Int Urogynecol J (1998) 9:154–157

International
Urogynecology
Journal

Original Article

The Pubourethral Ligaments – an Anatomical and Histological Study in the Live Patient

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Abstract: The aim of the study was to analyze the structure, relations and insertions of the pubourethral ligament in the living female. Thirty-five women, mean age 44 years, were studied. The intravaginal slingplasty (IVS) procedure, as performed via two paraurethral incisions, allowed immediate access to the structures in this area, the urethra, vaginal hammock, pubourethral ligaments and anterior portion of the pubococcygeus muscle. Histological biopsies were performed from the structures identified as ligaments. The pubourethral ligament descends like a fan from the lower part of the pubic bone. It consists of vaginal and urethral parts, joined together by thin fibrous threads, giving the appearance of a continuous sheet of amorphous connective tissue. Each part generally varies between 5 and 7 mm in width and 3–4 mm in thickness. The urethral part is approximately 2 cm long and inserts into the midpart of the urethra. The vaginal part is approximately 3–4 cm long. It inserts into the vaginal hammock posterolaterally, approximately 1 cm short of the bladder neck. Histologically the ligaments consist of smooth muscle, elastin, collagen, nerves and, blood vessels. The dissections confirm that the pubourethral ligaments are strong finite structures. Allowing for differences between cadavers and live patients, relationships and insertions are much as described by Robert Zacharin [1].

Keywords: Pelvic floor dysfunction; Pubourethral ligament; Urinary incontinence

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Introduction

In 1961 Robert Zacharin [1] described the coincidence of the pubourethral ligament (PUL) and the vaginal insertion of levator ani, also known as the anterior portion of the pubococcygeus. He hypothesized that these structures had an important role in continence, but offered no comment as to the actual mechanism. The importance of the pubourethral ligament in urethral closure has been disputed [2,3]. Indeed, its very existence as an anatomical entity is questioned [3]. The aim of this study was to examine in live patients the ligaments and muscles previously described in cadaveric specimens [1]. This was ethically possible because of the two paraurethral vaginal incisions used in a more evolved version of the intravaginal slingplasty operation [4]. The ligaments and muscles described by Zacharin [1] lie directly below these incisions.

Material and Methods

Thirty-five women, mean age 44 years (range 15–78), mean parity 2 (range 0–5) were studied. All patients were tested urodynamically and with stress exercise pad testing, which included 10 coughs and star jumps performed with a full bladder. Supine urine leakage and positive stress exercise pad tests were present in 29 patients. Six patients presented with symptoms of urge incontinence but with no significant history of stress incontinence, and no demonstrable urine loss either in the supine position or on stress exercise pad testing. These were assigned as the control group. There was no urodynamically diagnosed detrusor instability in either group. The intravaginal slingplasty (IVS) procedure [4], performed via two paraurethral incisions approximately

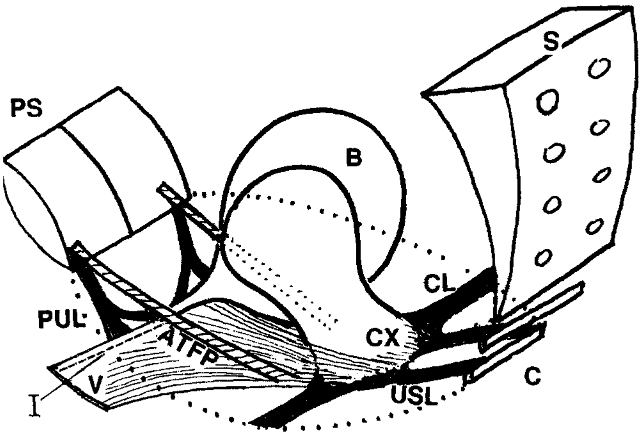

Fig. 1. The supporting ligaments of the vagina. Schematic representation, superolateral view. I = site of the paraurethral incision; B = bladder; PS = pubic symphysis; S = sacrum; ATFP = arcus tendineus fasciae pelvis; CX = cervix; V = vagina; PUL = pubourethral ligament; CL = cardinal ligament; USL = uterosacral ligament; C = coccyx. The dotted circle represents the pelvic girdle.

