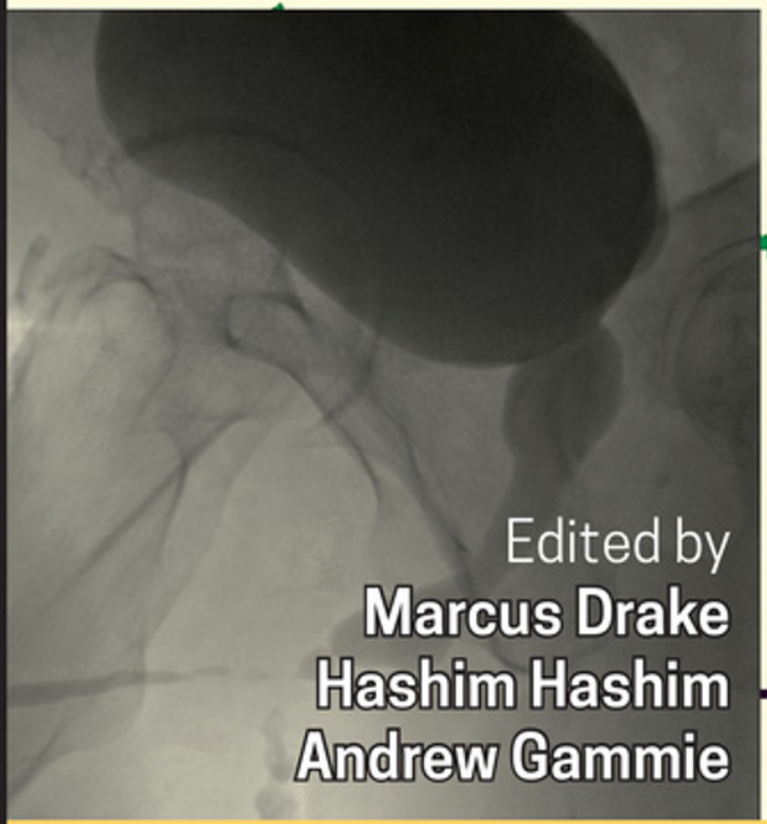
Fourth Edition

Abrams' URODYNAMICS



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WILEY Blackwell

Abrams' Urodynamics

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Contents

Abbreviations

ACh	Acetyl-choline
AD	Autonomic dysreflexia
ADH	Anti-diuretic hormone
AFC	Air-filled catheter
ANP	Atrial natriuretic peptide
AP	Antero-posterior
ARM	Anorectal manometry
ATP	Adenosine Triphosphate
AUDS	Ambulatory urodynamics
AUS	Artificial urinary sphincter
BCI	Bladder contractility index
BMI	Body mass index
BOO	Bladder outlet obstruction
BOOI	Bladder outlet obstruction index
BPE	Benign prostate enlargement
BPH	Benign prostatic hyperplasia
BPS	Bladder pain syndrome
BNI	Bladder neck incision
BNO	Bladder neck obstruction
BNP	Brain natriuretic peptide
BPO	Benign prostatic obstruction
BTX	Onabotulinum toxin-A
BWT	Bladder wall thickness
BVE	Bladder voiding efficiency
CC	Cystometric capacity
CEPNL	Cauda equina and peripheral nerves lesion (infrasacral)
CFS	Clinical Frailty Scale
CKD	Chronic kidney disease
CLPP	Cough leak point pressure
CNS	Central nervous system
CPAP	Continuous positive airway pressure
CSF	Cerebrospinal fluid
CSU	Catheter specimen of urine
CT	Computed tomography
CVA	Cerebro-vascular accident
DLPP	Detrusor leak point pressure
DLPV	Detrusor Leak Point Volume
DO	Detrusor overactivity
DOI	Detrusor overactivity incontinence
DRE	Digital rectal examination
DSD	Detrusor sphincter dyssynergia
DUA	Detrusor underactivity
ED	Erectile dysfunction
EBRT	External beam radiotherapy
EMG	Electromyogram
EUS	External urethral sphincter
FDA	Food and Drug administration
FFR	Free flow rate
Fr	French
FSF	First sensation of filling
FUTURE	Female Urgency, Trial of Urodynamics as Routine Evaluation
FVC	Frequency/volume chart
GI	Gastrointestinal
GUP	Good Urodynamic Practices
HR-ARM	High resolution anorectal manometry
HRM	High resolution manometry
IAS	Internal anal sphincter
IC	Intermittent catheterisation
ICI	International Consultation on Incontinence
ICIQ	International Consultation on Incontinence Questionnaire
ICIQ-B	International Consultation on Incontinence Questionnaire-Bowel symptoms
ICIQ-FLUTS	International Consultation on Incontinence Questionnaire-Female LUTS
ICIQ-MLUTS	International Consultation on Incontinence Questionnaire-Male LUTS
ICCS	International Children's Continence Society
ICS	International Continence Society
IR(ME)R	Ionising Radiation (Medical Exposure) Regulations
ISC	Intermittent self-catheterisation
ISD	Intrinsic sphincter deficiency
IVU	Intravenous urogram

