Underactive bladder, Fowler's syndrome are potentially curable by uterosacral ligament repair

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Abstract: Underactive bladder (UAB) is essentially an inability of the bladder to properly empty. UAB symptoms, when they co-occur with posterior fornix syndrome (PFS) symptoms (urge, frequency, nocturia, chronic pelvic pain), can be cured/improved, surgically by uterosacral ligament (USL) repair, non-surgically, by devices which give mechanical support of the USLs or strengthening pelvic muscle and ligaments with squatting-based exercises. The pathogenic pathway from weak USLs to UAB (and PFS) is that, when the muscles which externally open the posterior wall of the urethra contract against lax USLs, their contractile force weakens, and they cannot open the urethra adequately. The detrusor then contracts against a relatively unopened urethra to cause obstructive symptoms (i.e., UAB) such as slow stream, intermittent stream (stopping and starting), hesitancy (difficulty starting), feeling of incomplete emptying, and post-micturition dribble. Co-occurrence of PFS symptoms indicates that UAB may be part of the PFS, with USL causation, which can be tested by a tampon or probe in the posterior fornix. If the emptying (and other) PFS symptoms improve, it is a sign that UAB, and Fowler's syndrome (FS) can potentially be cured or improved by USL repair. Following USL repair, many studies have recorded very significant improvement in emptying symptoms, and objective tests, for example, postvoid residual (PVR), decreased natural bladder volume, and decreased emptying time. FS and UAB are most likely a part of the PFS and, therefore, potentially curable by USL repair.

Keywords: Underactive bladder (UAB); Fowler's syndrome (FS); urinary retention; Poiseuille's Law

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Introduction

The key points of the article are summarized in the video abstract (Video S1).

Underactive bladder (UAB) in the female, is not well defined, and not well understood, especially as the prostatic urinary obstructed syndrome seems very different from that of the female. Another point of confusion is that UAB does not correlate very well with urodynamic "detrusor underactivity" (DU). UAB is said to be a common clinical entity, occurring in up to 45% of females depending on definitions used (1). Prevalence increases significantly in elderly women.

According to the International Continence Society (ICS), UAB syndrome is "characterized by a slow urinary stream, hesitancy, and straining to void, with or without a feeling of incomplete bladder emptying sometimes with storage symptoms" (2).

The etiology and pathophysiology underlying UAB is said to be unknown. Based on impaired bladder emptying characteristics, it has been hypothesized that UAB can arise from damage or malfunction of peripheral afferent, efferent, or central nervous system pathways, and detrusor myopathy (3).

A recent retrospective study of 1,726 patients said to have UAB, with the diagnosis based on patient history, estimated that 11.5% of patients would fall into the idiopathic subclass, with neurogenic causes accounting for 84.6% and myogenic causes 2.6% (4). Neurogenic causation is not the experience of the authors. As will be demonstrated later, high cure rates have been achieved with uterosacral ligament (USL) repair in a substantial number of women with bladder emptying difficulties.

Highlight box

Key findings

- Underactive bladder (UAB) is potentially curable by uterosacral ligament (USL) repair.

What is known and what is new?

- UAB, Fowler's syndrome (FS) are said to have no known cause or cure.
- UAB, FS, are likely part of the posterior fornix syndrome (PFS).

What is the implication, and what should change now?

- If UAB and FS are preoperatively demonstrated to be part of PFS, they are potentially curable by USL repair.
- If a tampon or probe in the posterior vaginal fornix improves emptying, minimally-invasive USL surgical repair could be considered.

The aim of this review is to examine UAB from the perspective of the posterior fornix syndrome (PFS), of which UAB forms a part (5). PFS was first described in 1993 by Petros and Ulmsten (5). It consists of predictably co-occurring symptoms of urge, frequency, nocturia, chronic pelvic pain, abnormal emptying and raised post-void residual, caused by laxity in the USLs and cured or improved by surgical repair of the USLs (*Figure 1*, rectangle). It can also be improved non-surgically by strengthening pelvic muscle and ligaments with squatting-based exercises (7), and by tampons or devices which give mechanical support of the USLs.

