

Anatomical steps in the conceptualisation of the urethral ligament plication (ULP), a tape-free operation for stress urinary incontinence (SUI) cure

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INTRODUCTION

It is not sufficient to describe an anatomical structure. An answer is required to the question, 'what is it for'.

Salvador Gil-Vernet (1892–1987) was a famous Spanish anatomist and urologist and Nobel Prize nominee.

The anatomical structure in question is the role of the pubourethral ligament (PUL) in the cure of stress urinary incontinence (SUI). The 1990 Integral Theory, on which the tension-free vaginal tape (TVT) operation is based, described two separate closure mechanisms for the urethra, both reliant on the PUL, distally and at the bladder neck, with the bladder neck the most important.¹

With reference to [figure 1](#), the pubococcygeus muscle (PCM) stretches the two ends of the distal vagina 'H' forwards against PUL to close the distal urethra from behind. The levator plate (LP) pulls the bladder base and proximal urethra backwards against PUL to tension them before the downward contraction of the conjoint longitudinal muscle of the anus (LMA) against the uterosacral ligaments (USL) to close the bladder neck. The key role of a competent PUL was emphatically demonstrated by the transperineal ultrasound study ([figure 2](#)), where mechanical support of the PUL restores both bladder neck and distal urethral closure.²

PUL repair with a midurethral sling (MUS) became the cornerstone of SUI repair.³ A standard retropubic MUS performed via a midline incision was not able to easily address the repair of the distal closure mechanism ([figure 1](#)). In about 1995, Petros began performing the MUS via two parallel incisions in the vaginal sulcus between the bladder neck and symphysis, using a suburethral tunnel at the midurethra to

enable the application of the two arms of the sling behind the symphysis.⁴ This technique had built-in safety as regards avoiding injury to major blood vessels, bowel and obturator nerves, and it ensured the tape was placed exactly at the midurethra.⁴ The two-incision MUS had two parts: a standard MUS to repair the bladder neck closure mechanism and the second part was based on a live anatomical study of PUL⁵ ([figure 3](#)). It comprised the direct repair of attachments of the vaginal hammock to the PUL and the laterally placed PCM ([figures 3 and 4](#)).

PLICATING PUL FOR THE CURE OF SUI

The banning of the MUS because of intense political lobbying in the UK left a major gap in the operations that could be offered to women with SUI, none of which could match what the MUS offered. The fundamental part of the MUS was the creation of a firm PUL anchoring point for the closure muscles, as demonstrated in the imaging and pressure studies supporting the prototype MUS^{1 2} ([figures 1 and 2](#)). A dynamic video ultrasound study ([figure 2](#)) validated the original statement of the theory that SUI was mainly caused by laxity in the PUL ('L', [figure 1](#)).² SUI could be controlled by a haemostat test, which mechanically prevented PUL extension ([figure 2](#), right frame),² or permanently by harnessing the wound reaction to a tape precisely implanted in the position of the PUL³ by a MUS ([figure 1](#)), which worked by creating a collagenous artificial neoligament. The question arose would it be possible to repair PUL without a sling? Examination of the live anatomy of PUL⁵ ([figure 3](#)) and repair of the distal closure mechanism as in

