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# A comparative study between EMG uroflowmetry with and without a catheter in children

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## Abstract

**Objectives** To evaluate the effect of urethral catheterization on the accuracy of EMG uroflowmetry in children with non-neurogenic voiding disorders during pressure-flow (PF) studies compared to the non-invasive EMG uroflowmetry test.

**Methods** A retrospective study of children undergoing a urodynamic evaluation at our institution between 8/2018 and 7/2022 was employed. Urination curves and pelvic floor muscle activity were compared between PF studies and non-invasive EMG uroflowmetry test. The non-invasive test was selected as the standard benchmark.

**Results** 104 children were tested, with 34 children (33%) being able to urinate only in a non-invasive EMG uroflowmetry. The percentage of boys unable to urinate with a catheter was significantly higher than girls (54% vs. 13%, p-value < 0.001). In 70 children, a normal bell-shaped urination curve was found in 13 compared to 33 children in the PF studies and non-invasive uroflowmetry, respectively. PF studies demonstrated a specificity of 39% (95% CI 23–57) and a positive predictive value (PPV) of 61% (95% CI 53–67) in finding non-bell-shaped curves. Relaxation of pelvic muscles was found in 21 (30%) as opposed to 39 (55%) of children in invasive and non-invasive EMG uroflowmetry, respectively (p-value = 0.5).

**Conclusion** The accuracy of PF studies in children, primarily in boys, compared to the non-invasive uroflowmetry, was poor. This may pose potential errors in diagnosis and subsequent treatment. We recommend completing a non-invasive EMG uroflowmetry in cases where the child refused to urinate, or pathology was found, requiring a modification in treatment.

**Keywords** Urodynamic, EMG-flow, Voiding curves, Validity, Lower urinary tract symptoms

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## Introduction

Urodynamic studies (UDS) are a valuable tool for assessing lower urinary tract symptoms (LUTS). Both the filling phase and the pressure-flow (PF) phase of UDS provide detailedinformation that contribute to diagnoses [1–3].

Electromyography (EMG) uroflowmetry is an essential phase of PF evaluation and assists in determining treatment options.

In adults, It has been established that an 8Fr catheter or smaller does not cause a significant obstructive effect during voiding and does not affect the Qmax of uroflowmetry [4–7].

The International Children's Continence Society (ICCS) guidelines affirm that 6Fr or 7Fr catheters do not obstruct the urethra during voiding [3, 8]. However, little is known about the effect of a catheter in the PF phase of UDS in children. Following years of urodynamic tests, we have the impression that despite efforts to adjust the micturition environment to help the child relax and void, some children still fail to void with the catheter inserted. Pain, fear, or the unpleasant voiding in an unfamiliar environment can interfere with the child's ability to initiate normal urination. This raises questions regarding the accuracy of the EMG uroflowmetry in UDS when performed with a urethral catheter.

Non-invasive EMG uroflowmetry for evaluating lower urinary tract function has been shown to increase diagnostic accuracy and selection of appropriate treatment for non-neurogenic voiding disorders [9–12].

While non-invasive uroflow-EMG is well established as a tool for assessing the voiding phase, evidence of validation for UDS voiding with a urethral catheter is scarce. This study aimed to assess the accuracy of EMG uroflowmetry with a urethral catheter compared to the non-invasive uroflow-EMG in children with non-neurogenic voiding disorders.

## Methods

A cross-sectional design was utilized. We retrospectively reviewed UDS and EMG uroflowmetry in children performed at our institute.

### Patients and data collection

The study population included all children between 4 and 18 years of age who underwent UDS between August 2018 and July 2022 for non-neurogenic voiding disorders only. Indications for UDS included lower urinary tract dysfunction (incontinence, difficult urination, urgency or frequency) resistant to conservative treatment and recurrent urinary tract infections (UTIs). Included were children who underwent a non-invasive EMG uroflowmetry within one month of UDS. The timing of the uroflow tests, with or without a catheter, was at least six months after surgical intervention. The interval between the two tests was less than a month, with no change in treatment protocols during that time. Only the first UDS was used in children who underwent more than one exam during their years of surveillance. Only studies with voided volume of more than 50% of the expected bladder capacity were included, which is defined by ICCS as a reliable test [2]. Excluded were children who performed clean intermittent catheterization, and children with medical history of spinal cord defects.

