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Urodynamics

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With 95 Figures

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To our wives, Jean, Pat and Judy

Series Editor's Foreword

For centuries, physicians studied the appearance and characteristics of urine as a guide to the health of the individual. In contrast, the mechanism of micturition attracted little attention and, until recent years, the study of the lower urinary tract consisted mainly of some form of cystometry and in watching the force of the stream. Exactly when more precise measurements began can be debated but interest in the subject developed rapidly following the improved methods for measuring urinary flow rates introduced by von Garrelts in 1956. The level of interest and investigation in this subject has since grown quickly though not without debate. Now, after a quarter of a century of endeavour, urodynamics has an established place not only in urology but many other areas of medicine and this book is a lucid account of the current practice of the subject.

The special characteristic of this book is that it represents a very cohesive description of the subject as developed in one medical centre. The advantage of this is readily evident by the way in which the Authors have covered the subject, from patient assessment to organisation of urodynamic units, in a logical and practical style. The Authors have also planned the contents so that the reader can follow the evolution of the subject and thereby appreciate the way in which the subject has grown, how the terminology has developed and, perhaps most relevant, how to staff a urodynamic service.

Thus this book fully succeeds in putting the recent progress of this subject into perspective in medicine. Just as cardiac surgery changed so many of the previous concepts of cardiology, so the study of urodynamics has changed our understanding of the function of the lower urinary tract. This is not to imply that the story is complete: far from it, the Authors make this point clearly and offer suggestions as to where further clinical research must be pursued.

Overall, this book presents the "state of the art" and readers will draw their own conclusions about the relevance of urodynamics to their special interest, be it urology, gynaecology, paediatrics or neurology. The appendices on standardisation of terminology, on manufacturers of equipment and the bibliography are valuable items that complete this comprehensive text.

The Authors have achieved a splendid balance to the clinical practice of urodynamics: they can be certain that their readers will get the message.

Edinburgh, January 1983 Geoffrey Chisholm

Preface

On 26th October, 1964 an Inaugural Meeting was held at the Royal Society of Medicine in London, to form the Section of Measurement in Medicine. The occasion was an auspicious one; technological developments had been progressing rapidly during the preceding years and the stage had been reached when their contributions needed to be recognised by the medical profession. The introduction of electromanometry had suddenly converted physiological measurement from an experimental study in the research laboratory to a practical investigation in the clinical field and, as a result, a mass of original data was becoming available for assimilation by the clinician.

A new approach to a familiar subject stimulates fresh interest and lively debate, particularly when the conventional and time-honoured concepts are challenged. Urodynamic studies of the lower urinary tract were no exception and they have indeed provoked considerable controversy amongst urologists and gynaecologists, engendering intense enthusiasm from some and the inevitable scepticism from others. Time and experience have moderated the extreme views, so that both the contributions and pitfalls are more clearly identified. The investigations have produced detailed information relating to bladder and sphincter function, and they have been responsible for a fundamental reappraisal of the aetiology and the clinical management of lower urinary tract disorders. However, meaningful reports are obtained neither by purchasing expensive urodynamic equipment, nor by appointing a clinician with inadequate time to use it. Accurate diagnosis can only result from a careful correlation of the clinical assessment of the patient with a critical analysis of the urodynamic findings.

For the clinician, urodynamics can present a confusing picture and a feeling of antipathy towards the subject may readily emerge. The equipment appears complex and intimidating, the techniques invasive and uncomfortable for the patient and the results are written in a new language, which requires expert knowledge to interpret for clinical application.

This book has been written with the intention of removing the confusion about urodynamic tests and explaining their contributions. Hopefully, it presents a practical handbook on basic urodynamics, outlining its application in routine clinical practice. Not every patient with micturition problems requires urodynamic studies, but the modern clinician should be sufficiently informed to be able to select which patients may benefit, what investigations are indicated and how to interpret the results in terms of the clinical management. The authors have all been closely associated with the evolution of the Urodynamic Unit in Bristol, which has developed into a busy department from a modest beginning and this experience forms the background to the book. The views which are expressed are both personal and deliberately didactic, but hopefully a reasonable balance has been achieved on the more controversial issues.

