Int Urogynecol J (2001) 12:395–400


International Urogynecology Journal

*Original Article*

# Correlation of Urethral Closure Pressure, Leak-Point Pressure and Incontinence Severity Measures

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**Abstract:** The aim of this study was to determine whether water perfusion maximum urethral closure pressure (MUCP) correlates with Valsalva leak-point pressure (LPP), and which of these best correlates with subjective and objective incontinence severity measures. Fifty-two women with previously diagnosed genuine stress incontinence ($n = 46$), or mixed incontinence with a minor and controlled urge component ($n = 6$), were assigned an incontinence status grade based on interview and diary review. These women then completed visually observed standing LPPs at 250 ml bladder capacity, supine water perfusion MUCP determinations, pad tests and quality of life questionnaires. The urodynamic and severity measures were compared with correlation analysis or analysis of variance. A modest correlation exists between LPP and MUCP ($r$ = 0.50–0.62, $P < 0.001$). Both MUCP and LPP demonstrated significant decreases ($P < 0.01$) with increasing severity of assigned incontinence grade. A very low and insignificant correlation existed for these urodynamic parameters and pad loss or quality of life measures. MUCP and LPP correlate modestly with each other and both are comparable in predicting incontinence severity. Either can be used as the urodynamic measure to assess intrinsic sphincter deficiency.

**Keywords:** Incontinence severity; Intrinsic sphincter deficiency; Leak-point pressure; Maximum urethral closure pressure; Stress incontinence

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## Introduction

Stress urinary incontinence occurs whenever the urethra cannot increase its resistance to compensate for the sudden increase in abdominal pressure that occurs with coughing, laughing, sneezing, exercise or the Valsalva maneuver. It is generally accepted that the female urethra needs a normal sphincter that is well supported to accomplish this. Particularly in the United States, there have been attempts to subcategorize stress incontinence into anatomic (urethral hypermobility) incontinence or intrinsic sphincter deficiency (ISD) [1]. This subcategorization influences management: hypermobility stress incontinence is treated with anatomic supporting operations (colposuspension, urethropexy, sling procedures), whereas the poorly functioning but better supported urethral sphincter is treated with bulking agents, slings or artificial sphincters. In reality, this subcategorization is an oversimplification because many parous women with urethral hypermobility are continent. Stress incontinent women with hypermobility must therefore have some sphincter incompetence (or intrinsic sphincter deficiency).

Most practioners would agree with Bump et al. [2] that ISD should be diagnosed by a composite of historic, anatomic, urodynamic and clinical severity criteria. There is, however, considerable debate on what urodynamic measure best quantifies intrinsic sphincter deficiency – maximum urethral closure pressure (MUCP) or leak-point pressure (LPP). The gynecological literature emphasizes the use of the MUCP, because some retrospective studies have shown higher failure rates following Burch colposuspension in patients with preoperative MUCP $< 20$ cm$H_2O$ [3–5]. Other studies have not confirmed these results [6,7].

McGuire et al. [8] defined the abdominal pressure required to cause leakage by a Valsalva or coughing maneuver as the abdominal leak-point pressure (LPP). He found that when the LPP was less than 60 $cmH_2O$ 75% of stress incontinent women had type III videourodynamic findings and 81% had severe (grade 3) incontinence. In these same patients the authors performed manually withdrawn, water perfusion urethral pressure measurements and found 'no correlation between maximum urethral pressure and the grade or type of incontinence or the abdominal pressure required to induce urethral urinary loss'. The three reports in the literature reporting MUCP and LPP correlation analysis found statistically significant correlation coefficients in the range of 0.31 [9], 0.56 [10] and 0.62 [11]. These studies all used microtip catheters for the MUCP measurements. The advantages and disadvantages of microtip and water perfusion catheter methods have been well summarized by Griffiths [12]. Microtip catheters do not measure real fluid pressure within the coapted urethra, and perfusion methods have a slow response to rising pressure. Comparative studies have suggested the microtip catheters to be superior [13]. Was the lack of correlation in McGuire's study real or due to the water perfusion methodology? There are no studies in the literature comparing mechanically withdrawn water perfusion MUCP measurements with LPP. The first goal of this study was to determine whether mechanically withdrawn water perfusion MUCP correlates with LPP.