UAB

From the perspective of PFS (5) and the Integral Theory Paradigm (ITP) (8), UAB is essentially an inability of the bladder to properly empty because of the inability of the posterior pelvic muscles to externally open the urethra prior to micturition. Symptoms of UAB are slow stream, intermittent stream (stopping and starting) hesitancy (difficulty starting), feeling of incomplete emptying, and post-micturition dribble. These symptoms form part of the PFS (5). The only well described clinical entity related to inability of the bladder to properly empty is Fowler's syndrome (FS) (9). FS was originally described by Clare Fowler in young nulliparous women as urinary retention, characteristic electromyographic (EMG) abnormality in the striated urethral sphincter muscle and associated polycystic ovarian disease (PCOD). Later these EMG patterns were found in normal women and PCOD association was also discounted, which left only urinary retention. If we absent these now discounted original FS features, PCOD and specific EMG patterns, FS is essentially another form of UAB, which is, in turn, part of the PFS, as defined (5).

The anatomy of micturition and UAB

In the normal state, the opposite muscle forces (large arrows), close the urethral distally and also, at the bladder neck (*Figure 2*) (8). External opening of the urethra by pelvic muscle forces precedes normal micturition (8): the forward vector, pubococcygeus muscle (PCM) relaxes (signified by broken PCM arrows) and is accompanied by a fall in proximal urethral pressure (10); PCM relaxation releases the forward force applied by the vagina, "H", to the posterior urethral wall; this allows the backward/downward the levator plate/conjoint longitudinal muscle of the anus

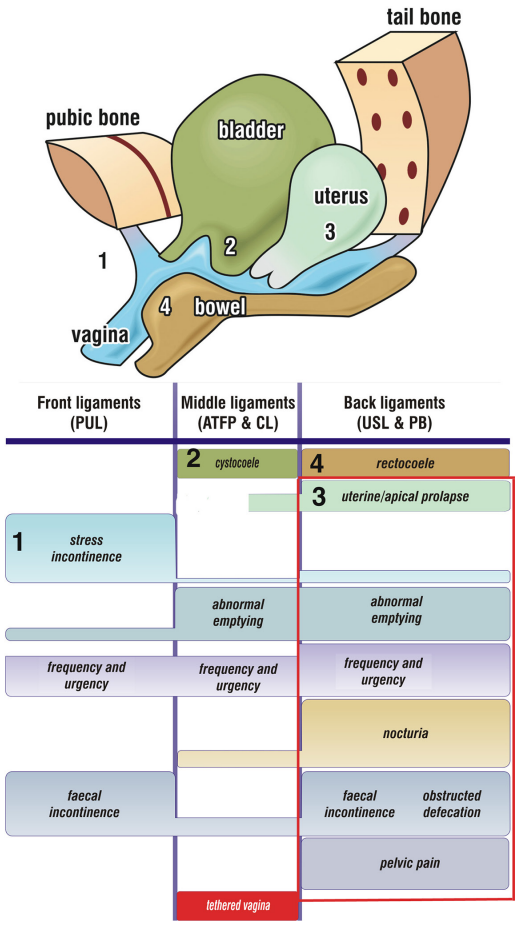

Figure 1 Diagnostic algorithm. Posterior fornix syndrome (red rectangle), comprises co-occurring grouped pain, bladder, and sometimes, bowel symptoms which may be caused by lax USLs and can be cured or improved by USL repair. Reused from (6). With permission from Peter Petros; retains ownership of the copyright. PUL, pubourethral ligament; ATFP, arcus tendineus fascia pelvis; CL, cardinal ligament; USL, uterosacral ligament; PB, perineal body.

(LP/LMA) muscle forces to pull open the posterior wall of the urethra, opening it from "C" (closed) to "O" (open), to facilitate micturition. The pubovesical ligament (PVL) contracts against the arc of Gilvernet on the anterior wall of the bladder, to prevent it prolapsing inwards against the combined backward/downward forces exerted by LP/LMA.

