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Consistency of uroflowmetry analysis in children among observers

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Abstract

Aim: The aim of the study is to compare the intra- and inter-observer interpretations of the same uroflowmetry study at two different times.

Materials and Methods: Two-hundred children with a voided volume of 50% above the expected bladder capacity were included. All traces were asked to be evaluated by 11 observers two times in a time span of 1 month. These observers consist of pediatric urologists ($n = 2$), pediatric urology fellows ($n = 2$), urology residents ($n = 5$), and certified urodynamics nurses ($n = 2$). Each uroflowmetry was asked to be assessed for three domains: voided volume (VV), detrusor sphincter dyssynergia (DSD), and flow curve pattern (FCP).

Results: Of the 200 patients with a median age of 10 (4–18) years, 128 (64%) were girls and 72 (36%) boys. The maximum flow rate and the median voided volume were found to be 20 (4–61) mL/s and 232 (116–781) mL. The Fleiss' kappa coefficient of VV, DSD, and FCP in the first assessment was 0.510, 0.501, and 0.346. In the second assessment, $\varkappa$ values were 0.530, 0.422, and 0.373. The best-agreed findings were similar at both times. These were found to be low VV (0.602 and 0.626) and intermittent pattern (0.500 and 0.553). Interpreters were found to have a statistically significant difference in agreement with their own interpretation at different times.

Conclusion: Both inter- and intra-observer reliability of the agreement point out the problem in the standardization of uroflowmetry. Inter- and intra-observer reliability of uroflowmetry interpretation can be increased by defining precise numbers and numerical algorithms.

KEYWORDS

children, detrusor sphincter dyssynergia, flow curve pattern, uroflowmetry

1 | INTRODUCTION

Uroflowmetry is an easy, cost-effective, and noninvasive urodynamic test. Therefore, it is used quite often in the initial assessment of children with lower urinary tract (LUT) symptoms. European Association of Urology (EAU) guidelines recommend two or more repeating tests under optimum conditions to ensure safe results.[1] The most important parameters in the uroflowmetry are flow curve patterns (FCP), voided volume (VV), flow rate, and detrusor sphincter dyssynergia (DSD) (if simultaneous electromyography was applied). The International Children's Continence Society (ICCS) defined standardized terminology of uroflowmetry and specific

FCP as bell-shaped, tower, staccato, interrupted, and plateau flow patterns.[2] However, the definitions of these FCP developed for the diagnosis of LUT dysfunctions are not clear. It is also known that there are differences in the interpretation of uroflowmetric parameters in clinical practice. In several studies with adults and children, intra-observer and inter-observer discrepancies in the interpretation of the same flow pattern have been reported.[3–6] These discrepancies were particularly associated with abnormal findings in uroflowmetry. Our hypothesis is that there may be inconsistencies between the observers in the evaluation of all uroflowmetric parameters because their definitions are not clear.

In our literature review, we did not find a study in which three parameters such as FCP, VV, and DSD were compared by intra and inter-observer on the same uroflowmetry traces. The aim of the present study is to compare the intra- and inter-observer interpretations of the same uroflowmetry study at two different times.

2 | MATERIALS AND METHODS

Uroflowmetry tests with electromyography (EMG) performed for any reason in our pediatric urology clinic were evaluated retrospectively. Ethical approval was obtained from the local ethics committee before the study (No: 09.2020.193). Tests with at least 50% VV of the expected bladder capacity (EBC) by age were included in the study.[2] The Koff formula (30 × [age in years + 1] mL) was used for the expected bladder capacity measurement.[7] A total of 200 children's uroflowmetric studies were selected for the study. Each uroflowmetry was assigned to a number between 1 and 200 and saved into a PDF. A cohort of 11 observers was asked to interpret these studies two times at a 1-month interval. The observer cohort consists of pediatric urologists ($n = 2$), pediatric urology fellows ($n = 2$), urology residents ($n = 5$, 1 fourth year, 2 third year, and 2 second year), and certified urodynamics nurses ($n = 2$). Three different parameters in uroflowmetry were interpreted by each participant. These parameters include VV (low, normal, and high), DSD (present and absent), and FCP (normal, staccato [fluctuating pattern], intermittent, plateau, and tower type). All participants were asked to interpret according to ICCS recommendations.[2] The chronological period was as follows: The 200 uroflowmetry included in the study were collected from the patients within 4 months (March 2019–June 2019). Afterward, it took a total of 6 months (July 2019–December 2019) for the observers to evaluate the tests twice. Finally, the statistical analysis and writing of the manuscript took 2 months.