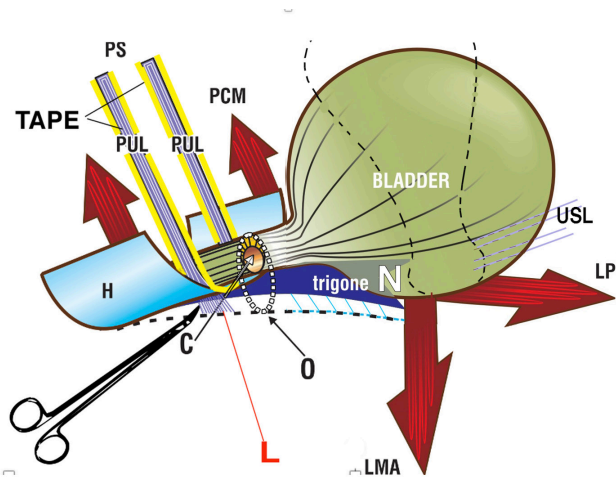


Figure 1 Haemostat mechanically supports PUL. A haemostat controls SUI by preventing the descent of a loose or weakened to 'L' as does a MUS tape, thus preventing the urethra from being pulled from 'C' (closed) to 'O' (open) by LP/LMA. H, distal vaginal 'hammock'; LP, levator plate; LMA, conjoint longitudinal muscle of the anus; PCM, pubococcygeus muscle; PUL, pubourethral ligament; SUI, stress urinary incontinence; USL, uterosacral ligament.

the two-incision MUS,⁴ gave birth to the hypothesis that PUL repair alone, using collagen-creating No. 2 or No. 3 polyester sutures, may be able to create sufficient new collagen in a weakened PUL by plicating it.

CALCULATIONS FOR THE VALIDITY OF NO. 2 POLYESTER SUTURES FOR URETHRAL LIGAMENT PLICATION (ULP) OPERATION

The theoretical part of the hypothesis was answered by extrapolating Instron Tensiometer testing of collagen produced from a rejected polyester graft. That experiment was part of a Doctor of Surgery thesis on the development of the MUS.⁶ The graft pulled out of the tensiometer grips at a loading of 0.64 megapascals (93 lbs/sq inch). Taking

this as a minimal figure and comparing it against the known breaking strain of pelvic ligaments,⁷ it was calculated that the collagen strength from even a No. 2 polyester suture would be some two orders of magnitude ($\times 100$) greater than the breaking strength of a pelvic ligament.

The known breaking strain of collagen, 18000 lbs/sq inch⁸ (124MPa) was confirmed by Svensson *et al*,⁹ who tested collagen fibrils to a mean strain value corresponding to a stress of 89 ± 15 MPa. Collagen fascicles tested by Svensson *et al* had a mean diameter of 0.27 ± 0.16 mm.⁸

THE SURGERY FOR ULP OPERATION

The hypothesis was tested surgically by direct repair of both PULs via two full-thickness parallel incisions from the bladder neck to the urethral meatus made in the vaginal sulci, exactly as described in the original operation.¹⁰ A thin connective tissue sheet covering the PULs was opened to reveal both parts of the PUL and PCM laterally (figures 3 and 4). The operation was performed in a space of approximately 2.5 cm^2 (online supplemental videos 1 and 2). A No. 2 or No. 3 polyester suture was inserted medially into the urethral part of the pubourethral ligament, then into the pubic part of the PUL, then into the external urethral ligament, then laterally into the pubococcygeus muscle, then tied, but not tightly. Incisions were closed with Vicryl sutures. In six women, the ULP operation was carried out with 300 mL in the bladder. In these six women, the No. 18 Foley catheter was inserted and removed as required, so cough tests could be carried out for continence at relevant stages of the operation, specifically: before starting, after the polyester suture on one side, then after suturing was completed on both sides.¹⁰

RESULTS

At 6 months postoperatively, 31/36 (86%) women with leakage on cough tests were cured of SUI, and 11/19

