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Association of Uroflowmetry Flow Rates with Post-Void Residual Volume: A Comparative Analysis of Peak and Average Flow

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Abstract: Uroflowmetry and post-void residual volume (PVR) are key non-invasive tools in evaluating lower urinary tract symptoms (LUTS). While peak flow rate (Qmax) is commonly used, the role of average flow rate (Qavg) in predicting incomplete bladder emptying remains unclear. This study aims to compare the association between peak and average uroflowmetry flow rates and post-void residual volume. An analytical cross-sectional study was conducted among adults presenting with LUTS. Uroflowmetry parameters (Qmax, Qavg, voided volume) and PVR were recorded. Analysis was restricted to voided volume ≥150 mL. Multivariable linear regression and logistic regression analyses were performed after adjusting for age, sex, and voided volume. An analytical cross-sectional study was conducted among adults presenting with LUTS. Uroflowmetry parameters (Qmax, Qavg, voided volume) and PVR were recorded. Analysis was restricted to voided volume ≥150 mL. Multivariable linear regression and logistic regression analyses were performed after adjusting for age, sex, and voided volume. A total of 197 patients were included. Both Qmax and Qavg were inversely correlated with PVR. In adjusted analysis, Qavg showed a stronger association with PVR ($\beta = -0.135$, $p < 0.001$) compared to Qmax ($\beta = -0.041$, $p = 0.024$). When both variables were included in the same model, only Qavg remained significant ($p = 0.005$). Qavg independently predicted PVR >100 mL (OR 0.65, $p = 0.014$), whereas Qmax did not. Average flow rate demonstrates a stronger and independent association with PVR than peak flow rate.

Keywords: *Uroflowmetry, Peak Flow Rate (Qmax), Average Flow Rate (Qavg), Post-Void Residual Volume (PVR), Lower Urinary Tract Symptoms (LUTS).*

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I. INTRODUCTION

Lower urinary tract symptoms (LUTS) are a common cause of morbidity among adults and represent a substantial proportion of urology outpatient consultations. These symptoms may arise from bladder outlet obstruction, detrusor underactivity, or a combination of both, and accurate assessment of voiding function is essential for appropriate diagnosis and management. The International Continence Society recommends the use of non-invasive investigations such as uroflowmetry and post-void residual volume (PVR) measurement as first-line tools in the evaluation of patients with LUTS. [1,2].

Uroflowmetry provides objective, quantitative information on urinary flow during micturition. The most commonly reported parameters are peak flow rate (Qmax) and average flow rate (Qavg). Qmax represents the maximum flow achieved during voiding and has traditionally been used as a surrogate marker of bladder outlet obstruction[3]. In contrast, Qavg reflects the mean flow over the entire voiding phase and may better represent sustained detrusor contractility and overall voiding efficiency.[4]

Post-void residual volume, usually measured by ultrasonography, is an important indicator of incomplete bladder emptying. Elevated PVR has been associated with adverse clinical outcomes, including recurrent urinary tract infections, bladder decompensation, and upper urinary tract deterioration. [5,6]

Several studies have explored the relationship between uroflowmetry findings and post-void residual urine, primarily in patients with LUTS or benign prostatic hyperplasia. Much of the existing literature has focused on either uroflowmetry curve patterns or peak flow rates.

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Studies assessing uroflowmetry patterns have demonstrated limited association with PVR. Guctas et al. found no statistically significant differences in PVR across uroflowmetry pattern groups despite significant differences in Qmax [7]. Similar findings have been reported in paediatric populations, where dysfunctional voiding patterns did not consistently correlate with residual urine volumes.[8]

Previous studies have demonstrated inverse relationships between urinary flow rates and PVR [9,10]. Chang et al. showed that larger voided volumes are associated with higher PVR, highlighting voided volume as an important confounder [11].

Physiologically, Qmax reflects a transient peak during voiding, whereas Qavg reflects sustained flow and may better represent detrusor contractility and voiding efficiency [12,13]. However, direct comparisons between these parameters remain limited.

Although uroflowmetry and PVR measurement are routinely used in the evaluation of LUTS, there is limited evidence guiding clinicians on which uroflowmetry parameter best reflects incomplete bladder emptying. While Qmax has traditionally been emphasized [3], physiological considerations suggest that Qavg may better reflect voiding efficiency [12,13]. This study aims to compare these parameters in a clinically relevant population.

II.METHODOLOGY

An analytical cross-sectional study was conducted at a tertiary care urology clinic in Sri Lanka. Adult patients aged 18 years and above presenting with lower urinary tract symptoms were included. Patients were required to have a voided volume of at least 150 mL. Patients with active urinary tract infection, catheterisation, neurogenic bladder, recent urological surgery within three months, or incomplete uroflowmetry data were excluded.

