

Pubovesical Ligament: A Separate Structure From the Urethral Supports ("Pubo-Urethral Ligaments")

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The position and mobility of the vesical neck influences not only continence but also the initiation of micturition. During an examination of urethral topography, there appeared to be two structures running from the region around the vesical neck to the pelvic walls which might influence vesical neck function. These structures, the urethral supports ("pubo-urethral ligaments") and pubovesical ligaments, have previously been considered to be synonymous terms for a single structure. To investigate this disparity, 1,500 serial histologic sections from eight normal cadavers were examined, 28 cadavers were dissected, and whole pelvis cross sections from an embalmed cadaver were studied.

Our observations indicate that there are two structures which run from the region around the proximal urethra and vesical neck to attach to the pelvic walls. The pubovesical ligaments are an extension of the detrusor muscle and its adventitia. They attach to the pubic bone and arcus tendineus fasciae pelvis. Their structure suggests that they contract to assist in vesical neck opening but would be poorly suited to provide support for the proximal urethra. The other structures represent the urethral supports ("pubo-urethral ligaments") which connect the vagina and periurethral tissues to the muscles of the pelvic diaphragm and to the pelvic fasciae. Their structure appears to be adequate to explain urethral support.

There are, therefore, two structures running from the tissues around the vesical neck to the pelvic walls. The structure of the pubovesical ligament suggests that it could assist in vesical neck opening, and the urethral supports could determine urethral position.

Key words: stress urinary incontinence, urethral anatomy, lower urinary tract anatomy

INTRODUCTION

Clinicians have long recognized that the support of the urethra is important to urinary continence [Jeffcoate and Roberts, 1952; Hodgkinson, 1953]. In the past, urethral position has been considered to be a relatively static phenomenon ascribed to inert connective tissue supports ("pubo-urethral or puboprostatic ligament") [Krantz,

Received for publication July 28, 1988; accepted August 3, 1988.

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1951; Milley and Nichols, 1971; Zacharin, 1963]. More recently, examination of the lower urinary tract with fluoroscopy and sensitive pressure-measuring catheters has demonstrated the mobility and dynamic pressure variations which occur during voiding and during rapid rises in intra-abdominal pressure.

Observations of the bladder and urethra at the onset of micturition reveal an active pull on the anterior vesical neck said to favor its opening [Turner-Warwick, 1979; McGuire, 1979; Power, 1954], an observation not explained by the usual descriptions of urethral support. Previous descriptions of the structures controlling vesical neck position are primarily of ligamentous attachments between the pubic bones and proximal urethra favoring continence. These observations of events during the initiation of voiding raise the question as to whether or not there might exist another structure which could assist in vesical neck opening.

These two conflicting aspects of vesical neck function, continence during urine storage and an active vesical neck opening at the initiation of urination, are two different aspects of lower urinary tract function which involve the tissues around the vesical neck. During an examination of urethral topography [DeLancey, 1986] and the structure of the extrinsic continence mechanism [DeLancey, 1988], there appeared to be a second structure in addition to the urethral supportive tissues which might influence initiation of micturition. It corresponded to the anatomists' term the *pubovesical ligament*, and appeared as if it might affect the onset of micturition. It has been the opinion of authors writing about the urethral supports that the term *pubovesical ligament* is synonymous with the "pubo-urethral ligament" [Zacharin, 1963; Milley and Nichols, 1971]. Whether or not these two structures are the same or separate structures has not been specifically investigated. It is the purpose of the present study to examine the tissues which surround the vesical neck to determine whether there is a single structure influencing the vesical neck (pubo-urethral = pubovesical ligament), or whether there are two separate structures which correspond to the two functions ascribed to this area—continence and initiation of micturition.

MATERIALS AND METHODS

The observations in this study were based on dissection of fresh and embalmed cadavers; serial histologic sections of the urethra, anterior vaginal wall, pubic bones, and pelvic diaphragm; and cross sections of the pelvic viscera.

