Urethral Sphincter Morphology and Function With and Without Stress Incontinence

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Purpose: Using magnetic resonance images we analyzed the relationship between urethral sphincter anatomy, urethral function and pelvic floor function.

Materials and Methods: A total of 103 women with stress incontinence and 108 asymptomatic continent controls underwent urethral profilometry, urethral axis measurement with a cotton swab, vaginal closure force measurement with an instrumented speculum and magnetic resonance imaging. Striated urogenital sphincter length was determined and its thickness was measured in the proximal sphincter, where its circular shape enables estimation of striated urogenital sphincter area. A length-area index was calculated as a proxy for volume.

Results: The striated urogenital sphincter in women with stress incontinence was 12.5% smaller than that in asymptomatic continent women (mean ± SD length-area index 766.4 ± 294.3 vs 876.2 ± 407.3 mm^3, p = 0.04). The groups did not differ significantly in striated urogenital sphincter length (13.2 ± 3.4 vs 13.7 ± 3.9 mm, p = 0.40), thickness (2.83 ± 0.8 vs 3.11 ± 1.4 mm, p = 0.09) or area (59.1 ± 18.4 vs 62.9 ± 24.7 mm^2, p = 0.24). Striated urogenital sphincter length and area, and the length-area index were associated during voluntary pelvic muscle contraction with more urethral axis elevation and increased vaginal closure force augmentation.

Conclusions: A smaller striated urogenital sphincter is associated with stress incontinence and poorer pelvic floor muscle function.

Key Words: urethra; urinary incontinence, stress; magnetic resonance imaging; female; muscle, striated

Abbreviations and Acronyms

CU/UVS = compressor urethra/urethrovaginal sphincter

KUCP = urethral closure pressure Kegel augmentation

MRI = magnetic resonance imaging

MUCP = maximum urethral closure pressure

POP-Q = Pelvic Organ Prolapse Quantification

SUS = striated urogenital sphincter

VCF = vaginal closure force

Submitted for publication November 10, 2008.

Study received institutional review board approval.

Supported by Office of Research on Women's Health and NICHD P50 HD 044406.

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† Financial interest and/or other relationship with Johnson & Johnson and American Medical Systems.

THE relative importance of urethral function and support has long been a controversy in evaluating and treating urinary incontinence. In the Research On Stress Incontinence Etiology study we recently reported the unexpected finding that urethral function measures were more strongly associated with stress incontinence than those of urethral support when women with stress incontinence were compared with asymptomatic matched controls.[1] MUCP in women with stress incontinence was 42% lower than that in women matched for age, race, parity and hysterectomy status, and it had an effect size that was remarkably higher than any other variable. (Effect size is a measure to determine how effective a variable is for distinguishing 2 populations and it is calculated by taking the difference of 2 population means divided by the pooled population SD.) MUCP effect size was 1.5, whereas measures of urethral support (point Aa, urethral axis movement by cotton swab

0022-5347/09/1821-0203/0
THE JOURNAL OF UROLOGY®

Vol. 182, 203-209, July 2009
Printed in U.S.A.
DOI:10.1016/j.juro.2009.02.129

testing) were no larger than 0.6. We explored whether differences in urethral sphincter anatomy could account for the differences in urethral function observed in these cohorts with and without stress incontinence.

MRI is an established means of studying the female urethra. It has been used clinically since the 1990s to evaluate urethral diverticula and neoplasms.[2] Strohbehn et al established the histological and radiological identification of its layers.[3] Several studies of normal asymptomatic women showed that urethral anatomy can be visualized with MRI.[4–7] However, to our knowledge differences in women with and without pelvic floor dysfunction have been not been directly compared and analyzed. We compared SUS length, thickness, area and volume estimates in women with and without stress incontinence, and explored the relationship between measures of sphincter size and other pelvic floor function tests.

