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ORIGINAL ARTICLE

Dynamic assessment of sling function on transperineal ultrasound: does it correlate with outcomes 1 year following surgery?

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Abstract

Introduction and hypothesis To correlate dynamic assessment of sling function using 2D and 3D transperineal ultrasound with outcomes following transobturator sling surgery.
Methods This is an unmatched case–control study of 100 patients who underwent transobturator sling surgery at our center between 2009 and 2012. Group A ($n = 50$) patients had successful outcomes and group B ($n = 50$) patients had suboptimal outcomes 1 year following surgery. The patients underwent 2D dynamic and 3D transperineal ultrasound. The two groups were compared with regard to the deformability of the sling on Valsalva, the concordance of urethral movement with the sling, and location of the sling.
Results When compared with group B, group A had a significantly greater number of patients in whom the sling deformed at Valsalva (flat at rest, curving into a c-shape at Valsalva), the urethral movement was concordant with the sling and the sling had a midurethral location ($p < 0.0001$). In all 17 patients in group B in whom the urethra moved in a concordant manner with the sling (34%), the sling did not deform on Valsalva maneuver and was located proximally. In all 15 patients in group A in whom the sling remained either flat or curved

(30%), the urethra moved concordant with the sling and the sling was in midurethral location.
Conclusions On 2D and 3D transperineal ultrasound, the best outcomes following transobturator sling surgery are associated with concordance of urethral movement with the sling, midurethral location, and deformability of the sling on dynamic assessment.

Keywords Ultrasound · Sling surgery · Outcomes · Dynamic assessment · Sling function

Introduction

The introduction of the midurethral sling has led to a paradigm shift in the management of stress urinary incontinence in the last decade. Ulmsten and Petros designed the midurethral sling to replace defective pubourethral ligaments [1, 2]. They hypothesized that increased intra-abdominal pressure in continent women might result in midurethral closure by forward stretching of the distal vagina by the pubococcygeus muscle and backward stretching of the proximal urethra around a competent pubourethral ligament [3]. However, continence following midurethral sling procedures may vary considerably [4] and the precise mechanism of action of midurethral slings remains uncertain.

Dynamic interaction of the urethra with the midurethral sling is a crucial determinant of the outcome following sling surgery. Dynamic functional assessment of in vivo sling behavior may prove crucial for improving our understanding of the mechanism of action of the midurethral sling and help to delineate reasons for failure. Several published studies have used 2D and 3D transperineal ultrasound to explore the importance of tape location and tape tension in ensuring continence [5–12]. However, despite the accessibility of the 2D

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transperineal sonographic modality, there is a paucity of qualitative data regarding the dynamic interaction of the urethra with the sling during periods of increased intra-abdominal pressure.

Hence, the primary aim of this study was to assess dynamic functional behavior in vivo of the transobturator sling (deformability, location of the sling, and the concordance of urethral movement with the sling) using 2D and 3D transperineal ultrasound and correlate the same with outcomes 1–2 years following transobturator sling surgery.

Materials and methods

We carried out an unmatched case–control study of 100 patients returning for their 1- to 2-year follow-up visit following transobturator sling surgery (Monarc™; American Medical Systems, Minnetonka, MN, USA) performed in the Section of Urogynecology and Pelvic Reconstructive Surgery, Department of Gynecology, Cleveland Clinic Florida between August 2009 and March 2012. Approval to carry out this study was obtained from the Institutional Review Board of Cleveland Clinic Florida. A total of 449 patients had undergone the surgery at our center between 2009 and 2012. Preoperative workup included detailed history and urogynecological examination including q-tip test of hypermobility, urinalysis, empty supine stress test, and evaluation for concomitant prolapse using the Pelvic Organ Prolapse Quantification (POP-Q) system. Multichannel urodynamic testing was done in all patients using air-charged catheters.

The transobturator sling surgery was performed using the same standardized surgical technique by two surgeons. Follow-up visits were scheduled at 2, 6, 12, 24 weeks, 1 year, and then annually following surgery.

