

Evaluation of four-dimensional ultrasound for diagnosis of female pelvic floor dysfunction and prognosis

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Summary

Objective: To evaluate the value and prognosis of four-dimensional pelvic floor ultrasonography in female pelvic floor dysfunction (PFD). **Materials and Methods:** Ninety postpartum women diagnosed with PFD in this hospital from December, 2016 to February, 2018 were selected for inclusion in this study. These women were divided into vaginal delivery and selective cesarean section groups. In addition, 45 women without PFD were selected as the control group. Four-dimensional pelvic floor ultrasound was used to diagnose the difference between the pelvic floor and pelvic diaphragm before and after resting state, tension, and anal contraction. **Results:** BSD, bladder neck movement length, and urethral posterior horn in the vaginal delivery group were significantly higher than those measured in the cesarean section ($p < 0.05$). The transverse diameter, anterior and posterior diameter of the diaphragm, and the thickness of the anal muscle were significantly higher in the vaginal delivery group than measurements made in the control group. Within the selective cesarean section group, the transverse diameter, anterior and posterior diameter of the diaphragm, and the thickness of the anal muscle were significantly higher ($p < 0.05$) in patients conducting a Valsalva maneuver than in the control group. **Conclusion:** The use of pelvic floor ultrasonography for patients with pelvic functional disorders has a high diagnostic coincidence rate. It can clearly display the pelvic cavity of the parturient and provide critical insight into the patient's condition, thus providing a reliable basis for patient treatment.

Key words: Four-dimensional pelvic floor ultrasound; Female pelvic floor dysfunction; Evaluation value; Prognosis.

Introduction

The main cause of female pelvic floor dysfunction (PFD) is abnormal pelvic floor function or structure. Postpartum women are at high-risk for the development of PFD [1-5]. The main clinical symptoms of the disease are pelvic floor tissue rupture or relaxation, pelvic organ prolapse, and urinary incontinence, all of which may have a serious impact on women's lives [6-11]. Therefore, it is necessary to diagnose the patient's condition in a timely manner, and take appropriate actions conducive to the alleviation of the patient's disease.

Four-dimensional pelvic floor ultrasound is characterized by repeatability, is non-invasive, does not require radiation, and can clearly image the maternal pelvic cavity [12-16]. In this study, 90 postpartum women with PFD admitted to this hospital from December, 2016 to February, 2018 were selected as the study group and evaluated by four-dimensional ultrasound.

Materials and Methods

Ninety (90) postpartum women with PFD admitted to this hospital from December, 2016 to February, 2018 were selected as study group, and 45 healthy people were selected as control group (Table 1). All patients were provided informed consent to the study and the study was approved by the Hospital Ethics Committee (approval number: prylz2016-003). Patients with multiple vaginal or medical abortions, abnormal liver or kidney function, his-

tory of other systemic diseases, severe cardiovascular or cerebrovascular diseases, patients with severe urogenital diseases, recent use of overactive drugs, or patients with mental disorders were excluded from the study. In the vaginal delivery group, 45 patients aged from 20 to 38 years were chosen, with an average age of 27.5 ± 3.9 years. Within this group gestation ranged from 37 to 40 weeks, with an average gestational period of 38.2 ± 2.3 weeks. The 45 patients in the selective cesarean section group aged 21 to 37 years, with an average age of $28.8 \pm$ years; 38 to 41 weeks of gestation, with an average gestational period of 39.6 ± 3.4 weeks. In the 45 cases within the control group the age ranged from 21 to 39 years and the average age was 27.8 ± 3.1 years.

