CEOG Clinical and Experimental Obstetrics & Gynecology

Three-dimensional transperineal ultrasound: is there a correlation among age, weight, delivery mode, and a change in the pelvic floor architecture in Korean premenopausal women?

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Summary

Purpose: The purpose of this study was to evaluate the morphological characteristics and related factors of changes to the female pelvic floor architecture during rest and the Valslva maneuver using three-dimensional (3D) transperineal ultrasonography (TPUS) in parous women. *Materials and Methods:* One hundred thirty-five premenopausal parous women (aged 29-50 years) were evaluated. The pelvic floor structures were measured during rest and during the Valsalva maneuver using 3D TPUS. *Results:* The delivery mode was an important affecting factor in determining the change of contractility of pelvic floor architecture. The factors of age and weight were associated with changes in the anus. *Conclusion:* The delivery mode might be a meaningful factor in the change of contractility of pelvic floor architecture. These measurements provide a baseline upon which further investigations in a larger cohort of subjects can be compared, to determine the range and change of the normal appearance of the specific pelvic structures.

Key words: Pelvic floor; Three-dimensional; Ultrasonography; Valsalva maneuver.

Introduction

The pelvic floor architecture is composed of complex structures, and changes in the muscular dimensions and arrangement vary dynamically. Pregnancy and childbirth have been shown to be major etiological factors for pelvic floor disorders, leading to connective tissue remodeling and a disruption of the normal pelvic floor function [1]. However, the effect of pregnancy and childbirth on pelvic floor anatomy has not been fully established. Active contraction plays a role in maintaining continence and it is important to study the change in pelvic floor architecture to evaluate these functions. The contractility of this area probably also plays an important role in maintaining continence and preventing prolapse. Alterations in pelvic floor muscle morphology and function have been associated with parity, age, weight, delivery mode, and other factors, but the relationship between the risk factors and pelvic floor change may be inconsistent. There have been few studies investigating changes in the contractility and distensibility of the levator hiatal dimensions during pelvic floor muscle contraction and the Valsalva maneuver.

Three-dimensional (3D) transperineal ultrasonography (TPUS), which is easily accessible, provides useful information about the morphological changes of the female pelvic floor. Using 4D ultrasonography with real-time imaging, the levator hiatus can be followed during maneuvers and provide both qualitative and quantitative information on muscle function [1, 2].

This study was designed to evaluate the female pelvic floor with high-resolution 3D-TPUS and to explore the potential covariates to the dimensions and change of female pelvic floor architecture including the impact of age, parity, weight, and mode of delivery in Korean parous women.

Materials and Methods

Subjects

This study is a prospective observational study on the association of pelvic floor changes between during rest and the Valsalva maneuver. One hundred thirty-five Korean female parous volunteers were evaluated by 3D TPUS between January 2009 and June 2011. Fifteen patients had to be excluded from analysis because of poor image quality. The volunteers underwent a semi-structured interview about their history, and continence status and the weight, height, parity, and delivery mode were recorded for each subject. The study was reviewed and approved by the Institutional Review Board of the Catholic Medical Center (HC08WZZZ0069), and written informed consent was obtained from all subjects prior to enrollment. Potential subjects were excluded if the period of delivery was within the past 12 months, if they had had any lower urinary tract or bowel symptoms within the past 12 months, if they had pelvic organ prolapse on pelvic examination, a past history of pelvic surgery, or previous use of pelvic floor muscle exercises, and an inability to perform a maximum Valsalva maneuver.

Three-dimensional -transperineal ultrasound examination

In total, 135 women underwent pelvic floor ultrasound imaging twice in the supine position and after voiding with a system with a 4-7.0 MHz transabdominal probe by one gynecologist in a tem-

Revised manuscript accepted for publication July 6, 2015

Clin. Exp. Obstet. Gynecol. - ISSN: 0390-6663
XLIII, n. 6, 2016
doi: 10.12891/ceog3182.2016

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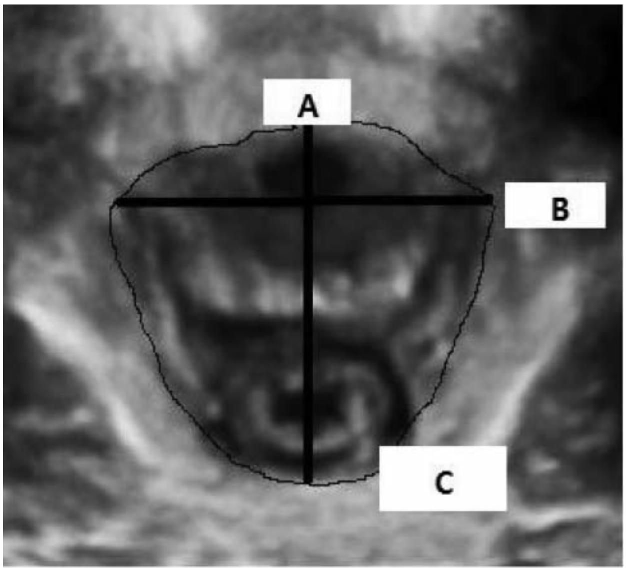

