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ICS educational module: The practice of uroflowmetry in adults

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ABSTRACT

Aim: To present the body of evidence behind the International Continence Society (ICS) educational module on "Practice of uroflowmetry in adults" which consists of a PowerPoint® presentation.
Methods: This evidence review has been prepared by a working group instituted by the ICS Urodynamics Committee. The method used included systematic literature review, consensus formation by the members of the Working Group, and review by members of the ICS Urodynamics Committee core panel.
Results: A total of 104 articles were included in this systematic review. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed. Evidence analysis was conducted along the following themes: physiology of voiding, pathophysiology of lower urinary tract dysfunction, technique of uroflowmetry, quality check of the uroflowmetry test, interpretation and reporting of uroflowmetry findings.
Conclusions: Uroflowmetry is the most commonly utilized diagnostic test in the evaluation of adults presenting with lower urinary tract symptoms. The practice of uroflowmetry exhibits variations which might lead to inconclusive or inaccurate assessments. The ICS educational module on the Practice of Uroflowmetry in Adults provides up-to-date and evidence-based guidance in an effort to establish standards in the technique, interpretation, and reporting of uroflowmetry.

1. Introduction

Uroflowmetry is a non-invasive urodynamic test, usually performed in combination with post void residual urine (PVR) assessment. The International Continence Society (ICS) has determined standards for good urodynamic practices (ICS-GUP 2016) which included recommendations about uroflowmetry [1]. The aim of this ICS educational module is to demonstrate the best practice of uroflowmetry testing for adult patients. Assessment of PVR is explained in a separate module [2].

The module does not include the indication(s) for uroflowmetry, which is discussed within the context of clinical practice guidelines. As stated in the ICS-GUP 2016, uroflowmetry is usually the initial screening test for persons with symptoms and signs of lower urinary tract (LUT) dysfunction (LUTD). Therefore, this module follows the motto: "A test should be done as technically adequate, patient friendly, efficient, and effective as possible". Furthermore, evaluation of the test should cover information about its representativeness and reliability, and the report should include description of the flow pattern, relevant parameters, and conclusion [1].

Herein, the technical evolution of uroflowmetry devices has been summarized [3], as well as diverse newer systems that are developed thereafter [4]. Technical aspects of uroflowmetry equipment [5] fall outside the scope of this teaching module. A discussion of the gaps in the current understanding of uroflowmetry has already been published [5,6] and this educational module has the intent to raise the standard of practice and the clinical quality of the uroflowmetry test.

2. Methods

A systematic literature review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [7,8]. Initial searches of the literature revealed key Medical Subject Headings (MeSH) of relevant studies, which were then used to search PubMed through June 22, 2023. Specifically, MeSH

