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# Cough transmission pressure to the bladder and urethra among continent and incontinent elderly women

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## Abstract

Although cough transmission pressures to the bladder and urethra are now being measured as part of the evaluation of an incontinent woman, there has not been a comprehensive study specifically focused among continent and incontinent non-institutionalized elderly women in order to understand the meaning of such measurements. To determine the characteristics and significance of the cough transmission pressures to the bladder and urethra, measurements were obtained from 69 continent and 100 incontinent elderly female respondents as part of an extensive urodynamic testing. Results showed that during coughing in the standing position, the increase in bladder pressure is significantly stronger among stress incontinent respondents than among continent and non-stress incontinent respondents ($p = 0.0022$). The increase in urethral pressure in the same group is marginally significant ($p = 0.066$). The mean transmission pressure ratio (urethral pressure ÷ bladder pressure) is less than 100% in all groups. They were higher among continent respondents (90%) and non-stress incontinent respondents (97%) than stress incontinent respondents (83%); however, the mean values between the 3 groups were not significantly different. The mean cough transmission pressures were significantly higher among chronic coughers than non-chronic coughers. When controlled for chronic coughing, the stress incontinent respondents have a significantly higher bladder pressure than continent and non-stress incontinent respondents. Significance of these findings in relation to the mechanisms of female geriatric incontinence are presented.

## Introduction

Advances in microtransducer technology and multichannel recorders have enabled us to investigate simultaneously many lower urinary tract functions with relative ease. Specifically, simultaneous measurements of intravesical, intraurethral and intrarectal pressures have been simplified so that these measurements are now becoming common procedures in the evaluation of patients with vesico-urethral dysfunctions. Although urethral profilometry (UPP) as a diagnostic test is controversial, one test that is gaining popularity is the measurements of cough transmission pressure to the bladder and urethra in the assessment of patients with urinary incontinence, either in the pre-operative or post-operative period [1, 2, 6].

To date, however, there has been no comprehensive study to analyze characteristics and the significance of the transmitted pressures to the bladder and urethra as well as the transmission pressure ratios among continent and incontinent elderly women. A study on urethral pressures must separate results by age group since urethral pressures differ significantly between younger and older age groups [3, 4]. To study the characteristics and significance of these pressures in the elderly, a subsample of the continent and incontinent volunteer respondents in our Medical, Epidemiologic, and Social Aspects of Aging (MESA) survey among non-institutionalized elderly in Wastenaw County, Michigan underwent both a clinical and urodynamic examination [5]. In this paper, we present results from these examinations.

## Materials and methods

The subjects consisted of 1953 respondents 60 y and older who were identified and consented to be interviewed in their home from a random probability sample of 13912 households in the county of Washtenaw, Michigan. (Two additional subjects who refused to give their ages are omitted from the analyses).

Of the 1953 household respondents interviewed, 1806 seniors were invited through telephone calls to visit the University of Michigan Turner Geriatric Clinic. The free clinic evaluation included answering a 40-min questionnaire similar to the one that they answered in their homes, a complete physical examination, including rectal and pelvic examination, and an analysis of the urine (dipstick and microscopic). At the end of the clinic visit all subjects were invited to undergo a free urodynamic testing. A total of 69 continent and 100 incontinent women ultimately participated in the testing.

The urodynamic testing started with an initial noninstrumented uroflowmetry and post-void residual urine measurement. An esophageal membrane catheter was inserted into the rectum for continuous abdominal pressure readings. A double sensor 8F microtransducer then was inserted and the sensors were placed appropriately with the aid of the fluoroscope. The tip sensor was placed inside the bladder and the proximal sensor was placed facing the lateral wall of the mid urethra. This position was taken to maintain consistency of measurement and reduce pressure variability as observed in the recordings from the anterior and posterior positions [12]. Cystometry with simultaneous urethral and rectal pressure measurements was performed with a flow rate of 100 mL $min^{-1}$ of 25% sodium diatrizoate solution. Bladder capacity was considered to be reached when tonus limb 3 was observed, when the subject complained of severe urge or when an intense desire to void, or a strong uninhibited detrusor contraction occurred. At the conclusion of cystometry passive (static) and dynamic urethral profilometry was performed with the participants in the supine and standing positions. At the conclusion of the urethral pressure profile, a pressure flow study (PFS) was performed.

