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Variation of distances from mid-urethra to the obturator foramen: an MRI study

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Abstract

Introduction and hypothesis—To estimate distances from the mid-urethra to the obturator foramina and to explore correlations between pelvic dimensions and body height.

Methods—This is a secondary analysis of a parent case-control study on the mechanisms of stress urinary incontinence. We measured pelvic dimensions on magnetic resonance images of women with (cases, $n=50$) and without (controls, $n=50$) stress urinary incontinence.

Results—The mean distance from mid-urethra to the obturator membrane among cases is 31.8 mm (left) and 32.1 mm (right), with a range from 25.9 to 42.0 mm. There were no significant differences in these distances when comparing left with right, or cases with controls. Weak correlation was found between the urethra-to-obturator foramina distances and heights only in the case subjects.

Conclusion—There is high variability in the distance from mid-urethra to the obturator foramina. Height should not be used as a predictor of dimensions in the lesser pelvis.

Keywords

Anatomy; Female; Obturator foramen; Stress urinary incontinence; Transobturator tape; MRI

Introduction

Since its invention in 1995 [1] tension-free vaginal tape (TVT) has gained great popularity owing to its efficacy and safety, becoming the standard treatment for stress urinary

incontinence. Nevertheless, complications such as bowel injury and haemorrhage have prompted research into various modifications. The transobturator approach outside-in (TOT) [2] avoided the retro-pubic space, and hence minimised the risk of perforation of the urinary bladder. Later, the TVT transobturator inside-out tape (TVT-O) was introduced [3] to further minimise the necessary dissection. TVT-O still carries a risk of haemorrhage [4] and damage to the anterior or posterior branch of the obturator nerve, especially when hip joints are in insufficient flexion [5, 6]. A new type of mid-urethral sling known as the mini-sling was introduced 5 years ago [7], aimed at reducing complications such as obturator neuralgia and at reducing the amount of foreign material.

Despite having a different fixation point for different mini-slings, the target area for most of the tapes is the obturator foramina with the obturator internus muscle or obturator membrane. Some of the mini-slings were reported to have lower efficacy than previous transobturator tapes [8–19]. One explanation offered for this is that the anchoring point was not reached in some cases [20, 21]. As there is almost no knowledge of the variation in the distances between the obturator foramina in women suffering from stress urinary incontinence, it is important for surgeons and manufacturers to know the normal ranges of distances from the mid-urethra to the obturator foramina, especially when designing mini-slings with fixed length, but also for other mini-slings, where shorter mesh tapes could lead to insufficient fixation and therefore result in failure of the procedure. Clinicians regularly use easily ascertained morphometric measures to predict outcomes that would otherwise require invasive measurements. For example, short stature is a known risk factor for caesarean section because of cephalopelvic disproportion [22–25]. If readily available proxy measurements, such as body height or pelvic dimensions that can be estimated by physical examination (such as the distance between the symphysis pubis and the coccyx), would similarly allow for accurate prediction of relevant transobturator distances, appropriate tape lengths could be designed more easily and efficiently at low cost.

We hypothesise that women with stress urinary incontinence have different pelvic dimensions in comparison to women without stress urinary incontinence. We aim to further test a secondary hypothesis that pelvic dimensions correlate with body height.

Materials and methods

This is a secondary analysis of magnetic resonance imaging (MRI) scans obtained for the Research on Stress Incontinence Etiology (ROSE) study [26], a case–control study comparing women with and without stress incontinence. The study was conducted in the Department of Obstetrics and Gynecology, University of Michigan, Ann Arbor, MI, USA and was approved by the local institutional review board (IRBMED #2002-0636). The ROSE study included women with daily stress urinary incontinence (cases) and demographically matched healthy, asymptomatic volunteers (controls). To be included as a case, subjects needed at least two episodes of stress urinary incontinence on a 3-day voiding diary and incontinence was objectively verified by a full-bladder stress test during the examination for the study. Group matching ensured that the two cohorts were matched for age, parity, race and hysterectomy. All subjects underwent proton-density MRI in the supine position at rest with images taken in axial, coronal and sagittal planes with 5-mm thickness.