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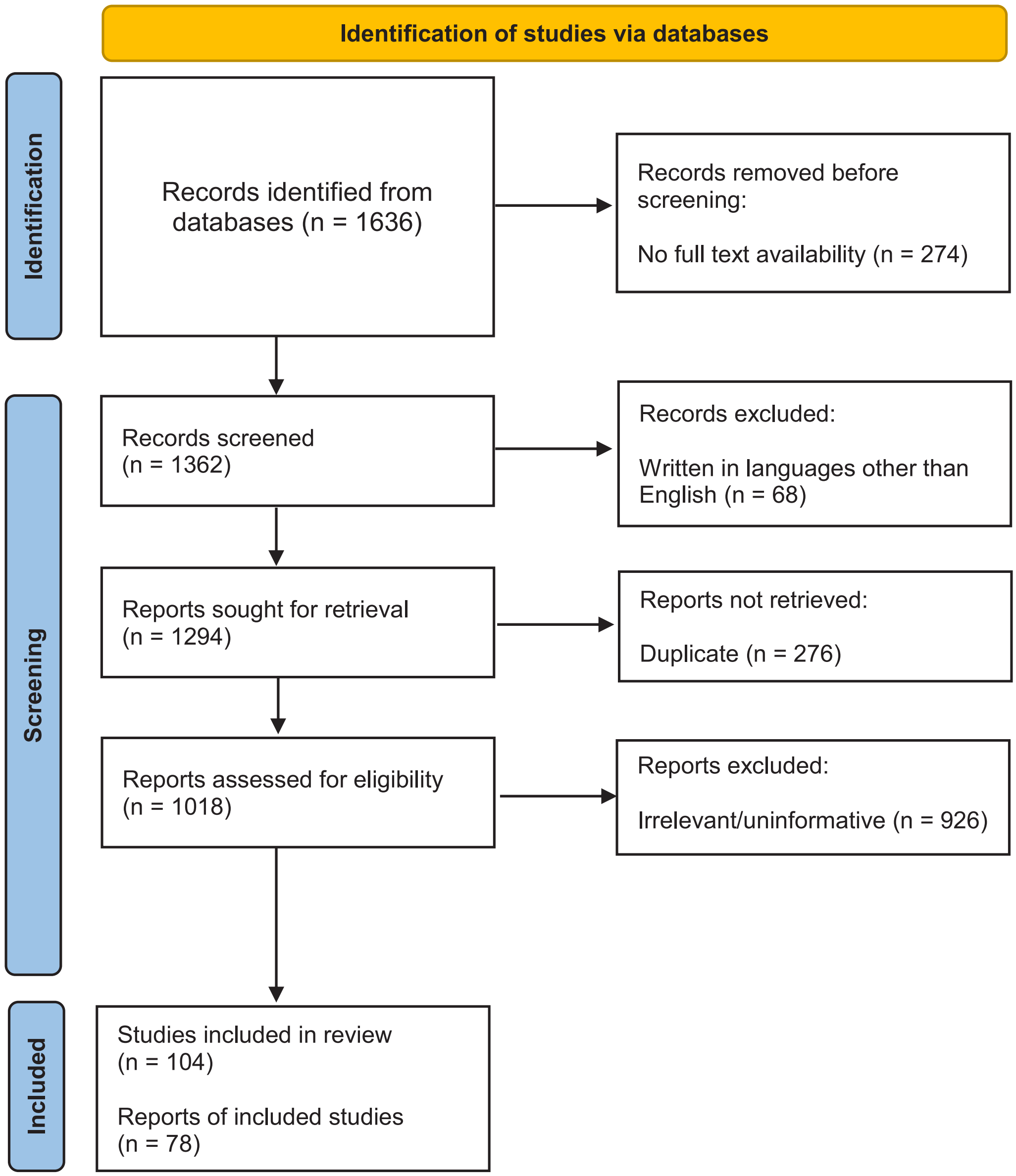

Fig. 1. PRISMA diagram.

search was conducted by combining the following terms retrieved from the MeSH browser provided by PubMed: "uroflowmetry", "adult", "reporting", "interpretation", "technique", "quality control". Subsequently, the search results were pooled, applying no limitations. The review was not registered, and a protocol was not prepared.

Two of the authors reviewed the title and abstract of all the records to select the papers relevant to the review topic. Landmark articles of relevance were separately included based on authors' discretion. Subsequently, the selected papers were assessed in full-text format by two other authors to collect all the relevant data.

After a PubMed search between the years 1967 and 2023, a total of 1636 publications were identified. Then, articles with no full text availability were removed, reaching the remaining 1362 articles followed by removing all articles written in languages other than English reaching a number of 1294. After removing 276 duplicates ($1294 - 276 = 1018$), we identified 1018 papers available for analysis. After a careful elimination of the irrelevant or uninformative studies, we identified 104 relevant papers which served as the evidence base for this manuscript and slide set (Fig. 1 - PRISMA Diagram).

Evidence analysis was conducted along the following themes: physiology of voiding, pathophysiology of LUTD, technique of uroflowmetry, quality check of the uroflowmetry test, interpretation and reporting of uroflowmetry findings.

