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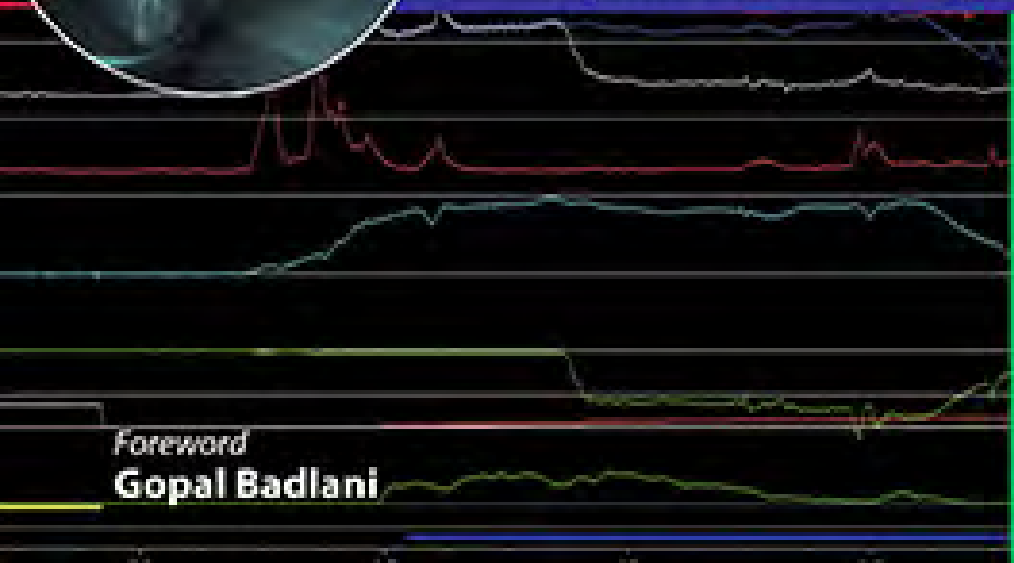
Manual of
URODYNAMICS



Mayank Mohan Agarwal



Foreword
Gopal Badlani

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CHAPTER

3 Uroflowmetry

Uroflowmetry is a simple and useful measure of urine flow characteristics of an individual. Its importance lies in its non-invasiveness, and ease of performance and interpretation. The equipment is relatively simple and inexpensive. The initial thought of objective assessment of strength of urinary stream dates back to early 20th century, when Havelock Ellis (1902) attempted to describe urinary flow in terms of cast distance of the urinary stream. The first description of formal uroflowmeter with graphical representation is attributed to Willard M Drake, Jr (1946) followed by von Garrelts (1956) who emphasized that flow rates are dependent on voided volume.

Uroflowmetry is the measure of urine flow rate over time (Figure 1) and represents the final outcome of bladder function and status of bladder-outlet.

Flow measurements depend on various factors, e.g. voided volume, age, sex, voiding position, body mass index (in women), natural habits, and overall comfort during the measurement and psychological inhibition.

Hence, it is relevant and rather important to ask at the end of the void whether the uroflow was 'representative' of their natural act of voiding. Estimation of post-void residual urine by ultrasound is an important part of the uroflowmetry. It will be discussed in detail in the later section.

Tips

- It is not uncommon to come across patients who find it difficult to 'perform' uroflow in unfamiliar surroundings, typically a busy, noisy out-patient clinic. Therefore, for correct interpretation of uroflow, it is of utmost importance to explain the procedure to the patient, have clean, quiet and conducive environment for the void and provision for all three common voiding positions (i.e. standing, sitting and squatting), at least the former two.
- Another important requirement often missed is adequately filled bladder. The patient should not be pushed to perform uroflow in haste, i.e. with underfilled bladder (which is likely to give insufficient information), nor should he/she be made to drink excessively or to wait too long for a 'really good' uroflow; in the latter scenario, patients often develop pain or uncomfortable urge to void which is not representative of their natural act.

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- The patient should be asked to perform voiding in his/her preferred voiding position. Position related changes have been studied extensively but without consensus; however, many authors have emphasized the importance of 'natural voiding position' in this regard. For example, if we ask a woman who has always voided/passed stools in squatting position, to perform uroflowmetry in sitting position, the results are likely to be non-representative.
- The patient should be adequately counseled that he/she is not supposed to 'perform' uroflowmetry. Rather, they should take it as a routine representative voiding act. Few important considerations in this regard, which need to be excluded from a void, are:
  - Patients may be straining unusually to give us their 'best' performance
  - Male patients with voiding symptoms often develop habit of 'squeeze and release' of penis during voiding. In this way, urine is collected in anterior urethra and suddenly released, resulting in a 'reassuringly' high flow.
  - Cruising: Ideally, urine should fall on one area of the funnel without cruising around. Artifactually high peaks may be observed if urine flows directly into the central hole of the funnel or the patients move the stream around.