Figure 1. — Some of the commonly used measurements for assessment of the hiatus: (A) anteroposterior hiatal area; (B) transverse diameter of levator hiatus; (C) area of levator hiatus.

perature-controlled room (25°C). The probe was covered with a sterile latex-free condom and placed on the perineum in the sagittal plane. Volume acquisition was performed at rest and during the Valsalva maneuver, and each pubovisceral muscle contraction took approximately four seconds to perform and was recorded. Measurements were performed as described by Dietz *et al.* [3], in the axial plane at the level of 'minimal hiatal dimensions'. The plane of minimal hiatal dimensions was identified in the middle-sagittal plane as the minimal distance between the posterior aspect of the symphysis pubis and the anterior border of the pubovisceral muscle. The following variables were measured in the rendered images in the plane of minimum hiatal dimension: (1) the anteroposterior (AP) and transverse diameters and the area of the vagina and the levator hiatus (LH) (Figure 1), and (2) the AP and transverse diameters and area of the anus. The contractility of pelvic floor architecture during rest and the Valsalva maneuver were compared between the normal spontaneous delivery (NSD) group and cesarean section (C-section) group. Ultrasound examination and off line analysis of the stored volumes were performed by the same physician.

Statistical analysis

Statistical analysis was performed using SPSS 12.0. Descriptive statistics for measured variables were calculated. A paired *t*-test, Student's *t*-test or Mann–Whitney *U*-test and Spearman correlation were used to compare differences in paired or unpaired continuous data as appropriate. A *p*-value of < 0.05 was considered significant.

Results

General data

The present study population included a consecutive series of 120 Korean parous premenopausal women during the period between January 2009 and June 2011. The mean age was 42.8 ± 5.2 years (range, 29-50) and mean BMI was 22.5 ± 1.7 (kg/m^2) (range 19.7-25.7). Parity history included 90 patients with NSD {mean number of full term deliveries per subject: two (range, 1-5); mean number of abortion: three (range, 0-5)}, and 30 patients with C-section deliveries {mean number of full term deliveries per patient: two (range, 1-3), mean number of abortions: two (range, 0-4); labor failure: six patients, other causes were fetal position, and maternal condition without labor: 24 patients}.

3D TPUS during rest and Valsalva maneuver

Table 1 shows the change of hiatal dimensions during rest and the Valsalva maneuver. Comparing the pelvic floor architecture between the NSD group (n=90) and C-section group (n=30), (1) vagina area (cm^2) was 5.33 ± 2.00 / 5.60 ± 1.14 (p = 0.704) at rest and 5.80 ± 1.94 / 5.67 ± 1.18 (p = 0.897) during the Valsalva maneuver; (2) levator hiatus area (cm^2) was 11.96 ± 2.27 / 13.35 ± 2.94 (p = 0.133) at rest and 12.35 ± 2.29 / 11.73 ± 2.73 (p = 0.209) during the Valsalva maneuver; (3) anus area (cm^2) was 2.69 ± 0.75 / 2.56 ± 0.79 (p = 0.662) at rest and 2.36 ± 0.83 / 2.06 ± 0.66 (p = 0.141) during the Valsalva maneuver. There were no significant differences in the pelvic floor architecture according to delivery mode during rest and the Valsalva maneuver. The authors studied the change of contractility of pelvic floor architecture between rest and the Valsalva maneuver in the NSD group and the C-section group (Table 1). In the NSD group, the AP and transverse diameters and area of vagina

Table 1. — *The differences of pelvic architectural parameters between normal spontaneous delivery and C-section group during rest and Valsalva maneuver.*