The ICS Urodynamics Committee presents this teaching module to serve as a standard educational tool for professionals involved in diagnostics and treatment of LUT dysfunctions. The teaching module consists of a PowerPoint® presentation, available via http://www.icsoffice.org/eLearning/, and this paper which serves as the scientific background based on literature review. The presentation and this manuscript contain experts' opinions where evidence is unavailable, especially regarding clinical practice aspects. These are marked with "eo" (expert opinion) on the respective PowerPoint® slides. Expert opinion implies reports from expert panels and organizations, not based on research.

Table 1
Studies on impact of voiding positions at uroflowmetry in men.

	Author, year	N	Population	Positions investigated					Higher Qmax (p*)	Higher Qave (p*)	Lower PVR (p*)	Lower voiding time (p*)	Lower voided volume (p*)
				Standing	Sitting	Squatting	Crouching	Other					
1	Riehmann, 1998	55	Healthy	X				Recum-bent	Standing	Standing	ND		
2	Yamanishi, 1999	24	Healthy	X	X			Lateral, prone, supine	Prone				
3	Unsal, 2004	36	Healthy	X	X		X		ND	ND	ND		ND
4	Unsal, 2004	88	Healthy, BPE-LUTS	X	X				ND	ND	ND		ND
5	Aghamir, 2005	20	Healthy, BPE-LUTS	X	X		X		ND	Sitting (in BPE)	Sitting (in BPE)	ND	ND
6	Amjadi, 2006	83	BPE-LUTS	X			X		Crouching	Crouching	Crouching	Crouching	
7	Eryildirim, 2006	30	Healthy	X	X	X			Sitting, squatting	Sitting, squatting	ND	ND	ND
8[a]	El-Bahnasawy, 2008	200	BPE-LUTS	X	X				ND	ND	ND	ND	ND
9	Salem, 2009	100	BPE-LUTS	X	X				Sitting	ND	Sitting	Sitting	
10[b]	Choudhury, 2010	61	Healthy	X	X	X			Standing, squatting	Standing, squatting	Standing, squatting	Standing, squatting	ND
11	Amjadi, 2011	31	Healthy	X	X	X			ND	ND		ND	ND
12	Koc, 2013	110	Healthy, BPE-LUTS	X	X				Sitting	Sitting	ND	ND	ND
13	Yazici, 2014	198	Healthy, BPE-LUTS	X	X				ND	ND	Standing	ND	ND
14	Goel, 2017	740	Healthy, BPE-LUTS	X	X				ND	ND	Sitting (in men >50yo)	Standing (in men >50yo)	
15	Khan, 2017	50	Healthy	X	X				Standing	Standing	ND		ND
16	Alrabadi, 2000	194	Healthy, BPE-LUTS	X	X				Sitting, standing		Sitting, standing		Sitting

P*: statistical significance.
ND: no difference.

[a] Men < 50yo and men with qmax > 15 ml/s had all parameters increased.

[b] Standing and squatting comparable in all parameters.

3. Results

3.1. Physiology of voiding

The normal LUT stores urine and is able to evacuate the stored volume whenever suitable. It is likely that evolutionary advantage gave mankind this ability, over continuously leaking urine or very frequent voiding. Leaving smell traces is not good in the wild. When born, and even earlier, a child has the ability to store and to void, however the bladder itself dictates the frequency of voiding. An autonomic reflex is built in to ensure this. This autonomic reflex becomes controllable via pelvic floor muscle activity, during potty training and social continence is the endpoint [9,10].

Dysfunction of the LUT causes symptoms and signs such as perception of altered flow rate. The detrusor provides the energy for voiding, but the resultant flow rate is dependent also on bladder outlet properties. The pelvic floor muscles can be relaxed voluntarily and through reflexogenic and antagonistic mechanisms induced by autonomic detrusor activity, which in turn opens the bladder outlet, enabling voiding. The outlet collapses and resumes its closing force after emptying. The smallest area in the outlet, which has been named as the "flow controlling zone", dictates the rate of flow. The flow controlling zone's anatomical location varies throughout the course of voiding, except in the case of a urethral stricture [9,10].