LUTD	Lower Urinary Tract Dysfunction
LUTS	Lower Urinary Tract Symptoms
M	Muscarinic
MCUG	Micturating cystourethrogram
MRI	Magnetic resonance imaging
MS	Multiple sclerosis
MSA	Multiple system atrophy
MSU	Mid-stream urine
MUCP	Maximum urethral closure pressure
MUI	Mixed urinary incontinence
MUP	Maximum urethral pressure
MUT	Midurethral tape
MVV	Maximum voided volume
NIRS	Near infrared spectroscopy
NLUTD	Neurogenic Lower Urinary Tract Dysfunction
NDV	Normal desire to void
NICE	National Institute for Health and Clinical Excellence
NP	Nocturnal polyuria
NPH	Normal pressure hydrocephalus
NPi	Nocturnal polyuria index
NUV	Nocturnal urine volume
OAB	Overactive bladder
OSA	Obstructive sleep apnoea
PA	Postero-anterior
p_{abd}	Abdominal pressure
PAG	Periaqueductal grey
PCR	Penile compression-release
PD	Parkinson's disease
p_{det}	Detrusor pressure
$p_{detQmax}$	Detrusor pressure at maximum flow rate
PFC	Prefrontal cortex
PFME	Pelvic floor muscle exercises
PFS	Pressure-flow studies
PMC	Pontine micturition centre
PMD	Post-micturition dribble
PNS	Parasympathetic nervous system
POP	Pelvic organ prolapse
POP-Q	Pelvic organ prolapse quantification
PPI	Post-prostatectomy incontinence
PRIMUS	PRImary care Management of lower Urinary tract Symptoms
PRO	Patient-reported outcomes
PSA	Prostate-specific antigen
PTNS	Percutaneous tibial nerve stimulation
p_{ura}	Urethral pressure
PUV	Posterior urethral valves
p_{ves}	Vesical pressure
PVR	Post-void residual
Q_{max}	Maximum flow rate
RAIR	Recto Anal Inhibitory Reflex
SBO	Spina bifida occulta
SCI	Spinal cord injury
SDV	Strong desire to void
SPL	Suprapontine lesion
SSCL	Sacral Spinal Cord lesion
SSL	Suprasacral spinal cord/pontine lesion
SNM	Sacral neuromodulation
SNS	Sympathetic nervous system
SUI	Stress urinary incontinence
TURP	Transurethral resection of the prostate
TVT	Transvaginal tape
TWOC	Trial without catheter
UAB	Underactive bladder
UDS	Urodynamics
UPP	Urethral pressure profile
UPSTREAM	Urodynamics for Prostate Surgery: Randomised Evaluation of Assessment Methods
USI	Urodynamic stress incontinence
UTI	Urinary tract infection
UUI	Urgency urinary incontinence
UUT	Upper urinary tract
VLPP	Valsalva leak point pressure
VUDS	Video-urodynamics
VUJ	Vesicoureteric junction
VUR	Vesicoureteric reflux
VV	Voided volume
VVF	Vesico-vaginal fistula
WFC	Water-filled catheter

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Preface

Lower urinary tract dysfunction (LUTD) produces a large burden on sufferers in particular, and on society in general. Lower urinary tract symptoms (LUTS) are very prevalent; 5% of children aged 10 years wet the bed. In all, 15% of women and 7% of men have troublesome incontinence. In elderly men of 75 years, benign prostatic hyperplasia occurs in more than 80% of individuals, with benign prostatic enlargement coexisting in up to half this group and half of these having bladder outlet obstruction. Most people with a neurological disease have some form of LUTD.

Urodynamics is invaluable in assessing people with LUTD. The need to support the clinical assessment with objective measurement is accepted by most clinicians specialising in the care of patients with LUTS. Since the first edition of this book in 1983, urodynamics has become more widely accepted. The number of urodynamic units worldwide has increased to enable access to this important testing modality. Almost every hospital of any significance embraces urodynamic investigations as an essential part of the diagnostic pathway for urology and gynaecology departments. Further, specialists in geriatrics, paediatrics and neurology recognise the importance of urodynamics in the investigation of a significant minority of their patients. The expertise involved in assessing neurogenic LUTD by urodynamicists can help neurologists refine their insights into the neurological deficit in individual patients. However, the take-up is not universal, especially worldwide. This may result from the perceived cost to the healthcare unit, the presumed unpleasantness to the patient, and the varied expertise in functional urology.

The objective of this book is to deliver a definitive manual of practical urodynamics, showing how urodynamic investigation contributes to the management of patients and describing the tests clearly and comprehensively. To do this means not only discussing the tests but also showing in which clinical areas they help management and those where urodynamic tests are largely pointless. It means concentrating on the common clinical problems and on the presenting symptom complexes, while pointing out any limitations and possible artefacts of investigation.

The Bristol Urological Institute (BUI) serves a large patient population in South West England and has developed skills in urodynamics and functional urology over several decades. It runs educational courses (the Basic Urodynamics course, the Certificate of Urodynamics, and the Expert Urodynamics course) which take place in the UK and several places globally, and also online. This makes the BUI one of the world-renowned leading units in female and functional urology generally, and urodynamics specifically, that is visited by healthcare professionals from all over the world. Professor Paul Abrams was not the only individual responsible for this strength, but his contributions to Urology in Bristol and worldwide are truly impressive. They include the development of the Abrams-Griffiths nomogram [1], which was adopted by the International Continence Society (ICS) as the Bladder Outlet Obstruction Index. He was a major promoter of the ICS Standardisations of Terminology in Lower urinary tract function, including being the first author on the paper which has been more widely quoted from urology than any other [2]. He also serves as one of the Chairs of the International Consultations on Incontinence. When he wrote the preceding editions of this book, his aim was to help a clinician with no previous experience in urodynamics to appreciate both the value and limitations of the subject and give the necessary practical advice on the use of the appropriate equipment in the correct situations. This was delivered with characteristic wit and imagination (see figure). One of the principal reasons for producing the 3rd edition was the publication of the ICS terminology report and the 'Good Urodynamic Practices' document [3]. With the updating of Good Urodynamic Practices [4], and

now the 'Fundamentals of Urodynamic Practice' document [5], it is timely to continue Professor Abrams' achievements in this fourth edition, the first to become an eponymous *Abrams' Urodynamics*. In it, we have aimed to stay true to the importance of the practical application of urodynamic tests, we draw on the latest scientific evidence, have sourced an extensive new tranche of illustrations, and have revisited the ICS Standardisations to reflect their revisions in recent years. In doing so, we wish to record our personal appreciation of and debt to Paul Abrams' inspiration, leadership, and support of us and countless others in this field.