Dissections of fresh cadavers were performed in the autopsy room of the University of Michigan Hospitals and of Wayne County General Hospital. Fourteen unembalmed cadavers ranging from 28 to 78 years of age (mean 53 years) were dissected. All had normal pelvic support evident on examination. Two were apparently nulliparous and three had previously undergone hysterectomy.

The space of Retzius was opened widely and a careful dissection of the urethra, bladder, vesical neck, vagina, and pelvic floor musculature was carried out, focusing on the connections of the viscera to the pubic bones and pelvic walls. In these dissections, which extended as far caudally as the superior aspect of the urogenital diaphragm, the strength of the various connections between the viscera (urethra, vesical neck, and vagina) and the pelvic wall (pubic bone, pelvic diaphragm and fasciae) were tested subjectively by pulling on them until they broke.

Preserved cadaver dissections were carried out in 14 female bodies ranging in age from 46 to 106 years (with a mean age of between 50 and 60 years). Two had

undergone hysterectomy and two were apparently nulliparous. Complete dissections as described for unembalmed cadavers were carried out. In addition, dissections of the urogenital diaphragm and external genital muscles were performed in these specimens.

For our microscopic studies 1,500 serial histologic sections made previously by Dr. Thomas Oelrich [1983] of the Department of Anatomy were examined. To prepare these slides, the pelvic viscera and their surrounding bone and muscle, were removed from eight cadavers ranging in age from 0 to 37 years. Specimens were fixed in 10% formalin. After the tissues were firmly solidified, the calcified portions of the pubic rami were removed and some specimens were cut in half in the mid-sagittal plane. Each specimen was embedded in paraffin and serial sections of approximately 25 μm thickness were made in either the horizontal, frontal, or sagittal plane. These sections were then mounted on 2 \times 3-in glass slides. Each slide was numbered to show the sequence of section. These tissues were then stained with a Mallory trichrome stain. In some series, alternate sections were stained specifically for elastin.

The serial sections were examined microscopically to determine the histologic nature of these tissues. The fiber orientation within these tissues was also determined with an 8 \times magnifying loupe and correlated with macroscopic observations. The identification of the different tissues studied was reviewed and confirmed by Dr. Theodore V. Fischer, of the Department of Anatomy. Distinction between smooth muscle and fibroblasts was made on histologic grounds since the stain employed does not always differentiate these tissues by staining characteristics.

Finally, horizontal cross sections were made of the intact pelvis from a nulliparous cadaver, 30 years of age. To do this the embalmed cadaver was frozen in dry ice and serial sections of the pelvis were cut in the horizontal plane at between 6- and 7-mm intervals on a band saw.

RESULTS

Before beginning a description of the pubovesical and pubo-urethral ligaments, a brief review of the space of Retzius' anatomy is necessary to understand the lateral attachments of these ligaments. On each side of this space, a band of connective tissue runs from the back of the pubic bone to the ischial spine (Fig. 1). This band is called the arcus tendineus fasciae pelvis, or the white line of the pelvis. It originates 1 cm from the midline and 1 cm above the inferior edge of the pubic symphysis. Near its origin, it is usually thin and well defined. Posteriorly as it approaches the ischial spine, it becomes broader and blends into the fasciae of the obturator internus muscle and levator ani from which it is derived.

A second white line, the arcus tendineus levator ani, is made up of the white tendons at the end of each of the fibers of the iliococcygeus portion of the levator ani muscle, which are lined up like a "picket fence" where they join the fascia of the obturator internus muscle. It can be seen from the inner surface of the pubic bone to the ischial spine on the obturator internus fascia from which the muscle originates, and should not be confused with the arcus tendineus fasciae pelvis.

