Variation of the obturator foramen and pubic arch of the female bony pelvis

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OBJECTIVE: The purpose of this study was to determine dimensions of the obturator foramen and pubic arch of the female pelvis and to assess for variability.

STUDY DESIGN: Ninety-six female pelvises were selected from the Cleveland Natural History Museum. The obturator foramen area, pubic arch angle, pubic ramus, pubic symphysis, and anterior urogenital triangle area were measured. Linear regression was used to evaluate independent associations.

RESULTS: There was considerable variability of the bony architecture. The mean obturator foramen area was 12.2 ± 2.1 cm^2 (range, 7.38-18.22 cm^2). After controlling for height, the pubic ramus width, pubic symphysis length, and interobturator foramina distance were significantly greater in European American women compared with African American women. Obturator foramen area increased with increasing height ($P = .0008$) but was not associated with race.

CONCLUSION: There is considerable variability in the bony architecture of the obturator foramen and pubic arch of the female pelvis. Race and height may account for some of these variabilities.

Key words: bony pelvis, obturator foramen, pubic arch, sling

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Minimally invasive procedures that include the mid urethral sling have revolutionized the treatment of stress urinary incontinence. The transobturator approach to the midurethral sling was introduced in 2001,[1] and its popularity has increased. This procedure involves placing a synthetic mesh tape underneath the mid urethra and passing it bilaterally through the obturator foramina. Trocars are used to place this mesh through the obturator foramina and can be passed from the genitofemoral fold to the mid urethra (outside-in approach) or from the mid urethra to the genitofemoral fold (inside-out approach). Multiple studies have demonstrated its safety profile[2-4] and efficacy.[5,6]

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The most common complications include leg or thigh pain,[7-9] mesh erosion,[10-12] and infection.[13-15]

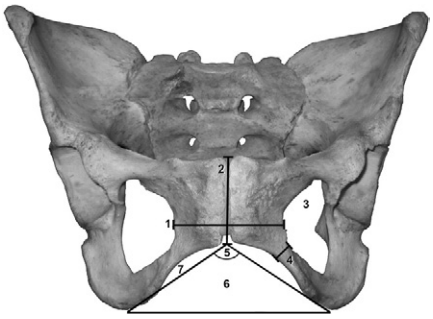
The success of the transobturator approach to the mid urethral sling has translated to several marketed procedural kits for prolapse treatment in which as many as 4 trocars are passed through the obturator foramina to facilitate the placement of synthetic mesh into the pelvis for vaginal support. Given the expanding use of the transobturator approach, several studies have given consideration to the surrounding anatomy,[16-19] but none has explored the bony pelvis. The objective of this study was to determine the dimensions of the obturator foramen and pubic arch of the female pelvis and assess for variability.

Materials and Methods

This study was approved by the Cleveland Museum of Natural History and was exempt from Institutional Review Board approval because it did not involve obtaining information about living individuals. Ninety-six disarticulated pelvises were selected from the Hamann-Todd collection at the Cleveland Museum of Natural History. This collection consists of >3100 human skeletons, with documentation of race, age, height, weight, and multiple other anthropometric measurements. Specimens that were < 18 years old at death and < 90 pounds at death and specimens whose height was more than or < 2 SDs from the mean were excluded. Damaged specimens were also excluded.

Pelvises were selected randomly from a list of available specimens and matched to the general height distribution of the entire female collection. Forty-seven African American and 49 European American pelvises were selected and reassembled with a technique that has been standardized for this collection. Specifically, the sacrum was articulated with the innominate bones at the sacroiliac joint, and the innominate bones were articulated at the pubic symphysis. Once articulated, the 3 bones were held in place by elastic bands. Given the absence of soft tissue, the pubic symphysis was separated by a 5-mm insert, which is a distance that has been demonstrated on magnetic resonance imaging studies.[20] Architectural bony landmarks were determined as per Standards for Data Collection From Human Skeletal Remains: Proceedings of a Seminar at the Field Museum of Natural History.[21] Three dimensional points of all pertinent bony landmarks were obtained with the MicroScribe G2 3D Digitizer (Immersion

FIGURE 1
Bony pelvis with lines denoting measured architectural landmarks



(1) Inter-obturator foramina distance; (2) Pubic symphysis; (3) Obturator foramen area; (4) Pubic ramus width; (5) Pubic arch angle; (6) Anterior urogenital triangle area; (7) Pubic ramus length.