Patients returning for their 1- to 2-year follow-up visit were retrospectively included in the study. At enrolment, the patients underwent a standardized cough stress test at 250-ml bladder volume and completed the UDI-6 validated questionnaire. Patients with a history of previous anti-incontinence surgery, a history of mixed incontinence with a predominance of urgency incontinence, and pelvic floor dyssynergia diagnosed on 2D transperineal ultrasound were excluded from the study. Patients with de novo development of overactive bladder symptoms or voiding dysfunction post-operatively were also excluded from the study. However, the study included patients who had undergone concomitant vaginal hysterectomy and/or anterior repair and a single-incision technique was used in those who underwent concomitant anterior repair. A fellow trained in sonography, who was blinded to the type of sling surgery and treatment outcomes, performed 2D and 3D transperineal ultrasound using the B K Medical Profocus Ultraview machine (Peabody, MA, USA) in all patients. The ultrasound examination was performed in the dorsal lithotomy position with a comfortably full bladder. 3D transperineal assessment of the sling at rest using the 8802 convex array transducer was performed first. The labia were parted and the probe was placed on the perineum taking care not to exert too much pressure to prevent distortion of the anatomy. The probe was positioned on the vaginal introitus at the external urethral orifice with the axis of the probe aligned to the patient's sagittal plane. The structures identified in the mid-sagittal plane included the bladder, urethra, the symphysis pubis, and the vagina. The sling was identified as a hyperechoic structure lying suburethrally. The transducer was moved in a fan-shaped manner for an extent of 140° approximately, from the left to the right of the patient, to obtain a 3D volume over 30 s that was digitally stored for future analysis.

This was followed by 2D transperineal real-time dynamic functional assessment of the sling location and function on Valsalva, using the 8802 transperineal transducer. The patients were asked to perform maximal Valsalva maneuver thrice and 20-s cineloops were recorded. The cineloop in which the urethra could best be seen in its entirety, from the urethrovesical junction up to the external urethral meatus, and its interaction with the sling, could be delineated clearly, was stored for future analysis. We then captured a 3D volume across the mid-sagittal plane in maximal Valsalva over 6 s. Two such 3D cubes were obtained and the volume in which the sling and the urethra could best be identified during maximal Valsalva was digitally catalogued for future analysis.

The 30-s 3D volumes obtained at rest, 6-s 3D volumes in the sagittal plane obtained at maximal Valsalva, and 2D films obtained during the Valsalva maneuver in each patient were analyzed. The parameters of dynamic sling function recorded were the deformability of the sling at maximal Valsalva, the concordance of urethral movement with the sling, and the location of the sling at maximal Valsalva.

Deformability of the sling

On 2D transperineal ultrasound, the sling was identified as a hyperechoic structure lying suburethrally. The shape of the sling at rest and the deformability of the sling from resting to maximal Valsalva and back were recorded in the cineloop film. The dynamic change in the shape of the tape was used to categorize three types of sling deformability:

1. Parallel to the urethral lumen at rest (flat or slightly curved in shape along its width at rest; Fig. 1) and deforms to a c-shape (Fig. 2) at maximal Valsalva
2. Parallel to the urethral lumen, both at rest and during maximal Valsalva: the tape remains flat or slightly curved in shape along its width and does not deform to a c-shape at maximal Valsalva
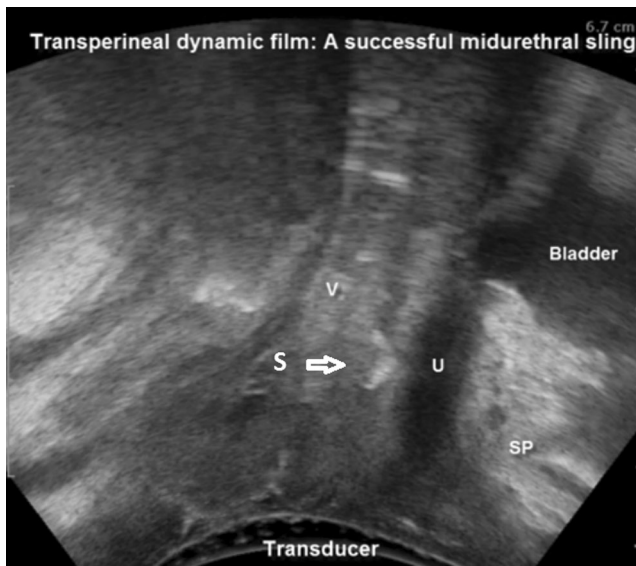
Fig. 1 The sling slightly curved at rest on 2D transperineal ultrasound (*arrow*). *S* sling, *V* vagina, *U* urethra, *SP* symphysis pubis

3. C-shaped at rest and during maximal Valsalva: the tape remains c-shaped along its width both at rest and during maximal Valsalva.