Marcus Drake, Hashim Hashim,
Andrew Gammie, 2020
Bristol Urological Institute
and University of Bristol

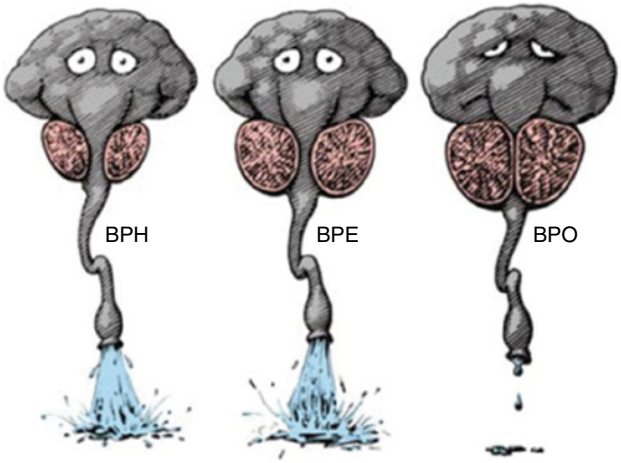

Figure A classic picture of the fundamental insights on the implications of prostate pathology for the male lower urinary tract, showing the relationships between benign prostate hyperplasia (BPH), benign prostate enlargement (BPE), and benign prostate obstruction (BPO). *Source*: Drawn by Alex James from a sketch by Paul Abrams in 1993.

References

1 Abrams, P.H. and Griffiths, D.J. (1979). The assessment of prostatic obstruction from urodynamic measurements and from residual urine. *Br. J. Urol.* 51 (2): 129–134.

2 Abrams, P., Cardozo, L., Fall, M. et al. (2002). The standardisation of terminology of lower urinary tract function: report from the Standardisation Sub-committee of the International Continence Society. *Neurourol. Urodyn.* 21 (2): 167–178.

3 Schafer, W., Abrams, P., Liao, L. et al. (2002). Good urodynamic practices: uroflowmetry, filling cystometry, and pressure-flow studies. *Neurourol. Urodyn.* 21 (3): 261–274.

4 Rosier, P., Schaefer, W., Lose, G. et al. (2017). International Continence Society Good Urodynamic Practices and Terms 2016: Urodynamics, uroflowmetry, cystometry, and pressure-flow study. *Neurourol. Urodyn.* 36 (5): 1243–1260.

5 Drake, M.J., Doumouchtsis, S.K., Hashim, H., and Gammie, A. (2018). Fundamentals of Urodynamic Practice, based on International Continence Society Good Urodynamic Practices recommendations. *Neurourol. Urodyn.* 37 (S6): S50–S60.

First Foreword

I feel honoured and humbled to find my name attached to this new edition, but need to set the record straight!

After graduating from Sheffield, I arrived in Bristol in 1972 to begin my surgical training. The surgical registrar (resident) was Michael Torrens, who was a neurosurgical resident, and about to become Roger Feneley's new research fellow in the newly founded urodynamic unit. Mike was going to use urodynamics to evaluate sacral neurectomy in women with intractable detrusor overactivity, then called 'detrusor instability'. After six months of general surgery, I rotated to the urology department and got interested in the older men coming for TURP for their 'prostatism'. Even then I was an annoying and inquisitive individual who constantly asked, 'Why ..... ?'. Mike suggested that I approach Roger to see whether I could start to assess these men, initially by urine flow measurement. I describe these beginnings of my urological life, as they were determined by serendipity. The opportunities I was given, and those I worked with, in that first year in Bristol determined the rest of my professional career. Mike's early encouragement and advice, and Roger's mentorship throughout, have been the bedrock of my professional development. Roger provided the environment where all young, naive but enthusiastic clinicians could speak without fear, knowing that their unanswered questions could be pursued in an academically sound manner according to the null hypothesis.

It has been my privilege and pleasure to work in academic and clinical teams that have been devoted to patient care, and free of rancour and division. The stability of the urodynamic team in Bristol was anchored by Roger initially, then by Angela Shepherd, followed by Lucy Swithinbank and now by Hashim Hashim. The technical side of urodynamics is also of paramount importance to the quality of service. From the beginning, Pat Lewis and then Sue Howell ensured that Bristol Urodynamics adhered to high technical standards, and the clinicians were kept on the 'straight and narrow': any upstart doctor was reminded who were the most important members of staff! We have continued to be most fortunate in having excellent scientific colleagues. Andrew Gammie is our first clinical engineer, and Laura Thomas is our first clinical scientist. With their involvement, not only has our urodynamic quality advanced, but our teaching activity too has been able to improve in quality.

I owe great debts to many others. I met and worked with Derek Griffiths, then in the physics department at Exeter. He was my urodynamic and scientific mentor, and he taught me 'intellectual honesty' – what I knew from what I thought I knew. We collaborated for many years, even after he moved to Holland and then to North America. Early on, I met Alan Wein and Linda Cardozo, who have both been very important in developing functional urology worldwide, and together we have worked closely with the International Continence Society (ICS) and in developing the International Consultation on Incontinence (ICI), and from that the ICI Research Society. Saad Khoury has been another valued mentor who made the ICI possible and has been an important and wise counsel for many years. The camaraderie of these old friends has been very important to me.

Urodynamics remains a controversial subject to the 'non-believers', and there remains much to be achieved in identifying its exact place in the evaluation of lower urinary tract dysfunction (LUTD). What is clear is that the *a priori* argument remains: the bladder, urethra and sphincter are, in engineering terms, a reservoir, outlet and valve, and therefore must be studied by pressure and flow measurements. The United Kingdom Continence Society (UKCS) has led the way in determining how urodynamics can improve and reach the quality standards of other physiological measurement units. Another of the fundamental problems, in managing patients' problems, is that the LUT is connected to the brain. Of course, this is essential, but it leads to enormous problems, as the nervous system is so incompletely understood. In any urodynamic team, there has to be a basic science including neurophysiological input, and Marcus Drake has

added that dimension to our work. Advances will not come until we develop our understanding of the interactions between the nervous system and the LUT. Marcus, like many other members of the urodynamic team, has completed his training in other centres, and this cross-fertilisation by ideas is essential for creative thinking. I am proud that I have had a part in appointing colleagues who will develop a wider range of skills than I have had. This is never a threat, only an opportunity.

