337 | 0.281 |
| During Valsalva | 18.26±5.11 | 12.97±8.42 | 3.036 | < 0.001 |
| **Anorectal articulation-pubic symphysis distance (mm)** | | | | |
| At rest | 18.56±2.04 | 17.70±3.61 | 1.136 | 0.160 |
| During Valsalva | 13.55±1.88 | 11.13±4.91 | 3.052 | 0.003 |
| **Posterior vesicourethral Angle (°)** | | | | |
| At rest | 113.04±6.95 | 126.84±9.35 | 6.028 | < 0.001 |
| During Valsalva | 135.23±9.62 | 142.37±11.47 | 3.463 | 0.001 |
| **Urethral Angle (°)** | | | | |
| At rest | 12.79±3.99 | 14.53±3.10 | 1.075 | 0.165 |
| During Valsalva | 9.96±5.88 | 15.79±6.34 | 1.002 | 0.130 |
| **Anterior and posterior diameter of hiatus of levator anal muscle (mm)** | | | | |
| At rest | 47.59±2.55 | 50.20±3.35 | 4.331 | < 0.001 |
| During Valsalva | 54.84±2.39 | 56.54±3.60 | 3.740 | 0.003 |
| Contraction | 41.36±2.59 | 44.93±3.01 | 6.533 | < 0.001 |
| **Bladder neck mobility (mm)** | 9.18±3.62 | 13.49±6.90 | 3.586 | < 0.001 |
| **Urethral mobility (°)** | 23.07±4.70 | 27.25±8.01 | 3.645 | 0.001 |
| **Anterior vaginal wall prolapses (Positive rate)** | 4 (5.00%) | 15 (25.00%) | / | 0.001 |
| **Vaginal vault prolapses (positive rate)** | 0 | 12 (20.00%) | | |
| **Posterior vaginal wall prolapses (positive rate)** | 1 (1.67%) | 2 (3.33%) | | |

**Table 3** Comparison of Elastic Modulus Parameters Between the Two Groups

| | Control Group (n=60) | Total Hysterectomy Group (n=60) | $t/\chi^2$ | *P* |
|---|---|---|---|---|
| **Left side elasticity of puborectal muscle (kPa)** | | | | |
| **At rest** | 27.56±3.91 | 33.82±3.25 | 8.991 | < 0.001 |
| **Contraction** | 58.24±1.40 | 57.78±3.93 | 0.919 | 0.463 |
| **Difference** | 30.68±4.36 | 23.96±3.50 | 9.406 | < 0.001 |
| **Right side elasticity of puborectal muscle (kPa)** | | | | |
| **At rest** | 27.59±4.02 | 33.67±3.43 | 5.683 | < 0.001 |
| **Contraction** | 57.87±1.44 | 57.62±3.83 | 0.905 | 0.216 |
| **Difference** | 30.28±4.27 | 23.94±3.59 | 8.654 | < 0.001 |

The efficacy of SWE combined with transperineal pelvic floor ultrasonography was evaluated. ROC curve was developed to evaluate the value of transperineal pelvic floor ultrasound combined with shear wave elastic imaging. The evaluation efficiency of transperineal pelvic floor ultrasound combined with shear wave elastic imaging was superior to that of transperineal pelvic floor ultrasound, as shown in Table 4 and Figure 1.

**Table 4** Efficacy of Transperineal Pelvic Floor Ultrasound Plus Shear Wave Elastography in PFD Evaluation

| Diagnostic Methods | AUC | SE | *p* | 95% CI | Sensitivity | Specificity | Youden Index |
|---|---|---|---|---|---|---|---|
| Transperineal pelvic floor ultrasound | 0.771 | 0.052 | 0.000 | 0.671–0.875 | 0.583 | 0.958 | 0.543 |
| Transperineal pelvic floor ultrasound + shear wave elastography | 0.792 | 0.048 | 0.000 | 0.692–0.889 | 0.636 | 0.949 | 0.583 |