TYPES OF UROFLOWMETERS

1. *Gravimetric (weight transducer):* It operates by measuring the weight of collected fluid or by measuring the hydrostatic pressure at the base of collecting cylinder.
2. *Rotating disk method:* Urine flow is directed onto a rotating disk, increasing the inertia of the disk. The power needed to keep the disk rotating at a constant speed is measured and is proportional to the flow rate of the fluid.
3. *Electronic dipstick method:* It uses a capacitance dipstick mounted on the collecting chamber that changes its capacitance as urine accumulates in the cylinder. The output signal is proportional to the accumulated volume of urine.
4. *Magnetic (integral trap magnetic uroflowmeter):* Urine flowing through a magnetic field generates voltage proportional to flow rate.

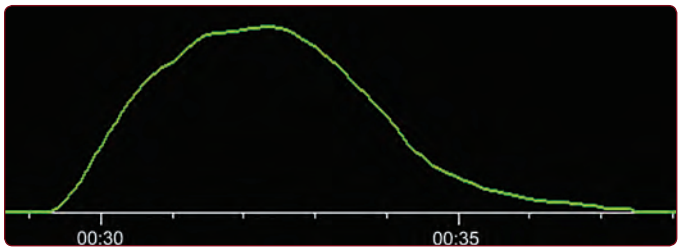

Fig. 1: Normal uroflow pattern—bell-shaped curve

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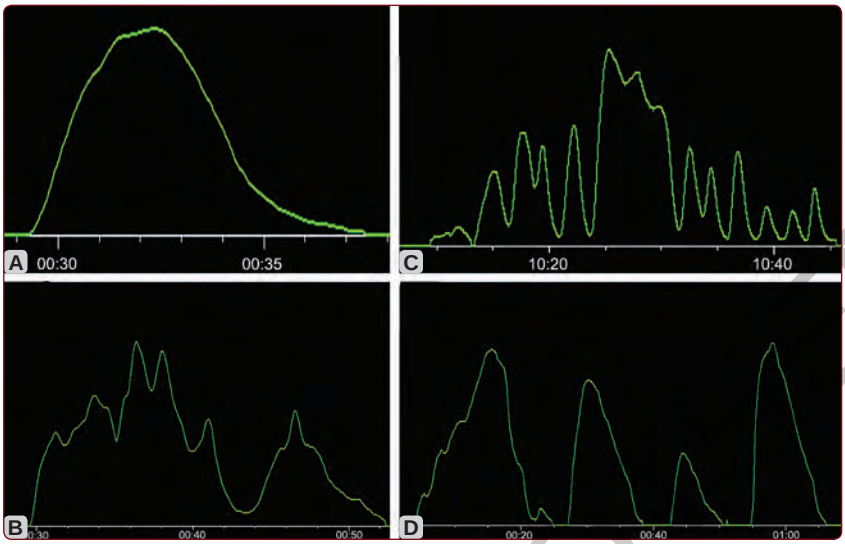

Figs 2A to D: Some uroflow patterns: (A) Normal; (B) Straining (irregular saw toothing); (C) Cruising (take a note of sharp peaks); (D) Squeezing (regular peaks)

One may acquire any of the types of uroflowmeter mentioned herewith. However, it is important to insure accuracy, safety and performance of the equipment as well as availability of after-sales service by the company. The desired clinical accuracy may differ from the technical accuracy of a flow meter.

STANDARDIZATION REQUIREMENTS OF THE EQUIPMENT

The ICS technical report recommended the following standards: a range of 0–50 mL/s for Qmax, and 0–1,000 mL for voided volume, maximum time constant of 0.75 s; an accuracy of + 5% relative to full scale, although a calibration curve representing the percentage error over the entire range of measurement should be made available. Full details of the standardization can be downloaded from the ***ICS website—http://icsoffice.org/Documents/Documents.aspx?DocumentID=1***.

Setup

Typically, simple non-invasive uroflowmetry does not require an elaborate setup and it can actually be setup in a toilet. It is rather desirable to have the uroflowmetry room resemble a clean toilet (Figure 3).