A superficial structure that runs from the vesical neck to the pelvic walls is the pubovesical muscle (Figs. 1,2). It is composed of a group of smooth muscle fibers which originate from the detrusor muscle at the vesical neck and insert into the

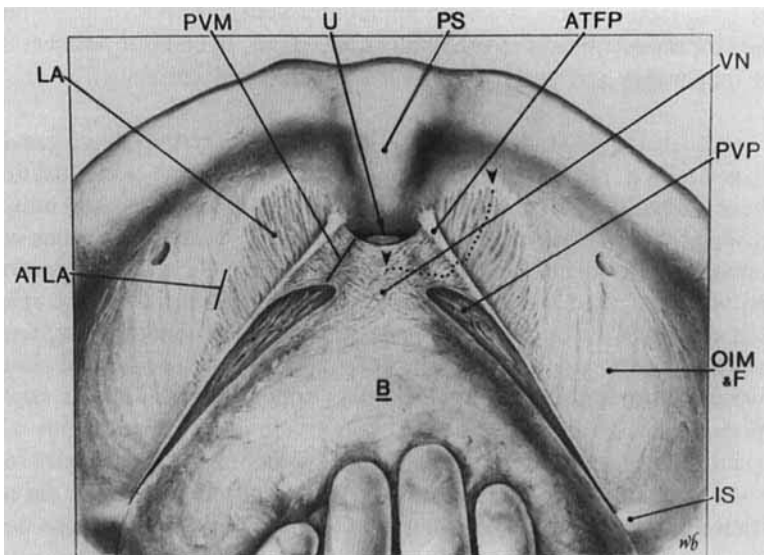


Fig. 1. Space of Retzius (drawn from cadaver dissection). Pubovesical muscle (PVM) can be seen going from vesical neck (VN) to arcus tendineus fasciae pelvis (ATFP) and running over the paraurethral vascular plexus (PVP). ATLA = arcus tendineus levator ani; B = bladder; IS = ischial spine; LA = levator ani muscles; OIM&F = obturator internus muscle and fascia; PS = pubic symphysis; U = urethra. Dotted lines indicate plane of section of Figures 2 and 3.

anterior portion of the arcus tendineus fasciae pelvis (Figs. 3,4). At the level of the vesical neck, these muscle fibers blend with the other smooth muscle fibers of the detrusor. They run in a transverse band across the anterior portion of the urethrovesical junction and can be seen as separate bundles for a short distance before becoming lost among the other detrusor fibers. Below the vesical neck the fibers of the pubovesical muscle lie anterior to the upper half of the urethra. These fibers, which lie over the urethra, are only loosely attached to its anterior surface, in contrast to the direct connection of these fibers on the anterior aspect of the vesical neck.

The arrangement of the smooth muscle fibers in the pubovesical muscle is similar in histologic appearance to the rest of the fibers of the bladder dome. The coarse texture of the smooth muscle bundles of the pubovesical muscle and detrusor are unlike the muscle of the urethra, trigone, or vaginal wall (Fig. 4). The pubovesical muscle is embedded in connective tissue, and when the muscle fibers and this connective tissue investment are considered together, they are called the pubovesical ligament.

The pubovesical muscles are delicate and, like other smooth muscle, easily torn. When they are lifted upward, a plexus of blood vessels can be seen running underneath them and along the lateral aspect of the urethra. This paraurethral vascular plexus contains vessels (Figs. 1-3) derived from the vaginal, inferior vesical, and possibly the pudendal vessels. They separate the pubovesical ligaments from the underlying urethral supports ("pubo-urethral ligaments").

