

Association of intrinsic sphincter deficiency with urine flow acceleration measurement

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Abstract

Background: Intrinsic sphincter deficiency (ISD) is associated with an inability to maintain mucosal coaptation either at rest or in the presence of stress resulting from damage to muscles or nerves that maintain tonus. The purpose of our trial was to determine the role of urodynamic measurements of flow such as maximum flow rate, flow time, and acceleration speed of flow to assess the urethral resistance on prediction of stress incontinence and ISD.

Materials and Methods: Our study was based on a retrospective analysis of urodynamic records of female patients performed for urinary incontinence. Mean flow rate, maximum flow rate, detrusor pressure at maximum flow, vesical pressure at maximum flow, maximum detrusor pressure, and flow rate at maximum detrusor pressure measurements were extracted from the voiding phase of urodynamic charts. The slope of the maximum flow was used to calculate acceleration of flow (Qacc). The urodynamic records of 142 women were reviewed and Qacc was measured.

Results: The mean age of the ISD group was 53.3 ± 12.5 (24-78) and of the non-ISD group 53.7 ± 12.5 (35-74). The mean Qacc ($30.3 \pm 16.1^\circ$ [mL/s²]) in the ISD group was significantly higher than in the non-ISD group ($21.6 \pm 9.6^\circ$ [mL/s²]). Urodynamic bladder capacity of the non-ISD group (432.3 ± 90.4 mL) was higher than the ISD group (389.2 ± 109) (P = .01).

Conclusion: The Valsalva leak point pressure and maximum urethral closure pressure measurements in assessing urethral function are not useful for predicting incontinence surgery failure. We demonstrated that Qacc is higher in ISD stress incontinent women than stress incontinent women. Qacc may demonstrate urethral resistance and tonus in a more reliable manner.

KEYWORDS

intrinsic sphincter deficiency, stress urinary incontinence, urodynamics

1 | INTRODUCTION

Stress urinary incontinence (SUI) is the involuntary leakage of urine with sudden effortful activities such as exercise, sneezing, or

coughing.¹ Urinary continence during stress maneuvers is maintained by several mechanisms. It is the result of a combination of passive anatomical coaptation and active muscle tone. Intrinsic sphincter deficiency (ISD) is associated with an inability to maintain mucosal coaptation either at rest or in the presence of stress resulting from damage to muscles or nerves that maintain tonus.²

Brief Summary: We examined the acceleration of flow on uroflow charts and showed that it was higher in ISD stress incontinent women than stress incontinent women.

The leak point pressure (LPP) concept is introduced as a single measure of degree of urethral coaptation and muscle tone.³

The urethra has two main functions which are to provide an effective continence mechanism and to allow adequate emptying of the bladder with minimal resistance. Urodynamic testing aims to objectively quantify urethral function and guide treatment by identifying patients with worse urethral function clinically recognized as ISD. The role of urodynamics in women with SUI has recently been debated.⁴ Urodynamic studies have been cited formerly as being potentially beneficial in assessing urethral function with either Valsalva leak point pressure (VLPP) or with maximal urethral closure pressure (MUCP). Additionally urodynamic workup is credited for predicting postoperative voiding dysfunction based on preoperative pressure flow studies.⁵⁻⁷ Although urodynamic studies have been available to clinicians and researchers for many years, recent trials have shown that VLPP and urethral pressure profile (UPP) measurements to assess urethral dysfunction have produced disappointing results. Based on evidences from the VALUE, VUSIS, and SISTER trials, VLPP and other urodynamic parameters do not seem to be useful for SUI patients, especially in predicting sling surgery failure.⁸⁻¹⁰

Light and Scott first used the term “superflow” to describe urine flow greater than 50 cc/s, indicating a significant reduction in the bladder outflow resistance.¹¹ Then in 2008, Smith and Appell found that average maximum flow was greater in patients with SUI compared to continent women, but flow rates were not predictive of ISD, defined as low LPP.¹² This hypothesis of low resistance to urine flow was not evaluated further in the literature. We have observed that patients with ISD have a lower urethral resistance, and the increase in maximum flow rate (Qmax) leads to increase in the acceleration speed of flow. The purpose of our trial was to determine the role of urodynamic measurements of flow such as Qmax, flow time, and acceleration speed of flow to assess the urethral resistance on prediction of stress incontinence and ISD. Additionally, we aimed to improve the outcome of midurethral sling surgery by measuring acceleration speed of flow instead of VLPP and MUCP.