UDS was performed using the Laborie Aquarius CT urodynamic system and in accordance with International Continence Society recommendations [13].

To compare UDS and non-invasive EMG uroflow tests, three pediatric urologists highly experienced with interpreting such studies reviewed the voiding curves recorded during each exam. Although not all three physicians were present in the exams, weekly meetings were conducted to discuss all test results and agree on the final study interpretation. The resulting voiding curves were divided into five main patterns: normal bell-shaped curve, tower-shaped curve, staccato-shaped curve, interrupted-shaped curve and low-amplitude-prolonged plateau-shaped curve [14].

Voided volume, Qmax and residual urine volume were recorded for each exam, while pelvic-floor muscle activity was assessed qualitatively, classified as "relaxed" or "active". Demographic and clinical characteristics, comorbidities, and medication treatment for each patient were also collected.

### Statistical analysis

Categorical variables were summarized by number and percentage, and continuous variables by the median and interquartile range (IQR). Chi-square test was used to examine differences in sociodemographic characteristics between children who succeeded in voiding with both the PF studies and non-invasive EMG uroflowmetry and children who only succeeded in voiding with the non-invasive uroflowmetry. McNemar test was used to examine differences in voiding curves and pelvic floor muscle activity between the PF studies and non-invasive EMG uroflowmetry. Paired t-test was used to compare voided volume, residual volume, Qmax and flow time between the two tests. Sensitivity and specificity were calculated for voiding curves (normal bell-shape/pathological), while the non-invasive uroflowmetry was selected as the standard benchmark. Additional analyses were performed using stratification by children's sex and age group. All analyses were performed using SPSS software version 27.

**Table 1** Baseline characteristics of children who underwent both PF study and non-invasive EMG uroflowmetry tests

| Characteristic | Total |
|---|---|
| No. of patients (%) | 104 (100) |
| Age (years), median (IQR) | 8 (6–11) |
| Males (%) | 50 (48) |
| Females (%) | 54 (52) |
| Anticholinergic use (%) | 7 (7) |
| **Medical Background** | |
| VUR (%) | 41 (39) |
| Dysfunctional Voiding (%) | 14 (13) |
| PUV (%) | 9 (9) |
| Single Kidney (%) | 7 (6) |
| CRF (%) | 5 (4) |
| None (%) | 28 (29) |
| **Previous Operations** | |
| Deflux Injections (%) | 21 (20) |
| Ureteroneocystostomy (%) | 11 (10) |
| PUV Ablation (%) | 9 (9) |
| Hypospadias Repair (%) | 4 (3.5) |
| None (%) | 59 (57.5) |
| **Symptoms** | |
| Incontinence (%) | 53 (51) |
| Recurrent UTI (%) | 32 (31) |
| Difficult Urination (%) | 11 (10) |
| LUTS (%) | 8 (8) |

*Abbreviations* EMG- electromyography; IQR- inter-quartile range; VUR- vesicoureteral reflux; PUV- posterior urethral valve; CRF- chronic renal failure; UTI- urinary tract infection; LUTS- lower urinary tract symptoms

**Table 2** Characteristics of children who agreed to urinate on both PF study and non-invasive EMG uroflowmetry tests compared to children who urinated only on the non-invasive uroflowmetry

| | Urinated on both tests | Urinated only on non-invasive test | *P*-value |
|---|---|---|---|
| Total (*N*=104) | 70 (67%) | 34 (33%) | - |
| Sex, males (*N*=50) | 23 (46%) | 27 (54%) | <0.001 |
| Sex, females (*N*=54) | 47 (87%) | 7 (13%) | <0.001 |
| Age 4–9 years (*N*=57) | 36 (63%) | 21 (37%) | 0.3 |
| Age 10–18 years (*N*=47) | 34 (72%) | 13 (28%) | 0.4 |