If these two urodynamic parameters assess sphincter function then they should correlate with symptom severity. Several investigators have demonstrated that low leak-point pressures are associated with a more severe assigned grade of incontinence severity [8,14,15]. Bump et al. [2] found that low MUCP and low VLPP correlated inversely with pad use and incontinence episodes. Although there was a trend for both low VLPP and low MUCP patients to have higher pad weights, only low VLPP reached statistical significance [2]. Urodynamic parameters did not correlate with incontinence–specific quality of life (QOL) instruments [16]. The second purpose of this study was to determine whether MUCP or VLPP correlated with subjective, objective and QOL incontinence severity measures.

## Materials and Methods

Fifty-two women were recruited to participate in a clinical trial of a new urethral bulking agent. The urethral injection outcome results are not reported in this paper. The local research ethics committee approved the study and all patients completed approved written consent forms. History, examination, stress tests and multichannel cystometrograms revealed that 46 women had genuine stress incontinence (GSI) and 6 had mixed incontinence (GSI and detrusor instability) with a minor and controlled urge component. All women were between 32 and 72 years of age, had had stress urinary incontinence for at least 12 months, and had failed at least 3 months of conservative therapy. Patients were excluded from study if they were under 18 or over 80 years of age, had an active urinary tract infection, had a bladder capacity $<250$ ml or a postvoid residual $>100$ ml, had a neurogenic bladder, had grade 3 prolapse of any compartment, had had previous bulking agent therapy, or were taking an $\alpha$-agonist or antagonist.

All patients had the same standardized evaluation, consisting of:

- *Incontinence grade*: All patients completed a 7-day diary of their voids, leakage episodes and precipitating events. Before urodynamic testing was performed, the diary was reviewed, the patients were interviewed and, based on the diary and interview, an incontinence grade was assigned according to the Stamey classification system [17].
  - Grade 0: continent
  - Grade 1: loss of urine with sudden increases in abdominal pressure (coughing, sneezing, laughing)
  - Grade 2: leaks with lesser degrees of physical stress, such as walking, standing erect from a sitting position or sitting up in bed
  - Grade 3: total incontinence; urine is lost without any relation to physical activity or to position.
- *Cotton swab (Q-tip) excursion angles*: The 40 women had cotton swab (Q-tip) angles [18] measured at rest and with maximum Valsalva effort, including coughing, by the first author using an orthopedic goniometer. The angles measured from the horizontal at rest and with maximal straining were recorded.
- *Valsalva leak-point pressure*: After voiding, a 7 Fr BARD triple lumen catheter was placed in the bladder and any residual removed. A balloon catheter was placed in the rectum. After filling to 250 ml with water in the standing position, each subject placed a foot on a footstool and was asked to bear down or push 'like pushing a baby out'. The patient was instructed to look at the monitor and to slowly increase bladder pressure. After swabbing the periurethral area dry, the investigator, using a handheld electronic marker, noted the precise instant that fluid was observed at the external urethral meatus. In a small subset of patients, if leakage could not be obtained with maximum Valsalva effort the patient was asked to gradually increase coughing efforts until leakage was observed. The bladder pressure rise over baseline until leakage occurred was measured three times and averaged. We observed the very high reproducibility of these repeated measures that has already been reported [8].
- *Maximum urethral closure pressures*: Following the technique of Brown and Wickham [19], at the same 250 ml bladder volume in the supine position, three consecutive urethral pressure profiles were obtained at a water perfusion rate of 2 ml/min and a mechanical withdrawal rate of 1 mm/s. The MUCP was the

difference between maximum urethral pressure and bladder pressure. The three MUCPs were measured and averaged.