2.1 | Statistical analysis

Data were collected using Microsoft Excel sheets and exported to R (R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/) for statistical analysis. Findings of the uroflowmetric study were asked to be evaluated for VV, DSD, and FCP by each interpreter.

Categoric variables were provided with percentages and continuous variables were provided with medians and minimum and maximum values. Initially, Fleiss' kappa (κF) was used to analyze inter-rater reliability (interRR) of each domain of uroflowmetric study for all groups. Cohen's kappa (κC) was also employed to describe the intra-rater reliability (intraRR) for each domain of uroflowmetry evaluation separately for each evaluation time. In interpreting the κF, and κC values, the Landis and Koch classification and interpretation criteria were used to indicate agreement (poor: 0.01–0.20, fair: 0.21–0.40, moderate agreement [MA]: 0.41–0.60, substantial agreement [SA]: 0.61–0.80, and almost perfect agreement [APA]: 0.81–1.00).[8]

3 | RESULTS

Uroflowmetric studies were performed on 128 (64%) girls and 72 (36%) boys. The median age of the study group was 10 (4–18) years. The median maximum flow rate (Q_{max}) and the median VV were found to be 20 (4–61) mL/s and 232 (116–781) mL, respectively.

IntraRR between the first and second evaluations for FCP is shown in Table 1. Cohen's kappa was found to be a minimum of 0.543 and a maximum of 0.979 (APA: 5, SA: 5, MA: 1). IntraRR for DSD is shown in Table 2. Cohen's kappa was a minimum of 0.618 and a maximum of 0.960 (APA: 5, SA: 6). IntraRR for VV is shown in Table 3. Cohen's kappa was a minimum of 0.692 and a maximum of 0.981 (APA: 9, SA: 2). On the other hand, intraRR evaluation revealed a statistically significant difference in the agreement of each interpreter with their own interpretation at different times (Figure 1). This evaluation showed a great difference for each interpreter, but with a κC greater than 0.6 which provided at least a substantial agreement.

Of all domain and findings, the best reliability of interpreter groups was low volume in VV (κF 1st evaluation: 0.602 and 2nd evaluation 0.626) and intermittent pattern in FCP (κF 1st evaluation: 0.500 and 2nd evaluation 0.553) (Table 4). Of all domains to be evaluated the best interRR in the first and second interpreter reports was found in VV followed by DSD,

TABLE 1 First and second evaluations of the observers (IntraRR) and Cohen kappa values in terms of flow curve pattern.