Once the pubovesical muscles and the underlying blood vessels have been removed, the tissues which support the urethra can be seen. These urethral supports

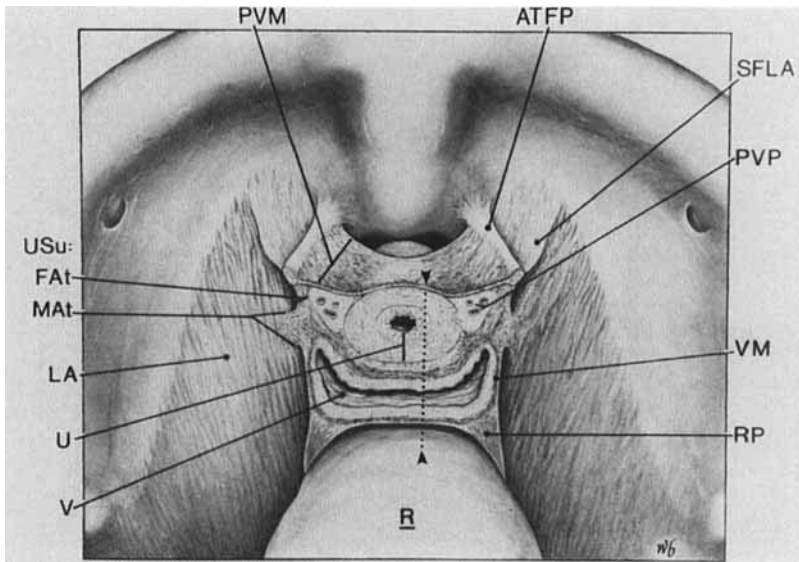


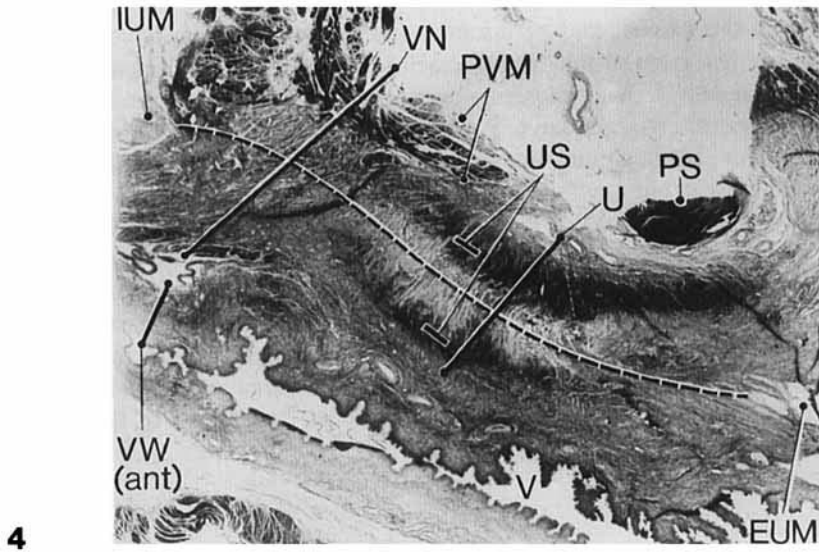
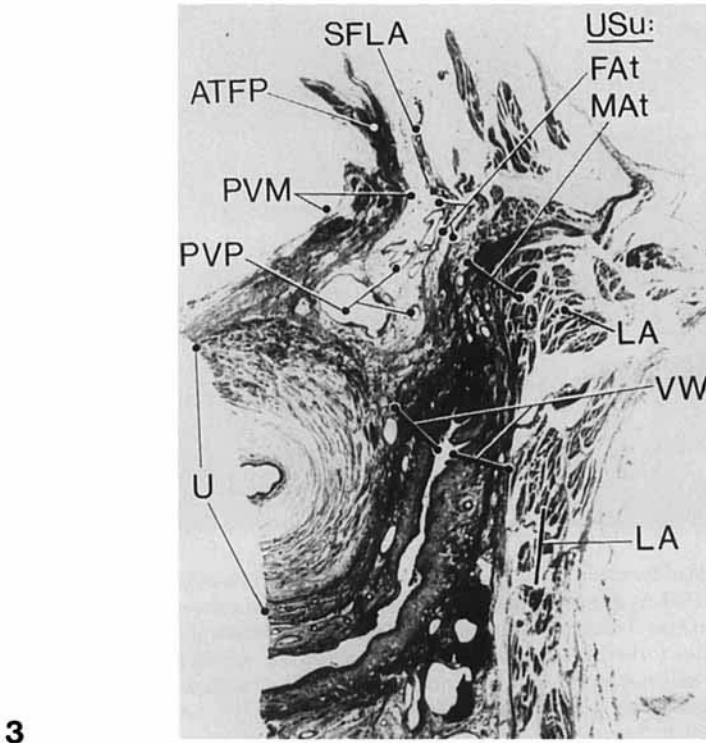
Fig. 2. Cross section of the urethra (U), vagina (V), arcus tendineus fasciae pelvis (ATFP), and superior fascia of levator ani (SFLA) just below the vesical neck (drawn from cadaver dissection). Pubovesical muscles (PVM) lie anterior to urethra and anterior and superior to paraurethral vascular plexus (PVP). The urethral supports (USu) (“the pubo-urethral ligaments”) attach the vagina and vaginal surface of the urethra to the levator ani muscles (MAAt = muscular attachment) and to the superior fascia of the levator ani (FAt = fascial attachment). Additional abbreviations: R = rectum; RP = rectal pillar; VM = vaginal wall muscularis; LA = levator ani muscles. Dotted lines indicate plane of section for Figure 4.