4. Pathophysiology

In general, the flow controlling zone of women is wider than in men and as a consequence flow rate is higher (requiring lower detrusor pressure). On the other hand, men with enlarged prostate void with higher detrusor pressure and lower flow rate because their flow controlling zone is narrowed by the size of the prostate. Differences in flow rate are also related to detrusor voiding contraction force which can vary between persons and voiding attempts and is sensitive to circumstances like all autonomic functions. Not only detrusor activity but also pelvic floor muscle force and relaxation show similar variability. Voiding requires mental relaxation and parasympathetic 'dominance' in the body systems [9,10].

5. Technique of uroflowmetry

5.1. Information for and preparation of the patient

Uroflowmetry is recommended as the first line examination for most patients with lower urinary tract symptoms (LUTS) in GUP 2002 and GUP 2016, ICI consultations and clinical practice guidelines [1,9,11,12]. This noninvasive urodynamic investigation requires it to be performed under the most typical, relaxing, and private circumstances to minimize physical and emotional discomfort [1].

Uroflowmetry equipment should be placed in a quiet environment that can be easily cleaned, with the machine ready for immediate use, as patients undergoing uroflowmetry might experience urgency. PVR measurement is ideally done in the same room and immediately following the void [13].

Patients should be clearly and adequately informed to void with a normal to strong, but not uncomfortable, desire to empty their bladder with a short meatus to flowmeter distance [1,14]. An explanatory leaflet about uroflowmetry which uses unambiguous wording will be beneficial for patient preparation [13]. Studies have shown that uroflowmetry curves and flow rates may vary significantly according to voided volume (VV) in healthy adults [15].

Data about the hydration status prior to the uroflowmetry test is limited. One randomized controlled trial including 40 patients with benign prostatic obstruction and 34 adult male volunteers demonstrated that consuming 1.5 L of water within 1 h before uroflowmetry improves outcomes, with significantly more prehydrated patients than controls being able to void volumes above 150 ml [16]. On the other hand, overhydration or deviation from daily routine in an effort to obtain reliable test results has the potential to obscure the actual clinical condition of the patient [eo].

The scarce evidence on the impact of the patient's emotional condition show that the VV is the most affected uroflowmetry parameter [17–20]. Rubilotta et al. showed that a substantial portion of the patients undergoing uroflowmetry exhibited uroflowmetry-related anxiety, reaching 53.5% in the naïve population. Almost one third of the patients reported poor reproducibility of their habitual micturition patterns with uroflowmetry and 58.1% scored high discomfort levels. Interestingly, prior experience with uroflowmetry did not improve the reproducibility and discomfort outcome in anxious patients [20].

Data regarding the suggested patient position for uroflowmetry are not conclusive and do not allow for a strong recommendation [21–50]. Tables 1 and 2 summarize the papers on this topic in men and women, respectively. Considering the available evidence and based on experts' experience, we concluded that patients should be permitted to undergo uroflowmetry in their accustomed position [1].

A recent study, which included healthy adult volunteers without LUTS, has demonstrated that higher flow rates and lower PVR could be expected in voiding pants down compared to voiding through the zipper [51]. Another interesting study brought up the possible impact

Table 2
Studies on impact of voiding positions at uroflowmetry in women.