	First evaluation					Second evaluation						
	Bell shape ***n*** **(%)**	**Staccato** ***n*** **(%)**	**Intermittent** ***n*** **(%)**	**Plateau** ***n*** **(%)**	**Tower** ***n*** **(%)**	**Bell shape** ***n*** **(%)**	**Staccato** ***n*** **(%)**	**Intermittent** ***n*** **(%)**	**Plateau** ***n*** **(%)**	**Tower** ***n*** **(%)**	**κC**	**Interpretation**
1st PU	94 (47)	36 (18)	24 (12)	26 (13)	20 (10)	98 (49)	38 (**19**)	24 (12)	22 (11)	18 (9)	0.950	APA
2nd PU	118 (59)	30 (15)	20 (10)	22 (11)	10 (5)	117 (58.5)	33 (16.5)	24 (12)	21 (10.5)	5 (2.5)	0.661	SA
1st fellow	100 (50)	59 (29.5)	13 (6.5)	19 (9.5)	9 (4.5)	83 (41.5)	79 (39.5)	21 (10.5)	8 (4)	9 (4.5)	0.676	SA
2nd fellow	122 (61)	23 (11.5)	31 (15.5)	14 (7)	10 (5)	119 (59.5)	21 (10.5)	31 (15.5)	18 (9)	11 (5.5)	0.924	APA
4th year resident	27 (13.5)	94 (47)	33 (16.5)	42 (21)	4 (2)	16 (8)	80 (40)	59 (29.5)	42 (21)	3 (1.5)	0.682	SA
3rd year resident	71 (35.5)	72 (36)	35 (17.5)	13 (6.5)	9 (4.5)	78 (39)	62 (31)	40 (20)	11 (5.5)	9 (4.5)	0.744	SA
3rd year resident	41 (20.5)	46 (23)	31 (15.5)	78 (39)	4 (2)	40 (20)	34 (17)	57 (28.5)	65 (32.5)	4 (2)	0.663	SA
2nd year resident	63 (31.5)	38 (19)	26 (13)	69 (34.5)	4 (2)	96 (48)	26 (13)	30 (15)	44 (22)	4 (2)	0.543	MA
2nd year resident	61 (30.5)	25 (12.5)	43 (21.5)	60 (30)	11 (5.5)	54 (27)	28 (14)	46 (23)	60 (30)	12 (6)	0.934	APA
1st nurse	49 (24.5)	69 (34.5)	59 (29.5)	20 (10)	3 (1.5)	48 (24)	71 (35.5)	58 (29)	21 (10.5)	2 (1)	0.979	APA
2nd nurse	49 (24.5)	65 (32.5)	65 (32.5)	17 (8.5)	4 (2)	54 (27)	58 (29)	62 (31)	21 (10.5)	5 (2.5)	0.808	APA

Abbreviations: APA, almost perfect agreement; KC: Cohen's kappa; MA, moderate agreement; PU, pediatric urologist; SA, substantial agreement.

TABLE 2 First and second evaluations of the observers (IntraRR) and Cohen's kappa values in terms of detrusor sphincter dyssynergia.

	First evaluation		Second evaluation			
	Absent n (%)	Present n (%)	Absent n (%)	Present n (%)	κC	Interpretation
1st PU	107 (53.5)	93 (46.5)	113 (56.5)	87 (46.5)	0.939	APA
2nd PU	128 (64)	72 (36)	131 (65.5)	69 (34.5)	0.704	SA
1st fellow	77 (38.5)	123 (61.5)	68 (34)	132 (66)	0.732	SA
2nd fellow	131 (65.5)	69 (34.5)	133 (66.5)	67 (33.5)	0.955	APA
4th year resident	83 (41.5)	117 (58.5)	58 (29)	142 (71)	0.688	SA
3rd year resident	78 (39)	122 (61)	76 (38)	124 (62)	0.854	APA
3rd year resident	79 (39.5)	121 (60.5)	49 (24.5)	151 (75.5)	0.618	SA
2nd year resident	94 (47)	106 (53)	117 (58.5)	83 (41.5)	0.652	SA
2nd year resident	116 (58)	84 (42)	113 (56.5)	87 (43.5)	0.938	APA
1st nurse	90 (45)	110 (55)	91 (45.5)	109 (54.5)	0.960	APA
2nd nurse	89 (44.5)	111 (55.5)	92 (46)	108 (54)	0.788	SA

Abbreviations: APA, almost perfect agreement; KC, Cohen's kappa; PU, pediatric urologist; SA, substantial agreement.

TABLE 3 First and second evaluations of the observers (IntraRR) and Cohen's kappa values in terms of voiding volume.