At the conclusion of the PFS, provocative stress testing was performed by recatheterizing the respondent and filling the bladder to cystometric capacity with sterile water.

After the anatomic urethral lengths were measured in the supine and then in the standing position, the catheter was removed. The subject, still in the standing position was then asked to cough vigorously three times to provoke any fluid loss per urethra. Any fluid loss was considered a positive result. The volume of urine leaked was also measured.

At the termination of the tests all participants were sent home with either 50 mg nitrofurantoin macrocrystals 3 times a day or trimethoprim-sulfamethoxazole twice a day for 3 days.

### *Demographic data and health status*

There were 156 (92%) white women and 13 (8%) nonwhite women participants to the urodynamic testing. This compared to 91% of white household respondents and 9% of nonwhite household respondents. At the urodynamic testing, there were 66% participant in the 60—69 age group, 27% in the 70—79 age group and 7% in the 80 year and older group. The self-assessed health status at the time of clinical evaluation was considered good to excellent by 94% of continent women and 87% of incontinent women who underwent urodynamic evaluation.

### *Continence status in the household survey and the clinical evaluation*

The continence status and the clinical types of incontinence at the household interview were based on a series of questions presented in an earlier report [5]. The continence status at the clinical evaluation was based on the impression of the clinician. This evaluation was made from the response to the clinical questionnaire and the result of the physical examination, which included a simple provocative stress test without instrumentation.

The clinical diagnosis of continence status, rather than the household self-reported continence status, was used to compare continent to incontinent participants with respect to the results of the urodynamic tests.

The clinical diagnosis closely replicates the diagnosis of a clinician in an office setting by using not only the history (questionnaire) but also other clinical information that is critical to arrive at a specific diagnosis.

*Definition of urodynamic data used in the analysis of the results*

The intravesical and intraurethral pressures were measured in the supine and then in the standing position. Supine urethral pressure (SUP UP), supine bladder pressure (SUP BP), standing urethral pressure (STD UP) and standing bladder pressure (STD BP) were measured with the double microtip transducer. The urethral pressure is at the region of the midurethra where the maximum pressure was obtained. Supine and standing maximum urethral closure pressure (SUP MCP and STD MCP) were obtained by subtracting the bladder pressure from the urethral pressure.

Transmission pressure to the baldder (TPB) and transmission pressure to the urethra (TPU), were computed by subtracting the pre-cough resting bladder and urethral pressure from the maximum pressure of the bladder and urethra respectively at the instant of coughing. This is reported as supine or standing transmission pressure. The transmission pressure ratio (TPR) was calculated by dividing TPU by TPB.

These urodynamic data were collected from clinic participants with diagnosis of continence, stress incontinence and non-stress incontinence. In addition, data from continent respondents with negative provocative stress test and incontinent respondents with positive stress test were also obtained.

*Statistical analysis*

Data in the tables are summarized as mean SD. The mean pressure of continents is compared to that of incontinents by a Behrens-Fisher two-sample t-test which does not assume that the variances are equal in the two groups. Two-sided p-values are reported. To compare mean pressures when there are three groups, a one-way ANOVA computed and the p-value is reported.

## Results

When comparing clinically diagnosed continent respondents and all stress incontinent respondents, the mean resting standing maximum closure pressure was less ($p = 0.0018$), resting standing bladder pressure was greater ($p = 0.018$) and maximum urethral pressure was less ($p = 0.020$) in the stress incontinent group than in the continent group. However, significant differences were not found with resting supine pressures. The non-stress incontinent group is closer to the continent group than to the stress incontinent group (Table 1).

No significant differences were obtained between clinically diagnosed continent with negative provocative stress test and clinically diagnosed incontinent with positive provocative stress test in terms of the mean resting supine urethral and bladder pressure and resting supine maximum closure pressure. The mean of resting standing bladder pressure was greater ($p = 0.016$) and standing maximum closure pressure was less ($p = 0.027$) in the incontinent group than in the continent group. However, no significant difference was observed in the mean of resting standing urethral pressure ($p = 0.14$) (Table 1).