are made of a dense connective tissue which can be seen beside the urethra arising primarily from the vagina, and periurethral tissues to attach laterally to the pelvic wall. There are two parts of this lateral attachment, a fascial attachment to the arcus tendineus fasciae pelvis, and a muscular attachment to the medial edge of the levator ani. These supportive tissues have traditionally been called the (posterior) pubo-urethral ligaments, although they do not insert exclusively into the pubic bone nor do they attach directly to the urethra.

The relative prominence of the arcus tendineus fasciae pelvis and pubovesical ligaments varied from one cadaver to the next. For example, the pubovesical ligament may be strikingly evident with relatively unapparent urethral supports, or, in another specimen, the situation may be reversed. When the arcus tendineus fasciae pelvis is not apparent as a discrete line, there is a generalized thickening in the fascia over the pubococcygeus and obturator internus muscles in this area, which takes its place functionally. The foregoing descriptions represent an “average” of the variations seen.

DISCUSSION

As clinicians began to recognize that the position of the proximal urethra and its relationship to the bladder base (posterior urethrovesical angle) were important in urinary continence the following question arose: What structure offers this support?



Figs. 3, 4

Gross anatomic studies [Krantz, 1951; Milley and Nichols, 1971; Zacharin, 1963] which discussed the structure responsible for maintaining the posterior urethrovesical angle described a mass of connective tissue which ran from the area of the proximal urethra toward the pubic bone which became taut and resisted further displacement when the urethra was pulled downward. This connective tissue was called the posterior pubo-urethral [Zacharin, 1963] or pubo-prostatic ligament [Krantz, 1951] and considered to be synonymous with the anatomical term the *pubovesical ligament* [Milley and Nichols, 1971; Zacharin, 1963]. Following this convention, we called the pubovesical ligament the pubo-urethral ligament in a previous report [DeLancey, 1986] before recognizing the difference between these two structures.

As more has been learned about the physiology of this area, it is now apparent that all aspects of vesical neck position cannot be adequately explained by a single ligamentous attachment between the proximal urethra and the pubic bones as is implied by the term *pubo-urethral ligament* and considering it to be synonymous with the pubovesical ligament. Two conflicting functions have been ascribed to these tissues. First, they have been described [Krantz, 1951; Zacharin, 1963] as the tissues which support the urethra and keep the vesical neck closed. Second, an active opening of the vesical neck has been observed [Turner-Warwick, 1979; McGuire, 1979] and has been attributed to contraction of the pubovesical ligament [Power, 1954].