	Author, year	N	Population	Positions investigated					Higher Qmax (p*)	Higher Qave (p*)	Lower PVR (p*)	Lower voided volume (p*)
				Standing	Sitting	Squatting	Crouching	Other				
1	Moore, 1991	80	Healthy		X		X			Crouching	Sitting	
2	Rane, 2000	49	Healthy					LFP	LFP	LFP	LFP	
3	Devreese, 2000	21	Healthy				X	Anteversion, Retroversion, LFP	ND	ND		Anteversion
4	Unsal, 2004	36	Healthy		X		X		ND	ND	ND	ND
5	Gupta, 2008	67	Healthy		X	X			Squatting	Squatting	Squatting	ND
6	Rane, 2008	54	Healthy		X		X	Anteversion	Anteversion	Anteversion	ND	ND
7	Chou, 2010	30	Healthy	X	X		X		Sitting, p significant only sitting vs standing	Sitting, p significant only sitting vs standing	ND	ND
8	Yang, 2010	45	Healthy	X	X	X			ND	ND	ND	ND
9	Chou, 2011	21	Elderly	X	X				ND	ND	ND	ND

P*: statistical significance.
ND: no difference.
LFP: lean forward position.

of hypoxia on voiding as they have shown marginal differences in maximum and average flow rates between uroflowmetry tests performed at low altitude versus high altitude [52].

Representativeness of uroflowmetry should be checked by asking patients whether voiding at the time of testing was a reliable representation of their usual voiding, and by assessing patient's frequency/voiding chart or bladder diary, as recommended in GUP 2002 and GUP 2016 [1,11,48,49].

In an ambiguous case, repeating the evaluation is advisable. There is no consensus regarding how many attempts could be made to allow for a reliable test performance [eo].

6. The test

6.1. Evaluation of the technical quality

Considerable variation exists in terms of the quality standards in uroflowmetry recording, reporting, and interpretation. In a recent study, uroflowmetry traces from two large studies of male LUTS (UPSTREAM and UNBLOCS) were evaluated against ICS standards of urodynamic equipment and practice [53]. Amongst 299 traces used for analysis, 47 (15.7%) did not display the volume or maximum flow rate. VV and PVR were missing in 3.7% and 14.4% of the tracings, respectively. Findings recorded in 10% (32/299) of the uroflowmetry traces were affected by artifacts and in only 2 out of these 32 a correction was applied to derive the actual Q_{max} data from a part of the trace unaffected by an artifact [53].

6.2. Reporting of the test

Uroflowmetry measures the flow rate of the urinary stream as volume per unit time in milliliters per second, (ml/s). Although modern urine flow meters allow a continuous graphic record of the urinary flow and includes data on the main parameters such as maximum flow rate (Q_{max}), Voided Volume (VV), flow time, average flow rate (Q_{ave}) and time to maximum flow, their software is not normally capable of differentiating physiological flow changes from artifacts. Therefore, direct interpretation and correction of the results is still mandatory to improve the diagnostic accuracy and to reduce artifacts [11,54].

Increasing bladder volume increases the potential bladder power, notably in the range from empty up to 150-250 ml [11]. A minimum VV of 150 ml has been arbitrarily specified as a threshold for meaningful interpretation of uroflowmetry results and therefore lower volumes could be a trigger for repetition of the test. However, one can also use the average or maximum VV, as calculated based on the bladder diary, as a measure of that individual patient's voiding habits and make decisions for repeat testing accordingly. It has been shown that maximum VV in bladder diary and maximum bladder capacity in uroflowmetry and cystometry are comparable in older children with non-neurogenic LUTD [55].

If the trace is not representative for the patient, or the test was done in a technically unreliable manner, based on the examiner's opinion, or if the result indicates an abnormality (VV and/or flow rate unexpectedly low or PVR unexpectedly high), the test should be repeated.

Regarding the reproducibility of uroflowmetry results, one study including 147 male patients with LUTS looked into the differences between flow rates recorded on two separate occasions (each of the two screening visits prior to enrollment in a clinical trial about alpha blockers). As a result, uroflowmetry results of this cohort were found to be reproducible. However, they also noted clinically relevant intra-individual differences in many patients [56].

Uroflowmetry report should at least include the Q_{max}, VV, and PVR. Other characteristics such as flow pattern and other parameters may be added [1,57].

Agarwal et al. underscored flow rate as being a function of bladder volume and proposed volume-normalized flow rate assessment to improve identification of the patients with LUTD and better assess the efficacy of a LUT procedure. Within this context, they found population-specific and bladder volume-based nomograms to be more specific and predictive than Caucasian nomograms that relate to voided volume instead [58].