We all have the duty to educate, and I hope this book will support that effort. Finally, I must thank my wife Kirsten and my children, the members of 'my crew', who ground me when necessary, and are ever tolerant and supportive. They have certainly become familiar with the basics of lower urinary tract function! So, in addition to developing the science of urodynamics, we have to help all people, as well as patients, to better understand their bladder function so that they can preserve their bladder health and help themselves when it 'plays up'.

Thank you, Marcus, Andrew and Hashim, for your collaboration in science and clinical work and for your friendship.

Professor Paul Abrams, Bristol
December 2020

Figure Marcus Drake, Hashim Hashim, Paul Abrams, and Andrew Gammie holding an extremely long flowmetry printout that exemplifies slow flow and terminal dribble. Bristol, September 2020.

Second Foreword

The name 'Paul Abrams' has been synonymous with expertise in many subjects associated with normal function and lower urinary tract dysfunction (LUTD), but none more so than the science, performance, interpretation and clinical utility of urodynamics of the LUT. I thought that I was a good organiser of subject material and a good and succinct writer when I picked up the first edition of *Urodynamics* in 1983, but I had to tip my hat to Paul. The 229 pages of this text rapidly became the 'gold standard', and the charts, tables and diagrams quickly became a part of my own presentations on the subject (properly referenced, of course!). I found the organisation of the subject, which included the science necessary to understand what happens during filling/storage and emptying/voiding, and how to properly measure and categorise the findings, to 'make sense' and enable understanding of where these straightforwardly explained techniques fit into the overall evaluation of LUTD. The notes on management were a bonus.

Subsequent editions (I am looking at the third now - 331 pages) have expanded the concepts and techniques that have occurred parallel to the advances in the related scientific disciplines, just as the terminology has evolved (please do not ever say 'urge incontinence' as opposed to 'urgency incontinence' in Paul's presence!). It is only fitting that the title of this book, the most complete text on the science and practice of urodynamics, now be preceded by Paul's name and carried on by members of the department that he developed.

Paul, congratulations on having the text renamed *Abrams' Urodynamics*, an honour well deserved!

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Part I

Basic Principles

1

Basic Urodynamics and Fundamental Issues

Marcus Drake[1], Andrew Gammie[2], Laura Thomas[3], Arturo García-Mora[4], and Hashim Hashim[2]

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CONTENTS

Introduction to Urodynamics

Urodynamics has two basic aims:

- **To reproduce the patient's symptomatic complaints while making key observations**
- **To provide a pathophysiological explanation by correlating the patient's symptoms with the urodynamic findings**

These two basic aims are crucial to the purpose of urodynamics – essentially, it is a diagnostic test that will aid in the management of patients. The need to make urodynamic observations reflects the fact that the patient's symptoms are important, but they might be somewhat misleading. Most patients with lower urinary tract dysfunction (LUTD) present to their doctor with symptoms. However, lower urinary tract symptoms (LUTS – Table 1.1) should not simply be taken at face value, since a range of differing mechanisms may result in rather similar symptomatic presentations. The statement 'the bladder is an unreliable witness' [2] reflects how symptoms are the starting point but do not actually identify the ultimate explanation. Since treatment should correct the underlying cause, it is necessary to identify mechanisms, avoiding assumption or prejudice coming from taking symptoms at face value. An excellent example of this is voiding LUTS in men, where the cause on urodynamic testing may prove to be bladder outlet obstruction (BOO) and/or detrusor underactivity (DUA); BOO should respond fully to surgery to relieve obstruction such as transurethral resection of prostate (TURP), while such surgery is potentially not helpful in the second [3]. Voiding LUTS in males are of unreliable diagnostic value, and only slow stream and hesitancy show any correlation with the urodynamic findings of BOO [4–6]. Even with flow rate assessment, one cannot be sure whether BOO is present (Figure 1.1). The difficulty of assessing LUTD by symptoms alone is the uncertainty about establishing truly what is going on in the individual describing them.

For women diagnosed by their symptoms as having stress urinary incontinence (SUI), only 50–68% have urodynamic stress incontinence (USI) [7, 8]. These studies also looked at patients with apparent overactive bladder (OAB) symptoms presumed to be the result of detrusor overactivity (DO), and here, the correspondence was

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Table 1.1 Classification of lower urinary tract symptoms (LUTS) [1].

Storage	Voiding	Post-micturition
Urgency	Slow stream	Post-micturition dribbling
Urinary incontinence	Splitting/spraying	Feeling of incomplete emptying
Increased daytime frequency	Intermittency	
Nocturia	Hesitancy	
Pain	Straining	
	Terminal dribbling	

Note: Do NOT forget to enquire about Pelvic Organ Prolapse in Women and Erectile Dysfunction in Men.*Source*: Modified from Abrams et al. [1].