2 | MATERIALS AND METHODS

This retrospective study was based on an analysis of the medical records of patients who consecutively underwent urodynamic evaluation for urinary incontinence between September 2015 and April 2019 at Bezmialem Vakif University, Istanbul, Turkey. This study was approved by our institutional review board (approval number: 18.340/2019). Demographic data including age, urinary symptoms, history of prior prolapse or incontinence surgery, initial Pelvic Organ Prolapse-Quantified (POPQ) stage, and postvoid residual volume were retrieved from the medical records. Women with previous incontinence or pelvic organ prolapse (POP) surgery, \geq stage 3 POPQ prolapse, external sphincter dyssynergia, neuromuscular disease, and neurogenic bladder were excluded from the study.

At baseline, a multichannel urodynamic investigation was performed for all women according to the recommendations of the

International Continence Society (ICS) [13]. LPPs were obtained during filling cystometry performed at supine position. Cough and VLPP measurements were obtained in a standard fashion at multiple bladder volumes beginning at 100 mL, and again at every 50-mL incremental increase until maximal functional bladder capacity was reached. Pressure flow studies were performed with the Locum urodynamic device (Aymed, Istanbul, Turkey), using 6F air-tip urethral catheters and 8F air-tip rectal catheters. The bladder was instilled with normal saline at a filling rate of 25 mL/min. Studies were performed by leaving one 6F catheter in the urinary bladder for measurement of intravesical pressure.

Average flow rate (Qave), Qmax, detrusor pressure at maximum flow (PdetQmax), vesical pressure at maximum flow (PvesQmax), maximum detrusor pressure (maxPdet), and flow rate at maximum detrusor pressure (maxPdetQ) measurements were extracted from the voiding phase of urodynamic charts. Filling volume, first desire to void, strong desire to void, and first leak volume were retrieved from the filling phase of urodynamic charts. The slope of the maximum flow was used to calculate acceleration of flow (Qacc). To measure the angle, we selected the most prominent rapid flow. Maximum Qacc was presented in mL/s² units. Figure 1 represents the measurement of angle with the measurement tool in the Adobe Acrobat Reader DC programme.

The women were asked to perform a Valsalva maneuver by gradually increasing their intra-abdominal pressure until they leaked urine. The LPP was defined as the lowest intravesical pressure (Pves) at which urine leakage occurred. LPP measurements were obtained in a standard fashion at multiple bladder volumes beginning at 100 mL and again at every 50-mL incremental increase until maximal functional bladder capacity was reached. Measurements at maximal capacity were recorded if there was no spontaneous detrusor activity VLPP. We used VLPP <60 cm H₂O as a cutoff value to describe ISD.

3 | STATISTICAL ANALYSIS

The data were sorted according to urodynamic continence status into a “normal urodynamic study group” and a “stress incontinence group” (including pure urodynamic stress incontinence and mixed incontinence). The stress incontinence group was further categorized into “ISD” and “non-ISD” groups. Data were expressed as mean \pm standard deviation. Statistical analysis was performed after normality testing (histogram analysis and/or Kolmogorov-Smirnov testing) using IBM SPSS, version 21 (IBM Inc, Armonk, New York). The Student *t* test was used for comparisons of normally distributed variables, and the Mann-Whitney *U* test was used for categorical variables. Interclass correlation coefficients (ICCs) were calculated to establish the interrater and intrarater reliability of measurements of flow angle to calculate flow acceleration. ICC values under 0.20 were considered poor; 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, good; and 0.81 to 1.00, very good. Correlation and multiple regression analyses were performed to assess relationships between angle of flow and other urodynamic parameters (Qmax, Qave, PdetQmax, PvesQmax, first leak volume, and LPP). *P* values of <.05 were considered to be statistically significant.