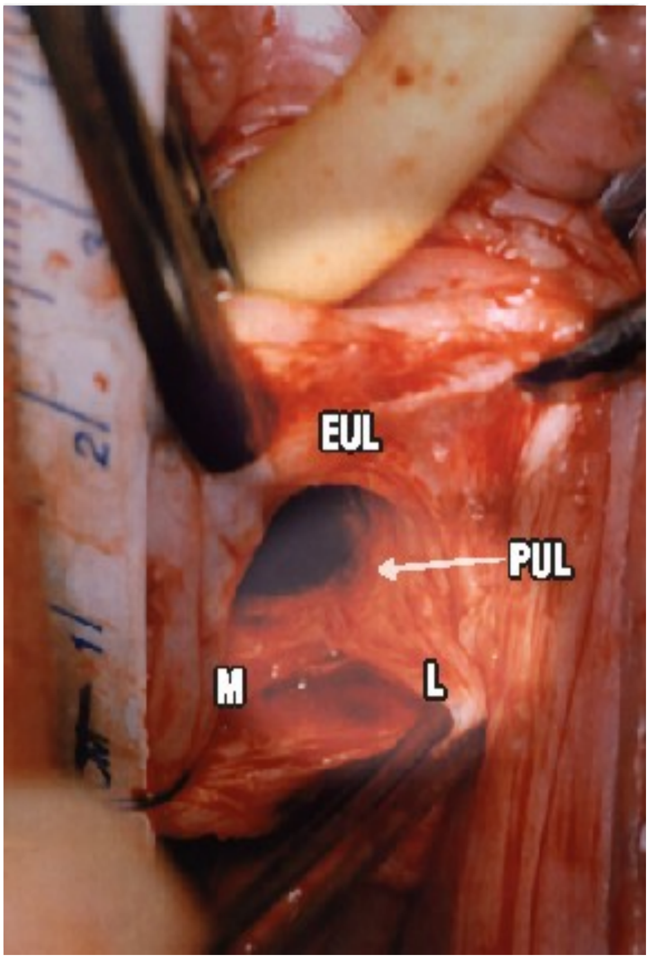

Fig. 2. Urethral and vaginal insertions of the pubourethral ligament (PUL). Perspective: looking directly into the anterior wall of the vagina; m = medial part of PUL inserting into midurethra; I = lateral part of PUL inserting into the upper part of the vaginal hammock. F = Foley catheter. The tape measure is positioned medially along the urethra. EUL attaches meatus to PS anteriorly

3–4 cm in length, allowed immediate access to the structures in this area (Fig. 1). The urethra, vaginal hammock and pubourethral ligaments were identified, as was the anterior portion of the pubococcygeus muscle (Fig. 2). The origin and insertions of the ligaments were studied and histological biopsies, no greater than 3 × 3 mm, were taken (Fig. 3). In order to give the reader a better perspective, the estimated positions of the urethral and vaginal branches of the PUL are outlined by solid black circles (Fig. 4). Clips 1, 2 and 3 delineate the

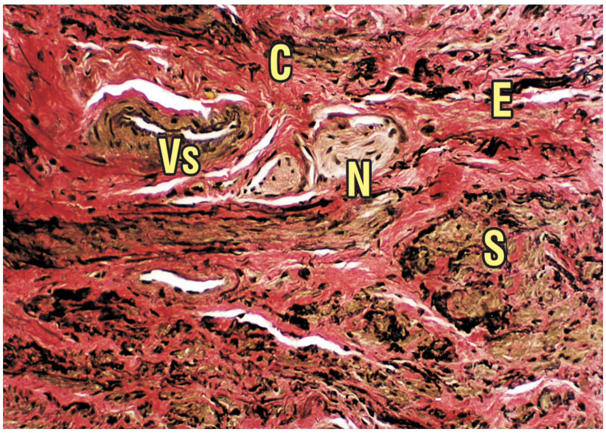

Fig. 3. Histology of the pubourethral ligament. Collagen (C) = red tissue; brown tissue = smooth muscle (S); black tissue = elastin (E); N = nerve tissue.