The mean supine cough transmission pressure to the bladder (maximum coughing bladder pressure minus pre-cough resting bladder pressure) is marginally significantly higher among the stress incontinent respondents than continent respondents ($p = 0.043$), and among incontinent respondents with positive stress provocative test than among continent respondents with negative provocative stress test ($p = 0.021$). The difference was much more pronounced in the standing position than in the supine position ($p = 0.0011$ and $p = 0.0032$) respectively (Table 2).

*Table 1.* Standing (STD) and supine (SUP) bladder (BP), urethral (UP) and maximum urethral closure (MCP) pressures reported by continence sttus: Mean ± SD

| | Continent | N | Stress incontinent | N | Nonstress incontinent | N | P-value cont vs stress |
|---|---|---|---|---|---|---|---|
| STD BP | 32.8 ± 7.6 | 62 | 36.0 ± 7.7 | 78 | 34.4 ± 8.1 | 17 | 0.018 |
| STD UP | 85.1 ± 18.9 | 62 | 77.6 ± 18.5 | 78 | 80.5 ± 19.2 | 17 | 0.020 |
| STD MCP | 52.3 ± 20.5 | 62 | 41.7 ± 18.2 | 78 | 46.1 ± 20.5 | 17 | 0.0018 |
| SUP BP | 17.4 ± 7.0 | 65 | 18.3 ± 9.0 | 78 | 15.8 ± 6.0 | 17 | 0.49 |
| SUP UP | 16.9 ± 17.2 | 65 | 60.0 ± 17.2 | 78 | 61.3 ± 21.9 | 17 | 0.52 |
| SUP MCP | 44.5 ± 17.1 | 65 | 41.7 ± 17.0 | 78 | 45.5 ± 22.9 | 17 | 0.33 |

| | Continent/neg stress test | N | Incontinent/pos stress test | N | P-value |
|---|---|---|---|---|---|
| STD BP | 32.8 ± 7.7 | 60 | 37.0 ± 7.3 | 31 | 0.016 |
| STD UP | 86.0 ± 18.4 | 60 | 79.3 ± 21.1 | 31 | 0.14 |
| STD MCP | 53.2 ± 20.1 | 60 | 42.3 ± 22.7 | 31 | 0.027 |
| SUP BP | 17.4 ± 7.2 | 63 | 19.3 ± 11.6 | 31 | 0.42 |
| SUP UP | 62.6 ± 17.0 | 63 | 59.8 ± 16.6 | 31 | 0.44 |
| SUP MCP | 45.2 ± 16.9 | 63 | 40.5 ± 18.1 | 31 | 0.24 |

*Table 2.* Standing (STD) and supine (SUP) transmission pressure to the bladder (TPB), to the urethra (TPU) and ratio (TRP) reported by continence status: Mean ± SD

| | Continent | N | Stress incontinent | N | Nonstress incontinent | N | P-value anova | P-value cont vs stress |
|---|---|---|---|---|---|---|---|---|
| STD TPB | 76.1 ± 30.9 | 62 | 93.4 ± 29.8 | 78 | 79.9 ± 18.7 | 17 | 0.0022 | 0.0011 |
| STD TPU | 63.7 ± 35.3 | 62 | 76.4 ± 31.3 | 78 | 73.1 ± 17.7 | 17 | 0.066 | 0.029 |
| STD TPR | 0.90 ± 0.49 | 62 | 0.83 ± 0.38 | 78 | 0.97 ± 0.31 | 17 | 0.40 | 0.38 |
| SUP TPB | 72.8 ± 37.6 | 65 | 84.7 ± 30.6 | 78 | 76.4 ± 38.9 | 17 | 0.12 | 0.043 |
| SUP TPU | 56.6 ± 32.5 | 65 | 62.3 ± 27.0 | 78 | 55.9 ± 32.6 | 17 | 0.47 | 0.26 |
| SUP TPR | 0.82 ± 0.50 | 65 | 0.80 ± 0.37 | 78 | 0.75 ± 0.32 | 17 | 0.76 | 0.67 |