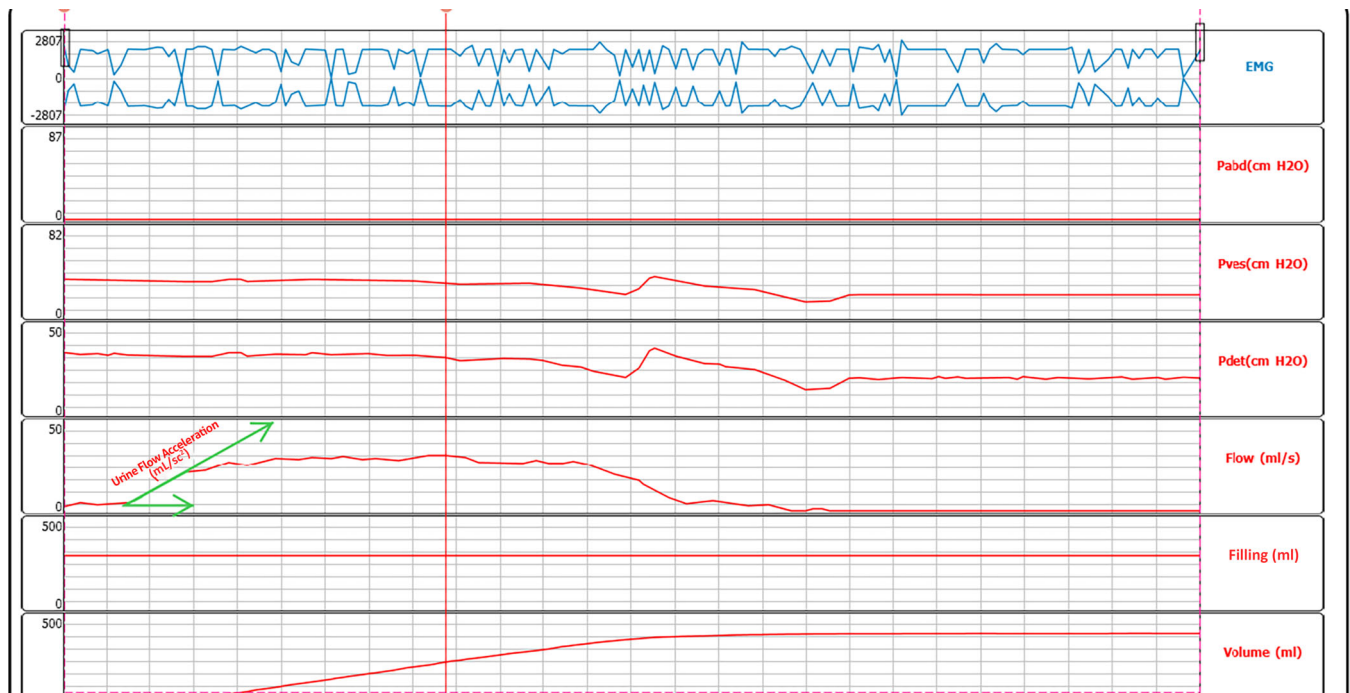


FIGURE 1 Measurement of maximum acceleration of flow (Qacc) with the Adobe Acrobat Reader DC programme. To measure the angle, we selected the most prominent rapid flow. EMG, electromyograph; Pabd, abdominal pressure; Pdet, detrusor pressure; Pves, intravesical pressure