The V ultrasound diagnostic instrument (General Electric) was equipped with a three-dimensional volume probe with a frequency of 4-8 Hz. Patients were required to empty their bladder prior to ultrasound (i.e., residual urine volume below 50 mL), the legs separated to fully expose the pudenda, and patients were instructed to practice the Valsalva maneuver. The patient first selected the appropriate supine position, knee flexion, and as far as possible valgus position, selected the lithotomy position, and the position of the probe was then placed on one side of the labia or perineal surface. With two-dimensional imaging, the urethra was the most common coronal section displayed, while showing both sides of the bladder base. The urethra was placed at the midline of the image. The three-dimensional mode

Table 1. — Comparison of general data of three groups of patients ($\bar{x} \pm s$).

Group	Cases	Age (year)	BMI (kg/m ²)	Height (cm)	Neonatal weight (kg)
Vaginal delivery group	45	27.5 \pm 3.9	24.3 \pm 3.8	157.9 \pm 4.8	4.1 \pm 1.6
Elective cesarean section group	45	28.8 \pm 3.2	25.5 \pm 2.9	156.8 \pm 3.7	3.9 \pm 1.4
Control group	45	27.8 \pm 3.1	22.4 \pm 2.8	158.1 \pm 3.1	-
<i>t</i>	/	1.294	2.391	2.125	1.935
<i>p</i>	/	> 0.05	> 0.05	> 0.05	> 0.05

was then activated and the size of the sampling frame was adjusted to the left and right maximum.

The depth of the bladder was included in the ultrasound analysis. Four-dimensional image acquisition system was begun at rest to acquire volume data, freeze the image, and process it at a later time. After the four-dimensional basin ultrasound examination was conducted at rest, both the patient and the probe were kept in their original position, and the patient was told to perform maximal Valsalva motion and maximal anal contraction, thus obtaining four-dimensional pelvic floor ultrasound volume data including tension and anal contraction. The patient was scanned twice at each location, and the probe was always stable to avoid damage to the patient's perineum caused by excessive compression of the probe.

The distance between the bladder neck, the inferior margin of the pubic symphysis, and the rotation angle of the bladder and urethra were measured on the median sagittal plane in resting state, tension state, and anal contraction state. The length of bladder neck movement was calculated according to the difference of BSD. Differences in the diaphragm hiatuses transverse diameter, anterior and posterior diameters, and levator ani muscles thickness in the control group under resting and tension were observed and recorded. The anterior and posterior diameters were measured in the plane, and the maximum anterior and posterior diameters were recorded as the anterior and posterior diameters of the hiatus.

Data were analyzed using SPSS ver 18.0. Counts were compared by X^2 (%) examination and the measurements were analyzed by t ($\bar{x} \pm s$) examination. $p < 0.05$ indicated a statistically significant difference.

Results

There was no significant difference in age, body mass index (BMI), height, and neonatal weight among the three experimental groups ($p > 0.05$). With regards to ultrasonic parameters of the BSD, the moving length of cervix vesicae and the posterior urethrovesical angle of vaginal delivery group were significantly higher than those in the cesarean section group ($p < 0.05$) (Table 2).

During the resting states, the anteroposterior diameter, transverse diameter, and thickness of levator ani muscle of the PFD group were significantly higher than those measured in the control group. These parameters within the vaginal delivery group were higher than those of elective

cesarean section group ($p < 0.05$) (Table 3).

During the Valsalva maneuver, the anteroposterior diameter, the transverse diameter, and the thickness of levator ani muscles were significantly higher in the PFD group than those measured in the control group ($p < 0.05$) (Table 4).

Discussion

In recent years, the incidence of female pelvic floor functional diseases has been on the rise and this has had a great impact on the quality of life of female patients. Thus, it is very important to make timely diagnostic measures in female patients. Correct diagnosis is effected by many factors such as the closure and concealment of pelvic tissue. The application of four-dimensional pelvic floor ultrasound diagnosis can improve the accuracy of the results and visualize the complex structure of the pelvic floor. Four-dimensional pelvic floor ultrasound can show perforation of levator ani muscle and rectal muscle function. It can also show the visual field of pelvic structure more clearly. The results of this study showed that the BSD, bladder neck movement length and posterior urethral bladder angle in the transvaginal delivery group were significantly higher than those in the cesarean section group ($p < 0.05$). This diagnostic method has good reproducibility, is more conducive to the prevention and control of diseases, thus providing a reliable basis for further treatment of patients.