Regarding how uroflowmetry results should be documented, the following recommendations were made [1,11,57,59]:

– Maximum urine flow rate should be rounded (smoothed) to the nearest whole number (e.g., a recording of 9.35 ml/s would be recorded as 9 ml/s). In order to make electronically read Q_{max} values more accurate, realistic, comparable, and clinically useful, an internal electronic smoothing of the flow rate curve is recommended. Particularly a sliding average over 2 secs should be used to remove positive and negative spike artifacts [11]. If curves are smoothed by hand, the same concept should be applied. Only flow rate values, which have been smoothed, either electronically or manually, should be reported.

– Regarding the technical capability of a flow meter, the following standards have been specified by the ICS: a range of 0-50 ml/s for Q_{max}, and 0-1,000 ml for VV [11].

– VV and PVR volume should be rounded to the nearest 10 ml (A VV of 233 ml would be recorded as 230 ml).

– Voided percentage (Void%) can be included in the report. Void% is the numerical description of the voiding efficiency, which is the proportion of bladder content emptied. Calculation: volume voided/(volume voided + PVR)*100% [13].

– If a flow/volume nomogram [6,60] is used, this should be stated and referenced (i.e., Siroky nomogram for men under 55, the Bristol Nomogram for men over 55, or the Liverpool nomogram which can be used in both female and male populations). Routine use of nomograms in the decision-making process has not been specifically recommended by guidelines or international organizations. Nomograms are not diagnostic but may be used to make comparisons of flow rate with different volumes (e.g., after therapy for LUTS) [13].

