International Journal of Gynecology and Obstetrics xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Gynecology and Obstetrics

journal homepage: www.elsevier.com/locate/ijgo

www.figo.org

CLINICAL ARTICLE

Variability of the pubic arch architecture and its influence on the minimal levator hiatus area☆

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A R T I C L E I N F O

Article history:
Received 9 September 2015
Received in revised form 20 November 2015
Accepted 15 April 2016

Keywords:
Endovaginal ultrasonography
Levator ani muscle
Minimal levator hiatus
Pubic arch angle

A B S T R A C T

Objective: To investigate the association between the minimal levator hiatus (MLH) area at rest with its surrounding soft-tissue and bony structures in nulliparous asymptomatic women with a normal levator ani muscle. *Methods:* A subanalysis was undertaken of a prospective study of the appearance of the levator ani in asymptomatic nulliparous women conducted between September 2010 and September 2011. The subanalysis included women with a normal levator ani muscle. Three-dimensional ultrasonography volumes were used to obtain pelvic floor measurements. *Results:* The analysis included 56 women with mean age of 43.0 ± 13.4 years. The mean MLH area was 13.1 ± 1.8 cm^2 (range 9.0–17.3). The pubic arch angle had no influence on the MLH area (Pearson correlation coefficient $r = 0.13$). Height and pubic arch length were positively correlated with the MLH area ($r = 0.26$ [$P = 0.52$] and $r = 0.50$ [$P < 0.001$], respectively). *Conclusion:* The MLH size of nulliparous women varied widely and was positively correlated with the height and pubic arch length of the women. Therefore, caution is warranted when interpreting the MLH area as an indicator of a levator ani defect or a predictor of pelvic organ prolapse without taking a woman's pelvic bone characteristics into account.

1. Introduction

The dimensions of the levator ani muscle (LAM) play an important part in the process of vaginal delivery. The opening in the LAM group through which the urethra, vagina, and rectum pass is called the levator hiatus, and is bound by the LAM laterally and posteriorly, and by the pubic bone anteriorly. The levator hiatus stretches during vaginal birth to let the fetus pass through the birth canal. Stretching beyond its elastic limits can lead to permanent trauma to connective tissue, neurons, and muscles [1]. The narrowest area of the hiatus is named minimal levator hiatus (MLH). Prior studies involving cadaver dissections [2] have demonstrated that the medial border of the MLH is comprised of pubococcygeus fibers; lateral to these fibers is a variable number of puborectalis fibers.

According to a geometric model, muscle damage during the second stage of labor could be caused by overstretching: the parts of the muscle that are stretched the most are the ones that are injured [3]. The largest tissue strain is recorded for the pubovisceral (pubococcygeal and iliococcygeal) muscle, which is the shortest and most medial LAM, and has a stretch ratio of 3.26 [1].

The MLH has been used as a marker for levator trauma [4–6]. Pelvic magnetic resonance imaging [7,8], transperineal ultrasonography [5], and endovaginal ultrasonography [9] have been used to assess the morphology of the MLH and to measure its area. Studies in women with pelvic organ prolapse have confirmed that a larger MLH area at rest and a more distensible MLH area with Valsalva maneuver can be an indicator of a defective LAM [5,10] and that these features are associated with pelvic organ prolapse [1,5,11].

The mean MLH area in women with a normal LAM has been reported as 14.25 cm^2, compared with 18.42 cm^2 among those with a severe LAM deficiency [6]. The mean MLH area at rest in women without and with pelvic organ prolapse has been reported as 14.98 cm^2 and 17.49 cm^2, respectively [5]. However, the MLH area also ranges widely (between 9 cm^2 and 17.7 cm^2) in nulliparous women with a normal LAM [2]. With such great variability in normal and abnormal measurements between individuals, it is essential to clarify the factors that are responsible for this variation before the MLH area can be used as an indicator of LAM injury and subsequent pelvic organ prolapse. The aim of the present study was to investigate the relationship between the MLH area and its surrounding soft-tissue and bony structures in nulliparous asymptomatic women with a normal LAM.

☆ Presented at American Urogynecologic Society/International Urogynecological Association Scientific Meeting; July 22–26, 2014; Washington, DC, USA. OP 041.

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http://dx.doi.org/10.1016/j.ijgo.2015.11.029
0020-7292/

2. Materials and methods

The present study was a subanalysis of a prospective cross-sectional study evaluating whether the appearance of the LAM among asymptomatic nulliparous women varied by age, which was conducted at the University of Oklahoma Health Sciences Center from September 1, 2010, to September 30, 2011 [12]. Campus and community advertisements were used to recruit nulliparous volunteers. All volunteers underwent a complete physical examination including pelvic organ prolapse quantification (POP-Q). Women without pelvic organ prolapse (POP-Q stage 0–1) entered the study for three-dimensional ultrasonography. The study was approved by the University of Oklahoma Health Sciences Center Institutional Review Board. Each woman provided written informed consent before participation in the study.

Imaging was obtained at the time of the primary visit for study recruitment using the BK Medical Ultrafocus (Peabody, MA, USA) and a 2052/8838 12-MHz transducer. All ultrasonography examinations were performed in an office setting. Participants assumed the dorsal lithotomy position, with hips flexed and abducted. No preparation was necessary; participants were asked to have a comfortable volume of urine in the bladder. No rectal or vaginal contrast was used. To avoid excessive pressure on surrounding structures and potential distortion of the anatomy, the probe was inserted into the vagina in a neutral position with no pressure on vaginal walls. To allow further analysis, the three-dimensional ultrasonography volumes were digitally stored.