The incidence of female pelvic floor functional diseases is gradually increasing. Relevant data show that about 10% to 30% of women in the United States suffer from pelvic floor fascia or muscle damage every year. In China, because patients have less understanding of the disease, women with pelvic floor functional disease commonly postpone treatment and react only when the disease is serious and they must undergo surgery. Therefore, it is necessary to strengthen early diagnosis of pelvic lesions.

Several distinct causes of PFD are currently recognized. During pregnancy, owing to aggravation of the uterus and constant changes in hormone levels, the enlarged pregnant uterus pulls on pelvic ligaments, nerves, and fasciae. This has a chronic impact on the pelvic cavity and pregnancy-induced changes the position of pelvic organs. Related studies have reported that the incidence of PFD in the first trimester is higher than that in the second trimester, and in the third trimester is higher than that in the first trimester.

PFD is also caused by abnormal pelvic floor structure and impaired pelvic floor function. The most common

Table 2. — Comparison of various parameters of pelvic floor ultrasound diagnosis of two groups of patients ($\bar{x} \pm s$).

Group	Cases	BSD (cm)	Moving length of cervix vesicae (cm)	Posterior urethrovesical angle (°)
Vaginal delivery group	45	2.1 ± 0.9	4.2 ± 1.2	157.6 ± 17.8
Cesarean birth group	45	1.6 ± 0.8	3.6 ± 1.1	147.3 ± 16.6
<i>t</i>	/	11.294	12.391	15.125
<i>p</i>	/	< 0.05	< 0.05	< 0.05

Table 3. — Comparison of various parameters of pelvic diaphragm hiatuses of three groups of parturients in resting states ($\bar{x} \pm s$).

Group	Cases	Anteroposterior diameter (cm)	Transverse diameter (cm)	Thickness of levator ani muscle (cm)
Vaginal delivery group	45	5.8 ± 1.4	4.2 ± 0.5	15.2 ± 1.6
Elective cesarean section group	45	4.9 ± 1.3	3.8 ± 0.8	14.8 ± 0.9
Control group	45	4.3 ± 1.1	3.2 ± 0.7	14.2 ± 0.7
<i>t</i>	/	12.294	13.191	13.125
<i>p</i>	/	< 0.05	< 0.05	< 0.05

symptoms are stress urinary incontinence (SUI) and pelvic organ prolapse (POP). In the past, there was no effective examination method for pelvic functional disorders and the principal method of diagnosis was to rely on gynecological screening. This resulted in a high rate of misdiagnosis and as the degree of pelvic floor structural lesions could not be observed directly, the adoption of effective treatment measures were difficult.

With the continuing development of ultrasound technology, a series of pelvic floor structure inspection methods have gradually become applied in the clinic. Four-dimensional pelvic floor ultrasound is a common clinical diagnosis method for female urinary incontinence and POP. Relevant reports have shown that pelvic floor ultrasonography can display effective images of rectum, vagina, bladder, bladder neck, and urethra in either the resting state or during the Valsalva maneuver. Four-dimensional pelvic floor ultrasound can also effectively image dynamic changes in bladder neck activity, urethral rotation and organ prolapse. Therefore, the use of this ultrasound modality can effectively image the morphology and structure of the pelvic diaphragm hiatus, and can accurately measure the size of the hiatus to provide a reliable basis for the diagnosis and treatment of PFD diseases. In this study, we determined that patients floor structure in resting state, tension, and anal contraction movement were significantly higher in the PFD group compared to the control group.

There are many factors leading to PFD, including a woman's condition during pregnancy, fetal weight, fetal position, and delivery mode - all of which may affect the patient's pelvic floor anatomy and produce nerve injury. Additionally, different delivery methods will produce different levator ani muscle fissures. For example, vaginal delivery, compared with selective cesarean section, has a greater impact as during delivery the fetus travels through the levator ani muscle resulting in fissure of pelvic floor muscles due

to stretching and dilation.

