MINI REVIEW

FUNCTIONAL UROLOGY

Knowledge of urethral closure mechanics helps to optimize surgical methodology of the midurethral sling operation

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The mechanism for urinary continence is not obstructive. Ultrasound and video data indicate that 3 striated muscle forces contract in opposite directions around a competent pubourethral ligament (PUL) to close the distal urethra and bladder neck. If PUL is loose, both mechanisms are invalidated, because striated muscles need a firm insertion point to function efficiently. The patient now loses urine on effort. Referring back to original research, the various steps involved in a midurethral sling operation are analysed with a view to optimizing surgical results. These include an analysis of what causes postoperative urinary retention, why the components of the distal closure mechanism need repair and simple steps to avoid nerve and blood vessel injury.

Key Words: midurethral sling ‹› pubourethral ligament ‹› surgical methodology ‹› urethral closure mechanism

INTRODUCTION

The first commercially available midurethral sling (MUS) [1] was based on the 1990 Integral Theory [2]. The original Theory comprised a series of original experimental works extending over 79 pages; in animals, discovery of a new surgical principle, how a precisely inserted tape could create new collagen to reinforce damaged ligaments; in humans, the discovery that 3 directional forces contracting against a competent pubourethral ligament to enact two separate but related closure mechanisms (see Video 'model' https://youtu.be/24LqT9LCRI8). Firstly, the urethral closure mechanism was described as the closure of the distal urethra by forward acting vector forces stretching the suburethral vagina forwards (Figure 4). Secondly, the bladder neck closure mechanism occurs when the bladder base and proximal urethra are pulled backwards and downwards to narrow the proximal urethra and 'kink' the bladder neck for closure (Figure 4). As well there was a description and critical analysis of the prototype MUS, how a precise pubourethral ligament (PUL) length was required for continence. Though the citations and related works of the Theory now number in the thousands, few have read it. Our aim is to show how an understanding of the original scientific experiments detailed in [2] may assist an individual surgeon to 'better understand' the surgical steps of MUS surgery and hopefully improve results.

The animal experiments showed infection from implants was not an issue, however, tissue reaction was, and varyied from minimal to florid.

Surgeones should advise patients that a reaction may occur and minimal mesh usage is advised.

Three directional forces require a firm PUL for urethral and bladder neck closure

Forward and backward muscle forces (arrows, Figure 4), contract separately against the pubourethral ligament (PUL) to close the distal urethra and bladder neck through two separate closure mechanisms (2) (see video 'model' https://youtu.be/24LqT9LCRI8). If PUL is loose ('L', Figure 5), muscle forces weaken, the urethra 'funnels' and urine is lost on effort. Both closure mechanisms are affected (see video 'virtual op.' https://youtu.be/0UZuJtajCQU). The video shows partial control with midurethral support but requires folding of the suburethral vagina for complete continence.

Surgical translation: always place tape at midurethra. The best way to do this is to create a hole immediately below the lower border of the symphysis, where PUL inserts into the midurethra. The hole allows precise vertical insertion so the instrument slides around the symphysis. It prevents slippage to the external iliac vessels or obturator nerves. Potential bleeding into the Cave of Retzius is unmasked and controlled by digital pressure. The suburethral vagina requires plication.

Surgical translation of the video diagnostic test (see video https://youtu.be/0UZuJtajCQU).

This test is especially useful in patients with mixed incontinence. Even if there is urge or cough-activated detrusor overactivity (DO), if the urine loss is controlled by this test, it can be predicted that both urinary stress intontinence (USI) and urge incontinenve will most likely be cured.

The essential role of intraurethral resistance in continence

The prototype retropubic sling [3] was configured in a way which allowed the tape (PUL analogue) to be lowered sequentially away from the symphysis, from tight to normal length. Tape length (PUL) was critical. The transition from leakage to continence was sudden and often came down to a few millimetres. This was attributed to the exponential nature of resistance to flow, inversely related to the 4th power of urethral radius (Poiseuille's Law).

Surgical translation – ideally, the MUS should be performed under local anesthesia. Post-operative urinary retention is the result of an overtight sling. Remembering that intraurethral resistance to flow is exponentially determined, there is not much margin between an 'overtight' (retention) and an 'over loose' tape (USI). Using local anesthesia (LA) helps remove the problems associated with post-operative contraction of the abdominal and pelvic muscles.