	First evaluation			Second evaluation				
	Normal, n (%)	Low, n (%)	High, n (%)	Normal, n (%)	Low, n (%)	High, n (%)	κC	Interpretation
1st PU	63 (31.5)	118 (59)	19 (9.5)	66 (33)	117 (58.5)	17 (8.5)	0.972	APA
2nd PU	60 (30)	122 (61)	18 (9)	62 (31)	116 (58)	22 (11)	0.715	SA
1st fellow	45 (22.5)	127 (63.5)	28 (14)	34 (17)	132 (66)	34 (17)	0.692	SA
2nd fellow	63 (31.5)	117 (58.5)	20 (10)	54 (27)	130 (65)	16 (8)	0.820	APA
4th year resident	25 (12.5)	156 (78)	19 (9.5)	29 (14.5)	153 (76.5)	18 (9)	0.920	APA
3rd year resident	29 (14.5)	153 (76.5)	18 (9)	27 (13.5)	153 (76.5)	20 (10)	0.947	APA
3rd year resident	42 (21)	147 (73.5)	11 (5.5)	35 (17.5)	152 (76)	13 (6.5)	0.911	APA
2nd year resident	106 (53)	74 (37)	20 (10)	103 (51.5)	78 (39)	19 (9.5)	0.903	APA
2nd year resident	45 (22.5)	134 (67)	21 (10.5)	41 (20.5)	137 (68.5)	22 (11)	0.917	APA
1st nurse	52 (26)	123 (61.5)	25 (12.5)	50 (25)	126 (63)	24 (12)	0.981	APA
2nd nurse	29 (14.5)	145 (72.5)	26 (13)	35 (17.5)	141 (70.5)	24 (12)	0.844	APA

Abbreviations: APA, almost perfect agreement; KC, Cohen's kappa; PU, pediatric urologist; SA, substantial agreement.

and FCP, respectively (κF 1st evaluation 0.51, 0.501, and 0.346; κF of 2nd evaluation 0.530, 0.422, and 0.373) (Table 4).

4 | DISCUSSION

Uroflowmetry is a first-line noninvasive urodynamic test that evaluates both storage and voiding functions in children with suspected LUT symptoms. ICCS recommends that uroflowmetry in children to be performed in a private room, in a sitting position, with support under the feet, and when normal urination desire is achieved.[9] In the same report, it was emphasized that the VV was more than 50% of the EBC and was repeated at least twice for accuracy and consistency. Also, voiding patterns have been described to aid in the diagnosis of LUT dysfunctions: bell-shaped, tower, staccato, interrupted, and plateau. Although the bell shape is the typical and expected voiding pattern, we know that abnormal patterns can also be seen in normal asymptomatic school children.[10] However, there is scanty

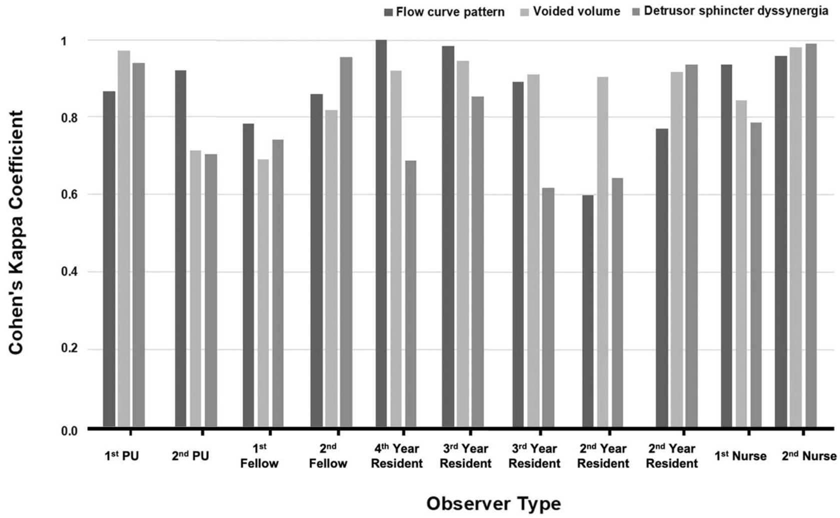

FIGURE 1 Flow curve pattern, voided volume, detrusor sphincter dyssynergia of all observers (IntraRR).