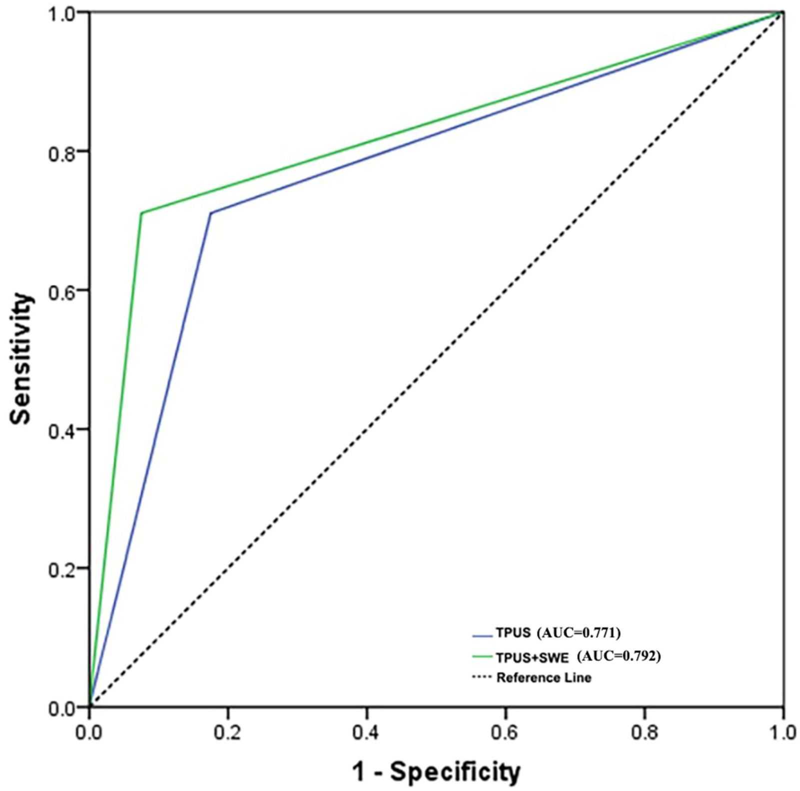


**Figure 1** ROC curve of TPUS and TUPS+SWE.
**Abbreviations**: TPUS, transperineal ultrasound; SWE, shear wave elasticity.

## Discussion

Hysterectomy is one of the most common surgical interventions for treating benign gynecological diseases. It is reported that nearly 500,000 hysterectomies are performed annually in the United States, making it one of the most frequently performed surgeries in women.[8] However, as an important organ in the pelvic cavity, the removal of the uterus can alter the structure and function of the pelvic floor. At the time of total hysterectomy, the most critical component of apical utero-vaginal support is compromised.[9] According to the "three-layer" theory of pelvic floor support based on the hammock theory, unless specific procedures are performed to reattach the vaginal cuff to the uterosacral ligament complex, level I support is lost in non-prolapse cases and not re-established in prolapse cases, potentially predisposing women to future vaginal vault prolapse.[10,11] Additionally, according to the holistic theory, hysterectomy disrupts the integrity of the pelvic floor, causing a void in the middle of the pelvic cavity and increasing the possibility of pelvic organ prolapse.[12] The surgery also damages the sympathetic or parasympathetic nerves distributed in the pelvic floor fascia and ligaments to varying degrees, thereby impairing the functions of the bladder, intestines, and vagina, which are innervated by these nerves. Therefore, for patients who need hysterectomy due to benign gynecological diseases, early diagnosis and prevention of possible postoperative pelvic floor prolapse symptoms are extremely beneficial for improving the post-operative quality of life of hysterectomy patients.

Transperineal ultrasound has become a widely adopted tool in the evaluation and diagnosis of pelvic floor dysfunction. In comparison to radiographic imaging and magnetic resonance imaging (MRI), ultrasound offers several benefits, including lower cost, real-time visualization, and dynamic assessment capabilities. With advancements in post-processing technologies such as multiplanar reconstruction, ultrasound-based evaluation of the pelvic floor muscles now approaches the diagnostic accuracy of MRI. Research indicates that transperineal ultrasound enables effective assessment of pelvic organ prolapse through continuous monitoring of organ position and movement.[13] In this study, transperineal pelvic floor ultrasound was employed to examine the pelvic anatomy of women who had undergone hysterectomy. When compared with healthy controls, the hysterectomy group exhibited significantly greater displacement of pelvic organs and an increased levator ani hiatus dimension during the Valsalva maneuver. These findings align with prior studies, reinforcing the association between an enlarged levator ani hiatus and pelvic organ prolapse.[14] Additionally, the hysterectomy group showed markedly higher mobility of the bladder neck, urethra, and the posterior urethrovesical angle both at rest and during Valsalva ($P < 0.05$), indicating altered spatial relationships among pelvic structures post-surgery and a heightened risk for stress urinary incontinence.[15] Long-term follow-up data revealed a higher prevalence of pelvic floor disorders in the hysterectomy group compared to the non-hysterectomy control group, which is consistent with existing literature.[16] Furthermore, patients who had undergone hysterectomy were more likely to develop anterior vaginal wall and vaginal vault prolapse. Beyond general pelvic floor weakness, this may be attributed to the anatomical shift following uterine removal—particularly affecting the anterior compartment—leading to more pronounced anterior pelvic organ descent relative to posterior structures.[17]