		Vagina			Levator hiatus			Anus		
		Rest	Valsalva maneuver	*p*-value	Rest	Valsalva maneuver	*p*-value	Rest	Valsalva maneuver	*p*-value
AP diameter (cm)	NSD	1.35±0.37	1.40±0.31	0.126	4.73±0.69	4.77±0.51	0.305	1.74±0.26	1.73±0.32	0.001
	C-sec	1.35±0.35	1.52±0.40	0.125	5.11±0.71	4.47±0.55	0.006	1.77±0.29	1.70±0.39	0.003
Transverse diameter (cm)	NSD	3.30±0.38	3.38±0.56	0.109	3.57±0.37	3.61±0.47	0.595	2.04±0.43	1.77±0.37	0.685
	C-sec	3.65±0.38	3.35±0.45	0.543	3.64±0.47	3.63±0.61	0.333	1.95±0.38	1.66±0.34	0.873
Area (cm^2)	NSD	5.33±2.00	5.80±1.94	0.267	11.96±2.27	12.35±2.29	0.658	2.69±0.75	2.36±0.83	0.001
	C-sec	5.60±1.14	5.67±1.18	0.820	13.35±2.94	11.73±2.73	0.097	2.56±0.79	2.06±0.66	0.041

Data are presented as the mean ± SD. NSD: normal spontaneous delivery. C-section: cesarean section.

Table 2. — *Correlations of pelvic floor architectures with age, height, and parity.*

		Age	Height	Weight	Parity
Vagina	AP diameter (cm)	0.121 (p = 0.203)	0.108 (p = 0.233)	0.007 (p = 0.772)	0.001 (p = 0.975)
	Transverse diameter (cm)	0.061 (p =0.374)	0.004 (p = 0.826)	0.064 (p = 0.362)	0.007 (p = 0.773)
	Area (cm^2)	0.266 (p =0.074)	0.099 (p = 0.294)	0.053 (p = 0.451)	0.124 (p = 0.238)
Levator hiatus	AP diameter (cm)	0.039 (p = 0.879)	0.023 (p = 0.558)	0.036 (p = 0.462)	0.047 (p = 0.402)
	Transverse diameter (cm)	0.099 (p = 0.702)	0.001 (p = 0.977)	0.020 (p = 0.588)	0.013 (p = 0.961)
	Area (cm^2)	0.002 (p = 0.882)	0.009 (p = 0.974)	0.008 (p = 0.747)	0.003 (p = 0.839)
Anus	AP diameter (cm)	0.170 (p = 0.016)*	0.036 (p = 0.282)	0.138 (p = 0.031)*	0.030 (p = 0.327)
	Transverse diameter (cm)	0.003 (p = 0.985)	0.136 (p = 0.440)	0.004 (p = 0.721)	0.015 (p = 0.488)
	Area (cm^2)	0.127 (p = 0.042)*	0.014 (p = 0.515)	0.180 (p = 0.015)*	0.059 (p = 0.174)

* Statistically significant difference ($p < 0.05$).

and levator hiatus were larger during the Valsalva maneuver than during rest without statistical significance. In the C-section group, the transverse diameter of the vagina and levator hiatus and the area of levator hiatus were larger during rest than during the Valsalva maneuver without statistical significance. The AP diameter of levator hiatus was larger during rest than during the Valsalva maneuver with statistical significance (p = 0.006). In the NSD group, the pelvic floor architecture tended to protrude more and was further distended during the Valsalva maneuver. Compared the NSD group, the pelvic floor architecture of the C-section group was more contracted during the Valsalva maneuver. Regarding the change in the anus the AP diameter and area of the anus were larger during rest than during the Valsalva maneuver and the anus was contracted more during the Valsalva maneuver ($p < 0.05$, Table 1). Age was positively correlated with anus AP diameter (r = 0.170, p = 0.016) and anus area (r = 0.127, p = 0.042). Also weight was correlated with anus AP diameter (r = 0.138, p = 0.031), and anus area (r = 0.180, p = 0.015) (Table 2). The parameters of pelvic floor architecture (vagina and levator hiatus) did not vary with age, height, weight, and/or parity.

Discussion

In this study, the authors utilized 3D TPUS to describe the effects of age, weight, parity, and delivery mode on levator hiatal dimensions, both in the anatomically measured values and on the contractility of hiatal dimensions during rest and the Valsalva maneuver. The female pelvic floor architecture could be affected various factors (age, parity, delivery, hormonal change, menopause, and physical activity), and these changes could affect the woman's life. Although ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) were used to evaluate the change in the pelvic floor architecture, there were many difficulties encountered in evaluating the dynamic changes of pelvic floor architecture. Simultaneous examinations (accurate physical examination and imaging study) during changes of pelvic floor architecture are important in understanding the change and pathophysiology of pelvic floor architecture. 3D TPUS has been important in providing a better understanding of the pelvic floor complex and superficial perineal structures and should make it possible to avoid unnecessary surgery and allow for conservative treatment [4-7].