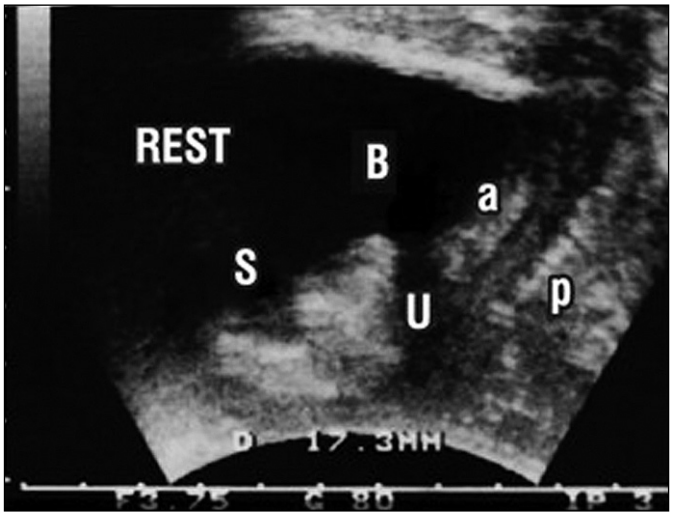

Figure 1. *Transperineal ultrasound 'REST'. Patient in semirecumbent sitting position.*
S – symphysis; U – urethra; B – bladder; a – anterior vaginal wall; p – posterior vaginal wall

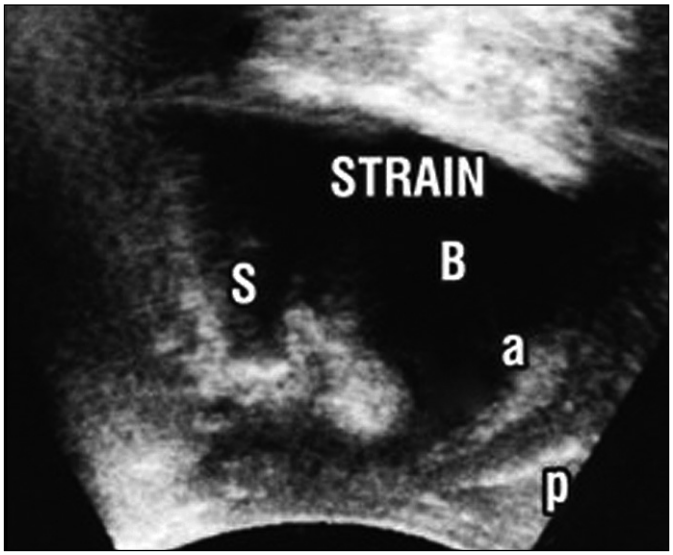

Figure 2. *Transperineal ultrasound 'STRAIN'. Patient pushes downwards (Valsalva). The posterior pelvic muscles stretch the vaginal walls 'a' and 'p' backwards to pull open the posterior urethral wall. The urethra opens out (funnels) both proximally and distally.*

If LA is not possible, spinal or epidural anesthesia works well. There is one simple rule to decrease urinary retention – whatever the surgical methodology applied, only tighten the sling over a no. 18 Foley catheter placed in the urethra.

The catheter gives an inbuilt protection to overtightening. Remembering that the difference between overtight and overloose may only be a few millimetres, tighten in steps. Tighten, remove the catheter,

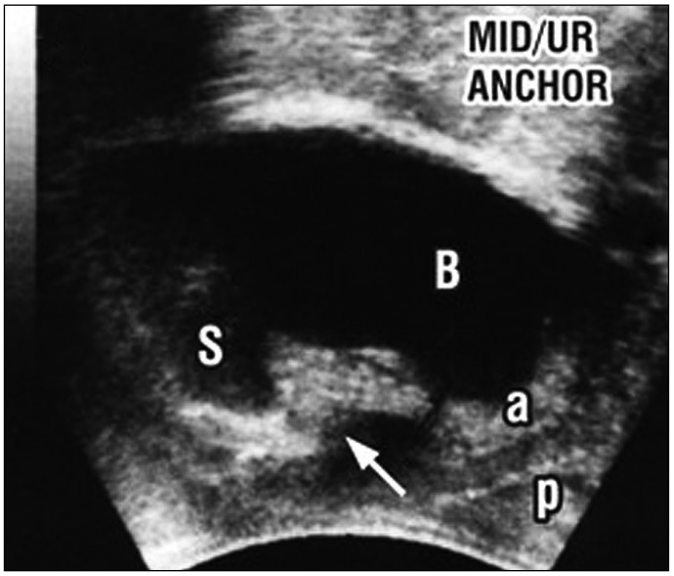

Figure 3. *Transperineal ultrasound 'MID/UR ANCHOR. A hemostat (arrow) is pressed gently upwards immediately behind the symphysis; this restores PUL length; 'a' & 'p' visibly tension, indicating restoration of the directional forces to enact bladder neck closure and distal urethral closure.*

test, insert the catheter, tighten more and so on. The common practice of inserting a no. 8 Hegar dilator after tightening does not particularly help in protecting from overtightening as all this does is expand the anterior urethral wall. It is the tape below which causes the obstruction.