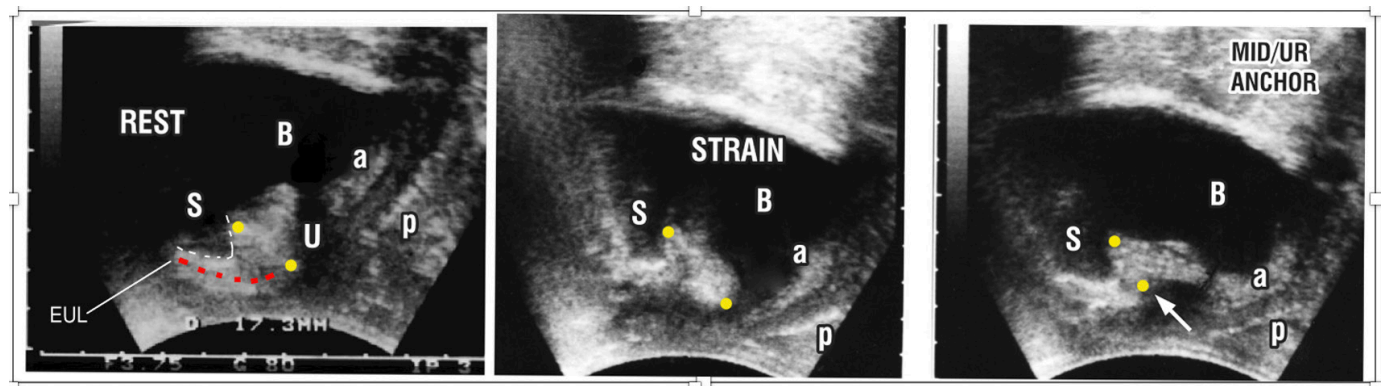


Figure 2 Transperineal ultrasound of a woman with stress urinary incontinence. (A) At rest, (B) during straining and (C) with a haemostat (white arrow) supporting the pubourethral ligament at midurethra. S, symphysis; U, urethra; B, bladder; a and p are the anterior and posterior walls of the vagina; the two yellow circles mark the length of pubourethral ligament extending from behind the lower border of the symphysis to the midurethra; red broken lines mark the anterior wall of the distal urethra. a, anterior wall of the vagina; B, bladder; EUL, external urethral ligament; p, posterior wall of the vagina; S, symphysis; U, urethra.

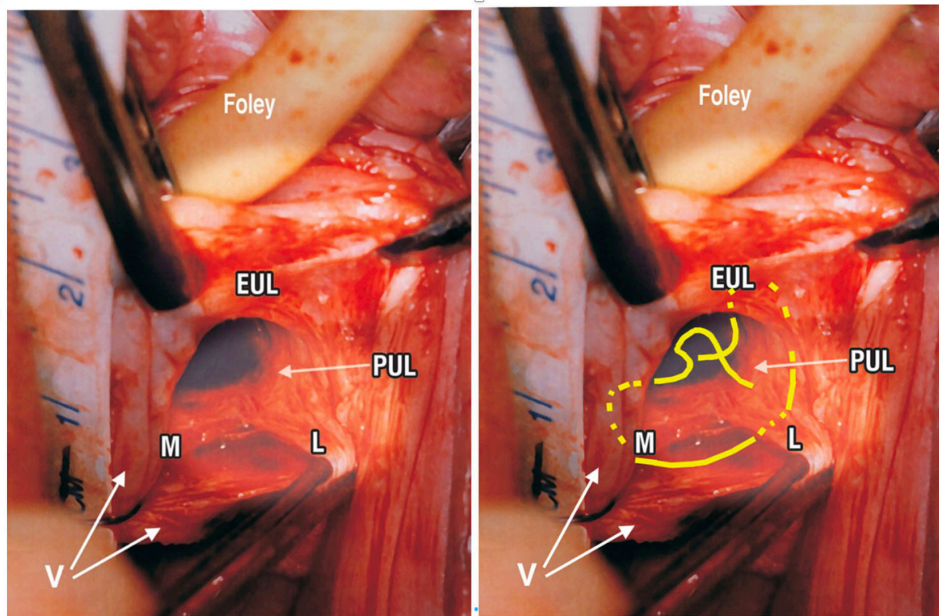


Figure 3 Live anatomy and surgical binding of loose PUL. (A) Original live anatomical dissection of PUL (left incision) during a two-incision IVS operation.⁵ The tape measure overlies the urethra. The left paraurethral sulcus has been incised along its length and opened out laterally with forceps. The EUL sits in front of the PS. The PUL originates behind the PS from its lower posterior part. Coming down from PS, PUL splits into two parts: medial (M) to insert into the side of the midurethra and L (lateral). 'L' attaches laterally to the PCM (not seen) and then comes down to attach to the vagina (V). The PCM is immediately lateral to PUL. (B) No. 2 or No. 3 polyester sutures bind both branches of PUL to fascias attached to pubic bone, urethra, vagina and PCM, essentially as performed in the original two-incision midurethral sling operation.⁴ EUL, external urethral ligament; PCM, pubococcygeus muscle; PS, pubic symphysis; PUL pubourethral ligaments;