Women who underwent vaginal deliveries had a higher urinary incontinence rate and rate of pelvic floor disorders than women who underwent cesarean deliveries [8, 9]. Levator ani muscle contraction is predominantly dependent upon pubovisceral and puborectalis components, which are at the greatest risk for stretch-related injury during labor [10]. Age, estrogen levels, genetic factors, and obesity may play a role in the pathophysiology of pelvic floor dysfunction [11, 12]. Pelvic floor reflexes can be altered by vaginal delivery [13]. There seems to be a reduction in the magnitude of reflex contraction after childbirth, and this reduction may be associated with the delivery mode [14]. Several studies have recently used US to determine the relation between the measurement of pelvic organ's descent, and the diameter and area measurements of the levator hiatus [3, 5]. Widening of the levator hiatus has been suggested as a cause of genital prolapse and measurements of the increasing levator hiatus area taken during the Valsalva maneuver may be either the cause or effect of pelvic organ descent [15-17]. Levator avulsions have been reported to occur in 13-40% of all women who delivered vaginally and have been associated with an increased hiatal dimension postpartum [18-20]. Shek *et al.* [21] reported that after cesarean delivery, there was a decrease in the mean hiatal area during the Valsalva maneuver, while in vaginal delivery without avulsion injury, the hiatal area was increased. Possible explanations for the traumatic pathogenesis in the pelvic tissue include alterations in the matrix of connective tissues and damage to the pelvic fascia, which may lead to a loss of contractility of the levator ani complex [1, 22]. This may arise as a result of damage to the muscle from distension, obstetric trauma, or neuropraxia of the pudendal nerve. Also, preexisting individual differences in the biomechanical properties of the pelvic floor and the connective tissue may result in differences in tissue rebuilding during pregnancy and delivery and have an impact on the development of pelvic floor disorders [1, 23]. In the present study, there were no differences in pelvic floor architecture according to delivery mode during rest and the Valsalva maneuver. Although the role of elective cesarean section in the prevention of pelvic floor disorders is currently controversial [8], vaginal delivery has been suggested as the main contributing factor to pelvic floor disorders. Pelvic floor change after delivery, aging, weight change, and multifactorial causes might be important contributing factors to pelvic floor architecture. Although there was no statistical significance, the measured parameters of pelvic floor architecture were larger during the Valsalva maneuver than at rest using the 3D TPUS in the NSD group. Vaginal childbirth can result in the enlargement of the levator hiatus, and there may be increased distensibility of the hiatus, which may represent another mechanism leading to the enlargement of the hiatus and pelvic organ prolapse [21]. When the present authors compared contractility in the NSD group with that of the C-section group, the transverse diameter of vagina and levator hiatus, the AP diameter of levator hiatus, and the area of levator hiatus were larger during rest than during the Valsalva maneuver. During the Valsalva maneuver, the contractility might be greater in C-section group than in the NSD group. The minimal hiatal area during the Valsalva maneuver decreased after cesarean delivery, but increased after vaginal delivery. Consequently, the delivery mode might be an important factor affecting the change of contractility in pelvic floor architecture. This may indicate that pregnancy itself causes permanent changes in the anatomy of the pelvic floor, leading to distensibility due to alterations in connective tissue properties.

The current ultrasound assessment of the anal sphincter is based on measurements during rest. However, active contraction plays a role in maintaining continence. In the present study, the parameters of anus were larger during rest than during the Valsalva maneuver in both groups.

In the present study, the factors of age, height, weight, and parity were not associated with changes of the vagina or levator hiatus. The AP diameter and area of the anus increased with increasing age and weight independently. There may be multiple causes, rather than only anatomical change, which could be more important to the change of pelvic floor architecture. If so, then a multiplanar study is needed to evaluate the dynamic change of pelvic floor architecture during various events, such as pelvic floor contraction. Although the limitations of the present study are its small sample size and the women's age (limited to 29-50 and included all parous woman), it is helpful to understand the factors affecting the change of the pelvic floor architecture in Korean women. The effects of parity and mode of delivery should be differentiated with long-term prospective studies which would provide the data necessary to quantify the excess risk of pelvic floor disorders that can be attributed to vaginal delivery.

In the future, the standard examination of pelvic floor architecture using 3D US, and larger prospective studies on the relation of the functional characteristics of change of pelvic floor architectures of women to age, weight, parity, and mode of delivery will be undertaken. This will help to treat women who have given birth and lost pelvic floor support, resulting in some degree of pelvic floor organ prolapse. In researching the association of change and contractility of the pelvic floor architecture, age and weight will be helpful in understanding pelvic organ prolapse and pelvic floor disorders.

Acknowledgements

This study was supported by The Korean Society of Ultrasound in Obstetrics and Gynecology Research Fund.

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