4 | RESULTS

During the study period, 384 urodynamic studies were performed for women with the complaint of urinary incontinence. The flowchart of the study is demonstrated in Figure 2. The charts were excluded for incomplete filling and voiding phase ($n = 28$), and <18 years/ >80 years of age ($n = 35$). The remaining urodynamic records of 321 women were reviewed by two (S.A. and A.F.G.K) experts. There was no incontinence in 130 subjects. Incontinent patients were categorized into three groups, namely: stress, mixed, and urge incontinence according to urodynamic diagnosis. Charts of 128 women showed urodynamic stress incontinence, and 32 had both urodynamic stress incontinence and detrusor overactivity. The urge incontinence group was composed of 16 women with wet and dry detrusor overactivity. Before final analysis, 18 records were excluded for incorrect measurements, extremely low bladder capacity, and/or low flow rates. At final analysis, 142 urodynamic records of women with stress incontinence were analyzed, and Qacc was measured as described above.

Mean age of the entire cohort was 52.7 ± 12.2 (22-78). The mean age of the ISD group was 53.3 ± 12.5 (24-78) and of the non-ISD group 53.7 ± 12.5 (35-74). Interrater and intrarater reproducibility of acceleration measurement was calculated for 20 randomly selected samples. Interperformer reproducibility between S.A. and A.F.G.K. was very good (ICC 0.88). Test-retest reproducibility of Qacc performed by the main evaluator (S.A.) was very good (ICC 0.84).

In the subgroup analysis of SUI, the mean Qacc ($30.3 \pm 16.1^\circ$ [mL/s^2]) in the ISD group was significantly higher than in the non-ISD group ($21.6 \pm 9.6^\circ$ [mL/s^2]) (Table 1) ($P < .0001$). Urodynamic bladder

capacity of the non-ISD group (432.3 ± 90.4 mL) was higher than the ISD group (389.2 ± 109) ($P = .01$). Qmax, Qave, PdetQmax, PvesQmax, first urine sensation volume, first-desire-to-void volume, strong-desire-to-void volume, and first leak volume measurements were similar in both groups.

In the correlation analysis, there were no significant correlations of first urine sensation volume, first-desire-to-void volume, strong-desire-to-void volume, first leak volume, urodynamic bladder capacity, voided volume, and age with Qacc. Qacc was weakly correlated with Qmax ($r = 0.15$, $P = .02$). We found a statistically significant correlation ($r = 0.3$, $P < .001$) between vesical pressure at maximum flow and Qacc, but there was no correlation between PdetQmax and Qacc.

5 | DISCUSSION

We found that the acceleration of urinary flow was higher in the ISD group. However, Qmax and Qave did not differ between the ISD and non-ISD groups. Smith and Appell have previously shown that Qmax and PdetQmax were not predictive of ISD (defined by a low abdominal LPP).¹² Their study has refuted the previous hypothesis that low pressure of the urethra and diminished impedance to urine flow would result in higher flow rates.¹³ Qave and voided volume in the POP population are less compared to healthy controls, and this should be considered when evaluating the results of patients with high-grade POP. In our study, we excluded \geq POP stage 3 patients to overcome this conflicting effect of prolapse on flow rate.

