

ANATOMY OF THE URETHRAL SUPPORTING LIGAMENTS DEFINED BY DISSECTION, HISTOLOGY, AND MRI OF FEMALE CADAVERS AND MRI OF HEALTHY NULLIPAROUS WOMEN

Hypothesis / aims of study

There has been no uniformity of opinion concerning the structures supporting the female urethra. Therefore, the aims of this prospective study were to define precisely the female urethral support structures at cadaveric anatomic dissection and histologic examination

and to determine which of these structures can be detected on MRI of cadaveric specimens and of healthy volunteers.

Study design, materials and methods

Dissection of seven formalin-preserved cadavers (age at death, 25–50 years; no parity history available) was performed by a professor of anatomy to explore the anatomy of the urethral supporting ligaments and was followed by MRI of the cadaveric specimens with ligamentous markers in place and then by histologic analysis of the dissected ligaments. MRI of 17 healthy nulliparous women (age range, 20–35 years; mean age, 25.5 years) was then performed using T2-weighted, dual turbo spin-echo, balanced fast-field echo, and STIR sequences. A standardized grid system that allowed us to record structural observations on sequentially numbered axial MR images was used by a radiologist who then applied a 4-point grading scale to assess ligament visibility. Three authors—one radiologist, one anatomist, and one urologist—then compared the appearance of each ligament seen in a cadaveric specimen with its appearance on MR images of the same cadaver and on MR images of volunteers

Results:

At cadaveric dissection we identified ventral and dorsal urethral ligaments. The ventral urethral ligaments included the pubourethral ligaments, which were found to consist of three separate components coursing anteroposterior from the bladder neck to the pubic bone (Fig 1); the periurethral ligament; and the paraurethral ligaments. Dorsal to the urethra, a slinglike ligament, which we believe should be named the “suburethral ligament,” was identified. This ligament had a distinct plane of cleavage from the anterior vaginal wall. The MRI findings in the volunteers correlated with the MRI and gross anatomic findings in the cadavers. The proximal pubourethral, periurethral, paraurethral, and suburethral ligaments had visibility scores of 3 (moderately visible) or 4 (easily visible) on MRI in 47%, 65%, 47%, and 53% of volunteers, respectively (Table 1).

Table (1) Compiled data of the 17 volunteers assessing the normal location and visibility of urethral ligaments on axial T2 weighted turbo-spin echo MR images.

Ligament	*Images number and MC	Sequence needed	The ligament was better visualized on which side	Visibility score (graded from 1 not visible to 4 easily visible)
Pubourethral	Images: *+1 and +2 MC: +1	T2WI TSE **Axial oblique BFFE	On both sides in 7 volunteers 41% On left side in 5 volunteers On right side in 2 volunteers	3 or 4 in 8 volunteers (47%) 2 in 6 volunteers 1 in 3 volunteers Mean: 2.5, Median: 2, Mode: 2
Periurethral	Images: +1 to +6 MC: +2, +3, +4	T2WI TSE	On both sides in 13 volunteers 76% On left side in 2 volunteers On right side in 2 volunteers	3 or 4 in 11 volunteers (65%) 2 in 6 volunteers Mean: 3.1 Median: 3, Mode: 4
Paraurethral	Images: +2 to +4 MC: +2	T2WI TSE	On both sides in 4 volunteer On left side in 5 volunteers 41% On right side in 2 volunteers	3 or 4 in 8 volunteers (47 %) 2 in 3 volunteers 1 in 6 volunteers Mean: 2.2 Median: 2, Mode: 1
Suburethral	Images: +1 to +4 MC: +2	T2WI TSE **Axial STIR	On both sides in 12 volunteers 71%. On left side in 1 volunteers On right side in 1 volunteers	3 or 4 in 9 volunteers (53%) 2 in 5 volunteers 1 in 3 volunteers Mean: 2.6 Median: 3, Mode: 3

* Images number, images on which ligament could be seen; MC, image(s) on which the ligaments was most commonly seen. # Numbers are in reference to the arcuate pubic ligament (APL), with positive numbers indicating a cephalad location in relation to this ligament. ** indicates special technique needed to best visualize the ligament. T2WI TSE, axial T2-weighted turbo spin-echo; BFFE, balanced fast field echo; STIR, short time inversion –recovery.