- *Pad test*: A quantification of urine loss with a pad test based on ICS recommendations was performed [20]. Immediately after the urethral pressure profiles were completed, so that each patient had a bladder volume of at least 250 ml, a weighed pad was placed on the perineum and the patient stood up from sitting 10 times, coughed vigorously 10 times, and climbed stairs for 1 minute. Pad weight was the difference in weight between the post-test pad and the dry pad before testing.
- *Quality of life (QOL) questionnaire*: All patients completed a 16-question QOL questionnaire from the 'Q' section of the SEAPI QMM [21] incontinence classification system. The number of points each subject receives divided by the total number of points possible is the percentage score for each patient. A higher percentage indicates greater restriction, impairment or unhappiness.

All data were then entered into the SPSS for Windows 10.0 statistical package. Student's *t*-test was used to compare means of normally distributed data. Pearson's correlation coefficients and their significance were calculated to identify significant relationships of normally distributed numeric data (MUCP, VLPP, Q-tip, QOL, age). Kendall's $\tau$ or Spearman's $\rho$ coefficients and their significance were calculated to explore relationships between normally distributed and abnormally distributed variables (pad weight, incontinence grade). The interpretation of correlation coefficients followed guidelines suggested by Cohen and Holliday [22]: $<0.19$, very low; 0.20–0.39, low; 0.40–0.69, modest; 0.70–0.89, high; and 0.90–1 very high. Analysis of variance (ANOVA) was used for normally distributed parametric data in more than two groups.

## Results

The mean age of the women in the study was 58 years (range 32–72) and mean duration of incontinence was 169 months (range 18–564). The mean MUCP was 23 $cmH_2O$ (SD 11) and the mean VLPP was 68 $cmH_2O$ (SD 37). Twenty-three patients (44%) had had previous incontinence surgery: these patients were significantly older (mean age 64 vs. 54 years), had less urethral mobility (mean Q-tip excursion 28° vs. 51°), lower MUCP (18 vs. 27 $cmH_2O$), lower VLPP (51 vs. 81 $cmH_2O$) and a higher grade of incontinence than the 29 patients without previous incontinence surgery ($\chi^2$ $P<0.05$ for all parameters).

### Correlation of VLPP with MUCP

The graph of VLPP versus MUCP is shown in Fig. 1. Six of the 52 patients did not demonstrate any leakage

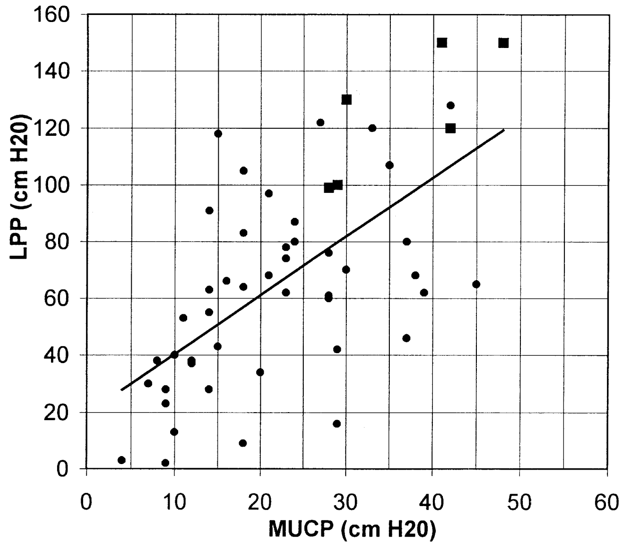


**Fig. 1.** Scatterplot of maximum urethral closure pressure (MUCP) versus leak-point pressure (LPP). Closed squares represent the 6 patients without observed leakage and the maximum increase in bladder pressure obtained. Correlation coefficient ($r$) = 0.62 ($P$<0.001), including all 52 subjects, or 0.50 ($P$<0.001) excluding the 6 subjects.

with Valsalva maneuvers, despite obtaining mean bladder pressure increases of 125 (range 100–150) $cmH_2O$. Compared to the other 46 subjects these 6 had significantly higher MUCP (mean = 38, range = 29–48) $cmH_2O$. These 6 data points are shown in Fig. 1 with solid squares by using the maximum bladder pressure increase that each subject obtained as the plotted VLPP. Including these 6 patients, the correlation of VLPP with MUCP was modest, with a correlation coefficient of 0.62 ($P<0.001$). Excluding these 6 subjects (which was done for all the remaining data analysis), the correlation coefficient ($r$) remains modest at 0.50 ($P<0.001$).