We randomly selected 50 cases and 50 controls by using the RAND function in EXCEL 2003, sorting the patients by the value received from the random number generation function and including the first 50 patients in each category (cases and controls). None of the subjects had undergone pelvic organ prolapse surgery or anti-incontinence procedures. The terminology used hereinafter is based on the current anatomical terminology (Terminologia Anatomica by FCAT [27]).

An anatomical schematic for our measurements is shown in Fig. 1. The urethra-to-obturator distances were measured on axial scans using ImageJ 1.44p software (<http://rsbweb.nih.gov/ij/>). Two investigators (P.H. and S.K.D.) made measurements independently and the average value was chosen. In addition, the senior author reviewed the MR images and the location of anatomical coordinates for measurements. The distances measured were the distance from the urethra to the obturator foramen on each side of the pelvis. The points were selected according to the following criteria reached by consensus of the research group to reflect the relevant anatomical landmarks for currently used anti-incontinence devices (and further displayed in Fig. 2). For the lower edge of the symphysis, we marked the point as the median inferior edge of the symphysis on the slice where “bridging” of the arcuate pubic ligament was visible and the pubic bones met in the following cranial slices. The lower part of the coccyx was determined by the most ventral edge of the most caudal slice where the coccyx was visible. The point at the mid-urethra was established as the third cranial slice (three slices at 0.5 cm intervals) where the muscular urethra was visible in a layer between the urethra and the vagina.

For the definition of the obturator foramen point we looked at three sequential slices above the mid-urethra and selected the image with the narrowest distance by trigonometric equation to produce the minimum distance. On images where the obturator membrane was visible, the point was placed at the junction of the ventral aspect of the obturator membrane and the pubic bone. When the obturator membrane could not be differentiated, the point was placed similarly at the inner edge of the pubic bone surrounding the foramen that attaches to the membrane.

Figure 2 displays points of measurement and procedural steps. Figure 2a displays the first slice where the muscular urethra can be seen. Figure 2b is the next cranial slice, where the lower edge of the symphysis is marked. Figure 2c shows the locations where the ventral edges of the obturator membrane are measured. Figure 2d and e further illustrate points marking the obturator foramina. Figure 2f demonstrates identification of the coccyx.

The three-dimensional coordinates (x, y, z) of each point in each slice were taken and distances calculated to avoid bias due to different inclination of the pelvis. The coordinates were entered into a spreadsheet and the distances were calculated using the Pythagorean

equation $\sqrt{((x_1-x_2)^2+(y_1-y_2)^2+(z_1-z_2)^2)}$. For statistical analysis we used the shortest distance from the urethra to the obturator foramen.

Wessa.net project was used for statistical analysis. We used Pearson's correlation to estimate inter-rater reliability. For testing normality of the total distances from the mid-urethra to the obturator foramina we used the Shapiro-Wilk test. For comparison of the groups of cases and controls and for comparison of the left and right sides we used two-sample Student's *t* tests and Wilcoxon tests. For the correlation between the measured distances and body height we used Spearman's rank correlation. Comparisons were considered significant for *p* values < 0.05. Absolute values of correlation coefficients from 0 to 0.4 were considered weak correlations, from 0.4 to 0.7 as moderate correlations, and from 0.7 to 1.0 as strong correlations.

As retrospective power calculations are controversial and add no new information [28], we did not perform post-hoc analysis.

Results

The mean body mass index ($\pm$ standard deviation [SD]) of the cases (women with stress incontinence) and controls (women without stress incontinence) was 29.3 ± 5.6 and 27.9 ± 6.4 .

respectively (p value comparing cases with controls=0.08); height was 163 ± 5.9 cm vs 162 ± 9.5 cm ($p=0.41$); and weight was 78.5 ± 15.4 kg vs 73.6 ± 16.9 kg ($p=0.08$).