Location of the sling at maximal Valsalva

The 3D cube obtained over 6 s during maximal Valsalva across the mid-sagittal plane was analyzed to determine the location of the sling at maximal Valsalva. The cube was manipulated to the mid-sagittal plane. The urethral length was determined from the urethrovesical junction up to the external urethral meatus in the mid-sagittal plane using the distance
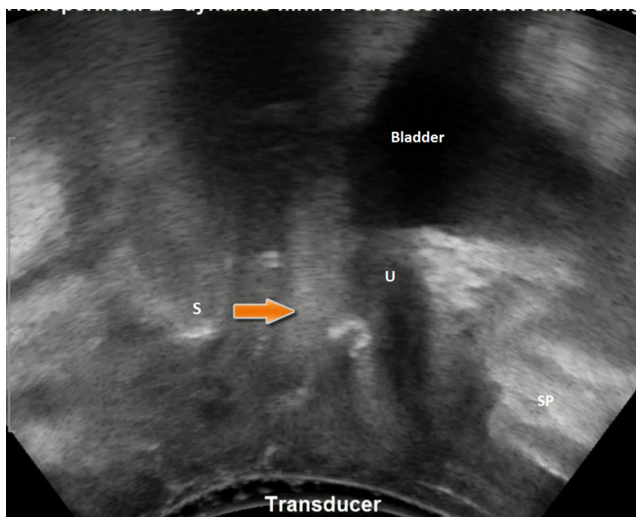
Fig. 2 The sling bent into a c-shape on Valsalva on 2D transperineal ultrasound (*arrow*). *S* sling, *U* urethra

function on the imaging software. Although the urethra is not a tube that follows a single straight line along its entire extent, it is straight in successive portions that form an angle with each other. The length of these straight portions was measured and added up to determine urethral length. The sling was identified as a hyperechoic structure lying suburethrally. The location of the sling on maximal Valsalva with regard to the urethral lumen was determined by dividing the urethra along its length into three equal parts: the proximal, mid, and distal urethra. The sling location at maximal Valsalva was characterized as proximal, mid, and distal based upon its correlation with urethral length. If the sling was located beneath both the proximal and the mid urethra or beneath both the mid and the distal urethra, the location was determined to be that under which a larger part of the sling was located.

Concordance of urethral movement with the sling during maximal Valsalva

The 3D cube obtained over 30 s at rest was manipulated until the mid-sagittal plane. The urethral length was determined from the urethrovesical junction until the external urethral meatus in the mid-sagittal plane. The sling was identified as a hyperechoic structure lying suburethrally. The location of the sling at rest with regard to the urethral lumen was determined by dividing the urethra along its length into three equal parts: proximal, mid, and distal urethra. The sling location at rest was characterized as proximal, mid, and distal based upon its correlation with urethral length.

The location of the sling relative to the urethral length at rest was compared with that at maximal Valsalva. If the sling location at maximal Valsalva relative to the urethral length was identical to that at rest, the urethra was considered to move concordantly with the sling. If the sling location at maximal Valsalva relative to the urethral length differed from that at rest, the urethral movement in relation to the sling was considered discordant.

At enrolment, the data recorded included the age, BMI, gravidity, parity, menopausal status, and smoking history. Preoperative urogynecological symptoms including incontinent events/day and pads used/day and urodynamic parameters of urethral function, namely, maximal urethral closure pressure and the Valsalva leak point pressure, were recorded. The enrolled women were divided into two groups based on treatment outcomes: group A, consisting of 50 patients who had successful outcomes 1–2 years following surgery, and group B, consisting of 50 patients who had suboptimal outcomes 1–2 years following surgery. Treatment outcome was decided based on a composite measure of failure: the presence of urine leakage during a standardized cough stress test at 250 ml and a "yes" answer to question 3 of the UDI-6 validated questionnaire (with a "no" answer to all other questions on the questionnaire).

The deformability of the sling on Valsalva, the concordance of urethral movement with the sling, and the location of the sling at maximal Valsalva of the two groups were compared.

Statistical analysis was performed using SPSS STATISTICS 20 (IBM SPSS, Chicago, IL, USA). Normality testing was performed. Summary statistics are reported as mean ± SD (95% CI) for normal data and median (interquartile range) for non-normal data. Chi-squared test was used for analysis of nominal data. Mann–Whitney U test was used for non-normal interval data. $p < 0.05$ was considered significant.