### Graded Incontinence Severity and Urodynamic Parameters

When patients were grouped by incontinence grade, significant differences were observed in the mean VLPP and MUCP for each incontinence grade (Table 1). The more severe the incontinence, the lower the VLPP and

**Table 1.** Maximum urethral closure pressure (MUCP) and leak-point pressure (LPP) for each incontinence grade

| | Grade 1 ($n$ = 17 for MUCP, 15 for LPP) | Grade 2 ($n$ = 33 for MUCP, 29 for LPP) | Grade 3 ($n$ = 2) | $P$ |
|---|---|---|---|---|
| MUCP ($cmH_2O$) | $28\pm3$ | $22\pm2$ | $5\pm1$ | 0.009* |
| LPP ($cmH_2O$) | $79\pm8$ | $54\pm5$ | $16\pm14$ | 0.004* |

Values are mean $\pm$ standard error.
*, significant difference between groups with one-way analysis of variance (ANOVA).

**Table 2.** Correlation coefficients of urodynamic, urethral hypermobility and incontinence severity measures

| | | LPP | Q-tip | Pad wt. | QOL | Grade |
|---|---|---|---|---|---|---|
| MUCP | $r$ | **0.50** | **0.67** | 0.09 | 0.10 | **−0.30** |
| | $P$ | **<0.001** | **<0.001** | 0.53 | 0.47 | **0.01** |
| LPP | $r$ | | **0.44** | 0.00 | −0.10 | **−0.36** |
| | $P$ | | **<0.01** | 0.98 | 0.51 | **<0.01** |
| Q-tip | $r$ | | | 0.05 | −0.02 | **−0.36** |
| | $P$ | | | 0.77 | 0.89 | **<0.01** |
| Pad wt. | $r$ | | | | **0.46** | **0.23** |
| | $P$ | | | | **0.001** | **0.05** |
| QOL | $r$ | | | | | 0.20 |
| | $P$ | | | | | 0.08 |

$r$, correlation coefficient; MUCP, maximum urethral closure pressure; LPP, leak-point pressure; Q-tip, urethral excursion angle measured from the horizontal with maximum straining; Pad wt, pad weight gain in grams after provocative activities; QOL, quality of life score; grade, assigned incontinence grade. Low or modest, but significant ($P<0.05$) correlations are in bold.

MUCP. In the correlation analysis (Table 2) incontinence grade had a low correlation with MUCP ($r=-0.30$, $P$=0.01) and VLPP ($r = -0.36$, $P<0.01$).

### *Correlation of Urodynamic Parameters with Subjective (QOL) and Objective (Pad Weight) Severity Measures*

The modified correlation matrix (Table 2) displays correlation coefficients and their significance. No correlation existed for VLPP or MUCP with QOL measures or pad wt.

### *Correlation of Urodynamic Parameters with Other Variables*

As is also shown in Table 2, VLPP and MUCP correlated modestly but significantly with Q-tip straining angle. In other words, increasing urethral hypermobility was associated with increased MUCP and VLPP values.

### *Correlation of the Different Incontinence Severity Measures*

The amount of fluid lost on pad testing correlated modestly with QOL score ($r = 0.46$, $P = 0.001$) but had a low correlation with incontinence grade ($r = 0.23$, $P = 0.05$) (Table 2). The two subjective measures of incontinence, QOL and incontinence grade, had a low and non-significant correlation ($r = 0.20$, $P = 0.08$).