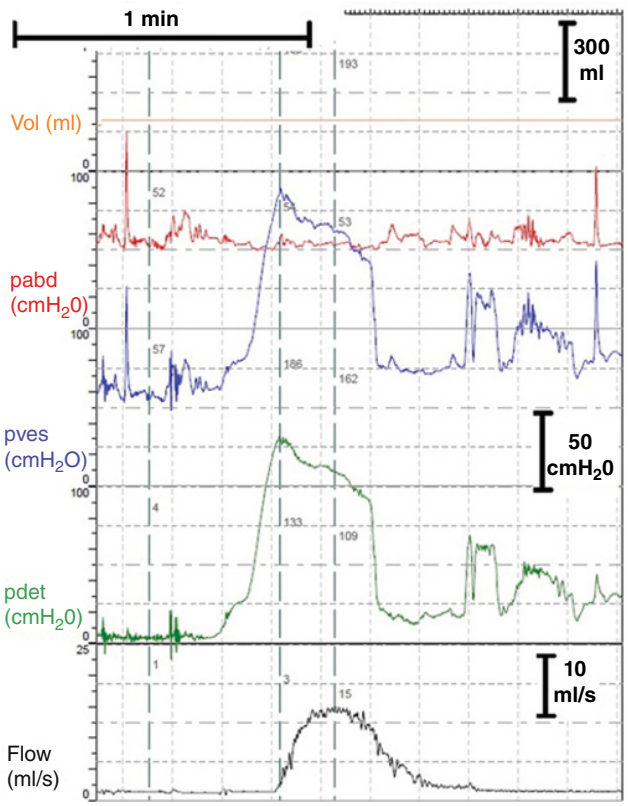

Figure 1.1 Flow rate testing in men gives an uncertain understanding. This man had previously done a free flow rate test which showed a reasonable maximum flow rate of 16 ml/s; taken alone, this might suggest he does not have bladder outlet obstruction (BOO). However, when he attended for urodynamics (see the pressure-flow study illustrated above), his flow rate was 15 ml/s as shown, but the pressure needed to achieve this was high, indicating BOO is present (see Chapter 14 for more details on assessing BOO in men).

33–51%. A key factor is the link to coughing, often used as a question to elicit a history of SUI; if a woman says 'I leak when I cough', it sounds like SUI. However, a cough can be a trigger to set off an overactive detrusor contraction, leading to detrusor overactivity incontinence (DOI) (Figure 1.2). Thus, the history may suggest that SUI treatment is needed, but for some of these women, the urodynamic observation identifies that DO treatment is the appropriate choice.

Accordingly, in both men and women, there is potential mismatch between reported LUTS and the LUTD identified by detailed investigation. This issue is particularly prominent in people with neurological conditions and children. In neurological disease, it is common for sensation to be absent or abnormal, making LUTS even more difficult to interpret. Children may find it difficult to describe their symptoms in any setting and particularly in a healthcare environment. Because symptoms have been shown to lack diagnostic specificity in the key clinical groups, it is not surprising to find that when surgery was based on symptoms alone, the results could be unsatisfactory. Urodynamic studies provide explanations for many symptoms based on mechanism and accordingly provide better support for therapy selection.

There is a well-recognised and substantial placebo effect for therapy in patients with LUTS. The symptoms of men with proven BOO, secondary to benign prostatic enlargement (BPE), can be improved in 40–60% of men in the placebo arm of drug studies. Such an effect can be surmised in men undergoing prostate surgery, but usually it is not sustained and in due course will be counterbalanced by the other effects of surgery, notably impairment of sexual function. Some patients submitted for surgery without objective confirmation of their condition potentially can do badly; this might reflect a poor-quality operation, or it may be that the problem lay in the preceding assessment. Urodynamics in modern practice gives greater insight into each patient's LUTD and hence helps advise patients on potential benefit and risks for intervention, to support their expectations of informed decision-making.

Ultimately, a successful urodynamics test is a clinically relevant investigation which seeks:

- to reproduce the patient's symptoms,
- to define bladder and urethral function,
- to provide precise diagnoses,

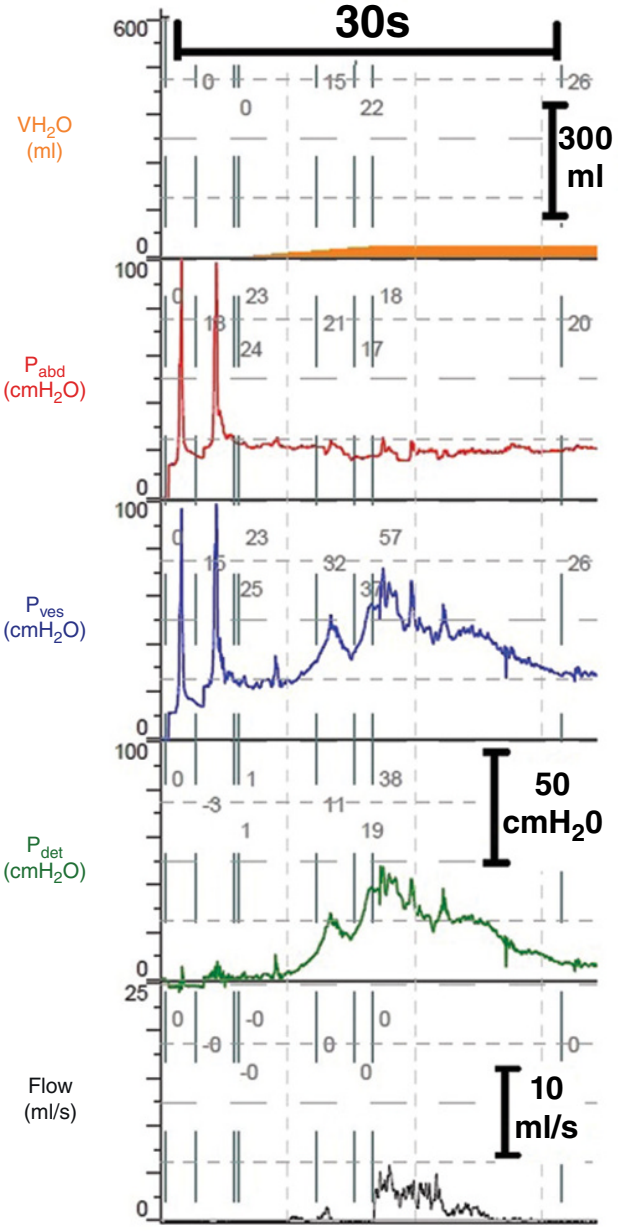

Figure 1.2 A woman who reported leakage with coughing in her history, suggestive of stress urinary incontinence (SUI). Her urodynamic test showed cough-provoked detrusor overactivity (DO) incontinence, and she described this as representative of her presenting complaint. Hence, this is not urodynamic stress incontinence, but effort-provoked detrusor overactivity incontinence; the symptomatic presentation was misleading and could have led to inappropriate surgery for SUI (see Chapter 13 for more details on assessing incontinence in women).