| | Continent/neg stress test | N | Incontinent/pos stress test | N | P-value |
|---|---|---|---|---|---|
| STD TPB | 75.9 ± 31.4 | 60 | 95.2 ± 26.8 | 31 | 0.0032 |
| STD TPU | 63.4 ± 35.8 | 60 | 75.9 ± 24.9 | 31 | 0.056 |
| STP TPR | 0.90 ± 0.50 | 60 | 0.79 ± 0.38 | 31 | 0.26 |
| SUP TPB | 72.5 ± 38.1 | 63 | 90.4 ± 31.9 | 31 | 0.021 |
| SUP TPU | 56.5 ± 32.9 | 63 | 62.5 ± 23.3 | 31 | 0.32 |
| SUP TPR | 0.83 ± 0.38 | 63 | 0.73 ± 0.24 | 31 | 0.13 |

The mean increase of intraurethral pressure during coughing from the pre-cough resting urethral pressure is significantly higher among stress incontinent respondents than among continent respondents when measured in the standing position ($p = 0.029$) but not in the supine position ($p = 0.26$).

Between continent respondents with negative stress tests and incontinent respondents with positive stress tests, the mean urethral pressure rise is marginally nonsignificant among the incontinent group ($p = 0.056$) in the standing position and not significant in the supine position ($p = 0.32$) (Table 2).

The transmission pressure ratio showed higher values among continent respondents than incontinent respondents. The supine and standing transmission pressure ratio among continent respondents are 0.82 and 0.90 respectively whereas among stress incontinent respondents the ratio in supine and standing positions are 0.80 and 0.83 respectively (Table 2). Among continent negative stress test respondents, the supine and standing position ratios are 0.83 and 0.90 respectively while among incontinent positive stress test respondents the ratios are 0.73 and 0.79 respectively (Table 2).

The mean bladder and urethral transmission pressures were compared between respondents with the following variables: usually have cough, smoker, asthma history, taking female hormones, pregnancy, incontinent during or after pregnancy, atrophic vaginitis, cystocele and rectocele. The only variable that showed a significant difference in pressures was on respondents usually having a cough and those not coughing. Significantly higher pressures were noted among coughers in SUP TPB ($p = 0.0001$), SUP TPU ($p = 0.013$), STD TPB ($p = 0.009$) and STD TPU ($p = 0.031$) (Table 3). There is also a difference between the stress grouping (continent vs. stress incontinent) after adjusting for coughing ($p = 0.0047$).

There was no significant difference between continent and incontinent respondents with regard to the mean cystometric bladder capacity (continent 416 ± 118 mL and incontinent 384 ± 116 mL, $p = 0.22$) nor the weight of the respondents, continent 140.8 ± 25 lbs and incontinent 147.9 ± 25 lbs, $p = 0.21$).

## Discussion

Our observations on passive urethral pressures, as previously reported, have confirmed the work of others that the maximum urethral pressures and the urethral closure pressure decreases with age [3,4,6]. Further, the decrease is observed in both continent and incontinent subjects. Moreover, the mean MUP and MCP among incontinent subjects are significantly lower than their continent counterparts when measured in the standing position but not in the supine position. This is reasonable because it can be postulated that the pelvic muscles are activated (increase tone) in the standing position and will tend to produce more compressive support to the urethra among continent respondents with better pelvic muscle support than the incontinent respondents with pelvic muscle relaxation.

Previous analysis of the values of the MUP and MCP showed that although there are differences, these values are inappropriate as a screening diagnostic tool since a great deal of overlap exists between stress incontinent and continent subjects [6]. However, when the testing is done, the standing position must be used since it maximizes the difference between a much higher rise in intravesical pressure and a relatively lower rise in urethral pressure among incontinent subjects. This is shown clearly on our results where the MCP in the standing position, but not in the supine posi-