## Discussion

This is the first study to compare water perfusion catheter MUCP measurements obtained from urethral pressure profiles with leak-point pressures. Although more cumbersome than microtip urethral catheters, water perfusion catheters are significantly less expensive and purists may argue that they more truly measure a pressure instead of a force on a microtip transducer membrane. We chose this methodology because the only other investigators to have used water perfusion methods reported no correlation [8]. We found modest (moderate) correlations (0.50–0.62) that are comparable to the range of 0.31 [9], 0.56 [10] and 0.62 [11] that other microtip catheter investigators have reported. It is possible that a mechanically withdrawn urethral pressure profile gives a more accurate measurement of urethral pressure than the manually withdrawn methodology described by McGuire et al. [8] In that study, urethral pressures were obtained by manually withdrawing the catheter until the urethral pressure aperture reached the point of highest pressure within the urethra, and then the catheter was fixed and the patient repositioned upright. It is unclear whether the maximum urethral pressure was measured after that repositioning: if so, catheter migration could account for the lack of correlation. Other differences between our technique and theirs include perfusion rate (2 ml/min vs. 1 ml/min), catheter diameter (7 Fr vs. 10 Fr) and urethral apertures (1 vs 2). No statistical correlation analysis was reported in their study, but patients with LPP >120 cm$H_2O$ had mean maximum urethral pressures of 54 cm$H_2O$, which was 20 cm$H_2O$ greater than the mean maximum urethral pressure of the patients with LPP <120 cm$H_2O$ [8]. These results suggest some correlation.

If MUCP and LPP were measuring the same biological phenomenon a higher correlation coefficient would be expected. With our correlation coefficient of $r=0.50$–$0.62$, then $r^2 = 0.25$–$0.38$. This means that only 25%–38% of the variation in one measure can be predicted by knowing the other measure. But these two measures are not measuring the same thing: MUCP measures urethral resistance at rest and LPP measures urethral resistance with increased abdominal pressure. Perhaps we should not expect any higher correlation. The incontinence severity correlations do not support either measurement as being superior to assess incontinence severity.

We deliberately did not evaluate our urodynamic data with threshold or cut-off values (e.g. MUCP <20 cm$H_2O$ or VLPP <60 cm$H_2O$). We believe that ISD and hypermobility are not dichotomous subcategories, and most incontinence patients have both ISD and hypermobility components. We do not believe that stress incontinence can be subcategorized with any threshold number. For this reason, correlation analysis was used. In addition, the absolute value of the MUCP measurement may vary with different methodologies. A subset of 18 patients in this study had microtip urethral pressure profile measurements that gave higher MUCP values than those obtained from perfusion methods. Interestingly, the repeatability was better with the perfusion methodology. The methodology matters – a recent study found consistently and significantly lower MUCP measurements with fiberoptic catheters than with microtip catheters [23]. There also is no consensus on whether LPP is measured as an absolute value or as an increase in baseline. For all these reasons, management decisions based on cut-off or threshold values of continuous variables should be considered skeptically.

In the VLPP and MUCP correlation study (Fig. 1) 6 patients did not leak despite increasing their bladder pressure by more than 100 $cmH_2O$. We debated what to do with this set of patients with higher MUCP and milder incontinence. These patients demonstrated the sign of stress incontinence during other evaluations, and consequently we thought it was reasonable to consider their LPP in Fig. 1 to be at least the highest pressure above baseline obtained. If included, the correlation coefficient was 0.62, but as can be seen from Tables 1 and 2, they were not included in any of the subsequent analyses and therefore the correlation coefficients are generally less than if they had been included. We do believe that if a patient increases their bladder or abdominal pressure >100 $cmH_2O$ and does not leak, they will not have urodynamic evidence to support the diagnosis of ISD.

Incontinence grade was the severity outcome that correlated most strongly with the urodynamic measurements. This is consistent with previous work on VLPP [8,14,15] but, unlike McGuire et al. [8], our work also shows the same results with MUCP. As patients recorded leakage with less and less physical activity, both their VLPP and MUCP declined.