*Abbreviations* EMG- electromyography

## Results

A total of 104 children were included in our study. There were 50 (48%) males and 54 (52%) females with a median age of 8 (IQR: 6–11) years. Regarding past medical history and past surgical history, 41 (39%) children had vesicoureteral reflux (VUR), 9 (9%) underwent excision of a posterior urethral valve (PUV), 11 (10%) children underwent ureteral re-implantation surgery and 9 (9%) were characterized as dysfunctional voiders (DV). The common symptoms found in children undergoing UDS and non-invasive EMG uroflow were 53 (51%) children with symptoms of urinary incontinence and 32 (31%) children with recurrent UTIs (Table 1).

Out of 104 children who underwent UDS and non-invasive EMG uroflow, 34 (33%) refused or could not void on UDS and voided only with non-invasive EMG uroflow. There were no significant demographic differences between children who agreed to void on both exams versus those who voided only on the non-invasive EMG uroflow in the different age groups. However, the later included a significantly higher percentage of males (54% vs. 13%, p-value<0.001) (Table 2).

In comparing the voiding curves of 70 children who underwent both non-invasive EMG flow and UDS, only 30 (42%) children had concordant results. While a normal bell-shaped curve was observed in 33 (47%) children with the non-invasive EMG uroflow, only 13 (18%) had the same result on UDS (p-value=0.02). Out of 15 (21%) children with interrupted voiding curves on non-invasive EMG uroflow, only 5 (7%) had a concordant interrupted voiding curve on UDS (p-value=0.09). UDS showed more children with plateau-shaped (21% vs. 11%) voiding curves than seen on non-invasive EMG uroflow ($p<0.001$). In comparing pelvic-floor muscle electrical activity between non-invasive EMG-uroflow and UDS, 36 (51%) children had concordant muscle relaxation or activation. While 39 (55%) children were able to normally relax their pelvic floor muscles during voiding on the non-invasive EMG-uroflow, only 21 (30%) children were able to do so on UDS (p-value=0.5). Comparison of additional parameters between the PF test and the non-invasive EMG uroflowmetry test found significant differences in mean voided volume (209 vs. 165 ml, respectively, p-value 0.02), mean Qmax (11.9 vs. 16.6 ml/second, respectively, p-value 0.01) and mean flow time (32.4 vs. 17.9 s, respectively, p-value 0.03). In contrast, mean residual volume was similar in the two tests (33 vs. 31 ml, respectively, p-value 0.6). (Table 3).

Based on UDS, 51 (72%) children had abnormal voiding curves, compared to 37 (52%) with non-invasive EMG uroflow. Among children with abnormal voiding curves based on non-invasive EMG uroflow, 31 were also classified as having an abnormal curve on UDS, yielding a sensitivity of 83% (95% CI: 68–93). Among 33 children who had a normal bell-shaped voiding curve with non-invasive EMG uroflow, 13 were also classified as having a normal bell shaped voiding curve with UDS, thus yielding a specificity of 39% (95% CI: 23–57). A false positive result was demonstrated for 20 children (60%) classified with an abnormal voiding curve on UDS, thus yielding a positive predicting value (PPV) of 61% (95% CI: 53–67). Stratification by sex and age had a limited effect on the sensitivity of abnormal voiding curves on UDS. Slight differences were observed in the specificity (with