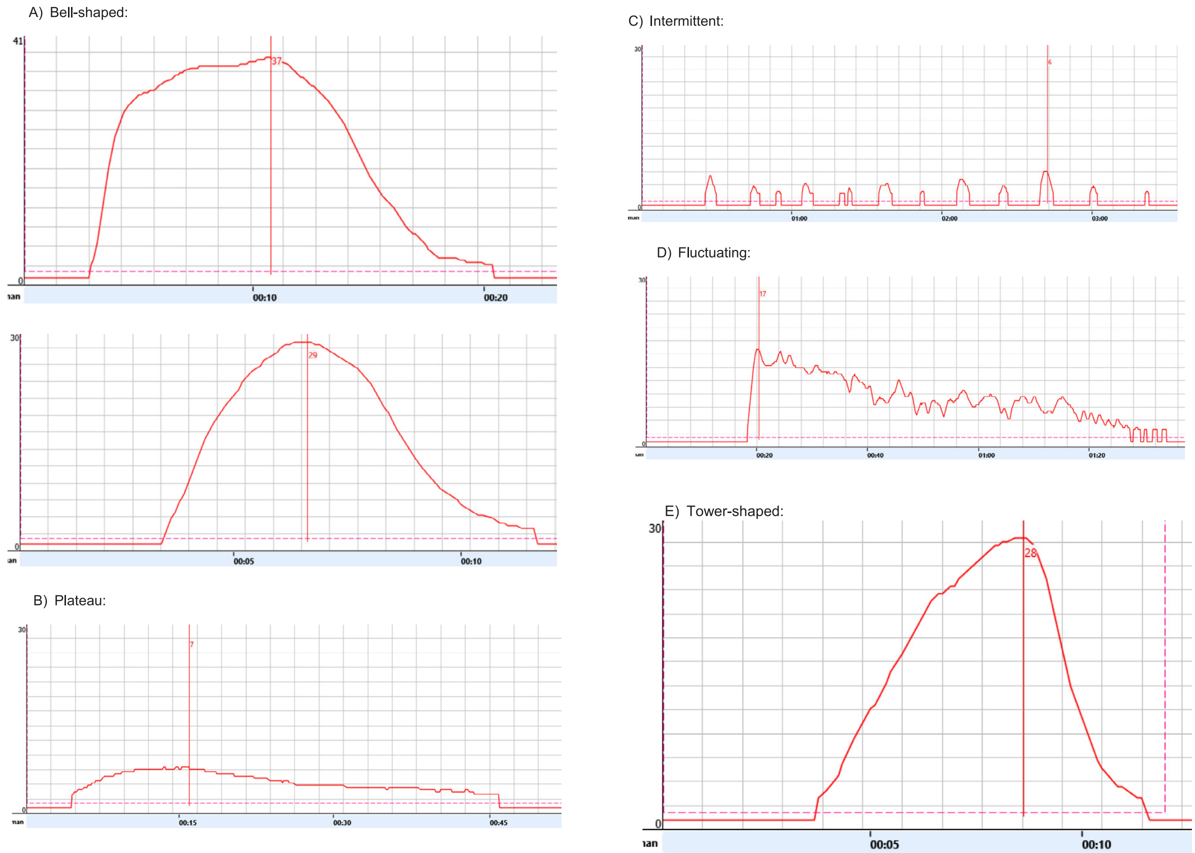

Fig. 2. Uroflowmetry flow patterns.
Source: Obtained from the archives of Dr. Tufan Tarcan.

– The position of the patient during voiding studies should be reported.

In free uroflowmetry, the pattern of the flow curve may deviate from the bell shape, but accurate information about the cause of abnormal voiding cannot be derived from a flow curve alone. Although flow curves can vary in configuration according to the volume voided as well, some information can be obtained and reported [54,57,61]. Flow patterns can be subcategorized based on the visual demonstration of the curve. However, clear distinctions cannot be made between each, especially tower- and bell-shaped might resemble each other closely (Fig. 2).

Uroflowmetry results can also be utilized to assess outcome following surgeries involving LUT such as transurethral procedures to treat LUTS attributable to benign prostate enlargement (BPE-LUTS) (including well established modalities like transurethral resection of the prostate [TURP] or holmium laser enucleation of the prostate [HoLEP] as well as minimally invasive alternatives like water vapor thermal therapy [Rezum] or prostatic urethral lift [Urolift]) [62,63] and urethroplasty due to hypospadias [64] or urethral stricture disease [65].

It is advisable to upload the graphic representation of the flow curve to the patient's chart in addition to the numeric test results [eo]. The scale of the printing should be adjusted in order to make the curve easily visible. Scaling of the printout has been suggested as follows: 1 mm can equal 1 s on the *x*-axis and 1 mL/s and 10 mL VV on the *y*-axis, but the trace must be clearly readable whatever scale is used [1,13].

The recommendations pertaining to the good practice of uroflowmetry have been summarized in the form of a checklist in the paper published by Gammie A. and Drake M [13].

7. Flow rate patterns

Normal flow trace (Fig. 2A)

The flow curve has a "bell" shape: Q_{max} is reached in the first 30% of VV and within 3 to 10 s from the flow start. However, a bell-shaped curve does not necessarily imply a normal flow pattern. Women with dysfunctional voiding who strain to release urine can manage to generate a "normal looking" flow trace [66]. Similarly, women with "normal" findings (bell-shaped curve, Q_{max} greater than 15 mL/s and a postvoid residual volume of less than or equal to 20% of bladder volume) on non-intubated uroflowmetry might be diagnosed with various forms of LUTD on comprehensive urodynamic studies [67].

Decreased flow and plateau trace (Fig. 2B)

These are the most common abnormal flow traces seen in practice and are represented by a dampened curve with low Q_{max} and long flow time. Two types of patterns can be observed. A urethral stricture gives a plateau-shaped trace with little changes in flow rate and minimal difference between Q_{max} and Q_{ave} [68–70]. The flow pattern associated with benign prostatic enlargement may appear relatively normal during the first third of the voiding, although the Q_{max} will be reduced, but the latter part of the trace usually is elongated into a pronounced tail of reducing flow rate [71,72]. A plateau-shaped curve may also be seen with an underactive detrusor during a long continuous abdominal strain [73].