We were surprised to find that there was no significant correlation of the urodynamic parameters with the objective quantitative outcome measurement (pad wt.) or the other subjective outcome measure (QOL). This is consistent with the result reported by Theofrastous et al. [16], except that they found a low inverse correlation ($r = -0.28$, $P$=0.04) with VLPP and pad weight. Perhaps pad testing is not rigorous enough to discriminate large volume (severe) from small volume (mild) incontinence patients. It is noteworthy that QOL and pad weight had a significant modest correlation with each other suggesting validation of these tools as measurements of subjective and objective outcomes.

ISD is often equated with a fixed immobile, poorly functioning urethra, and our data indeed showed this. Lower Q-tip straining angles were associated with lower MUCP and lower VLPP. Although not shown in the table, this significant correlation also existed for the resting Q-tip angle.

The stereotypical ISD patient is older, has had previous incontinence surgery, has low MUCP, low VLPP, minimal urethral hypermobility and severe incontinence with minimal activity. The role of pad testing and condition specific quality of life instruments remains to be determined.

In summary, MUCP and VLPP correlate modestly with each other and both are limited, but comparable in predicting severity. They both measure urethral resistance and either can be used as the urodynamic measurement of an ISD component to the stress incontinence. Prospective outcome studies after intervention are needed with both of these urodynamic parameters to determine their utility.

*Acknowledgements.* Financial support was received from Bard Urological Division, Covington, George, USA.

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**EDITORIAL COMMENT: Measurements of urethral integrity remain an important research area for urinary incontinence researchers. The technical aspects of data acquisition are probably critical for proper scientific comparison of different measurements. A quantitative, reproducible assessment of severity is still lacking, although the authors point out some weak relationships between conventional sphincteric measures and incontinence severity. Further work in this area has the potential to assist the treatment triage of incontinent women.**

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## Review of Current Literature

**Bladder Outlet Obstruction in Women: Definition and Characteristics**

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*Neurourol Urodyn* 2000;19:213–220

The purpose of the study was to define and examine clinical, endoscopic, radiographic and urodynamic characteristics of bladder outlet obstruction in women. In a database of 587 women with voiding symptoms, were characterized as either obstructive or irritative. Urodynamic evidence of obstruction was defined as a non-invasive uroflow of <12 ml/s on repeated studies, combined with detrusor pressure at a maximum flow rate of >20 $cmH_2O$. During the pressure/flow study, simultaneous videofluoroscopy of the bladder outlet and EMG recording were performed. The site of obstruction was defined as the narrowest point in the urethra during voiding cystourethrography. At endoscopy urethral obstruction was inferred by visibile signs of a narrowed urethra; the urethra feeling narrow because it gripped the cystoscope; or the bladder neck and urethra appearing to be compressed from without, similar to benign prostatic hyperplasia in men. Thirty-eight women (6.5% of the study population) met the criteria for bladder outlet obstruction. The etiologies were prior incontinence surgery (10), severe genital prolapse (9), urethral stricture or narrowing (5), primary bladder neck obstruction (3), learned voiding dysfunction (2), detrusor–sphincter dyssynergia (2), urethral diverticulum (1), and idiopathic (6). The most common symptoms in women with obstructive symptoms were a weak stream, straining to void, and a feeling of incomplete emptying. However, in the patients diagnosed with bladder outlet obstruction, one-third had irritative voiding symptoms only and most had mixed obstructive and irritative symptoms. Radiographic evidence of obstruction was found in one-third of obstructed patients, and endoscopic evidence in 45% of the urodynamically obstructed patients.

*Comment*

This is a diagnosis not frequently made in the absence of prior incontinence surgery or severe prolapse. In the current study these were the most common problems. Urethral stricture in women is rare without a preceding surgical or traumatic event. Patients with multiple sclerosis are most likely to have dyssynergia. This leaves a very small number of patients who have either a learned voiding dysfunction or a primary bladder neck obstruction.