**Table 3** Comparison between PF studies and non-invasive EMG uroflowmetry

| | Non-invasive EMG uroflowmetry | Pressure Flow study | Children with concordant data | *P*-value |
|---|---|---|---|---|
| **Voiding curve** | | | | |
| Total | 70(100%) | 70 (100%) | 30/70 (42%) | - |
| Bell Shape | 33 (47%) | 19 (27%) | 13/70 (18%) | 0.02 |
| Interrupted | 15 (21%) | 13 (19%) | 5/70 (7%) | 0.09 |
| Staccato | 11 (16%) | 22 (32%) | 5/70 (7%) | 0.2 |
| Plateau | 8(11%) | 15 (21%) | 6/70 (8%) | <0.001 |
| Tower | 3 (4%) | 1 (1%) | 1/70 (1%) | 0.04 |
| **Pelvic-floor muscle activity** | | | | |
| Total | 70 (100%) | 70 (100%) | 36/70 (51%) | - |
| Relaxed | 39 (55%) | 21 (30%) | 13/70 (18%) | 0.5 |
| Active | 31 (45%) | 49 (70%) | 23/70 (32%) | - |
| Mean Voided Volume mL (SD) | 165 (93) | 209 (100) | - | 0.02 |
| Mean Residual Volume mL (SD) | 31 (46) | 33 (70) | - | 0.6 |
| Mean Qmax mL/sec (SD) | 16.6 (6.4) | 11.9 (5.6) | | 0.01 |
| Mean Flow time sec (SD) | 17.9 (14.5) | 32.4 (20.3) | | 0.03 |

*Abbreviations* SD- standard deviation; EMG- electromyography

overlapping confidence intervals), being lower in males than in females (Table 4).

## Discussion

PF evaluation with a urethral catheter as part of urodynamic studies is the common practice tool in assessing lower urinary tract dysfunction in children and determining appropriate treatment. The urethral catheter is essential for measurements such as opening pressure and detrusor contractility [2]. However, the catheter has a disruptive effect on children's normal voiding behavior and their ability to void.

The ICCS guidelines for urodynamic studies note that voiding with a catheter is unnatural and therefore children may experience difficulty voiding with a catheter in place, but on the other hand point out that small-caliber catheters of 6 or 7Fr do not obstruct the urethra and allow normal flow of urine [8]. In the current study, the catheter's disruptive effect was evident. Of 104 children who underwent urodynamic testing, 34 (33%) failed to urinate or refused to void with the catheter during the PF phase. Thus, before addressing the test's accuracy, it is imperative to note that a significant percentage of children will not initiate voiding with a catheter, largely due to reasons other than the organic effects associated with their pathology. Similar studies that tested the effect of the catheter on pressure flow also found that a substantial proportion of children could not void in the urodynamic test. For example, in a study by Fugaru et al., 15% of children who underwent UDS could not void in the presence of the catheter, and therefore, pressure flow has not been determined for these children [15].

The effect of urinary catheters on PF results in adult males was assessed in several studies. Most of these studies dismiss the obstructive effect of a catheter during voiding, similar to the ICCS guidelines. For example, Reynard et al. noted no significant difference in maximal flow rate in a study of 59 men who underwent PF testing with and without an 8Fr catheter. A more extensive cohort study by Harding et al. demonstrated no significant effect on Qmax during the PF phase in 200 men with and without a small caliber catheter [4, 6].

Selected studies, mainly in adult women, did note an obstructive effect of a catheter during voiding [16]. In adult males, Zhao et al. observed that an 8Fr catheter significantly affected the maximal flow rate in a study of 40 men with BPH, which correlated with the degree of bladder outlet obstruction. Klingeler et al. reported similar results in an earlier study of 64 men with BPH [5, 17].

In adult women, Scaldazza et al. observed that even 6Fr and 7Fr transurethral catheters might obstruct micturition in a study of 60 women undergoing PF studies for LUTS evaluation. A more extensive study by Constantini et al. of 239 women with LUTS demonstrated reduced