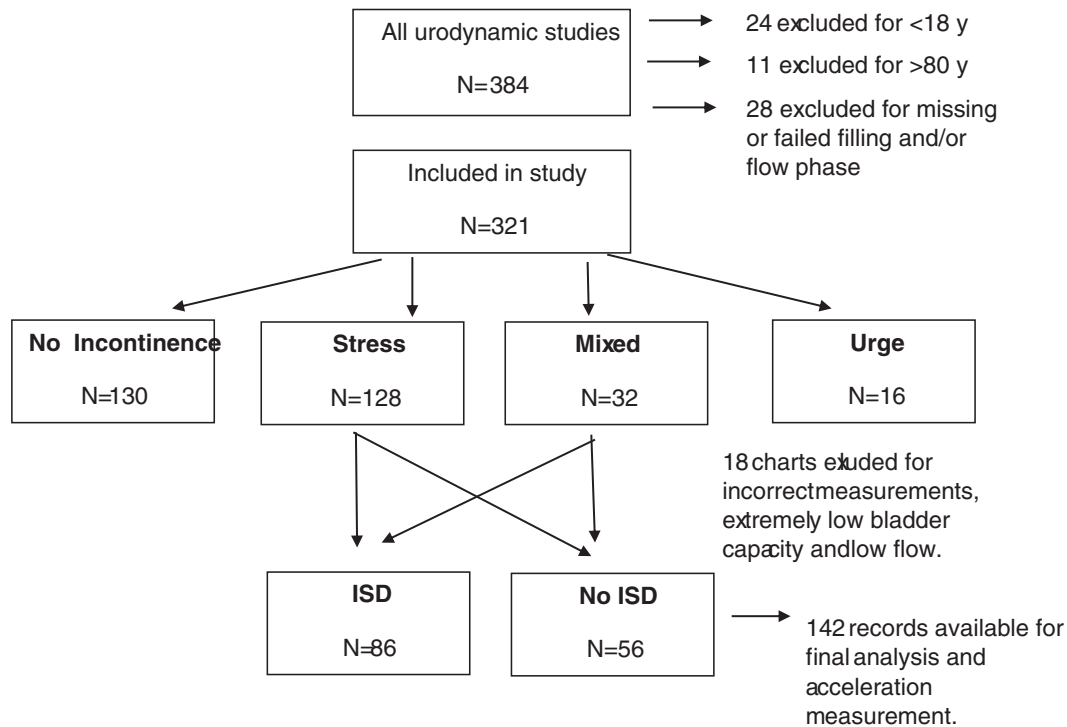


FIGURE 2 Flowchart of the study. ISD, intrinsic sphincter deficiency

TABLE 1 Comparison of urodynamic measurements of women with ISD and non-ISD stress incontinence

	ISD (n = 86)	Non-ISD (n = 56)	P
Qacc (mL/s ²)	30.3 ± 16.1	21.6 ± 9.6	<.0001
Qmax (mL/s)	25.5 ± 13.6	25.9 ± 13.4	.8
Qave (mL/s)	8.5 ± 4.9	9.3 ± 5.3	.3
PdetQmax (cm H ₂ O)	25.1 ± 19.5	32.2 ± 22.9	.1
PvesQmax (cm H ₂ O)	76.9 ± 34.1	83.9 ± 34.7	.2
Pdetmax (cm H ₂ O)	59.4 ± 46.9	61.2 ± 35.8	.8
First urine sensation (mL)	113.4 ± 84.8	115.4 ± 67.8	.9
First desire to void (mL)	222.3 ± 90.4	247.5 ± 89.3	.3
Strong desire to void (mL)	358.3 ± 125.8	418.3 ± 117.6	.1
Bladder capacity (mL)	389.2 ± 109	432.3 ± 90.4	.01
First urine leak volume (mL)	203.9 ± 117.3	234.3 ± 114.2	.1
LPP (cm H ₂ O)	42.7 ± 13.8	94.6 ± 20.5	<.0001

Note: Statistical comparisons by Student t test; bold indicates statistical significance.

Abbreviations: ISD, intrinsic sphincter deficiency; LPP, leak point pressure; Pdetmax, maximum voiding detrusor pressure; PdetQmax, detrusor pressure at maximum flow; PvesQmax, vesical pressure at maximum flow; Qacc, acceleration of flow; Qave, average flow rate; Qmax, maximum flow rate.

Normal continence can be provided by normal anatomical position of the urethra and intrinsic continence mechanisms maintaining the resistance of the bladder outlet higher than the intravesical pressure. The intrinsic urethral mechanism is composed of tonic contraction of intrinsic muscle, intact neurologic input (lower motor neurons in Onuf nucleus and pudendal nerve), and healthy vascularization of the urethral mucosa and submucosa, thus enabling the coaptation of the urethral wall. In addition to these intrinsic mechanisms, extrinsic supportive structures such as the intact pubourethral ligament, lateral supports of

vagina, endopelvic fascia, and levator ani muscle are required for proper anatomical positioning of the urethra. Any damage in the functional and anatomical component or a combination of defects can result in stress incontinence. Dysfunction of the intrinsic mechanism with or without anatomical support loss results in decrease in tonus and resistance that can cause ISD.⁵ We hypothesize that decrease in tonus or resistance can be related to facilitated flow. Our hypothesis is based on the principles of Doppler that resistance and compliance can alter the Doppler waveforms and acceleration index.¹⁴ This facilitation can indirectly be

measured by Qacc. In this study, we suggest Qacc as a novel yet easy measurement to evaluate urethral function.