It should be clean, quiet, cool, adequately lit and conveniently located and lockable from inside. It should preferably have a wash-basin. Various types of chairs are available, ranging from simple western commode-like chair (Figure 3)

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to the most advanced electromechanical chairs (Figure 4). The latter are typically a part of invasive multichannel UDS unit rather than simple uroflowmetry. Nevertheless, the latter are helpful in making squatting position.

The essential parts of a uroflowmeter are as follows (Figure 5):

- Base-plate, the basic measurement transducer
- Beaker, the receptacle for urine
- Funnel
- Stand
- Connections
- Processor
- Printout
- Wired/wireless.



Fig. 3: Uroflowmetry setup at New Medical Center Specialty Hospital,Abu Dhabi, UAE

HOW TO READ AND INTERPRET UROFLOW DATA

Measurements

The following measurements are recommended by the ICS during uroflowmetry (Figure 6):



Fig. 4: Urodynamic setup of PGIMER, Chandigarh, India with electromechanical fluoroscopy-compatible urodynamic chair (Sonesta)



Fig. 5: Parts of a uroflowmeter

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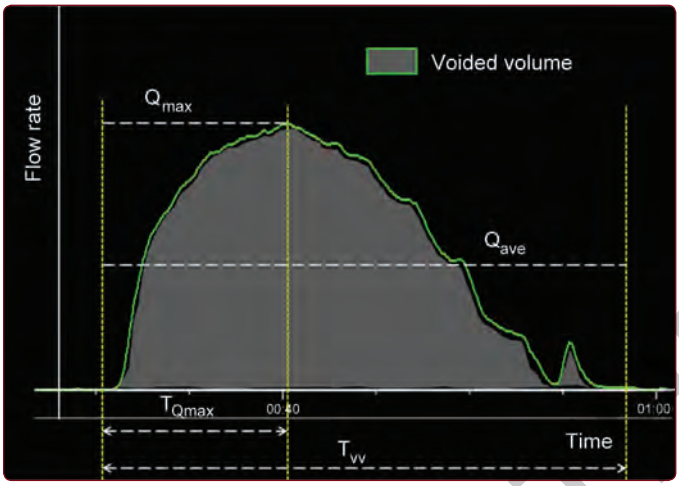

Fig. 6: Analysis of uroflowmetry graph

- *Flow rate (Q; mL/sec):* It is the amount of fluid (urine) expelled out of urethra per unit time. The following two flow-rates are specifically mentioned:
  - *Maximum flow rate (Qmax):* It is the maximum measured value of Q. It is generally reached by initial 1/3rd of volume. However, variations are quite common.
  - *Average flow rate (Qave):* It is the average representation of the whole flow, i.e. voided volume/flow time. It's value is generally half of Qmax. However, in intermittent flow states, this relation differs and Qave < ½ Qmax. In calculating Qave in intermittent flow, time without flow is disregarded.
- *Voided volume (VV; mL):* It is the total volume of urine/fluid collected into the uroflow-beaker. Please note that any urine not collecting in the beaker is not measured by the flowmeter and this may significantly affect the calculation of flow rates.
- *Flow time (Tvv; sec):* Time over which measureable flow occurs. In intermittent flow, time without flow is subtracted from the total voiding time to give flow-time. In continuous flow, voiding time equals flow time.
- *Time to Qmax (TQmax; sec):* Time taken from start of flow to Qmax. It is generally about 1/3rd of flow time, but may vary. In our separate studies on healthy men and women, mean and standard deviation of these values were 30.9±12.3% and 36.7±15.5% respectively.

Flow Patterns (Figures 7A to E)

Careful study of flow pattern can assist the numerical information in the interpretation of uroflowmetry. The following patterns are described:

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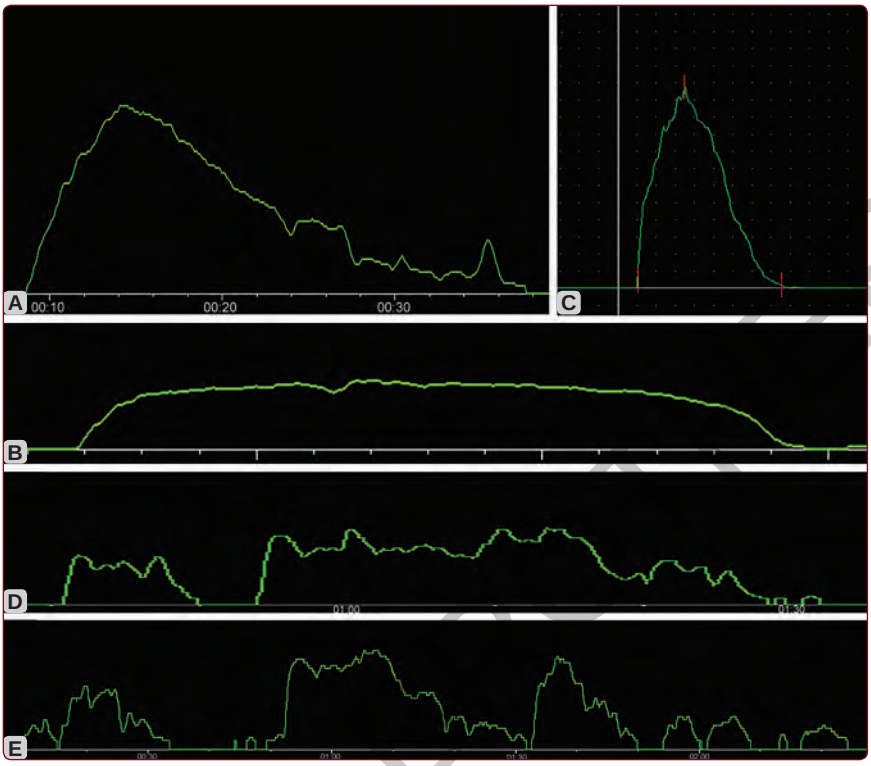

Figs 7A to E: Some recognized abnormal uroflow-patterns. (A) Compressive obstruction; (B) Constrictive obstruction; (C) Overactive bladder; (D) Detrusor underactivity; (E) Intermittent voiding pattern

a. *Normal:* It is a bell-shaped curve (meso-kurtotic type) with Qmax reached in initial 1/3rd of the void (usually 3–10 seconds); however, significant variations may be observed depending on various factors.
b. Bladder outlet obstruction:
   - *Compressive*, e.g. benign prostatic hyperplasia or bladder neck obstruction. Pattern of initial part of void till Qmax may seem normal, but there is terminal prolongation. Qave is generally more than half of Qmax.
   - *Constrictive*, e.g. urethral stricture. A low Qmax is rapidly reached and flow rate remains relatively constant at that, giving a box-like or plateau-shaped appearance. There is no significant difference between Qmax and Qave.
c. *Detrusor Overactivity:* Peaked type of flow pattern (leptokurtotic) abnormally high Qmax are reached in unusually short time (<3 seconds). This happens due to high contraction velocities of the detrusor.

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d. *Detrusor Underactivity:* This low pressure, low flow pattern is very variable with Qmax generally reached by half-way or even in the second half of the void. There can be a significant overlap with obstructed patterns.
e. *Intermittent:* The flow is not continuous; the uroflow shows an interrupted pattern. Generally, straining in the presence of poor or absent detrusor contraction gives saw-toothed appearance with relatively fixed height of each flow (signifying similar amplitude of abdominal straining).

Intermittent flow due to high grade prostatic obstruction generally is not associated with straining and has more crescendo-decrescendo pattern.

Postvoid Residual Urine (PVRU)

It is important to measure PVRU immediately after uroflowmetry. This indicates the status of detrusor function with respect to the outlet resistance, whether bladder outlet obstruction (BOO) or detrusor underactivity (DUA). It can be measured effectively by abdominal ultrasonography. Volume estimations vary depending upon the shape of the bladder, which is even more important in PVRU, where the shape is more of a squashed football. However, for practical purposes, the formula D1 X D2 X D3 X 0.7 gives a reasonable estimate of PVRU; whereas, D1 and D2 are mutually perpendicular diameters in sagittal plane and D3 transverse diameter in coronal plane. Automated bladder-scanners designed for the measurement of PVRU come in handy for this purpose (Figure 8). Finally, one must understand that ultrasound gives only an estimate based on formulae which may vary widely from the actual measurement.



Fig. 8: Hand-held bladder scan

Obviously, the most accurate measurement of PVRU is by urethral catheterization. It carries a risk of introducing infection, particularly in men. Therefore, it is permissible only in circumstances when the patient already does periodic self-catheterization (e.g. orthotopic neobladder, detrusor underactivity) or the free-uroflowmetry is to be immediately followed by an invasive multichannel UDS.