**Table 4** Comparison of normal "Bell Shaped" and abnormal urination curves on PF studies and non-invasive EMG uroflowmetry tests

| | Abnormal curve (PF /non-invasive EMG uroflowmetry) | Normal curve (PF /non-invasive EMG uroflowmetry) | Sensitivity (95% CI) | Specificity (95% CI) | Positive predictive value (95% CI) | Negative predictive value (95% CI) |
|---|---|---|---|---|---|---|
| All children | 31/37 | 13/33 | 83% (68-93) | 39% (23-57) | 61% (53-67) | 68% (48-83) |
| Sex, males | 11/12 | 3/11 | 91% (62-22) | 27% (6-60) | 57% (47-67) | 75% (26-96) |
| Sex, females | 20/25 | 10/22 | 80% (59-93) | 45% (24-67) | 62% (52-71) | 66% (44-83) |
| Age 4-9 years | 16/20 | 6/16 | 80% (56-94) | 37% (15-64) | 61% (50-71) | 60% (33-81) |
| Age 10-18 years | 15/17 | 7/17 | 88% (63-98) | 41% (18-67) | 60% (49-69) | 77% (45-93) |

*Abbreviations* CI- confidence interval; EMG- electromyography; PF- pressure flow

Qmax in PF studies with every diameter of the transurethral catheter [18, 19].

A comparison of the effect of a catheter during voiding between adult men and women was previously presented by Cheng et al. [20]. Contrary to the results, which did not demonstrate a significant difference between men and women in transurethral catheter effect on PF, the current study observed that in children, the percentage of boys who failed to void with the catheter was nearly four times as high as in girls (13% vs. 54%). The reason for that could be explained by the longer and curved urethra in young boys compared with girls, which results in a greater degree of pain and discomfort, which interferes with micturition.

The high percentage of children who failed to void with the transurethral catheter raises concerns regarding the test's reliability and its ability to correctly evaluate PF and inform treatment plans in children who voided successfully.

There is a paucity of studies in children that validate the PF phase in invasive urodynamic studies. To validate part of this phase, voiding parameters were compared with and without catheters.

Non-invasive EMG uroflowmetry was subjected to validation studies which proved it to be a valid tool for evaluating and devising treatment plans for LUTS [12]. Thus, following our impression of difficulties or failed voiding with the catheter during the PF study, we have scheduled all the children to a non-invasive EMG uroflowmetry. According to our data, no children had a normal bell-shaped micturition curve in the PF test if they had an abnormal one in the non-invasive uroflow test. Thus, we think that the choice of the non-invasive test as the "gold standard" is justified.

We found poor correlation between PF studies and noninvasive EMG uroflow results. In fact, only 30 children (42%) had identical micturition curves in both tests. In children with identical micturition curves in both tests, results most commonly showed a normal bell curve. Thus, children with normal micturition curves in the noninvasive uroflow succeeded in voiding better in the PF study and achieved an identical bell curve. Children whose micturition curve was abnormal in the non-invasive uroflow had abnormal curves in the PF study as well but showed different patterns than the curves recorded during the non-invasive uroflow.

Pathological micturition curves were observed more frequently and distinctly in invasive urodynamic studies. While nearly 50% of children demonstrated normal bell-shaped micturition curves without a catheter, the percentage of children with normal curves dropped significantly in the PF studies, with only 30% of children demonstrating normal curves.

Pathological micturition curves such as plateau-shaped curves were observed more frequently in the invasive test. These curves suggest an obstructive pattern and correspond to the adult studies which demonstrated that the catheter had an obstructive effect in PF studies [21].

Interrupted and staccato micturition curves were observed with high frequency in invasive catheter studies. These results suggest difficulty achieving relaxation of the sphincter and pelvic floor muscles.

We agree with the assumption that the urethral stimulation, pain, and anxiety caused by the urethral catheter interferes with children's ability to relax the sphincter and pelvic floor muscles as is necessary for normal micturition [22]. This is evident in our results as well, as 55% of children sufficiently relaxed pelvic floor muscles during noninvasive EMG uroflowmetry, while in the PF studies, 70% of children demonstrated increased pelvic floor muscle tension on EMG. Although not statistically significant, we suspect that this tendency implies difficulties to relax pelvic floor muscles with the catheter.