Given the surgical strategy of hysterectomy, the pelvic cavity becomes empty after the operation, the ligaments become loose, and the force on the pelvic floor muscles changes. These factors may be one of the causes of pelvic floor prolapse after hysterectomy. Levator ani trauma plays a key role in the pathophysiology of pelvic organ prolapse. Indeed, the associated urogenital hiatus ballooning leads to a fourfold higher risk of pelvic organ prolapse development in women after obstetric levator avulsion (LA).[18] LAM fibers shorten and atrophy due to denervation after hysterectomy, meanwhile the thickness of LAM also changes due to the degeneration of muscle cells.[19] Currently, shear wave elastography is widely used in the assessment of tissue stiffness in the breast, prostate, liver and muscle, with advantages such as high repeatability and objectivity. Shear wave elastography can quantify the elasticity and stiffness of muscle tissue, thereby evaluating muscle contraction function. This method has good intra- and inter-observer consistency. Moreover, previous studies have confirmed that it is a reliable method for quantitatively assessing the hardness of LAM.[20,21] In this study, shear wave elastography was used to quantitatively evaluate the contraction ability and hardness of the puborectalis muscle, thereby reflecting the pelvic floor muscle support function. The results showed that there was a statistically significant difference in the Young's modulus of the puborectalis muscle at rest between the resection group and the control group. The Young's modulus values of the bilateral levator ani muscles in the resection group were higher, indicating greater muscle hardness and lower elasticity, indirectly suggesting that the pelvic floor muscle function was weakened after total hysterectomy. These results were consistent with previous studies.[19,22] This might be related to the changes in the composition of the puborectalis muscle. After surgery, the vascular bed in the muscle tissue without the corresponding nerve was significantly reduced, the elastic muscle atrophied and degenerated, and the fibroblasts increased and deformed. All these factors could lead to increased muscle hardness[22] and decreased muscle elasticity.[23] However, there was no significant difference in the elastic modulus between the two groups during contraction, suggesting that the overall contraction ability of the muscle was still acceptable To better clarify the changes in pelvic floor muscle elasticity, this study introduced the difference in the elastic modulus of the left and right levator ani muscles at rest and during contraction between the two groups (resection group vs control group), aiming to further clarify the changes in muscle hardness. The results indicated that the changes in the elastic modulus of the patients in the resection group were small during contraction and at rest, confirming that although the changes in the elasticity of the levator ani muscle during contraction were not obvious in this study, the contraction efficiency was reduced (smaller difference), suggesting a possible decrease in the contraction force of the pelvic floor muscle. This study further analyzed the value of shear wave elastography-assisted transperineal pelvic floor ultrasound in evaluation, showing that the combined use of transperineal pelvic floor ultrasound and shear wave elastography has a better assessment effect than using transperineal pelvic floor ultrasound alone, and is worthy of clinical promotion.

However, this study mainly focused on the short-term follow-up results after hysterectomy and was a single-center study with a relatively small sample size, which may have certain biases in statistical results. In the next step, the sample size can be further expanded and the follow-up time can be prolonged to provide data support for fully explaining the assessment of pelvic organ prolapse after hysterectomy.

## Conclusion

In conclusion, total hysterectomy can damage the pelvic floor support function. Transperineal pelvic floor ultrasound can qualitatively and quantitatively evaluate female pelvic floor function, and shear wave elastography can quantify pelvic floor muscle function. The combination of the two can provide multi-dimensional assessment of pelvic floor function, providing comprehensive and reliable basis for the early prevention and intervention of pelvic floor dysfunction in clinical practice, which is conducive to actively strengthening pelvic floor function and improving the quality of life.

## Data Sharing Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

## Statement of Ethics

This study was performed in line with the principles of the Declaration of Helsinki. For the studies using all the clinical data were approved by Medical Ethics Committee of Chongqing Health Center for Women and Children (Registration Number: (2023)-011). All patients involved were approved and signed a written agreement. All patients related in this article were written informed consent to publish their case (including publication of images)

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The authors have no conflicts of interest to declare in this work.

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