The above description pertains to the performance of uroflowmetry and acquisition of numerical and graphical information. The following discussion concentrates on how to interpret this information:

We recollect from the introduction that the most important determinant of uroflow rates in a given individual is voided volume. Therefore, before declaring any uroflow abnormal, information of voided volume is essential. For example, a Qmax of 15 mL/sec may be considered subnormal at a VV of 400 mL; however,

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it would be within the normal range at 150 mL. There are a couple of ways to objectively interpret Qmax and Qave in relation to VV.

Flow-volume Nomograms

These are the curves plotted between Q (y-axis) and VV (x-axis) and represent distribution of normal Q-VV relations. Various nomograms are available for both the sexes and different age groups. Of these, Siroky and Liverpool nomograms for adult men and Liverpool nomograms for adult women have been in common use worldwide (Figures 9A to D).

We have observed that normal Q-VV relations in our population (both men and women) are below par compared to these nomograms. We developed and validated nomograms based on local north Indian population which are eponymed as PGIMER nomograms (Figures 10A to D).

We have found that the lower 68% confidence limit line in each of these nomograms gives a reasonable cut-off for abnormal flow, requiring further investigations. Moreover, any value above median line represents essentially normal flow.

Volume Corrected Q

Another concept useful to correctly interpret uroflow is volume corrected flow rate (cQ) or flow-volume index (VQI). It is defined differently for men and women as follows:

- $cQ^* = Q/\sqrt{BV}$ (for men in standing and squatting position and women in sitting position)
  * Qmax or Qave. BV (bladder volume) = VV + PVR
- cQ is conceptually similar to body mass index (BMI); BMI = weight (Kg)/[height (m)]^2. We know that BMI is a well accepted derivation of weight and height and used instead of either for defining and categorizing obesity. Similarly, cQ can be utilized in defining voiding dysfunction. The reference values of flow rates and corrected flow rates in Indian population are as follows:

	Men	*Women*
Qmax	24.1± 7.9	23.5 ± 9.3
Qave	13.9 ± 4.8	13.3 ± 6.0
cQmax	1.41 ± 0.44	1.44 ± 0.42
cQave	0.80 ± 0.28	0.81 ± 0.27

Indications can be broadly classified into:

- *Screening:* for voiding dysfunction in patients presenting with voiding type LUTS irrespective of etiology (e.g. benign prostatic hyperplasia, bladder neck dysfunction, pelvic floor spasticity, neurogenic bladder)

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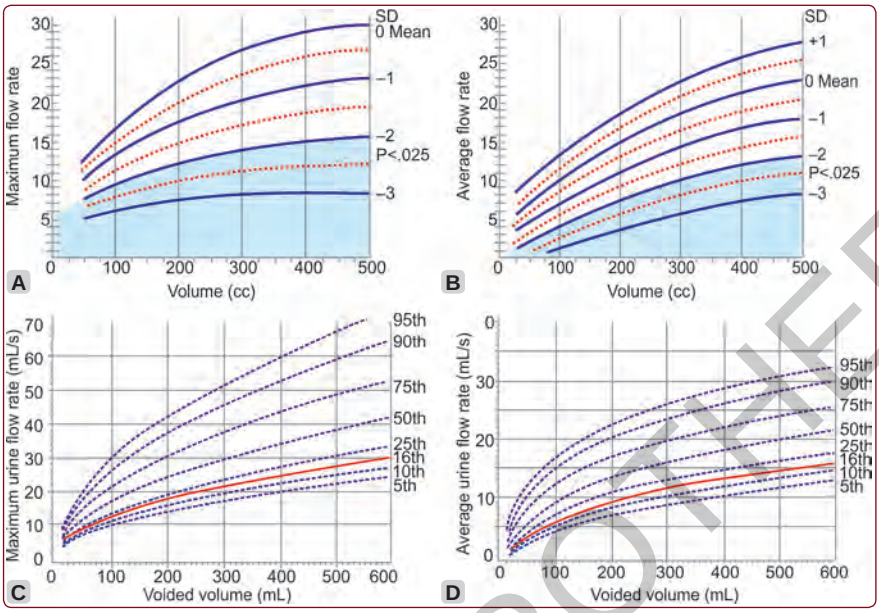
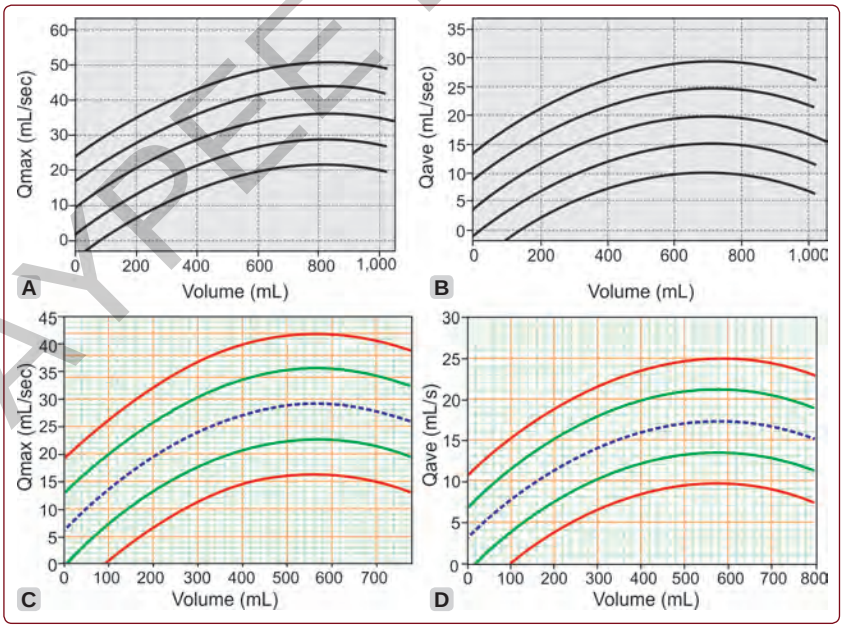