Comparing the results of PF studies and noninvasive EMG uroflowmetry, we found the PF study's sensitivity to be fairly good at 83%. Thus, if the noninvasive uroflowmetry is normal, the invasive PF study will most likely show similar results. In contrast, the PF study's specificity was very low, at 39%. With a high number of false positives of 60% and a low PPV of 61%, it appears that the invasive catheter study demonstrates high false pathological micturition characteristics which apparently do not reflect the child's true micturition patterns.

As mentioned above, studies that validate the PF test in children and compare it to uroflowmetry without a catheter are largely missing from the clinical literature. One exception is a recent study by Fugaru et al. (2023) [15], which examined the effect of urethral catheterization in PF compared to uroflowmetry without a catheter in a group of 46 children. The study did not exclude children with spinal issues, which could indicate neurogenic voiding disorders, but excluded children who could not void spontaneously with the catheter in place. Fugaru et al. found reduced Qmax and flow index during PF compared to uroflowmetry without a catheter. These findings are congruent with studies in adults and with our current study.

Our study's strengths include a large study population from a tertiary referral center consisting of children of varying ages, which represent a large and varied urinary pathologies in children. We consider heterogeneity a strength of the study because the inclusion of a diverse population presenting with different urological disorders (apart from the excluded neurological urinary disorders) provides a more reliable validation of the PF test for different pathologies. An additional strength is the fact that the comparison between PF studies and non-invasive uroflowmetry studies was performed using a paired method on the same child. All children had exams no longer than one month apart, with no treatment or medication regimen change. Therefore, even if PUV, for example, represents a unique pathology, the results from children with PUV are unlikely to affect the group analysis. Furthermore, the inclusion of this group provides useful information about the differences between the tests in these patients.

The major limitation of our study is its retrospective design. The urodynamic tests are naturally open to many artifacts and their interpretation are open to errors in a retrospective analysis. Although highly experienced urologists interpreted both the pressure-flow (PF) studies and the non-invasive EMG uroflowmetry tests, only qualitative assessment of EMG activity was obtained-classified as “relaxed” or “active”. Another limitation of the study is the difference in voided volume between the two tests since the amount of voided urine can potentially affect the flow rate. The median voided volume was 44 mL lower in the non-invasive uroflow test than in the pressure flow test, most likely due to bladder filling to maximum capacity in the latter. To mitigate the potential effect of this confounding variable, we excluded non-invasive uroflow tests that have not fulfilled the ICCS test reliability criteria of over 50% expected bladder capacity.

## Conclusion

In summary, the level of accuracy of EMG uroflowmetry with the use of a catheter in children, in comparison to the non-invasive uroflowmetry was low, and even lower in boys compared with girls. We demonstrated a low specificity and PPV of the EMG uroflowmetry in finding pathological urination patterns. This may pose potential errors in the diagnosis and subsequent treatment. We recommend considering the completion of non-invasive EMG uroflowmetry in cases where the child refused to urinate or in cases where pathology was found, requiring a modification in treatment.

### Abbreviations

| | |
|---|---|
| PF | Pressure-flow |
| PPV | Positive predictive value |
| UDS | Urodynamic studies |
| LUTS | Lower urinary tract symptoms |
| EMG | Electromyography |
| ICCS | International Children’s Continence Society |
| UTIs | Urinary tract infections |
| IQR | Interquartile range |
| VUR | Vesicoureteral reflux |
| PUV | Posterior urethral valve |
| DV | Dysfunctional voidin |

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None.

### Author contributions

S.B: Study conception and design, analysis and interpretation of results, draft manuscript preparation. R.M: Study conception and design, analysis and interpretation of results. B.S: Study conception and designD. B.M: Study conception and design, analysis and interpretation of results, supervision of manuscript preparation.

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### Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

### Ethical approval

The study protocol was approved by our Institutional Review Board- Helsinki Department, Rabin Medical Center. Approval number- 059520-RMC.

### Consent to participate

As approved by our Institutional Review Board- Helsinki Department, Rabin Medical Center, Approval number- 059520-RMC, in this study patients consent forms were not required.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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