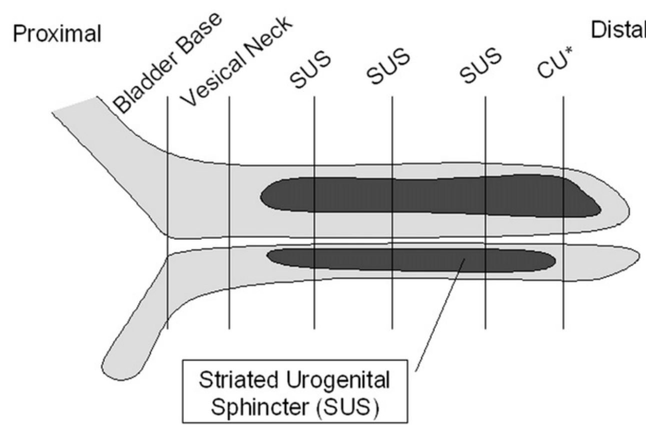

Figure 1. Characteristic anatomical urethral regions divided by 5 mm slice thickness. Urethral length equals number of slices from bladder base to SUS, vesical neck length equals number of vesical neck slices and SUS length equals number of SUS slices with each slice at 5 mm intervals. Asterisk indicates that slice contains CU/UVS and is part of SUS.

MATERIALS AND METHODS

This case-control cohort study included 103 women with daily stress urinary incontinence and 108 asymptomatic continent controls.[1] Study inclusion and exclusion criteria, the protocol and the groups were described in the original report.[1] Briefly, women with stress incontinence and asymptomatic controls who had never undergone surgery for pelvic floor disorders were recruited through university based gynecology and urology clinics, and local advertisements. Stress continence was confirmed by a 3-day diary and full bladder stress testing. Group matching was done based on factors associated with stress incontinence, including age, race, parity and hysterectomy status. The protocol included urethral profilometry, POP-Q, cotton swab urethral axis determination, VCF with an instrumented speculum and MRI to assess levator ani defect status using a previously described system.[8]

Urethral Length

Identifying characteristic female urethral structures on MRI was based on our previous anatomical study,[9] and on comparison of anatomy and MRI scans.[3] Axial MRI scans in each individual were reviewed to determine slices containing the bladder base, the vesical neck and SUS, including CU/UVS (fig. 1).[7] Figure 2 shows an example using MRI. Each slice was considered to have a single predominant region, that is each slice was identified as the bladder base, vesical neck or SUS but not 2 designations. The length of the vesical neck, SUS and total urethral length were calculated by multiplying the number of slices in which these structures were seen by the 5 mm interval between each slice.

SUS Thickness Measurements and Area Estimations

All axial MRI slices determined to contain SUS were analyzed quantitatively (fig. 3). When outer and inner SUS edges were well enough defined, they were digitally measured with Image J, version 1.34 (National Institutes of Health, Bethesda, Maryland). SUS thickness was calculated by taking the difference between the outer and inner diameters, and dividing by 2 (fig. 3). Measurements of each analyzed MRI slice were reviewed by at least 2 of us. Proximal portions of SUS are best suited to measurement because the borders are usually well-defined and approximate a circle. SUS distal portions, including CU/UVS, cannot be analyzed quantitatively in this way because the muscle forms a strap over the urethra and not an encircling ring.[6] SUS area was calculated as the difference between the circular areas represented by the outer and inner diameters (fig. 4). The number of trilaminar urethral slices in which the mucosa, submucosa and SUS were seen as clearly distinct layers were counted.

Length-Area Index as Volume Proxy

A length-area index was developed as a composite estimate of volume. It was calculated by multiplying the mean SUS area in the 2 most proximal slices by SUS length. Proximal rather than distal SUS slices were better suited to quantitative area measurement, as described. Furthermore, the proximal SUS is the site where striated muscle length and thickness are lost with aging.[10] The average of the areas in the first 2 SUS slices was used. When only 1 SUS slice was present, the area of the single slice was used.

RESULTS

Original Report Findings

Demographics of the stress incontinent and continent groups that were previously described[1] are briefly summarized. Women with and without stress incontinence did not differ in age, parity, race, menstrual status, percent receiving hormone replacement therapy or hysterectomy status. Those with stress incontinence had a higher body mass index than continent women (mean ± SD 30.4 ± 6.6 vs