- to define the most significant abnormality,
- to allow selection of most appropriate treatment, and
- to predict post-operative problems.

This book describes how these can be achieved across a wide range of settings, complying with modern practice standards, and how to deal with challenges that may be encountered.

The Urodynamic History and Examination

When meeting a new patient with LUTS, it is important to establish a rapport. The LUTS present must be captured systematically, identifying the severity of individual symptoms and the bother each causes to the patient, preferably by using a symptom score completed before the appointment. There are several developed by the International Consultation on Incontinence Questionnaires group [9] which can suit a wide range of patients. They have the advantage of efficiently capturing both severity and bother for each symptom.

The history needs to cover several influences, for example:

- previous urological treatments,
- urinary tract infections (UTIs) – confirmed or suspected,
- obstetric and gynaecological background (in women),
- bowel function,
- sexual problems, including sexual trauma in the past, or recent emergence of sexual dysfunction,
- medical problems and medications, and
- the possibility of an underlying neurological condition.

Malignancy and neurological disease are key considerations. Undiagnosed cancer, such as bladder, prostate, gynaecological, or pelvic malignancy, must also be considered and is potentially at the back of the patient's mind, even if they don't say so [10]. Most patients with neurological disease have been diagnosed as such before coming to have LUTS assessed. However, some conditions can cause LUTS early on in the disease process. In these patients, it is possible that no one has yet realised the situation. Urological clinics sometimes encounter LUTS which turn out, on investigation, to have been caused by a neurological problem that has not yet been diagnosed – 'occult neurology' [11]; the main conditions which can cause this sort of situation are described in the last part of this chapter.

Patients referred for urodynamics will have been examined in a general way, either in the hospital clinic from which the referral originated, or by the patient's general practitioner (primary care physician). Hence, the urodynamic staff should concentrate efforts on a physical examination relevant to the symptomatic complaints and the possible underlying pathophysiological processes, for example:

- features suggestive of wider problems, such as neurological disease (e.g. slurred speech, altered gait, and tremor),

- abdominal examination to identify scars from previous surgery, or a distended palpable bladder, and
- internal examination to assess pelvic floor tone and contraction, pelvic organ prolapse, or formal prostate evaluation.

Urine examination should be performed in all patients, in the form of a urine dipstick to help rule out obvious causes for the LUTS. Other tests, such as blood tests (e.g. renal function and prostate-specific antigen), radiology, and endoscopy, have their indications and may need to be conducted alongside the ongoing LUTD assessment in accordance with the applicable clinical guidelines.

Invasive urodynamic studies are generally not indicated early in the pathway. They follow on once

1) careful investigations have been performed to exclude other pathologies that might mimic LUTD,
2) a bladder diary has been completed,
3) urinary free flow rate test and post-void residual (PVR) have been done, and
4) conservative treatment, which may include testing out response to medications, has been undertaken for a sufficient duration.

The Aims and Considerations of Urodynamics

A urodynamic test has several aims:

- To reproduce the patient's symptoms
- To define bladder and urethral function
- To provide precise diagnoses
- To define the most significant abnormality
- To allow selection of most appropriate treatment
- To predict potential post-operative problems
- To assess the results of treatment

The prelude to a urodynamic test is to identify the information needed, which can be described as 'formulating the urodynamic question'. The needs of the patient are fundamentally to resolve bothersome symptoms and reduce possible future problems. The history, symptom score, and bladder diary will help specify the situation. It follows that the needs of the clinician are to help suitable therapy selection and ensure avoidance of harm by identifying causative mechanisms. The urodynamicist should be considering 'what do I want to know about this patient?' It can be considered in terms of the micturition cycle ('What is wrong with storage, what is wrong with voiding?') and in terms of the lower urinary tract organs ('What is wrong with the bladder, what is wrong with the bladder outlet?'). In this way, the urodynamicist is in a position to consider 'Which urodynamic investigations need to be performed to define this patient's problems?'

This question will concentrate the clinician's thought processes on undertaking only those investigations which can help to make the diagnosis or indicate the line of management. For example, if a young male patient previously had urethral stricture treatment and voiding LUTS have returned, urine flow measurement will be the principal urodynamic test to identify if stricture recurrence is likely.

Once the questions have been defined, it will become apparent which urodynamic tests to do, as discussed below. The next question should be: 'Is the investigation likely to be of benefit to the patient?' This question reflects how the increased knowledge generated by the test might influence the clinical management. Several aspects are relevant, including:

1) *Individual considerations*: Is there therapy available, and is the patient healthy enough to tolerate the therapy?
2) *Disease knowledge*: In a difficult clinical area without effective treatment, urodynamic insights may facilitate introduction of treatment options in the future. An example is the introduction by the International Continence Society (ICS) of the concept of underactive bladder syndrome [12], which currently has no specific effective treatment but which will stand a better chance of future therapy development now that a terminology framework is in place.
3) *Financial cost and risks of testing*: The incidence of UTI after a UDS test is 2–3%, and some discomfort may be experienced.
4) *Potential harm the tests could do*: In particular, 'Is the urodynamic unit able to make a reliable diagnosis?' with erroneous diagnosis being the greatest concern. Three factors are crucial:

- The urodynamic technique should be free of technical artefacts.
  - The results of investigations should be reproducible.
  - The clinician should be properly trained and able to interpret the results of the urodynamics (Figure 1.3).

From a technical point of view, the tests must be carried out in a careful way, continuously monitoring during the test and eliminating artefacts (see Chapters 18 and 19). The clinician needs to allow for variation in LUTS from day to day and symptomatic progression over longer timescales. At the end of the urodynamic tests, it is pertinent to ask 'Did the urodynamic studies reproduce the patient's complaints and did the complaints correlate with known urodynamic features?' Answers to this question would be yes, no, or partially.