The anterior pelvic cavity includes the urethra and bladder, the middle pelvic cavity includes the cervix, uterus and vagina, and the posterior pelvic cavity includes the anus and rectum. The primary parameter of urethra and bladder neck anatomy is the activity of bladder neck and the mobility of bladder neck is closely related to female SUI. Mobility is also closely related to the mode of delivery in patients with PFD. The activity of the bladder neck and the incidence of uterine prolapse in the selective cesarean section group were higher than that measured in the vaginal delivery group. The causes of this phenomenon are were mainly due to changes in the pelvic floor muscle anatomy during vaginal delivery.

During vaginal delivery, the pelvic floor may undergo mechanical or nerve damage and the main supporting tissue of the pelvic floor would become the pelvic floor. As pelvic floor injury continues to increase, pelvic fascia rupture and extension and support structures gradually weaken ultimately effecting the anatomical position of pelvic organs, resulting in abnormal function. In this study, four-dimensional basin ultrasound was used to measure the thickness of the levator ani muscle. The results showed that muscle thickness in women with vaginal delivery was significantly higher than normal during the Valsalva maneuver. The results showed that the anterior and posterior diameters of the pelvic diaphragm hiatus, and levator ani muscle thicknesses were significantly higher in the PFD group than in control group ($p < 0.05$). Therefore, the application of four-dimensional ultrasound to assess the anatomical structure of patients allows clinicians to make an earlier diagnosis and take timely and reliable preventive and treatment measures.

The diagnosis of PFD has always relied on gynaecological examination but, in the past, there is no effective and reliable examination method. With the continuous develop-

Table 4. — Comparison of various parameters of pelvic diaphragm hiatuses of three groups of parturients in Valsalva maneuver ($\bar{x} \pm s$).

Group	Cases	Anteroposterior diameter (cm)	Transverse diameter (cm)	Thickness of levator ani muscle (cm)
Vaginal delivery group	45	6.1 ± 1.2	4.9 ± 0.8	23.3 ± 4.9
Elective cesarean section group	45	4.7 ± 1.3	4.1 ± 0.9	20.8 ± 4.8
Control group	45	4.5 ± 0.9	3.9 ± 1.0	18.2 ± 3.4
<i>t</i>	/	11.394	12.391	13.125
<i>p</i>	/	< 0.05	< 0.05	< 0.05

ment of diagnostic technologies, ultrasound and MRI technology have been developed and more widely used. MRI has been recognized mainly because it produces clear imaging of tissues in the pelvic floor, and confirms many contraindications such as patients with metal contraceptives and pacemakers which cannot be examined. However, MRI examination is expensive and commonly patients cannot afford this procedure, therefore MRI cannot be generally used as a routine pelvic floor examination approach.

Ultrasound diagnosis is lower-cost, safe, and non-invasive. Dynamic observation has been favored by many patients and has been widely used in the field of gynaecology and obstetrics. Reports show that starting during the 1980s, specialists used ultrasound diagnostic techniques to examine patients through the abdomen, perineum, rectum, and vagina to diagnose disease. This study found that transperineal ultrasound does not cause distortion of pelvic floor structural imaging, and that imaging can be dynamically observed. The female pelvic floor is a three-dimensional structure and it is difficult to define the complete shape of the patient's pelvic floor and the relationship between the pelvic floor organs and the surrounding tissues by using two-dimensional ultrasound. Four-dimensional ultrasound is a relatively new imaging technology that can clearly display the structure of the pelvic floor and both transverse and sagittal planes. Further, the morphology of the face and coronal plane can be obtained and a complete sonogram of the diaphragmatic foramen is also achievable.