*Table 3.* Standing (STD) and supine (SUP) transmission pressure to the bladder (TPB), to the urethra (TPU) and ratio (TPR) separated by respondents who stated that they usually have a cough and those who do not: Mean ± SD

| | Not coughing | N | Coughing | N | P-value |
|---|---|---|---|---|---|
| STD TPB | 81.6 ± 29.8 | 119 | 95.8 ± 28.4 | 40 | 0 009 |
| STD TPU | 68.7 ± 32.7 | 119 | 80.1 ± 26.6 | 40 | 0.031 |
| STD TPR | 0.88 ± 0.45 | 119 | 0.89 ± 0.28 | 40 | 0.85 |
| SUP TPB | 71.6 ± 29.2 | 122 | 101.2 ± 40.4 | 40 | 0.0001 |
| SUP TPU | 56.3 ± 30.5 | 122 | 68.4 ± 24.8 | 40 | 0.013 |
| SUP TPR | 0.82 ± 0.39 | 122 | 0.75 ± 0 25 | 40 | 0.24 |

tion, is significantly less among incontinent than continent subjects. It should be pointed out that in the standing position both the bladder and urethral pressures increase when compared to the supine position. However, the rise in bladder pressure is significantly more when compared to the rise in urethral pressure. This is true for both the passive and dynamic urethral profilometry.

The mean transmission pressure ratio among all three groups studied was less than 100%. As expected, the incontinent group has the lowest ratio (83%) whereas the continent respondents (90%) and the non-stress incontinent subjects (97%) have to ratio closer to 100%.

The lower TPR among the stress incontinent women is a reflection of the higher transmission of cough pressure to the bladder than the urethra. This is contrary to the presently held belief that the lower TPR among stress incontinent women is due to reduced transmission of pressure to the urethra since our data showed an almost equal to even higher transmission of pressure to the urethra among the stress incontinent group than among continent respondents. What stands out is the significantly higher cough transmission pressure to the bladder among the stress incontinent group when compared to the continent or non-stress incontinent respondents.

In 1961, Enhorning observed that the increase in cough bladder pressure is higher among stress incontinent than continent subjects [7]. However, when stress incontinent patients were compared with normals of the same age in his series, the maximally increased intravesical pressure was not significantly different between the 2 groups. However, he had few cases in the 60 yr and older group and therefore comparison between groups may not be meaningful. Hilton and Stanton also observed this pressure transmission discrepancy between continent and incontinent subjects. They reported that whereas all groups of stress-incontinent women generated intravesical pressure rises of similar magnitude on coughing, the symptom-free women, despite being given similar instructions, developed significantly lower intravesical pressure increments [8].

The significantly higher rise in intravesical pressure and the relatively lower increase to the urethral pressure among incontinent subjects when compared to the continent subjects are probably major contributors of stress incontinent mechanisms among elderly women. This is more so among the elderly since their maximum closure pressure is already significantly lower when compared to a younger counterpart. Because of this pattern, during coughing, there will be further loss of urethral closure pressure predisposing them to incontinence.

In order to analyze the influence of coughing, the pressures of respondents with chronic cough were compared to those of respondents who did not have chronic cough. Chronic coughers produced a significantly higher increase in intravesical pressure than the non-coughers. The urethral pressure increase was also higher among the coughers than non-coughers; however, the rise in the bladder is always higher than the rise in urethral pressure. After adjusting for coughing however, there is still a significant difference between stress incontinent respondents and the continent respondents with regards to standing bladder pressure increases but not with urethral pressures. These findings suggest that although chronic coughers may generate more pressure than non-coughers, there must be other factors causing the stress incontinents to produce much higher bladder pressures during coughing than the strength of the cough itself.

Examination of other variables including smoking, asthma, number of pregnancies, number of births, vaginal atrophy, cystocele and rectocele and use of female hormones showed no effects on the pressures of continent and incontinent respondents.

One possible explanation for the difference in bladder pressure during coughing between continent and stress incontinent respondents is the degree of mobility of the bladder and the proximal urethra. The hypermobility of the bladder and the bladder neck in women with primary stress incontinence is believed to be due to poor pelvic muscle support. The increased mobility of the bladder among stress incontinent women allows the bladder to posteriorly rotate and prolapse into the pelvic outlet against the posterior vaginal wall. Occlusion of the pelvic outlet allows the bladder to absorb the cough pressure rather than be partially vented to the outside of the pelvic outlet through the vaginal canal which may be partially open when the bladder is fixed and well suspended

(Fig. 1). Since the bladder is relatively fixed among continent and non-stress incontinent respondents, the outlet may not be occluded thereby allowing the abdominal pressure to be partially vented rather than absorbed by the bladder cavity (Fig. 2).