Interpretation of results

Both our anatomic cadaveric dissections and subsequent MR imaging evaluation of cadavers and volunteers have proved that: a. The pubourethral ligaments (PUL) consist of three closely associated paired ligaments: the proximal, intermediate and distal PUL, coursing anteroposterior from the bladder neck to the symphysis pubis. b. To our knowledge, the current study is the first to demonstrate that the proximal PUL can be detected on MR images of living volunteers c. The ligaments dorsal to urethra, which we have found do not originate from the urethra or from the vagina, but run retro-urethral forming a suburethral sling.

Implications for Patient Care: a. True consensus on the definition and function of and the names given to the minute structures

supporting the urethra may eventually serve to improve our understanding of the functional urethral anatomy, as well as of the anatomic rationale for successful surgical repair. B. With the improved knowledge of female periurethral anatomy resulting from our study, other series, including outcome-related investigations, can be initiated to evaluate further the role of MRI in the management of patients with stress urinary incontinence.

Concluding message

Our results present evidence that may help resolve previous controversies regarding the MR appearance of the ventral urethral ligaments and that better define the course of the ligament dorsal to the urethra, the suburethral ligament. We hope that this detailed anatomic information about the structures involved in continence may lead eventually to improvements in the treatments for women with stress urinary incontinence.

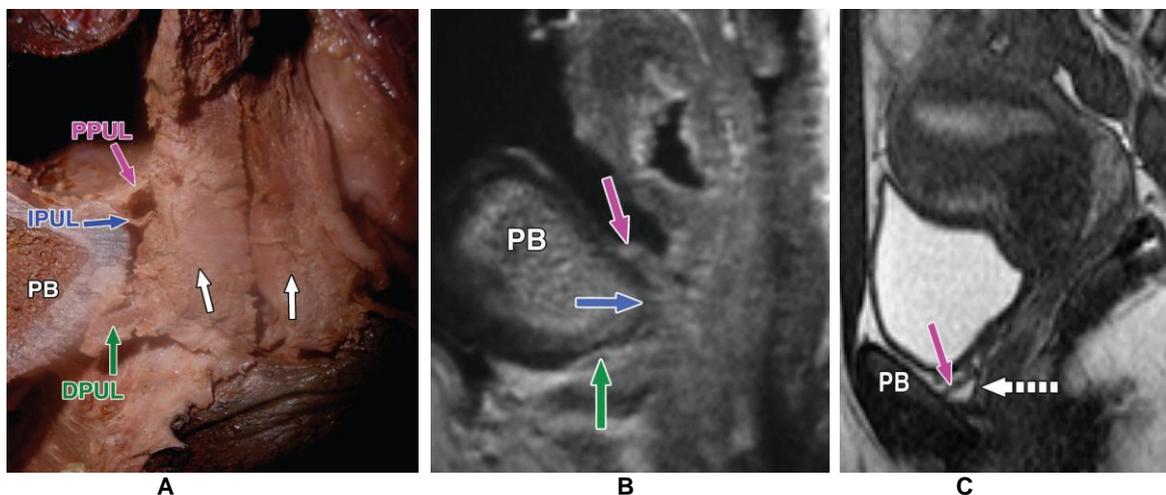


Fig. 1—Anatomic dissection and MR images of pubourethral ligaments (PULs) in cadaver with corresponding MR appearance of PULs in healthy nulliparous volunteer. **A**, Digital image of sagittal section from female cadaver shows three PULs coursing anteroposterior from pubic bone (PB) to urethra: proximal PUL (PPUL, pink arrow), intermediate PUL (IPUL, blue arrow), and distal PUL (DPUL, green arrow). White arrows delineate anterior and posterior urethral wall. **B**, sagittal proton density MR images (TR/TE, 4,000/18) of cadaver shown in **A**, shows the proximal PUL (pink arrow), intermediate PUL (blue arrow), and distal PUL (green arrow); all are of intermediate signal intensity. PB = pubic bone. **C**, Sagittal T2-weighted turbo spin-echo MR image (5,000/132) in 28-year-old female volunteer shows proximal PUL (pink arrow) with its bone attachment to back of pubic bone (PB) at junction of its upper two thirds and lower one third. White arrow points to periurethral ligament.

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Was the Declaration of Helsinki followed?	Yes
Was informed consent obtained from the patients?	Yes