TABLE 4 Fleiss' kappa (ϰF) interobserver reliability in the first and second evaluation for all observers.

	First evaluation		Second evaluation	
	ϰF	Best agreement (ϰF)	ϰF	Best agreement (ϰF)
FCP	0.346	Intermittent pattern (0.500)	0.373	Intermittent pattern (0.553)
DSD	0.501	NA	0.422	NA
VV	0.510	Low voiding volume (0.602)	0.530	Low voiding volume (0.626)

Abbreviations: ϰF, Fleiss' kappa, DSD, detrusor sphincter dyssynergia; FCP, flow curve pattern; NA, not available; VV, voiding volume.

information on how consistent those parameters are interpreted by physicians or urodynamics nurses at different experiences or even by the same interpreter at different times. In this study, we found some inconsistencies among observers in the interpretation of uroflowmetry.

In the literature, there are several studies that evaluate FCP as intra- and inter-observer. In a study in which FCP of 190 healthy children were interpreted by two urologists, good interobserver agreement in interpreting each curve type was reported (ϰ = 0.71).[3] In the same study, the intraRR agreement in interpreting each type of uroflowmetry shape was reported good, with a ϰ value of 0.73. InterRR agreement in abnormal curves was found to be poor (ϰ = 0.07). The high ϰ value detected for the interRR agreement in this study can be attributed to the fact that it was performed on nonsymptomatic children. On the other hand, lower ϰ values were reported in studies that included abnormal FCP. In a study, in which 25 randomly selected uroflowmetry curves were evaluated by 58 urologists, the interRR agreement was reported as moderate for the normal pattern (ϰ = 0.46).[6] Participants could correctly predict the current diagnosis of only 36% of the cases. In terms of experience (less than 5 years, 5–10 years, and more than last year), the interRR agreement was close to each other (ϰ = 0.44, 0.48, 0.46, respectively). Vijverberg et al. declared intraRR agreement was 0.47 for staccato, 0.65 for interrupted, 0.55 for flow time, and 0.65 for obstruction.[11] In addition, the interRR agreement was 0.44 for staccato, 0.95 for interrupted, 0.71 for flow time, and 0.73 for obstruction. Similarly, in our study, interRR agreement was found to be fair agreement in both the first and second evaluations (ϰ = 0.346, 0.373, respectively). The best agreement was achieved in the intermittent pattern at both the first and second evaluations (0.500 and 0.553, respectively). We think that the low ϰ value for the interRR is affected by the selection criteria of the uroflowmetries and participant structure in the study. All uroflowmetries in our study were collected from children with LUT symptoms. This may have increased the proportion of abnormal FCP. Also, the participants consisted of not only senior pediatric urologists, but also fellows, residents, and urodynamic technicians. The fact that the intermittent pattern has the best agreement suggests that its definition is clearer than the others.

The voided urine volume is another important parameter evaluated in uroflowmetry. Also, appropriate VV is necessary for the reliability of uroflowmetry. The Koff formula is often used to calculate the EBC by age, and the ICCS recommends a volume greater than 50% of the EBC for reliable flow patterns.[7,9] However, due to the difficulty of reaching even this volume in some children, other formulas have been developed. In a study evaluating the voiding curves of 930 healthy children aged 4–9 years, the smallest capacity at which the bladder can perform well during voiding was examined.[12] The researchers reported in the study that the formula of years × 5 + 50 mL showed the lowest acceptable bladder capacity to obtain a reliable FCP. It is known that for the reliable FCP, not only the lower limit of VV but also the upper limit is effective.