Consistent with previous studies, in our study there was no difference in Qmax, Qave, and PdetQmax between ISD and non-ISD stress incontinence. This may be explained with the defective support mechanism to resorb pressure transmission. Stress incontinence is not a unique pathology; thus, dysfunction of tonus or hypermobilization of urethra may coexist which make it difficult to define ISD. Clinically, urethral function can be measured by LPP and MUCP. LPP is defined by the ICS as the intravesical pressure at which urine leakage occurs due to increased abdominal pressure in the absence of a detrusor contraction. The MUCP is produced by the high-pressure zone of the midurethra relative to the bladder. MUCP less than 20 cm H₂O is accepted as a cutoff value to diagnose ISD. VLPP < 60 cm H₂O is also frequently utilized to diagnose ISD.^{3,15} In addition to the poor reliability, sensitivity, and specificity of MUCP, many factors potentially effect VLPP measurement and reliability as well.¹⁶⁻¹⁸

The diagnosis of ISD is critical for deciding on a therapeutic option and success of the surgical procedure. New measurements and diagnostic criteria are needed to support the ISD diagnosis due to the significant limitations of VLPP and MUCP measurements we mentioned above. At this point, our results which support the role of acceleration speed of flow in the diagnosis of ISD are promising. As a less invasive alternative, the role of free-flow Qacc may also be researched as uroflow measurement of the urine acceleration may be less uncomfortable for patients and more practical for clinicians.

The strength of this study is the novel measurement of the angle of the flow which gives the acceleration speed of the dominant flow. Our study includes a large number of women and interpretations that were standardized techniques with a universal unit and software. The power of the study was calculated as 0.86, when μA was 30.1, μB was 21.6, and σ (standard deviation) was 16, and sample size was calculated as 40 cases in each group, when β was .20. The major limitation of our study is the lack of free uroflow and UPP measurements. Transurethral catheterization of the bladder is crucial for pressure and flow recordings; however, these catheters decrease flow rates and increase flow time or result in an intermittent flow. Therefore, our measurements could be affected by transurethral catheters. According to previous studies, there was no difference between 4.5 and 6F catheters, but significant differences in measurement existed between 4.5 and 7F catheters in invasive flow recordings.¹⁹⁻²¹ We believe that the 6F catheters that we used would not alter flow characteristics and interpretation. We use gravimetric free uroflows in our clinic. The use of this method of measurement may cause delay and change of flow due to turbulence and resistance effect of the container. However, comparison of uroflow diagrams and acceleration speeds can contribute to the evaluation of flow characteristics. Other limitations of this study are the retrospective design because of potential selection biases and unplanned data collection methods.

6 | CONCLUSION

What we know about the flow rate comes from a small number of studies limited to the measurement of Qmax. The VLPP and MUCP

measurements in assessing urethral function are not useful for predicting incontinence surgery failure. The Qacc may demonstrate urethral resistance and tonus in a more reliable manner. The Qacc is higher in ISD stress incontinent women than stress incontinent women. The potential role of flow acceleration speed on ISD diagnosis and anti-incontinence surgery failure should be evaluated in well-designed future studies. Developing a nomogram based on these future studies has a potential to aid the diagnosis of ISD.

CONFLICT OF INTEREST

We disclose that all authors have no conflict of interest.

AUTHOR CONTRIBUTIONS

A.F. Gokmen Karasu: project development, data collection, and manuscript writing. S. Aydin: Data analysis and manuscript writing. S. Kalkan: manuscript writing/editing. C. Ersoz: manuscript writing/editing.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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