In the Bristol unit, we believe the presence of the clinician, or an experienced practitioner who is aware of the therapeutic possibilities of subsequent treatment, is very beneficial during tests. This individual can then consider

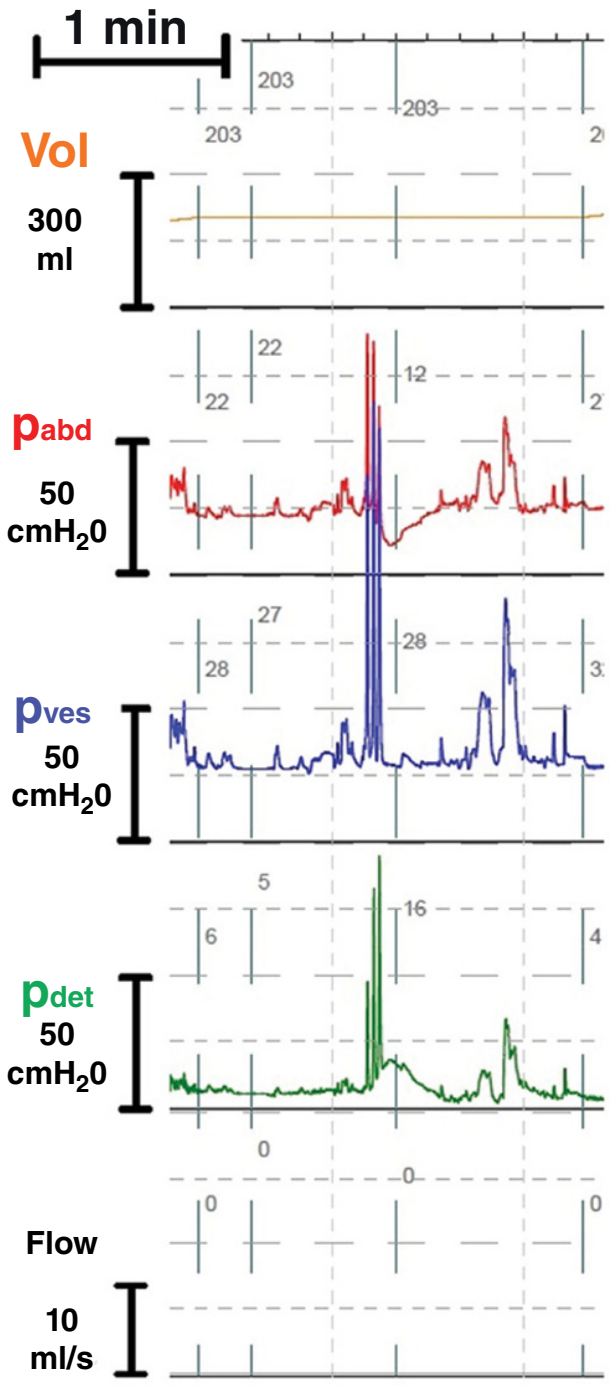

Figure 1.3 The importance of training and interpretation. This trace shows a brief moment from a filling cystometry. It illustrates a transient rise in detrusor pressure after a cough (green tracing), which resembles the detrusor overactivity (DO) seen in Figure 1.2 (but with no associated incontinence). Inspection of the bladder pressure trace (blue tracing) shows there was no bladder contraction associated with the detrusor pressure change, so this is not DO- despite the appearance. The actual explanation is that the cough caused the rectal catheter to shift, causing the recorded drop in abdominal pressure (red tracing) – an entirely different process from an involuntary bladder contraction. Proper training and interpretation will ensure that a mistaken diagnosis of DO is avoided.

whether the sensations felt by the patient during testing fit with the patient's reported everyday experiences and how they may relate to the urodynamic observations. Occasionally, during urodynamic studies, the patient may complain of a symptom they do not generally experience in everyday life, for example, urgency. Alternatively, a urodynamic abnormality may be noted which does not correlate with the patient's symptoms. These discrepancies can be detected and put into perspective if the clinician is present. However, if the urodynamics is delegated to someone with minimal urodynamic experience, the matching of LUTS to observations which underpins therapy selection is less direct. They may likely develop a basic test report which is observational and does not have the clinical interpretations at its heart. This report is of huge importance in therapy decision-making, with potentially life-long implications for the patient. Accordingly, a surgeon making decisions based on a basic report must consider: 'Does the report make sense in the context of the patient's symptoms and preceding tests?' and 'Can the features mentioned in the report be identified on the plotted traces, and is anything visible on the traces not mentioned in the report?'

In some instances, more than one abnormality is detected, so it is important to ask: 'Can urodynamics decide which abnormality is the most significant, if more than one is detected?' Multiple abnormalities are commonly seen in patients with neurogenic LUTD. They also occur in non-neurological patients, such as in women with mixed urinary incontinence. Treatment should be directed to the most significant and/or troublesome abnormality. Hence, the correspondence between the patient's symptomatic complaint and the urodynamic findings is important and needs to be documented in the report.

As well as seeking answers to the above questions, the urodynamicist needs to define the goals of the invasive urodynamic investigation, and these can be listed as follows:

- To **increase diagnostic accuracy** above that which can be achieved by non-urodynamic means.
- To **make a diagnosis on which a management plan can be based**. OAB is usually treated empirically; if a patient fails conservative and medical therapy, urodynamic proof of DO is appropriate prior to invasive surgery.
- If there are coexisting abnormalities, to **provide evidence to determine which abnormality should be treated first**. In a female patient with mixed urinary incontinence, it is usually possible to decide which is the main problem and so establish the treatment priority by careful assessment during urodynamics.
- To **define the current situation as a baseline for future surveillance**. In spinal cord trauma, it is usual to perform urodynamics after spinal shock has resolved. These baseline urodynamics establish whether there is a detrusor contraction in reaction to bladder filling and

whether or not detrusor-sphincter-dyssynergia (DSD) has developed. DSD is a potentially dangerous condition, as discussed in Chapter 16.