Bladder capacity is controlled by neuromuscular and vesicoelastic mechanisms. The detrusor muscle can reach sevenfold its length during bladder filling.[13] In addition, there is an optimal range in which the detrusor muscle can perform sufficient contraction for efficient bladder emptying and, a positive correlation between the pressure on the bladder wall and the bladder diameter. An overstretched bladder wall has been experimentally shown to impair detrusor contractility, and this may result in insufficiency of voiding function.[14] It has been reported that Qmax, PVR, and FCP are adversely affected at volumes higher than 115% of EBC,[15,16] and therefore it is recommended by the ICCS not to exceed 115% of EBC for uroflowmetry.[9] In the present study, all uroflowmetry had a volume greater than 50% of EBC and, the interRR agreement was moderate in both the first and second evaluations ($\kappa = 0.510$, 0.530, respectively). Interestingly, the best agreement was achieved on the low voiding capacity in both evaluations ($\kappa = 0.602$, 0.626, respectively). In the IntraRR agreement, nine observers were APA and two observers were SA. We think that the moderate agreement in VV can be explained by the widespread use of formulas for calculating bladder capacity in children. At this point, we should emphasize again that we did not use PVR values in this study. Interpreters were only asked to evaluate the amount of VV during uroflowmetry. Although it is not correct to comment on the bladder capacity based on the VV alone, the raters may have benefited from the above-mentioned formulas.

Idiopathic DSD is another challenge for pediatric urologist in the management of LUTS. Due to the lack of coordination between the bladder and the urethral sphincter, it may cause dysfunctional voiding with the sign of a staccato voiding pattern. In the diagnosis of DSD, invasive methods such as pressure-flow study, video urodynamics, and voiding cystourethrography can be used, as well as a noninvasive method such as uroflowmetry with EMG. However, in our literature review, no study was found regarding intra- or interRR agreement of DSD on uroflowmetry in children. In a study in which 210 video urodynamics were evaluated by four raters (two neurourologists, neurourology fellow, and urology postgraduate year 2 resident), the κ value was found to be 0.26 among experts and 0.1497 and 0.2967 among experts and fellows.[17] The authors attributed this result to the lack of standardization in the diagnosis of DSD in video urodynamics. In our series, moderate interRR agreement was determined for DSD in both the first and second evaluations ($\kappa = 0.501$, 0.422, respectively). We consider that the staccato pattern accompanying the EMG activity in uroflowmetry causes an increase in the agreement among the raters.

The study has some limitations. We did not evaluate the maximum and average flow rate as it is a numerical value. Young et al. reported that the minimally acceptable Qmax value was 11.5 mL/s in children aged ≤6 years and 15.0 mL/s in children aged ≥7 years.[18] In another study, the maximum and mean flow rates in children aged 5–10 years were 15.26 and 7.68 mL/s for boys; 17.98 and 9.19 mL/s for girls, respectively.[19] Although some studies on the normal values of urinary flow rates in children have been published, there is no widely used nomogram today. EMG lag time for primary bladder neck dysfunction was not evaluated. The uroflowmetries were not interpreted by dividing them into subgroups according to their primary diagnosis. Observers were not also divided into groups according to their experiences, and the interRR comparison was performed on all 11 participants.

5 | CONCLUSION

Uroflowmetry is an indispensable part of the evaluation of LUT symptoms in children with its noninvasive and easy-to-apply features. However, we think that the deficiencies in its standardization cause differences in interpretation among the observers. Inter- and intra-observer reliability of uroflowmetry interpretation in children can increase with defining precise numbers and numerical algorithms.

AUTHOR CONTRIBUTIONS

Cagri Akin Sekerci: Concept-design; data interpretation; manuscript drafting and writing; statistical analysis, literature screening. **Yiloren Tanidir**: Data interpretation; statistical analysis. **Tufan Tarcan**: Supervision. **Selcuk Yucel**: Concept-design; data interpretation; manuscript drafting and writing; supervision.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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.

ETHICS OF APPROVAL STATEMENT

Ethical approval was obtained from the local ethics committee before the study (No: 09.2020.193).

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