The predictive value of uroflowmetry flow rates and trace pattern in women with pelvic organ prolapse (POP) was assessed by some retrospective studies. For example, Çetinel et al. did not find any statistically significant difference between the median Q_{max} values of the patients with mild/moderate prolapse and those without prolapse, while the patients with severe prolapse had significantly lower median

Q_{max} values [74]. In another retrospective study of the same group on 148 women with voiding difficulty, the prolonged/tail-shaped free urine flow curve patterns were the independent predictors of bladder outflow obstruction (BOO). Sensitivity and specificity values for the prolonged/tailed free flow pattern to predict BOO in women were 82.5 and 60%, respectively [75].

Intermittent flow traces (Fig. 2C)
This flow pattern will display discrete peaks with spikes similar to a fluctuating curve but unlike the latter pattern, there will be segments where zero flow between these peaks exists [76]. These traces may reflect several types of voiding dysfunction and often necessitate further investigation by pressure-flow study, if that is deemed clinically relevant. Straining, pelvic floor overactivity, detrusor sphincter dyssynergia (DSD) or poorly sustained/fluctuating detrusor voiding contraction can produce irregular and/or interrupted flows. Flow traces are also very variable because they may occur in the presence or absence of BOO or detrusor underactive voiding contraction [77]. Flow tends to be relatively slow, and the stream is usually continuous in case of straining. Flow has a relatively smooth pattern in pelvic floor overactivity whereas a saw-tooth pattern is typical for DSD. Slow changes in flow rate can be expected in the presence of poorly sustained detrusor contractions [eo].

Fluctuating flow traces (Fig. 2D)
This flow pattern is irregular and fluctuating throughout voiding, but the flow never reaches zero during voiding. This pattern is usually interpreted as a sign of discoordination between the bladder and the sphincter with intermittent sphincter overactivity during voiding (i.e., dysfunctional voiding). It could also indicate straining to void. It will be seen as sharp peaks and troughs in the flow curve. The fluctuations should be larger than the square root of the Q_{max}, as defined in the pediatric literature [78].

Tower-shaped trace (Fig. 2E)
This is a sudden, high-amplitude curve of short duration that is interpreted in pediatric urology as being the result of an overactive detrusor contraction [78]. However, there is no evidence that the tower-shaped pattern is associated with detrusor overactivity or overactive bladder, in adults.

Irregular traces or artifacts
Artifacts in the flow curve should also be recognized. A patient who kicks the flowmeter can appear to have an automatically derived normal Q_{max}. Other artifacts might be created by variations in the direction of the urinary stream within the funnel of the flow meter ("cruising") or due to the habit of squeezing the tip of the penis or foreskin during voiding ("squeezing") [14].

Although innovations in flow meter technology and software have significantly reduced misinterpretation, individual reporting of the uroflowmetry pattern is still relevant. In order to improve uroflowmetry standards and clinical utility, it is ideal if an appropriately trained nurse or physician directly reviews the test results and curves and integrates them with clinical interpretation in the final report.

8. Gaps in knowledge (future areas of research) Research questions

- How should we assess the test-retest reliability of uroflowmetry findings?
- What is the correlation between the VV recorded in uroflowmetry versus functional bladder capacity/average VV calculated based on bladder diary?
- Can abnormal flow pattern(s) exist in the absence of significantly elevated PVR? Is it possible to predict PVR based on flow pattern?
- How shall we interpret the impact of double voiding on uroflowmetry parameters?
- Can flow and voiding times be used to aid diagnosis of lower urinary tract dysfunction?

9. Conclusions

Uroflowmetry is the most commonly utilized diagnostic test in the evaluation of adults presenting with LUTS. The ICS educational module on the Practice of Uroflowmetry in Adults provides up-to-date and evidence-based guidance and establishes standards in the technique, interpretation, and reporting of uroflowmetry.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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