Uroflowmetry was performed according to International Continence Society standards. Peak flow rate, average flow rate, and voided volume were recorded. Post-void residual volume was measured immediately after voiding using ultrasonography.

The primary outcome was post-void residual volume, analysed both as a continuous variable and as a categorical variable, with clinically significant PVR defined as greater than 100 mL.

Continuous variables were summarised using mean and standard deviation. Categorical variables were presented as frequencies and percentages. Correlation analysis was used to assess unadjusted associations. Multivariable linear regression with log-transformed PVR and logistic regression were performed adjusting for age, sex, and voided volume. A p value less than 0.05 was considered statistically significant.

III. RESULTS

➢ *Study Population and Demographics*

A total of 242 uroflowmetry records were reviewed. After excluding recordings with voided volume less than 150 mL and missing PVR values, 197 patients were included in the final analysis. The majority of participants were male (n = 185, 93.9%), with 12 females (6.1%). The mean age was 64.1 ± 14.9 years.

Table 1 Demographic characteristics (n = 197)

Variable	Value
Age (years), mean ± SD	64.1 ± 14.9
Male, n (%)	185 (93.9)
Female, n (%)	12 (6.1)

➢ *Uroflowmetry Parameters*

The mean voided volume was 352.6 ± 165.8 mL. The mean peak flow rate (Qmax) was 14.4 ± 8.6 mL/s, while the mean average flow rate (Qavg) was 6.9 ± 4.1 mL/s.

Table 2 Uroflowmetry Parameters

Parameter	Mean ± SD
Voided volume (mL)	352.6 ± 165.8
Qmax (mL/s)	14.4 ± 8.6
Qavg (mL/s)	6.9 ± 4.1

➢ *Post-Voided Residual Volume*

The mean post-void residual volume was 55.1 ± 61.8 mL.

Table 3 Distribution of PVR

Category	n (%)
<50 mL	120 (60.9)
50–100 mL	41 (20.8)
>100 mL	36 (18.3)

➢ *Unadjusted Association*

Both Qmax and Qavg showed statistically significant inverse correlations with PVR.

Table 4 Correlation Analysis

Parameter	r	p value
Qmax	−0.23	<0.001
Qavg	−0.26	<0.001

➢ *Adjusted Analysis (Continuous PVR)*

After adjustment for age, sex, and voided volume, both Qmax and Qavg were significantly associated with PVR when analysed separately. However, when both variables were included in the same model, only Qavg remained independently associated with PVR, while Qmax was no longer statistically significant.

Table 5. Linear Regression (Log-Transformed PVR)

Variable	β (95% CI)	p
Qmax	−0.041 (−0.076 to −0.005)	0.024
Qavg	−0.135 (−0.212 to −0.058)	<0.001
Qavg (adjusted for Qmax)	−0.204 (−0.346 to −0.062)	0.005
Qmax (adjusted for Qavg)	0.037 (−0.027 to 0.102)	0.256

➢ *Prediction of Clinically Significant PVR (>100 mL)*

In logistic regression analysis, both Qmax and Qavg were significant predictors of elevated PVR when analysed individually. However, in the combined model, only Qavg remained an independent predictor.

Table 6. Logistic Regression

Variable	OR (95% CI)	p
Qmax	0.86 (0.79–0.94)	<0.001
Qavg	0.66 (0.53–0.81)	<0.001
Qavg (adjusted)	0.65 (0.47–0.92)	0.014
Qmax (adjusted)	1.00 (0.88–1.14)	0.992

IV. DISCUSSION

This study demonstrates that average flow rate is more strongly and independently associated with post-void residual volume compared to peak flow rate in adults with lower urinary tract symptoms. Although both parameters were inversely associated with PVR, only Qavg remained significant after adjustment for confounders.

Peak flow rate reflects a transient maximum during voiding and may be influenced by patient effort and abdominal straining. In contrast, average flow rate represents sustained urinary flow and is therefore more reflective of overall voiding efficiency and detrusor contractility.

Previous studies have shown limited predictive value of uroflowmetry patterns[7], supporting the need to focus on quantitative parameters. The present findings suggest that Qavg may be a more reliable non-invasive marker of incomplete bladder emptying.

Clinically, these findings are relevant in settings where urodynamic studies are not readily available. Qavg may help identify patients at risk of elevated PVR and guide further management.

Limitations of this study include its cross-sectional design and the predominance of male participants, which may limit generalizability. Additionally, underlying pathophysiology was not confirmed with invasive urodynamic testing.

V. CONCLUSION

Average flow rate demonstrates a stronger and independent association with post-void residual volume compared to peak flow rate. Incorporating Qavg into routine uroflowmetry interpretation may improve the assessment of incomplete bladder emptying in patients with lower urinary tract symptoms.

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