The flow mechanics of micturition and UAB

In *Figure 2* the pressure/flow chart graphically demonstrates the effect of external opening of the urethra on the resistance to urine flow "R". "R" is exponentially determined inversely to the fourth power of the radius (Poiseuille's Law) (11-16). For example, if the urethra can be opened by the LP/LMA from "C" (closed) to "O" (open) even as little as 0.5 mm (say from 3.5 to 4 mm) (*Figure 2*), the pressure required for the detrusor to expel urine falls from 180 to 100 cm H_2O for a 50 mL/s flow rate. If the urethra can be opened out to almost double this diameter, say from 3.5 to 6 mm, only 20 cm H_2O detrusor pressure is required to empty the bladder at a 50 mL/s flow rate.

Figure 3 is from a video X-ray study of micturition in a normal patient. It compares the position of the organs at rest with normal micturition against vertical and horizontal co-ordinates taken from bony points. Note the backward and downward stretching of the rectum, vagina and bladder during micturition, which can only be explained by external muscle forces acting on the organs. Note also how the distal segment of the urethra appears to have been pulled backwards behind the vertical co-ordinate, consistent with relaxation of the forward vector and consequent backward stretching by the backward vectors. The posterior urethral wall has been significantly opened out, perhaps to double the original diameter. The EMG chart in *Figure 4*, taken from a cylindrical EMG probe in the posterior fornix of the vagina, confirms that the pelvic muscle contracts to open the urethra preceding the outflow of urine.

Figure 5 comprises superimposed rest/straining organ and myography with X-rays and vascular clips applied to the vagina at midurethra "1", bladder neck "2" and bladder base "3". During micturition, the clips, the vagina (broken lines) and the rectum R_m seem to be forcibly stretched backwards and downwards apparently by downward angulation of the LP moving to LP_m (LP at micturition; broken lines). These organ movements mirror what is shown in *Figure 2*, two external muscle forces stretching the vagina, bladder base and posterior urethral wall backwards and downwards to open out the outflow tract. Opening out the urethra exponentially reduces urethral resistance to flow and so facilitates urine evacuation by detrusor contraction (11-16).

In a normal woman, once the urine starts flowing, the urine in the urethra being incompressible, resists the elastic closure forces of the urethra and surrounding tissues and removes the need for the pelvic muscles to continue to contract. In *Figure 4*, the disappearance of the EMG signal indicates that the pelvic muscles cease to contract as the detrusor contraction is now sufficient to expel the urine.