Our histologic examination of this region has revealed that there are two different groups of fibers embedded within the connective tissue in the region of the vesical neck. The subtle nature of the separation between these tissues and similar macroscopic appearance of smooth muscle and inert connective tissue may explain why this distinction had not previously been recognized. Although the difference between these structures is best seen histologically, once their microscopic structure was appreciated, it was possible to demonstrate them on gross dissection as well. These different tissues correspond to the two different aspects of vesical neck functions mentioned above. These are 1) the pubovesical ligaments and 2) the urethral supports ("pubo-urethral ligaments").

Within the pubovesical ligaments are bands of smooth muscle similar in appearance to, and continuous with, the detrusor muscle. This muscle is appropriately called the pubovesical muscle, and makes up the bulk of the pubovesical ligament. It has been described by both Woodburne [1968] and Gil-Vernet [1968] (named the

Fig. 3. Cross section of the urethra (U), vaginal wall (VW), and levator ani muscles (LA) from the right half of the pelvis taken just below the vesical neck at approximately the same level shown in Figure 2. The pubovesical muscles (PVM) can be seen anterior to the urethra and the periurethral vascular plexus (PVP) and attach to the arcus tendineus fasciae pelvis (ATFP). Urethral supports (USu) run underneath (dorsal to) the urethra and vessels. Some of its fibers (MA_t) attach to the muscle of the levator ani (LA), while others (FA_t) are derived from the vaginal wall (VW) and vaginal surface of the urethra (U) and attach to the superior fascia of the levator ani (SFLA). Magnification × 5.

Fig. 4. Sagittal section of vesical neck (VN), urethra (U), and anterior vaginal wall (VW (ant)) cut lateral to the urethral lumen (position indicated by broken line). Bladder at upper left, external urethral meatus lower left. Pubovesical muscle (PVM) is visible anterior to the urethra and can be seen to resemble detrusor muscle which is visible anterior to the internal urethral meatus (IUM). Additional abbreviations: EUM = external urinary meatus; US = urethral sphincter (striated muscle); PS = pubic symphysis. Magnification × 2.5.

precervical arc by the latter author). The only difference the present study finds is in the attachment of these fibers primarily to the arcus tendineus fasciae pelvis rather than the pubic bones. These tissues are not suited to provide urethral support, but could, as other authors have hypothesized [Power, 1954; Ingleman-Sundberg 1949], explain the active opening of the vesical neck seen at the onset of micturition.

The other structure, the urethral supports, comprises the clinically evident supportive tissues of the urethra. We have chosen the term *urethral supports* rather than *posterior pubo-urethral ligaments* for these tissues because we feel it reflects the diverse nature of the tissues which work together to achieve urethral support. It avoids the implication that these are inert ligamentous bands attaching the urethra directly to the pubic bones. This term, therefore, denotes a group of fibrous tissues with a similar function, and as such is a usage similar to the term *inner ear*, which represents a multifaceted functional unit.

The urethral supports are composed of the attachment of the vagina and periurethral tissues to the pelvic walls (one fascial and one muscular) and are separated from the pubovesical ligaments by a para-urethral vascular plexus and lie posterior to the urethra. These structures seem well suited to provide the clinically evident support of the urethra, and correspond to the support tissues traditionally called the posterior "pubo-urethral ligaments," even though they are derived primarily from the vagina rather than the urethra and do not attach directly to the pubic bones but insert into the pelvic fasciae and muscles. Because of the intimate connection of the urethra to the vagina [Krantz, 1951], these supports could influence urethral position, even though they are not directly connected to it. These lateral attachments have previously been described by White [1909] and Richardson et al., [1981], and their contribution to urinary continence is supported by the success with which their surgical repair alleviates stress incontinence [Richardson et al., 1981]. The detailed nature and structure of these tissues are the subject of ongoing study and will be the subject of a future report.