The vagina is a fibromuscular duct structure, has its own shape, is not fixed, and its cross-sectional imaging is crucial. The shape of the cross-sectional performance is determined by the surrounding connective tissue pulling the vaginal wall. Within the scope of the pelvic diaphragm hiatus, the composition of the connective tissue around the vagina is more complex: the rectovaginal septum is between the vagina and rectum, vaginal septum is between the vagina and urethra, and the paravaginal connective tissue refers to both sides of the vagina. The connective tissue of the anterior and posterior walls of the vagina is completely separated during the process of migration to the pelvic lateral wall. The connective tissue of the posterior wall of the vagina is eventually inserted into the pelvic fascia tendon arch and the levator ani tendon arch through a complex process. The connective tissue of the anterior wall of the

vagina moves directly to the pelvic lateral wall, inserting the pelvic fascia tendon arch and the levator ani. Therefore, on the transverse section, the vaginal wall will be affected by right anterior, right posterior, left anterior, and left posterior pulling forces forming a "butterfly" shape of the vaginal transverse section. If the vagina shows such a butterfly shape the integrity of the connective tissue around the vagina is largely compromised. Vaginal morphology will also change and this can assist in judging the integrity of the connective tissue around the vagina. Ultrasound observation and analysis of vaginal cross-sectional morphology during pregnancy indicates these abnormalities appear in late pregnancy, and the disappearance of the vaginal posterior horn on one or both sides of the vagina indicates abnormal connective tissue structure and reduced support around the vagina in late pregnancy. Patients with urinary incontinence are more likely to have morphological changes in the vaginal transverse section during the third trimester of pregnancy than those without urinary incontinence, suggesting that urethral continence is closely related to the supportive role of the paravaginal connective tissue. When the vaginal connective tissue is damaged, the ability of urethral continence becomes evident marked by leakage of urine. Therefore, understanding and clarifying the changes of pelvic floor supporting structures during pregnancy can provide a basis for imaging PFD-related factors, understanding the pathogenesis of PFD during pregnancy, and understanding the impact of these changes on the pelvic floor support system. Identifying these factors in a timely manner may prevent PFD.

Four-dimensional pelvic floor ultrasound cannot only display all the organs that require examination, but also image the bladder neck, urethra, vagina, and pelvic floor supporting structure from any angle. These features can also be collectively examined during a single session, hence, four-dimensional pelvic floor ultrasound is faster and more accurate.

Pregnancy is one of the primary risk factors for PFD and the relationship between pregnancy and the pelvic floor support system is one of the important considerations in the study of PFD. Based on understanding the changes of pelvic floor support structure during pregnancy, as well as the effects of vaginal delivery, further study of these effects can provide a more precise diagnosis and more favor-

able treatment methods. If the pelvic floor support structures are found to be damaged during pregnancy, it is necessary to strengthen the levator ani muscle to prevent pelvic floor function deterioration which can aggravate the patient's symptoms. During the examination, pelvic floor ultrasound is very important for the diagnosis of PFD, and can be used as an auxiliary means of surgical treatment for patients. It can be used to guide the positioning of patients during surgery and an important means to evaluate the effect of surgery. Because of the limitations in this study, we cannot comment on the value of pelvic floor ultrasound in patients with surgery, and further analysis of this topic is warranted.

In conclusion, four-dimensional pelvic floor ultrasonography has a high diagnostic coincidence rate in patients with PFD. This imaging technique can clearly display the pelvic cavity and determine the patient condition to provide a reliable basis for diagnosis and treatment.

Acknowledgments

This project was supported by the Pudong New Area Health and Family Planning Commission Subject Leader Course Project (Grant No. PWRd 2017-06), Youth project of Shanghai Pudong New Area Municipal Health Bureau (Grant No. PW2018B-04) and Pudong New Area Science and Technology Development (Grant No. PKJ2018-Y11).

Conflict of Interest

The authors declare no conflict of interest.

Submitted: August 04, 2019

Accepted: October 08, 2019

Published: December 15, 2020

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