Results

The two groups were comparable with regard to their demographic data, i.e., age, BMI, parity, smoking history, and menopausal status ($p > 0.05$; Table 1). The median (interquartile range) weeks of follow-up were also similar in the two groups (78 [17] vs 67 [15]; $p = 0.92$). The rates of concomitant prolapse surgery, including anterior repair were similar in the two groups ($p > 0.05$; Table 1). The severity of incontinence, as measured by preoperative incontinence events per day (median [interquartile range]: 3 [2] in both groups; $p = 0.32$) and pads used per day (median [interquartile range]: 2 [1] in both groups; $p = 0.4$)] was similar in the two groups. The two

groups matched with regard to their preoperative urodynamic measures of urethral function, the maximal urethral closure pressure (median [interquartile range] of 92 [34] in group A vs 90 [28] in group B; $p = 0.16$) and Valsalva leak point pressure at capacity (median [interquartile range]: 78 [18] in group A vs 82 [24] in group B; $p = 0.75$).

Table 2 details the in vivo characteristics of the sling, as seen on transperineal ultrasound. Table 3 shows the deformability of the sling and the concordance of urethral movement with the sling during the Valsalva maneuver considered together.

Compared with group B, group A had a significantly greater number of patients in whom the sling deformed at Valsalva (flat along its width at rest and curved into a c-shape at Valsalva), the urethral movement was concordant with the sling and the sling was located beneath the mid urethra ($p < 0.0001$; Table 2). The concordance of the urethral movement with the sling was the most important factor in ensuring continence (100% patients in group A vs 34% in group B) followed by mid urethral location of the sling on maximal Valsalva (84% in group A vs 12% in group B) and deformability of the sling (70% in group A vs 10% in group B), in that order (Table 2). The urethrovesical junction moved distal to the sling in 12 patients (24%) in group B who had discordant movement of the urethra relative to the sling (Figs. 3, 4).

Table 1 Demographic data, surgical history, severity of incontinence

Variable	Group A (n = 50) Successful outcome	Group B (n = 50) Suboptimal outcome	p value
Age in years, median (interquartile range)	60 (19.34)	56 (23.46)	0.17
BMI (kg/m^2), median (interquartile range)	24.16 (6.8)	25.5 (7.2)	0.43
Parity, median (interquartile range)	2 (1)	2 (1)	0.47
Smoking, n (%)	14 (28)	16 (32)	0.09*
Menopause, n (%)	35 (70)	32 (64)	0.37*
Concomitant surgery, n (%)*			
Anterior repair	36 (72)	42 (82)	0.09
Vaginal hysterectomy	9 (32.4)	9 (32.14)	0.76
Other prolapse surgery	16 (32)	15 (30)	0.48
Prior prolapse surgery	7 (14)	6 (12)	0.56
Severity of incontinence, median (interquartile range)			
Incontinent events per day	3 (2)	3 (2)	0.32
Pads per day	2 (1)	2 (1)	0.43
Urodynamic parameters, median (interquartile range)			
MUCP (cm of H$_2$O)	92 (34)	90 (28)	0.16
VLPP at capacity (cm of H$_2$O)	78 (18)	82 (24)	0.75

MUCP maximum urethral closure pressure, VLPP Valsalva leak point pressure

p value: Mann–Whitney U test

*p value: Chi-squared test

Table 2 In vivo characteristics of the sling, as seen on transperineal ultrasound

Variable	Group A (n = 50) n (%)	Group B (n = 50) n (%)	Odds ratio (95% CI)	p value
Deformability of the sling				
Flat to C shape on Valsalva No change	35 (70)	5 (10)	21 (6.96–63.36)	<0.0001*
Remains flat	10 (20)	24 (48)		
Remains curved	5 (10)	21 (42)		
Concordance of urethral movement with sling on Valsalva				
Concordant	50 (100)	17 (34)	193 (11.24–3,325.47)	0.0003**
Discordant	0	33 (66)		
UVJ moves distal to the sling	0	12 (24)		
Location of sling				
Mid urethra Altered location	42 (84)	6 (12)	38.5 (12.31–120.36)	< 0.0001**
Proximal urethra	8 (16)	41 (82)		
Distal urethra	0	3 (6)		

UVJ ureterovesical junction

*p value: Chi-squared test

**p value: Fisher's exact test

Group A: successful outcome; group B: suboptimal outcome

In all 5 patients in group B in whom the sling deformed at Valsalva (Table 3), the urethra moved in a discordant manner from the sling. In 3 (60%) of these 5 patients, the sling was located beneath the proximal urethra. In all 17 (34%) patients in group B in whom the urethra moved in a concordant manner with the sling, the sling did not deform on dynamic assessment and was located beneath the proximal urethra. In all 15 (30%) patients in group A in whom the sling remained either flat or curved, the urethra moved concordant with the sling and the sling was located beneath the mid urethra (Table 3).