The problem which arises in considering the pubovesical ligaments and the urethral supports (posterior "pubo-urethral ligaments") to be synonyms for a single structure is illustrated in the study by Wilson et al. [1983], who found that the bladder fibers running from the vesical neck to the pelvic walls (and called the "pubo-urethral ligaments" in their report) are the same in patients with and without incontinence. The unexpected implications of this observation that the supportive tissues of the urethra are unchanged in patients with stress incontinence, however, rest upon the assumption that the terms *pubo-urethral ligament* and *pubovesical ligament* are synonyms and is in conflict with clinical concepts of stress incontinence and urethral support. The findings of the present study indicate that the tissues sampled in Wilson's study were the pubovesical ligament and not the supportive tissues of the urethra, and this explains why they were no different in continent and stress-incontinent patients.

The exact interplay between these two tissues is yet to be determined. Certain problems, such as the difficulty some patients experience postoperatively when the urethra was fixed in position, may reflect a disturbance of the normal interplay of these two tissues. The findings of the present study, separating these two structures, may help us to a better understanding of urethrovesical physiology as studied by current and future urodynamic techniques.

CONCLUSIONS

The pubovesical ligaments are separate structures from the urethral supportive tissues (“pubo-urethral ligaments”). Recognition of this fact should help provide a sound morphologic basis for understanding observations of lower urinary tract physiology.

ACKNOWLEDGMENTS

The author would like to thank Dr. Thomas M. Oelrich for making available the histologic material used in this study.

REFERENCES

- DeLancey JOL (1986): Correlative study of paraurethral anatomy. *Obstet Gynecol* 68:91–97.
- DeLancey JOL (1988): Structural aspects of the extrinsic continence mechanism. *Obstet Gynecol* 72:296–301.
- Gil-Vernet S (1968): “Morphology and Function of the Vesico-Prostato-Urethral Musculature.” Trevisio: Libreria Editrice Canova, pp 39–40.
- Hodgkinson CP (1953): Relationships of the female urethra in urinary incontinence. *Am J Obstet Gynecol* 65:560–573.
- Ingleman-Sundberg A (1949): The pubovesical ligament in stress incontinence. *Acta Obstet Gynecol Scand* 28:183–188.
- Jeffcoate TNA, Roberts H (1952): Observations on stress incontinence of urine. *Am J Obstet Gynecol* 64:721–738.
- Krantz KE (1951): The anatomy of the urethra and anterior vaginal wall. *Am J Obstet Gynecol* 62:374–386.
- McGuire E (1979): Urethral sphincter mechanisms. *Urol Clin North Am* 6:39–49.
- Milley PS, Nichols DH (1971): Relationship between the pubo-urethral ligaments and the urogenital diaphragm in the human female. *Anat Rec* 170:281–283.
- Oelrich TM (1983): The striated urogenital sphincter muscle in the female. *Anat Rec* 205:223–232.
- Power RMH (1954): An anatomical contribution to the problem of continence and incontinence in the female. *Am J Obstet Gynecol* 67:302–314.
- Richardson AC, Edmonds PB, Williams NL (1981): Treatment of urinary incontinence due to paravaginal fascial defect. *Obstet Gynecol* 57:357–362.
- Turner-Warwick R (1979): Observations on the function and dysfunction of the sphincter and detrusor mechanisms. *Urol Clin North Am* 6:13–30.
- Wilson PD, Dixon JS, Brown ADG, Gosling JA (1983): Posterior pubo-urethral ligaments in normal and genuine stress incontinent women. *J Urol* 130:802–805.
- White GR (1909): Cystocele: A radical cure by suturing lateral sulci of vagina to white line of pelvic fascia. *JAMA* 53:1707–1710.
- Woodburne RT (1968): Anatomy of the bladder and bladder outlet. *J Urol* 100:474–487.
- Zacharin R (1963): The suspensory mechanism of the female urethra. *J Anat* 97:423–427.