- To **predict problems that may follow treatment interventions**. Elderly men with BOO and coexisting DO should be warned that whilst their urine flows and other voiding symptoms should be improved by TURP, OAB symptoms due to DO may persist and in fact leakage due to the DO may occur.
- To **provide evidence that decides the timing of treatment**. In patients with neurological disease (e.g. meningomyelocele) being treated by antimuscarinics, ultrasound may show the development of upper tract dilatation. Urodynamics are vital to confirm whether or not poor bladder compliance is the cause, such that intervention is needed.
- To **exclude abnormalities which might interfere with the management**. For example, in patients with SUI being considered for an artificial urinary sphincter (AUS), demonstration of DO or poor bladder compliance would indicate the need for extra treatment to ensure that the additional problem is resolved (Figure 1.4).
- To **assess the natural history of** LUTD. Our unit, by investigating men and women studied many years ago, provided important evidence as to the natural history of LUT dysfunction [3, 13, 14].
- To **assess the results of treatments**. Simple urodynamics tests, such as urine flow studies, should be used

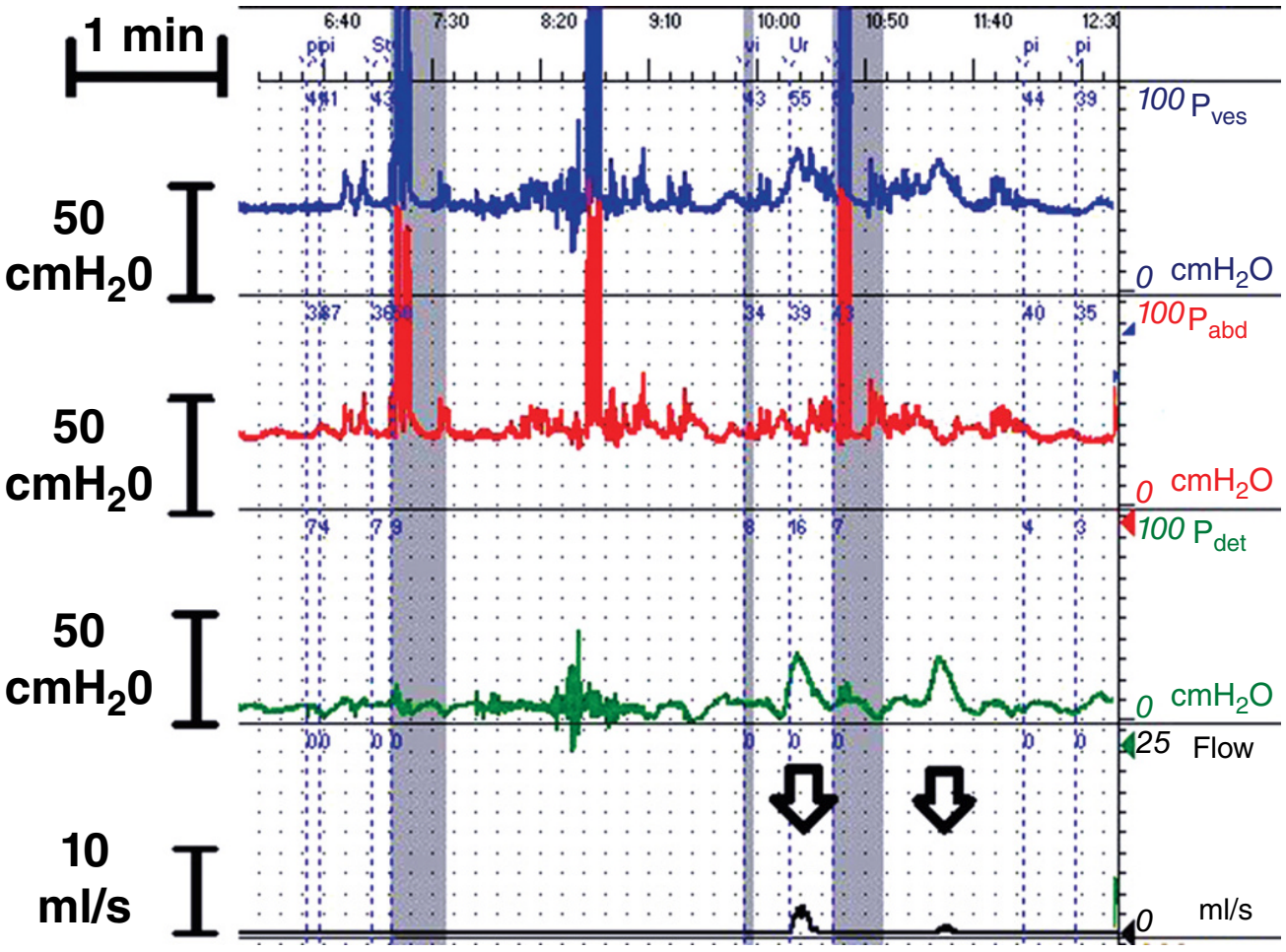

Figure 1.4 A man with a functioning artificial urinary sphincter (AUS) previously placed to treat post-prostatectomy incontinence; he subsequently complained of painful urgency incontinence. This illustration shows a small section of the filling phase, with a series of forceful coughs (stress testing) that did not cause leakage; a fully active AUS can resist 61–70 cmH_2O pressure. While he did not experience stress incontinence despite several forceful coughs, he did experience leakage with low amplitude of detrusor overactivity (DO) (black arrows), and it is hard to explain how forceful coughs did not cause leakage yet low amplitude DO did – we speculate this was due to the sustained nature of the DO pressure change, allowing greater effect on the pressure in the urethra. Indeed, pressure building up in his proximal urethra may have been responsible for the discomfort he described with his urgency incontinence. Note, this trace is not displayed with the correct sequence of traces; the bladder pressure should not be at the top for 'logistical' reasons, notably for the fact that some of the trace may go off the top of the page, as in this case.