Discussion

Our study demonstrates that concordance of urethral movement with the sling, deformability of the sling at Valsalva (flat at rest along its width and deformed to a c-shape at Valsalva), and the location of the sling at maximal Valsalva are all correlated with outcomes following transobturator sling surgery.

The mechanism of action of the midurethral sling is still not fully understood, despite the popularity of this treatment modality. Midurethral positioning of the sling has been regarded as important in achieving urinary incontinence, as it allows the tape to act as a fulcrum to produce dynamic kinking of the

Table 3 Deformability of the sling and concordance of urethral movement with the sling during the Valsalva maneuver considered together

Deformability of the sling	Movement of the urethra relative to the sling	Group A n = 50 n (%)	Group B n = 50 n (%)	p value
Change from flat to C shape (n = 40)	Concordant	35 (70)	0	0.0012
	Discordant	0	5 (10)	
Total		35	5	
Remains flat (n = 24)	Concordant	10 (20)	7 (14)	0.001
	Discordant	0	17 (34)	
Total		10	24	
Remains curved (n = 21)	Concordant	5 (10)	10 (20)	0.105
	Discordant	0	11 (22)	
Total		5	21	

p value: Fisher's exact test

Group A: successful outcome; group B: suboptimal outcome
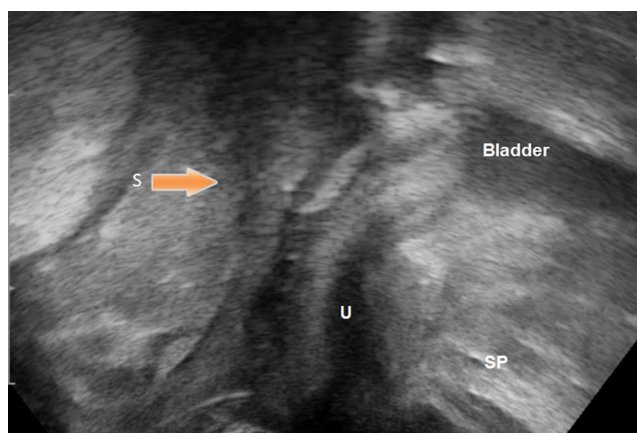
Fig. 3 The relation of the urethrovesical junction with the sling at rest (2D transperineal ultrasound). The sling is lying beneath proximal urethra. *S* sling, *U* urethra

urethra [5, 13] or as a mechanical device to enhance the increase in intraurethral pressure [10, 11] with stress. Dynamic kinking of the urethra with straining has been seen in 87–92% of women in whom a midurethral sling has been implanted [14–16]. Therefore, theoretically, dynamic changes in the interaction of the urethra with the sling during periods of sudden and/or sustained stress appears to be a crucial factor in ensuring successful outcomes following midurethral sling surgery.

Morphological features related to the midurethral sling have been studied previously, including tape location and tape tension [5, 6, 8–12]. However, real-time imaging reveals a more complex interaction between the urethra and the tape than can be captured by looking at individual parameters of tape location and tension in isolation. Based on our results, it is apparent that the best outcomes are associated with concordance of urethral
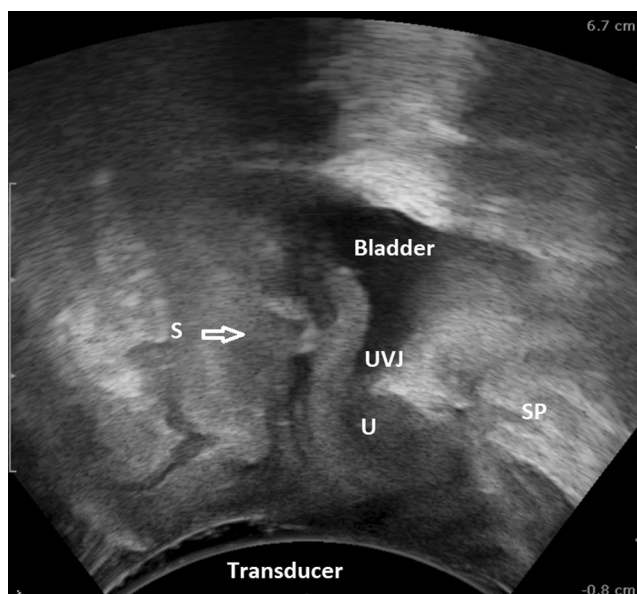
Fig. 4 The urethrovesical junction (*UVJ*) moving distal to the sling at Valsalva (2D transperineal ultrasound). *S* sling, *U* urethra, *UVJ* urethrovesical junction, *SP* symphysis pubis