Ultrasound validation that PUL needs to be shortened and reinforced at surgery [4]

Funneling and incontinence on effort are controlled when a hemostat supports PUL from stretching. Figures 1–3 are the analogue of the video. The arrow at midurethra clearly shortens PUL site. This removes the laxity 'L' (Figure 5), restoring the system from 'USI' to 'continence' (Figure 4). This change is explained by a supported PUL restoring the strength of the forward and backward closure vectors (arrows). None of the events in Figures 1 to 3 can be explained by pressure transmission theories, thereby invalidating them. Critical PUL length requirement for continence has been independently validated [5].

Repair of the distal closure mechanism

Patients cured of urine leakage on coughing may complain of sudden loss of urine, often a small leakage, which they describe to be 'like a bubble escaping'. The cause may be a loose distal closure mecha-

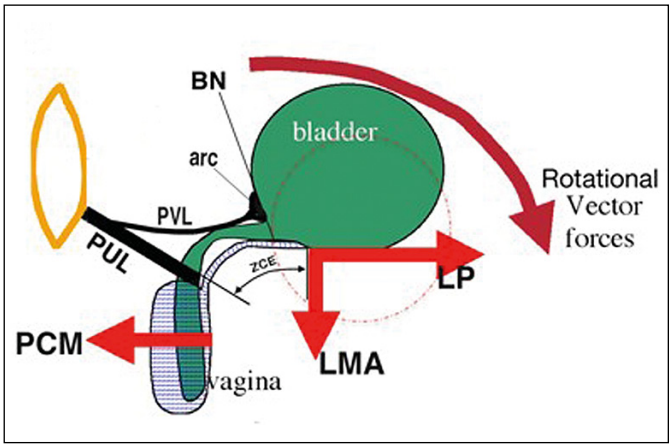

Figure 4. *Urethral closure (straining) by oppositely acting striated muscle vectors (arrows).*
The pubococcygeus muscle (PCM) stretches the distal suburethral vagina forward against the pubourethral ligament (PUL) to close the distal urethra; m. levator plate (LP) stretches the distal vagina, bladder and proximal urethra backwards. This action tenses PUL and PVL; m. longitudinal muscle of the anus (LMA) pulls the proximal vagina and bladder base downwards against the uterosacral ligaments; this action rotates the bladder (broken circle) to close the urethral 'kink' at the bladder neck (1). Zone of critical elasticity (ZCE) signifies the significant elasticity in the vagina required to allow separate action of the opposite muscle vectors (arrows).

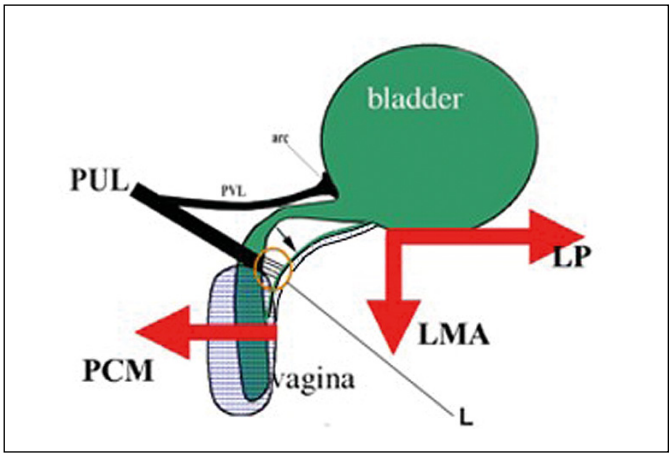

Figure 5. *PUL is loose and has lengthened by 'L' (circle). LP and PCM weaken; LP/LMA contraction now funnels the bladder, as in Figure 3.*

nism (see video https://youtu.be/0UZuJtajCQU). The distal closure mechanism acts to seal the urethra. It should be repaired routinely during all MUS operations. The technique is simple – take the midurethral incision to within 0.5 cm of the meatus to allow access to the external urethral ligament (EUL). Locate the EUL which attaches the meatus

to the anterior surface of the symphysis. With a no. 18 Foley catheter in the urethra, penetrate EUL with a needle attached to a 00 Vicryl suture, insert into the fascial wall of the vagina on the same side, then into the opposite side of the vagina, then into the contralateral EUL. Tie the suture with minimal tension.

CONFLICTS OF INTEREST

The first author is the co-inventor of the retropubic midurethral sling. All operations on human subjects were performed with written informed consent, guarantees of confidentiality and under IRB observation and review over a 5-year period, 1988 to 1993. The study protocol number is RPH HR.221.

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