The reduced pressure increase in the urethra when compared to the bladder regardless of the continence status and the fact that the mean TPU for incontinent subjects is higher than continent subjects are also surprising. Since the static urethral pressures are significantly lower in the elderly women when compared to the younger women [3], it is very plausible that the reduced pressure increases in the urethra are partially mediated by muscular contractions which may be reduced in the elderly when compared to their younger counterparts. Faysal *et al.*, reported urethral pressure increase of approximately twice the increase in bladder pressure among young continent subjects whose ages range from 18 to 35 yr [9]. However, Bunne and Obrink, in a study of older subjects, observed a reduced urethral pressure increase when compared to bladder pressure increase during coughing in both continent and incontinent respondents [10]. The present study and the Bunne and Obrink study are contrary to previous reports among younger subjects. Among younger subjects, there appears to be a clear distinction between young continent subjects and young stress incontinent subjects [9]. It has been postulated that the proximal urethra gets out of the pelvic cavity beyond the urogenital diaphragm and therefore does not receive enough transmission of pressure from the abdomen. However, in our subjects, many of the continent respondents with less than 100% urethral pressure increase when compared to the bladder increase are well suspended and do not manifest any hypermobility. Also, although the transmission pressure ratio among incontinents is consistently lower than continent respondents, the difference was not significant. These findings lend more credence to the theory that the pressure changes in the urethra (increase) with cough is partially an active reflex contraction of the sphincteric muscles [9, 10].

The progressive reduction of the urethral pressure as age advances and the universally reduced ratio of to urethral bladder pressures during coughing may very well be due to weakening of the sphincteric muscles and/or reduced reflex response of the sphincteric muscles to cough and other events that increase abdominal and bladder pressures.

Normally, as bladder capacity increases, the reflex sphincter actively increases [11]. In the elderly, this response may not be optimal. Such a reduced response may explain the predisposition of the elderly women to urinary incontinence when the bladder is full and is exposed to a relatively minor increase in intra-abdominal pres-

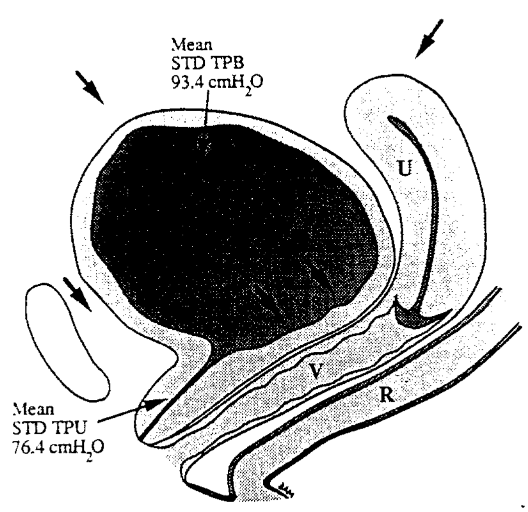


*Fig. 1.* Proposed cough transmission pressure in stress incontinence status.

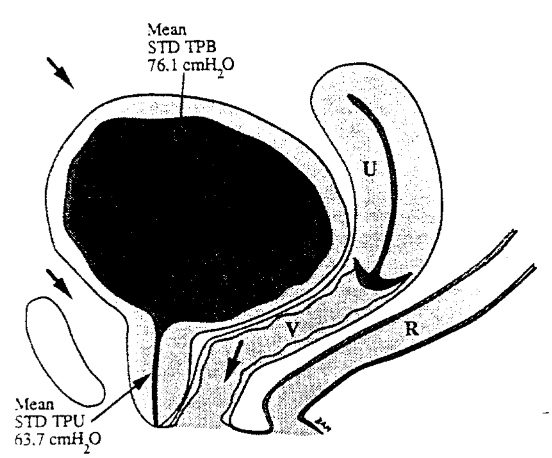


*Fig. 2.* Proposed cough transmission pressure in nonstress and continence status.

sure. This may also explain the increase in episodes of urge incontinence among elderly women who may not be able to reflexly contract their sphincter with great force during episodes of detrusor hyperreflexia.

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