movement with the sling, followed by midurethral location of the sling and deformability of the sling on dynamic assessment in that order. In 15 patients in group A (Tables 2, 3), the sling did not deform on Valsalva (i.e., it did not curve into a c-shape from flat at rest along its width). However, a successful outcome was ensured because the sling was located in the correct position (midurethral) at maximal Valsalva and the urethra moved in a concordant manner with the sling. Conversely, the sling deformed on Valsalva in 5 patients in group B (Tables 2, 3). However, the outcome was still suboptimal as the urethra moved in a discordant manner with the sling and the sling was not located beneath the mid urethra at maximal Valsalva. Therefore, it is probable that the three morphological parameters of in vivo dynamic behavior studied work together to compensate for the failure of an individual parameter to ensure a successful outcome. Hence, it may be incorrect to base our conclusions regarding outcomes on any one individual parameter. In addition, there may be other factors that we did not assess that could be involved in successful sling surgery.

Our results suggest that the concordance of urethral movement with the sling is the most crucial factor responsible for ensuring success of the surgery. All patients in group A demonstrated concordant movement. In our opinion, concordance of urethral movement with the sling is a measure of the fixation of the sling to the midurethral soft tissue that appears to be essential for dynamic urethral compression to be achieved during sudden and/or prolonged periods of increased intra-abdominal pressure. Sling failure may be associated with a sling that has not fixated itself well to the suburethral connective tissue or that has been inserted too loosely, and therefore, even though the sling has scarred in following surgery, the urethra and surrounding tissue move independently of it at Valsalva. Therefore, even if the sling is confirmed on static 2D and 3D ultrasound to be placed in the correct location, dynamic assessment may show that the urethra moves independently of it on cough/Valsalva. Such a sling cannot exert a dynamic compression effect on the urethral lumen, leading to failure. In some patients with failed slings due to a lack of suburethral fixation, the urethrovesical junction is even seen to move distally to the sling on dynamic assessment (12 patients in our study; Table 2). Additionally, a sling that is located proximally and does not deform at Valsalva may still exert an obstructive effect on the urethra (if not a kinking effect) if the urethral movement is concordant with the sling, thus leading to a successful post-surgical outcome. Significantly, it must be mentioned that it is the urethra that moves independently of the sling and not the opposite [17]. The use of the single-incision technique in patients who underwent concomitant anterior repair may conceivably explain the absence of concordant urethral movement. However, as the number of women who underwent concomitant anterior repair is similar in the two groups and none of the patients in group A exhibited discordant urethral movement, it is unlikely to be a confounding factor.

It must be noted here that although all patients in group A exhibited concordant movement of the urethra with the sling, all patients with concordant movement of the urethra with the sling did not have a successful outcome (Table 2). In all these patients (17 patients in group B), the sling was located proximally and did not deform along its width at maximal Valsalva.

Our results are supported by Yang et al. [10], who studied dynamic morphological characteristics of the TVT-O tape in 98 women using introital ultrasound. They described five types of urethral descent in relation to the tape during stress ranging from type 1 (vertical descent without urethral encroachment at the level of the tape) to type V (rotational descent with a concave curvature less than 120°). Type 1 occurred in 7 of the 9 patients in whom sling surgery had failed in their study. They postulated that when the binding between the tape and urethra was weak, the urethra slid across the arc of the tape during the Valsalva maneuver. The vector of the posterior urethral wall was altered and directed anteriorly by the moving tape (type 1 urethral descent). Yang et al. concluded that this dynamic action of the posterior urethral wall exerted only transient constricting effects on urethral function [10]. The opposite scenario played out when the binding of the tape to the urethra was good (urethral descent type II). Yang et al., however, performed sonographic assessment at the 3-month milestone following surgery and surgery had failed in only 9 patients at that early point. Their study is limited by a sample size that is too small to draw any definite conclusions. Our study overcomes this limitation, as it is a case–control study with an equal population of patients in whom sling surgery has failed. The terminology we have used in our study is also much simpler, but clinically useful. In another study of 56 women who had undergone the TOT procedure, Yang et al. found that in women with successful outcomes, the tape position became more caudal relative to the symphysis pubis on straining, while remaining at the middle to lower-middle portion of the urethra [12]. This suggests that the tape moved in accordance with urethral motion during increased intra-abdominal pressure [12], thus supporting the findings of our study.