The inter-rater reliability for pelvic distance measurements, as calculated by Pearson's correlation, was 0.92. Normal distribution of total distances from the urethra to the obturator foramina was confirmed both for cases and controls by the Shapiro–Wilk normality test (data not shown).

In cases, the mean total distance from one obturator foramen to the other while passing underneath the mid-urethra was 64.0 mm (SD 5.5; median 63.4 mm; 25th percentile 59.8 mm; 75th percentile 67.9 mm, range within 1.5 IQR 53.1–78.4 mm; Fig. 3). The similar mean total distance for controls was 62.0 mm (SD 6.3; median 61.5 mm; 25th percentile 57.3 mm; 75th percentile 66.3 mm; range 50.1–79.9 mm; Fig. 3).

The mean distances from the mid-urethral point to the obturator foramen for the left and right sides were similar within groups. Furthermore, there were no statistically significant differences in these measures when comparing cases and controls (Table 1).

The mean distance in the cases from the lower edge of the symphysis to the coccyx was 94.5 mm (SD 8.8). The same distance in the controls was 95.0 mm (SD 9.9); $p=0.80$ in the comparison of cases and controls.

There were several statistically significant correlations between measurements of the transobturator distances and body height or the symphysis-to-coccyx distance (Table 2). The only significant correlations with body height were in the incontinent cases, whereas the distance between the symphysis and the coccyx was only significantly correlated with the transobturator measurements in continent controls. Despite statistical significance, these correlations are considered weak, with all correlation coefficients calculated to be less than 0.4.

Discussion

This study describes the distances between the urethra and the obturator foramina as seen on the MRI scans of living women suffering from stress urinary incontinence (cases) and healthy, asymptomatic volunteers (controls). The results of this study suggest that the distances traversed by trans-obturator tapes vary widely, but are not significantly different in cases and controls.

The range of distances from the urethra to the obturator membrane is at half of the mean distance. This spread is similar to interobturator distances based on physical measurements of a collection of bony pelvis [29]. In our subjects, the shortest necessary tape length in cases is 53.1 mm and 50.1 mm in controls. By contrast, the longest necessary tape length is 78.4 mm and 79.9 mm respectively. These data suggest that fixed-length mini-slings will be too short and/or tight for a number of women. The narrowest transobturator length was 67.7 % of the longest distance required in cases and 62.7 % in controls. This implies that for proper placement into similar positions (i.e. into the obturator membranes) in different pelvis, the length of mini-slings needs to be adjustable.

Information about the distances from the mid-urethra to the obturator foramina is important, both to surgeons and to manufacturers, in order to enable them to improve their devices so that they better comply with actual female anatomy. This information may decrease the likelihood that new devices will result in clinical failure, as was seen in the first group of mini-slings [8, 10–12, 14–17, 19, 30–33]. We must caution, however, that warnings based

on these data are limited only to devices currently in use, which follow an anatomical path similar to that measured in this study.

Linear measurements of the pelvis can be challenging. Axial slices allow measurement of only two dimensions. With the information about the cranial–caudal position of the slice the coordinate for the third dimension can be obtained. The third cranial slice from the urethral meatus is the usual point of insertion of the mini-slings, considering that the slice thickness is 5 mm. As the inclination of the pelvis can vary from subject to subject, we evaluated three consecutive slices and used the shortest distance from the mid-urethra to the obturator foramen obtained from each series. This served to eliminate bias introduced by different shapes of the obturator foramen or by different pelvic inclinations. In order to verify that the distances we analysed were anatomically accurate, we built several three-dimensional models using 3D Slicer (version 3.4.4, Brigham and Women's Hospital, Boston, MA, USA) and measured the same distances. The results did not differ significantly between the 3D models and those obtained from 2D MRI slices (data not shown). The analysis was much faster and easier when measuring coordinates in 2D slices using ImageJ rather than by producing 3D models for each subject. In addition, by measuring coordinates on the original MR images, we avoided the loss of resolution and introduction of error inherent in the production of 3D models.