Ridgeway. Variation of the obturator foramen and pubic arch of the female bony pelvis. Am J Obstet Gynecol 2008.

Corporation, San Jose, CA) by 1 author (B.R.; Figure 1). The MicroScribe G2 3D Digitizer uses digital optical sensors and has accuracy up to 0.02 cm. The equipment and measuring techniques were evaluated for reliability before recording measurements.

Using the 3-dimensional points, the distances between the inferior pubic symphysis and each bilateral distal ischiopubic rami and the distances between the distal ischiopubic rami were calculated mathematically. The urogenital triangle area was also calculated by standard geometric equations. The pubic angle was measured with a protractor; the obturator foramina were traced and scanned digitally, and the areas were calculated with Image-J (US National Institutes of Health, Bethesda, MD). Because there were no significant differences between right and left sides, the measurements were averaged. Pelvic dimensions were described as mean ± SD and range. Height measurements were performed postmortem in a standardized fashion. Race was assigned at the time of autopsy.

JMP software (version 6.0; SAS Institute Inc, Cary, NC) was used for statistical calculations. Continuous and categoric data were analyzed with the Student *t* test and chi-square test, as appropriate. Given the height differences between races, multivariate analysis was performed with linear regression to evaluate independent associations of height and race to bony architecture. Coefficient of variation was calculated by dividing the SD by the mean and is useful for comparing the degree of variation within a data set.

Results

The results of the bony pelvis measurements are noted in the Table. The mean obturator foramen area was 12.2 ± 2.1 cm^2 (range, 7.4-18.2 cm^2), with a coefficient of variation of 17% (Figure 2). The mean pubic arch angle was 75 ± 12.3 degrees (range, 44-110 degrees), with a coefficient of variation of 16.4%. Obturator foramen area, pubic arch angle, urogenital triangle area, and interobturator foramina distance were all positively correlated with height (all $P < .03$).

The average height at death was greater for African American specimens compared with European American specimens (165.5 cm vs 160.2 cm; $P = .0003$), which is consistent with the Hamann-Todd collection. After controlling for height, we found that the pubic ramus width, pubic symphysis length, and interobturator foramina distance were significantly greater in European American women ($P < .04$ for each), compared with African American women.

FIGURE 2
Innominate bones (pubic symphysis to the left) of two specimens

This is an example of the variation encountered in the obturator foramen area. The top specimen has an area of 16.6 cm^2 and the bottom specimen has an area of 7.4 cm^2.

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TABLE
Variations in bony architecture of the obturator foramen and pubic arch

Measurement	Annotation in Figure 1	Mean	SD	Range	Coefficient of variation (%)[a]
Interobturator foramina distance (cm)	1	5.7	0.5	4.3-6.9	8.8
Pubic symphysis length (cm)	2	3.2	0.4	2.1-4.3	12.5
Obturator foramen area (cm^2)	3	12.2	2.1	7.4-18.2	17.2
Pubic ramus width (cm)	4	1.3	0.3	0.8-2.0	23.1
Pubic arch angle (deg)	5	75.0	12.3	44-110	16.4
Anterior urogenital triangle area (cm^2)	6	32.2	4.8	22.0-47.3	15.0
Pubic ramus length (cm)	7	8.6	0.6	6.6-9.8	6.9

[a] Ratio of SD to the mean.

Ridgeway. Variation of the obturator foramen and pubic arch of the female bony pelvis. Am J Obstet Gynecol 2008.