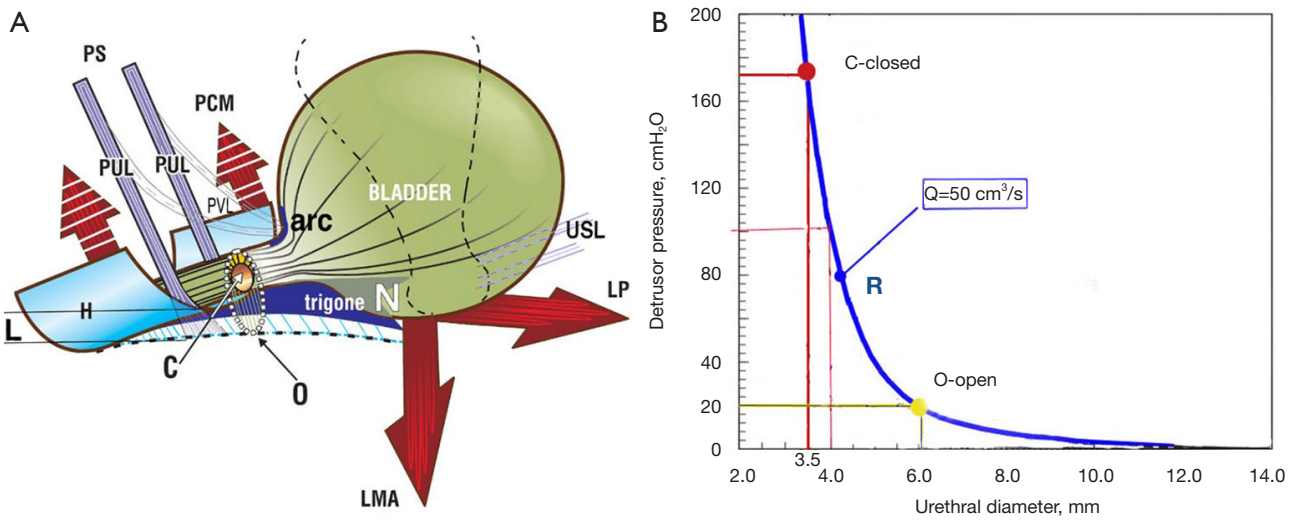

Figure 2 External opening of urethra exponentially lowers detrusor pressure required for micturition. (A) Three directional pelvic muscles, PCM, LP/LMA contract against the PUL and the USL. Broken lines = position of the anterior vaginal wall during micturition. (B) Pressure flow curve. "R", urethral resistance to urine flow. Reused from (6). With permission from Peter Petros; retains ownership of the copyright. H, the suburethral vaginal hammock; arc, arc of Gilvernet, a smooth thickening on the anterior wall of the bladder; C, closed urethra; O, opened urethra (by LP/LMA); L, PUL being elongated to allow external opening by LP/LMA; S, sacrum; LP, levator plate; N, urothelial stretch receptors; PS, pubic symphysis; PCM, pubococcygeus muscle; PUL, pubourethral ligament; PVL, pubovesical ligament; USL, uterosacral ligament; LP/LMA, levator plate/conjoint longitudinal muscle of the anus muscle.

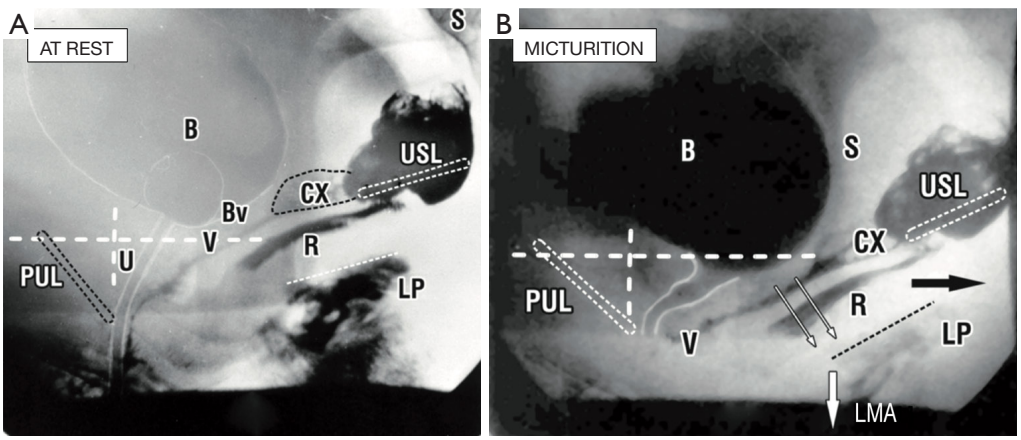

Figure 3 Micturition X-rays. Normal patient: X-rays at rest (A) and during micturition (B), same patient in sitting position. The white lines are vertical and horizontal co-ordinates taken from bony points. At rest, slow twitch contractions angulate bladder "B", urethra "U", vagina "V" and rectum "R" around the insertion of the pubourethral ligament "PUL" at midurethra. 10 mL radioopaque material has been injected into the levator plate "LP" vagina and rectum. During micturition (B), the urethra has moved backwards from the vertical co-ordinate, suggesting relaxation of the forward vector. The vagina and rectum appear to have been stretch backwards by a backward vector ("LP", black arrow). The anterior part of the "LP" has been angulated downwards apparently by the downward vector "LMA" (conjoint longitudinal muscle of the anus, white arrow) acting against the cervix "CX"/uterosacral ligament "USL" complex. The backward/downward vectors (thin diagonal arrows) create a diagonal vector force which seems to be pulling open the posterior urethral wall. Reused from (6). With permission from Peter Petros; retains ownership of the copyright. Bv, vesico-vaginal ligament; S, sacrum.