As it is not practical or feasible to analyse the anatomy of every patient by MRI prior to surgical treatment for stress urinary incontinence, it would be ideal to use easily obtained proxy measurements to estimate pelvic distances. We therefore compared the distance from the mid-urethra to the obturator foramen with height and with the distance between the symphysis pubis and the coccyx. Unfortunately, we found only a weak correlation between these measures. It can therefore be concluded that neither body height nor the distance from the pubic symphysis to the coccyx should be used as a strong predictor of the dimensions in the lesser pelvis needed to determine the necessary tape lengths. It should be noted that there were several correlation coefficients in our analysis that were statistically significant (Table 2), but the rho values were low (all less than 0.4). As such, the clinical usefulness of these correlations is expected to be of limited value. The weakness of correlation can be further demonstrated using the relationship with the highest correlation coefficient—the association between body height and the distance between the mid-urethra and the obturator foramen on the right side in the incontinent cohort. Using Pearson's correlation coefficient, we calculated the coefficient of determination, also known as r^2 ("r squared"). In this particular case r^2 is 0.14, suggesting that 14 % of the variability of the measured distance in pelvic dimensions can be explained by body height, whereas the remaining 86 % is due to other factors.

Conclusion

We find that the distance traversed by transobturator slings is quite varied. As such, mini-slings with fixed tape lengths may fail to correct stress urinary incontinence because of anchoring in other structures and/or different tensioning. In patients with greater transobturator distances, we would expect to either see overtensioning of the tape with possible urgency or obstruction or that the sling might not reach the desired anchoring sites. In patients with shorter distances, it would be expected that the fixed-length tape would either be too loose or anchored differently from what is recommended by the manufacturers. Possible options for future mini-sling designs include variable penetration into the obturator membrane or allowing for different anchoring locations in order to achieve proper tensioning.

Further research on specific mini-sling devices is required to test the hypothesis that surgical success or failure rates depend on the distance from the mid-urethra to the obturator foramina.

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Fig. 1. Conceptual diagram showing our measurements. The red ribbon shows the expected path of the transobturator tape from the medial aspect of the obturator foramen on each side to its location at the mid-urethra in the midline. Measurements were taken from a point under the mid-urethra

Fig. 2.

Selection of points of measurement on magnetic resonance imaging slices. **a** displays the first MRI slice where the muscular urethra can be seen. **b** is the next cranial slice, where the lower edge of the symphysis is marked. **c** shows the locations where the ventral edges of the obturator membrane are measured, along with the mid-urethral and symphysis pubis points. **d** and **e** reveal similar points identifying the obturator foramina. **f** shows the coccyx

Fig. 3. Box plot charts presenting total transobturator distances measured in women with stress urinary incontinence (cases) and demographically matched controls. The borders of the boxes include the median (*central line*), and the interquartile range (IQR), i.e. the 25th and 75th percentiles (*lower and upper lines*). The whiskers illustrate observed values within the limits of 1.5 times the IQR

Table 1

Distances from the mid-urethra to the obturator foramina in cases and controls. Data are presented as mean (standard deviation [SD])

	Cases				Controls			
	Mean (SD)				Mean (SD)			
	Left	Right	p value (left vs right)	Total	Left	Right	p value (left vs right)	Total
Mean distance (mm)	31.8 (3.4)	32.1 (2.7)	0.53	64.0 (5.5)	30.6 (3.3)	31.4 (3.4)	0.23	62.0 (6.3)
								p value (total distance—cases vs controls)
								0.08

Table 2

Correlations between the mid-urethra-to-obturator foramina distances and body height or the symphysis-to-coccyx distance. Data are presented as Spearman's ρ (p value)

	Correlation with body height Spearman's ρ (p value)	Correlation with symphysis–coccyx Spearman's ρ (p value)
Left side: cases	0.26 (0.07)	0.04 (0.79)
Right side: cases	0.38 (0.007)	0.05 (0.71)
Total: cases	0.34 (0.02)	0.08 (0.59)
Left side: controls	0.15 (0.28)	0.29 (0.04)
Right side: controls	0.01 (0.94)	0.36 (0.01)
Total: controls	0.09 (0.55)	0.35 (0.01)