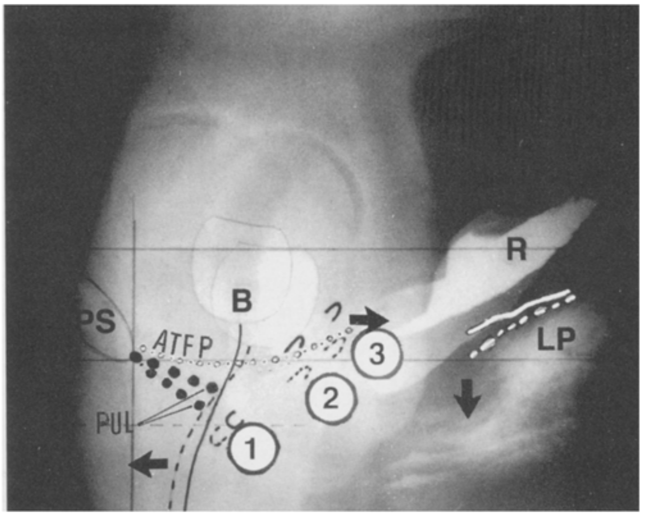

Fig. 4. Stretching of the vagina in opposite directions around the pubourethral ligament during straining. This figure represents a resting standing lateral X-ray superimposed on a straining X-ray in a normal patient. Solid lines = 'resting closed' position of structures, and broken lines = straining positions. Vascular clips have been applied to the vagina in the areas of the midurethra, '1', bladder neck '2', and 3–4 cm behind the bladder base, '3'. Radio-opaque dye delineates the Foley catheter balloon (B), rectum (R) and levator plate (LP). ATFP = arcus tendineus fasciae pelvis; PUL = presumed position of the pubourethral ligament, lower circles representing urethral insertion and upper circles the vaginal insertion; PS = pubic symphysis; white lines denote the superior border of LP. PUL and ATFP are shown only in their resting positions.

position of the vagina, unbroken lines during resting and broken lines during straining. The position of the arcus tendineus fasciae pelvis (ATFP, Fig. 4) was estimated by graphically connecting the bladder neck and bladder base clips to the lower border of pubic symphysis (Fig. 4). Local ethical permission was obtained for the study.

Results

The pubourethral ligament (PUL) descends like a fan from the lower part of the pubic bone, opening out into vaginal and urethral parts and joined together by thin threads (Fig. 2). This gave the initial appearance of a continuous sheet of amorphous connective tissue. The medial and lateral divisions of the ligament only became evident when a forceps was inserted to open out a channel for the IVS tunneler, an essential part of the IVS operation [4]. Each part of the PUL generally varied between 5 and 7 mm in width, and 3–4 mm in thickness. The urethral part of the PUL is approximately 2 cm long and inserts into the midpart of the urethra. The vaginal part is approximately 3–4 cm long, inserting into the vaginal hammock posterolaterally, approximately 1 cm short of the bladder neck. Immediately adjacent to this insertion laterally is the pubococcygeus muscle. There was a wide variation in the size of these ligaments, even within the same patient. In 1 patient the urethral part of the left ligament was exactly twice the width of the right ligament. In the 78-year-old patient the ligament on one side was hardly 3 mm wide. Although laxity in the PUL is considered to play a role in the pathogenesis of female stress incontinence [2], it was not possible to diagnose such laxity purely on the basis of the anatomical dissections. The morphology of the ligaments was not quantifiably different when comparing the urge (control) and stress incontinent groups. Histologically, the ligaments consisted of smooth muscle, elastin, collagen, nerves, blood vessels and, in 25% of cases, striated muscle (Fig. 3). This varied from just a few strands to significant amounts. Although the operations were performed with operating loupes, striated muscle was not aparently obvious as forming part of the ligament.