The importance of sling location in ensuring continence is controversial. However, the studies that have challenged the importance of sling location either defined sling location using the symphysis pubis as the reference point [9] or studied the TVT retropubic sling [8, 9, 18]. We believe that it is important to consider the location of the sling relative to the urethral length, as the sling forms a fulcrum for dynamic urethral closure. Because of its retropubic location, the TVT sling procedure may be associated with increased tape tension and urethral compression, which may compensate for any inappropriate sling location, while still maintaining continence. It must again be emphasized that it is not simply one parameter, but the complex dynamic interaction of multiple factors working together that ensures continence. Therefore, studies that explore only sling location at rest are essentially determining the effects of only one individual parameter, which, although important, does not work alone in vivo. Additionally, our study shows that it is not sling location at rest alone, but sling location at maximal Valsalva, that may be of critical importance. If the urethral movement is not concordant with the sling, the location of the sling relative to the urethral length at maximal Valsalva would necessarily differ from that at rest.

Kociszewski et al. correlated the dynamic changes in TVT sling shape seen on transperineal ultrasound with outcomes in 72 women [5]. They found that 98% of patients, in whom the tape was flat at rest along its width in the midsagittal plane and curved into a c-shape during straining, were continent after surgery. There was improvement in one case (2%) and none of these patients was classified as a failure. However, in 39% of the patients, no change was visible in the sling shape along its width on straining in the midsagittal plane. In the 11% of patients in whom the tape position was flat along its width at rest and during straining, the failure rate was highest, at 25%. In the 28% of patients in whom the sling was c-shaped along its width at rest and on straining, the failure rate was 10%.

Kociszewski et al. contend that the deformation of the sling along its width to a c-shape at Valsalva indicates that tension is being exerted on the urethra [5]. They therefore postulated that a sling that remained flat along its width both at rest and on straining was too far away from the urethra and hence the sling exerted no effect. Conversely, they extrapolated that a TVT tape that is already c-shaped along its width at rest is an indication of too much tension being exerted on the urethra and therefore may be associated with voiding dysfunction. This is supported by Dietz et al., who also stated that most suburethral tapes can assume a tight c-shape, in particular at Valsalva [19]. The more pronounced this effect is at rest, the tighter the tape may be assumed to be [19]. However, the c-shape seen at rest may be a reflection of the tape bending or twisting following insertion and not necessarily a tight sling placement. A loosely placed tape can also assume a c-shape along its width and therefore it is the distance of the tape from the urethral lumen at rest that would seem to be more predictive of voiding dysfunction than the presence of a c-shaped tape at rest.

Our study has certain limitations. Treatment outcomes were assessed by the surgeons who had performed the procedure. Therefore, investigator (detection) bias cannot be ruled out. Exertion of too much pressure on the introitus with the probe can potentially distort the urethral anatomy. However, care was taken to place the probe gently between the labia to circumvent the problem. The study included patients who had undergone concomitant vaginal hysterectomy and/or anterior prolapse repair. However, the number of such patients was similar in the two groups ($p > 0.05$; Table 1). The treatment outcomes were based on a strict criterion of cure and patients who had improved subjective outcomes were not included.

Therefore, the sonographic picture associated with successive grades of improvement in continence was not studied. The study has unique strengths: the imaging was performed by a trained fellow who was blinded to the treatment outcomes. All enrolled women had undergone the same midurethral sling procedure (transobturator) using only one sling product at a single center, thereby negating the effects of variable evaluation methodology, surgical technique or interpretation of outcomes.

In conclusion, on 2D and 3D transperineal ultrasound, the best outcomes following transobturator sling surgery are found to be associated with concordance of urethral movement with the sling, midurethral location, and deformability of the sling on dynamic assessment during Valsalva.

Compliance with ethical standards

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