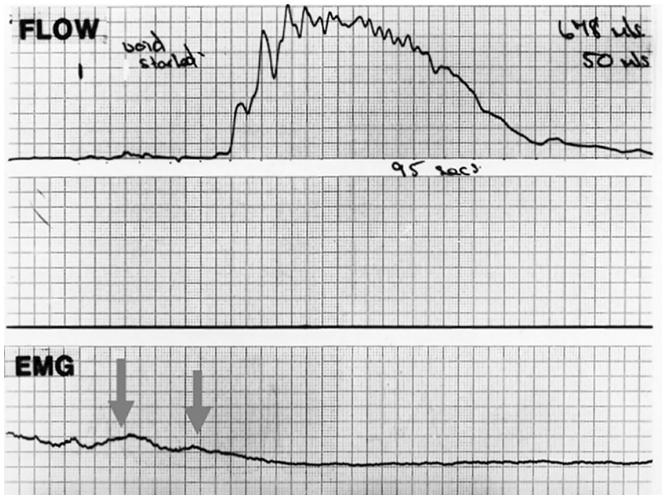

Figure 4 Normal flow chart. The electromyography in the vaginal fornix shows pelvic muscle contraction before urine flow starting and ceases once flow is established. The explanation for pelvic contraction ceasing after urine is in the urethra is that water is incompressible; the bladder smooth muscle spasms until the bladder is completely empty. Reused from (6). With permission from Peter Petros; retains ownership of the copyright. EMG, electromyography.

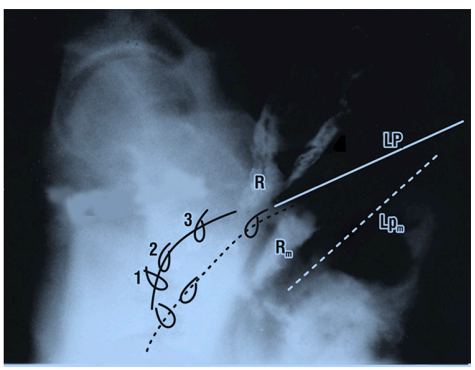

Figure 5 Active opening of urethra during micturition. X-ray of organs during normal micturition (broken lines) superimposed on X-ray at rest (unbroken lines). Vascular clips have been applied to 1. midurethra, 2. bladder neck, 3. bladder base. The vagina is stretched backwards and downwards by downward angulation of the levator plate LP_m, during micturition. Note backward/downward extension of all three vaginal clips during micturition, validating active muscle action exerted on the anterior vaginal wall, apparently by downward angulation of LP. Reused from (6). With permission from Peter Petros; retains ownership of the copyright. LP, position at rest; LP_m, levator plate at micturition; R, rectum at rest; R_m, rectum displaced downwards and backwards at mmicturition.

Pathogenesis of urinary retention and bladder emptying dysfunctions

With reference to *Figure 2*, if the USLs are weak, whether congenitally (for example in FS), injury at childbirth or by collagen breakdown after the menopause, the LP/LMA muscles which contract against them weaken, and the system becomes unbalanced. Compensatory forward-acting closure muscle action by the PCM narrows the distal urethra. The detrusor expulsion pressure needs to rise, and the patient experiences symptoms of "underactive bladder". Perhaps a better description is "obstructed micturition".

In *Figure 6*, the urodynamic flow chart and EMG are from a woman with urinary retention (or "UAB"). The flow is very slow and prolonged; according to underlying theory (8), this pattern indicates detrusor contraction against an unopened urethra.

Urinary retention: tiring of the external opening mechanism

Two important anatomical causes of abnormal bladder emptying, according to the underlying theory (8) and *Figure 1* are cystocele and uterine prolapse. This is pictorially

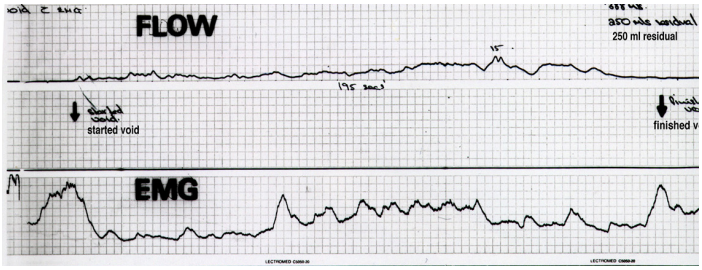

Figure 6 Obstructed micturition chart. Compared to *Figure 4*, the chart shows slow urine flow "stopping and starting" pattern. The EMG in the vaginal fornix shows the pelvic muscles repeatedly contracting to try and open the urethral tube, not so successfully as the flow is very slow and prolonged, indicating detrusor contraction against an unopened urethra. Reused from (6). With permission from Peter Petros; retains ownership of the copyright. EMG, electromyography.