Discussion

Zacharin's anatomical studies of the pubourethral ligament [1] have inspired many discussions and operations, including the various versions of the intravaginal slingplasty (IVS) operation. Though structures consistent with these ligaments had previously been observed [2], a formal anatomical study in the living patient was not ethically possible until the vaginal part of the IVS operation was changed from a single midline incision to twin lateral incisions. Because symptoms of the unstable bladder have been improved by correcting vaginal and ligamentous laxity in three zones of the vagina [4], it was possible to assign 6 patients without demonstrable stress incontinence as the control group.

De Lancey's observations [5] of no separately identifiable structures in the gross anatomical specimen were, at first sight, quite plausible. On making a full-thickness incision in the vaginal epithelium, and opening out its medial and lateral borders, no specific ligamentous structures were immediately identifiable. Only a broad sheet of what appeared to be vaginal fascia was visible. Closer study, however, confirmed Zacharin's observations of two main branches of the pubourethral ligament, medial (urethral) and lateral (vaginal), interconnected by fine strands of tissue.

Biomechanically, these strands appeared to act much like wires on a suspension bridge, spreading the muscle forces generated by the pelvic floor over a greater area of vaginal membrane. That the PUL is not an anatomical entity and is merely connective tissue [3,5] was not supported by previous [6] or present histological findings. These confirmed the presence of smooth muscle, nerves and blood vessels, prerequisites for the active contractile role performed by any ligamentous structure. The presence of distensile (elastin) and contractile (smooth muscle) structures provides an anatomical basis for Cruikshank's hypothesis [7] that the PUL distends during straining. Radiological studies [8] confirm this hypothesis. Downward and backward displacement of the vagina and urethra at their PUL insertion points has been demonstrated [8]. Cruikshank's cadaveric studies also confirmed that the PUL is a discrete anatomical structure [7].

The presence of striated muscle in the histological studies is difficult to explain. It is likely that this was simply a striated muscle reflection on to the PUL, not part of the ligament itself.

Hypothesized Function of PUL

Study of Fig. 4 permits further development of a previous hypothesis based on video X-ray, EMG, digital palpation and anatomical studies [9,10]. It was hypothesized [2,8–10] that the PUL acts as a tethering point for vaginal stretching by three opposite muscle forces (arrows). The backward force (backward arrow) originates in the region of the ischial spine [10]. ATFP inserts at the ischial spine [3]. This insertion gives an anatomical basis for the hypothesis that the backward force (arrow) stretches the ATFP, and therefore the vagina (clips 2 and 3), backwards. The downward force then rotates the now rigid ATFP downwards, much like a trapdoor, to close off the bladder neck. The pubovesical ligament's insertion into the anterior wall of the bladder [11] (not shown), provides a rigid rotation point for the formation of the bladder neck [2,8–10]. The backward stretching of the vagina (clips 2 and 3, Fig. 4) pretensions the vaginal hammock [8]. The urethra is then closed from behind by application of the forward force to each side of the underlying vaginal hammock (forward arrow, Fig. 4). This hammock closure mechanism, attributed to De Lancey [5], was described as such in 1990 [2] and again in 1993 [8]. The dynamic forces activating this mechanism were demonstrated radiologically in 1993 [8], and by ultrasound in 1990 [2].

Conclusions

The dissections confirmed that the pubourethral ligaments are strong finite structures. Allowing for differences between cadavers and live patients, relationships and insertions are much as described by Robert Zacharin [1].

Acknowledgements. I am grateful to Professor Byron Kakulas and Drs V. Fabian, P. Panegyres and D. Dasig, from the Department of Neuropathology, Royal Perth Hospital, and also to Dr Robert Russell, consultant pathologist, for assistance with the histological studies.

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EDITORIAL COMMENT: The 'pubourethral ligament' was first identified and described anatomically by Zacharin in 1961. Much debate continues regarding the existence, identification and function of this structure. The present anatomical and histological study confirms the existence of the pubourethral ligaments, 'as described by Robert Zacharin', as a genuine anatomical structure in vivo. The study strengthens the recently reported findings of a discrete pubourethral ligament found on cadaveric dissection by Cruikshank and Kovac. The author then speculates as to the function of this ligament in maintaining continence, although no attempt is made in the study design to answer this very important question.