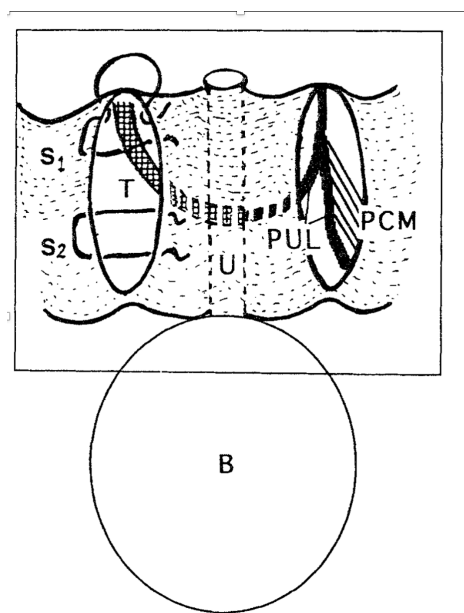


Figure 4 Two-incision IVS operation.⁴ Perspective: looking upwards into the anterior vaginal wall. The paraurethral incisions have been opened out. The right-hand side represents the normal anatomy. The left-hand side represents the tape (T), and the horizontal mattress sutures, S1 attaching the hammock deep into the origin of the PUL and S2 into the PCM. PUL, urethral and vaginal insertions of the pubourethral ligament; PCM, anterior portion of the pubococcygeus muscle.

(58%) were cured of concomitant urge.¹⁰ At 12 months, the cure rate was 83%. There were five surgical failures, four immediately postoperatively and one after 3 months. Reference to the original experimental animal studies¹ indicated that collagen 1, the key structural support of the PUL, had formed by 3 months, an optimistic sign for a longer-term cure. The study¹⁰ was registered, carried out under ethics community control and with written patient informed consent.

DISCUSSION

'What is it for?'. The main structural component of PUL and all ligaments is collagen. Collagen depolymerises 48 hours prior to delivery¹¹ and loses 95% of its strength. The ligaments and vaginal fascia are plasticised, allowing them to stretch without rupturing (ruptured ligaments are rarely seen during reconstructive surgery). Though collagen structure is restored after delivery, the ligaments are often in an extended form, which causes SUI (figures 1 and 2) and pelvic organ prolapse. At menopause, collagen breaks down and is excreted as hydroxyproline throughout the menopause.¹² This explains the higher incidence of prolapse and incontinence in post-menopausal women.

Two of the major discoveries of the 1990 Integral Theory concerned collagen: its role in causing SUI and mixed incontinence¹ and a method for creating new collagen by harnessing the tissue reaction from implanted tapes.¹³



The success of No. 2 and No. 3 polyester sutures for SUI cure by PUL plication indicates that wide-bore polyester suturing could be applied to all pelvic ligaments, cardinal for transverse defect cystocele, uterosacral for uterine prolapse and repair of deep transversus perinei ligaments for perineocele and descending perineal syndrome. These operations have been applied by colleagues in small numbers, with promising results for these conditions at 12 months.

CONCLUSIONS

The ligament repair method promises another method besides tapes for repairing the collagen of damaged ligaments. So far, it seems to be fulfilling its promise, at least for SUI. If SUI repair can be validated over a longer period, say 2 years, it is reasonable to look at other applications of this method, such as organ prolapse and lower urinary tract symptoms cure.

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