evident in the figure surmounting the diagnostic algorithm: lax USLs will weaken the opening forces LP/LMA; a cystocele will dissipate the muscle forces which stretch the anterior vaginal wall backwards to open the urethra.

External opening out of the outflow tract (*Figure 2*) exponentially lowers the urethral resistance to flow, inversely by the 4th power of the radius (Poiseuille's Law) (11-13). It can be assumed, that the difference between the flow charts, *Figure 4* (normal) and *Figure 6* (obstructed), is failure of the external mechanism to adequately open out the urethra. Repeated traction by the striated muscles, as shown in the EMG (*Figure 6*), would lead to tiring of the opening muscles, resulting in the bladder not being fully emptied, and retention. Observation of the video resting and micturition X-rays (*Figure 3*) shows a doubling of the urethral diameter by what are clearly external muscle forces. As demonstrated in the pressure flow chart (*Figure 2*), the expulsion pressure required for a flow of 50 mL/s between a diameter of 3.5 and 6 mm falls from 180 to 20 cm H_2O. In a mathematical model, Bush *et al.* calculated, that in order to achieve the funnel shape in *Figure 3* without external opening, a detrusor pressure 2 orders of magnitude, 100 times greater than 160 cm H_2O would be required, equivalent to a column 160 metres high (13).

Surgical and non-surgical treatment of non-iatrogenic urinary obstruction

Strengthening the USL, if possible, non-surgically (7), or surgically (15,17-20), can cure or improve UAB symptoms, presumably by restoring the contractile power of LP/LMA which contract against the USLs. The LP/LMA now more easily opens out the posterior urethral wall to reduce resistance to urine flow by bladder contraction. Using squatting-based pelvic floor exercises, Skilling reported that 23 women with pre-treatment mean residual urines of 202 mL (range, 50–550 mL), were reduced post-treatment to 71 mL (range, 15–450 mL) (P≤0.005) (7). Following surgical repair of the USL with a TFS minisling tape, Petros *et al.* (14,15) reported reduction of pre-treatment residual urine from mean 271 mL preoperatively to 53 mL post-operatively (P<0.005) (15). Mean emptying time for this group (n=29) decreased from 41 s (12–130 s) to 31 s (7–130 s) (P<0.005) (13). Petros and Goeschen *et al.* reported similar findings (17,18).

Challenging UAB and FS criteria by USL sling surgery

In urodynamically validated surgical studies, Goeschen *et al.* (18), Petros (15,17), and Himmler *et al.* (20) followed PFS protocols for diagnosis and surgery to repair USL laxity, using posterior slings. All reported high surgical cure rates for the PFS conditions (*Figure 1*, red rectangle).

Conclusions

The urodynamically validated surgical data indicate FS and UAB are most likely a part of the PFS, which are therefore, potentially curable by repair or mechanical support of USLs.

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All clinical procedures described in this study were performed in accordance with the ethical standards of the institutional and/or national research committee(s) and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patients for the publication of this article and accompanying images. Human participation in the video was by patient permission on the basis it was deidentified.

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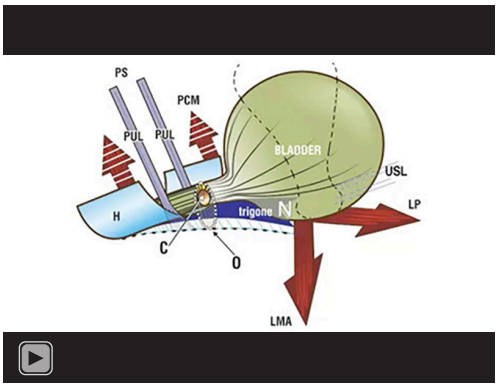
Supplementary



Video S1 Video abstract.

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