The three-dimensional ultrasonography volumes were subsequently used to evaluate the LAM. The LAM was classified as normal if the full length of the muscle (including its attachment to the pubic bone) and its full thickness could be visualized. Only women with a normal muscle were included in the present analysis.

All measurements of the LAM were obtained in the plane of the MLH. The MLH plane is an axial plane on which the anterior–posterior diameter is the shortest distance between the pubic symphysis and the levator plate. The midsagittal plane was used to identify this line (Fig. 1A). The axial plane was rotated posteriorly and was advanced cephalad parallel to the anterior–posterior line (Fig. 1B and C). The midsagittal plane was expanded to make the whole volume visible.

The pelvic floor measurements included the MLH area, the pubic arch angle, the levator ani angle, and the length of the pubic ramus from the pubic symphysis to the levator muscle attachment point on each side. The pubic arch angle was defined as the angle between the right and left inferior pubic rami at the pubic symphysis (Fig. 2). The levator ani angle was defined as the angle between the right and left LAM bundles posterior to the rectum. In addition, the free pubic arch length was determined; it was defined as the sum of the lengths of the free pubic rami on the left and right.

SAS version 9.2 (SAS Institute, Cary, NC, USA) was used for all statistical analyses. Summary statistics were created for categorical and continuous variables. Pearson correlation coefficients were calculated using the PROC CORR procedure in SAS to explore the relationship between the MLH area and continuous covariates. $P < 0.05$ was considered statistically significant.

3. Results

In total, 56 women were included in the present analysis. Another six women had undergone ultrasonography but were deemed to have an abnormal LAM. Most of the included women were white and were not menopausal (Table 1). The mean age, height, and body mass index of the participants are given in Table 1, and the mean MLH area and other pelvic floor measurements are given in Table 2.

Both the women's height and their free pubic arch length were positively correlated with the MLH area, although the correlation between height and MLH area was not statistically significant (Table 3). Height was correlated with the pubic arch length ($r = 0.23$), but the finding was not statistically significant ($P = 0.08$). The MLH area was not correlated with the pubic arch angle ($r = 0.14$; $P = 0.32$). There was no correlation between pelvic floor measurements and menopause, hormone replacement therapy, or history of hysterectomy (data not shown).

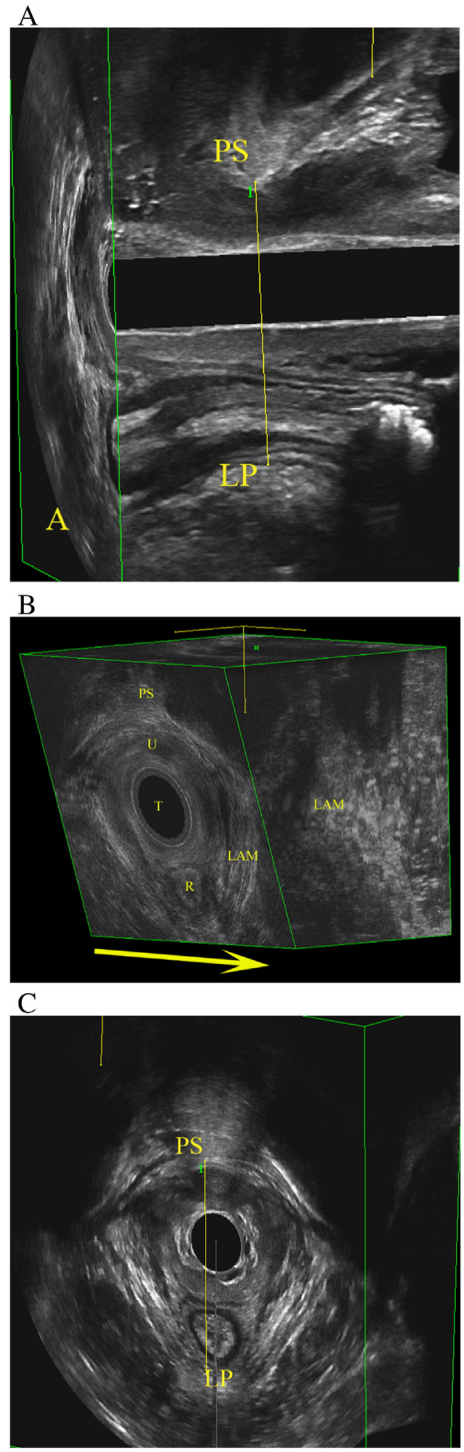

Fig. 1. Three-dimensional ultrasonography of the minimal levator hiatus area. (A) Midsagittal view used to determine the shortest distance between the pubic symphysis and the levator plate. (B) Manipulation of the volume in midsagittal view to have access to the axial view of the minimal levator hiatus. The arrow indicates the direction of manipulation. (C) Axial view of the shortest distance between the pubic symphysis and the levator plate. Abbreviations: PS, pubic symphysis; LP, levator plate; U, urethra; T, transducer; R, rectum; LAM, levator ani muscle.