Figs 9A to D: Flow volume nomograms developed on Caucasian population. Siroky nomograms for men—Qmax-VV (A), Qave-VV (B); Liverpool nomograms for women—Qmax-VV (C), Qave-VV (D)



Figs 10A to D: PGIMER flow-volume nomograms developed on Indian population for women (A and B) and men (C and D)

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- *Evaluation of clinical response:* To the medical/surgical management of above conditions.

SUGGESTED READING

1. Agarwal MM, Shivkumar SP, Roy K, et al. Rationalization of interpretation of Uroflowmetry for a non-Caucasian (Indian) population: development and validation of volume-normalized flow rate index and flow-volume nomograms. Neurourol Urodynam. 2013. [Epub ahead of print]
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Manual of URODYNAMICS

This book is a highly illustrated, descriptive and comprehensive resource for understanding, performing and interpretation of urodynamics. The salient reader-friendly features of this book are:

- Each chapter is full of illustrations, photographs and graphs supporting the text
- Difficulties, errors and artefacts encountered during various urodynamic tests and their troubleshooting have been described lucidly
- Theoretical description has been supplemented with clinical case discussion, wherever appropriate
- A full chapter on clinical cases with a variety of lower urinary tract symptoms—how they presented, what urodynamic query was generated, how the urodynamic study was planned and interpreted, and how did it correlate with the clinical outcome
- Easy-to-understand description and discussion of difficult urodynamic concepts, e.g. full interpretation of Schafer nomogram, CHESS curve, DAMPF and QCO
- Presentation of clinically relevant novel concepts arising out of years of personal experience and thorough research, e.g. PGIMER nomogram for Indian patients, volume-normalized flow rate index and plateau detrusor pattern for the diagnosis of pelvic floor dysfunction.



Mayank Mohan Agarwal MBBS MS (Surg) DNB (Surg) MRCS (Ed) MCh (Urol) DNB (Urol) is presently working as an Assistant Professor of Urology in the Postgraduate Institute of Medical Education and Research (PGIMER), India. He has been instrumental in setting up an advanced urodynamic laboratory in the urology department of this institute. He is also working as a Urology Specialist in the New Medical Center Specialty Hospital, Abu Dhabi, UAE. He has been involved in the clinical practice, education and research of urodynamics since 2006. He has firsthand experience of performing and supervising over two thousand urodynamic studies. He has guided several theses on this topic, many of which have been published in peer-reviewed scientific journals. He visited urodynamic setups in various North American institutions, viz. Memorial Sloan-Kettering Cancer Center (MSKCC), New York, USA; University of California, Los Angeles, USA; Wake Forest, North Carolina, USA; and Weill Cornell, New York, USA during the awarded fellowships. The validation of the Indian population-specific flow-volume nomograms (eponymed PGIMER nomograms), the novel concept of volume-normalized flow rate index, the micturitional urethral pressure profilometry in bladder outlet obstruction and identification of plateau detrusor pattern in patients with pelvic floor dysfunction are accredited to the author's research. He has been invited for presentations/demonstration on urodynamics in national and international scientific fora including World Congress of Endourology, American Urological Association and International Continence Society.

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