Bristol, 1983

Paul Abrams
Roger Feneley
Michael Torrens

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Contents

Chapter 1

Introduction

The Background

The conventional approach to disorders of the lower urinary tract has been based on the accurate localisation of the anatomical abnormality causing the symptoms. Thus, particular emphasis has been placed on such clinical features as the size of the prostate or the degree of vaginal prolapse; on the radiological demonstration of bladder trabeculation, residual urine after micturition or the urethro-vesical angle; and finally on the endoscopic appearances of the bladder neck and prostate. The significance of this type of evidence is now open to considerable debate and the conflict of opinion regarding the value of these anatomical findings was becoming apparent during the 1960s. For example, in 1963, Keitzer and Benavent considered that panendoscopy was the most important diagnostic procedure in bladder neck obstruction, but in 1965 Zatz raised doubts about its validity. The traditional teaching regarding both outflow obstruction in the male and urinary incontinence in the female seemed to lead only in one direction, towards more and more prostatectomies for the urologist and an increasing number of either vaginal or suprapubic repair procedures for the gynaecologist. The introduction of urodynamic investigation not only caused reappraisal of the traditional concepts, but also identified new criteria for the selection of patients for operative treatment.

The Evolution of Urodynamic Units

Interest in the hydrodynamics of micturition had been simmering since the early cystometric studies in the nineteenth century, but it was the advent of electronics that acted as the catalyst for modern urodynamic studies. In 1956 von Garrelts described a simple practical apparatus, using a pressure transducer, to record the volume of urine voided as a function of time and thus, by derivation, urine flow rates could be calculated. His work stimulated a revival of interest in cystometry, because it was then possible to record the bladder pressure and the urine flow rate simultaneously during voiding. As a result, normal and obstructed micturition could be defined in terms of these measurements (Claridge 1966) and a formula was applied to express urethral resistance (Smith 1968). Enhorning (1961) measured bladder and urethral pressures simultaneously with a specially designed catheter and he described the pressure difference between them as the urethral closure pressure. He demonstrated that a reduction of intraurethral pressure occurred several seconds prior to detrusor contraction at the initiation of voiding. This appeared to be related to the relaxation of the pelvic floor, thus confirming the electromyographic studies of Franksson and Petersen (1955).

These original research studies rapidly led to the application of urodynamic investigations in the clinical field. Radiological studies of the lower urinary tract, using the image-intensifier and cine or video-tape recordings, were already established and their value in the assessment of micturition disorders had been described (Turner Warwick and Whiteside 1970). Thus it was a relatively simple step to combine cystourethrography with pressure flow measurements (Bates et al. 1970). Later, more sophisticated techniques, using EMG recordings of the pelvic floor, were employed, particularly for neuropathic bladder problems (Thomas et al. 1975). These clinical studies during the 1970s emphasised the need to investigate the function as well as the anatomical structure of the lower urinary tract, when evaluating micturition disorders. Urodynamics was established as a necessary service commitment, rather than a research tool.

At the same time as these technical developments were arising, an increasing awareness of the clinical problem of urinary incontinence was becoming apparent. From Exeter, the work of Caldwell (1967) had initiated considerable interest in the subject, as a result of his approach to the treatment of incontinent patients with electronic implants. In his Sphincter Research Unit a small receiver was developed, which could be placed subcutaneously in the abdominal wall and activated by a small external radio frequency transmitter. Platinum iridium electrodes led down to the pelvic floor muscles, which could be stimulated to contract, thus raising urethral resistance. Other forms of electrical stimulation were also being advocated at this time, such as pelvic floor faradism applied under general anaesthetic (Moore and Schofield 1967) and a variety of external electronic devices which could be placed in the anal canal or vagina to stimulate pelvic floor contraction (Hopkinson and Lightwood 1967; Alexander and Rowan 1968).

The Research Concept

These developments formed the background that led to the opening of the Clinical Investigation Unit at Ham Green as a small research project in 1971. This had a threefold commitment. First, there was a need to develop the urodynamic techniques and to discover whether these investigations gave objective results, which were reliable, repeatable and of diagnostic value. Secondly, the Unit provided facilities for research studies by medical staff during their training in surgery. Training programmes in surgery have an important role in maintaining a high standard of clinical practice, but they have tended to encourage an inflexible and stereotyped attitude towards diagnosis and treatment. The advantage of a period of research discipline was being recognised at this time and the presentation of original work in the form of a thesis for a higher university degree was becoming an accepted part of the career structure in surgery. Finally, there was an urgent need to reconsider the clinical management of the common yet troublesome disorders of the lower urinary tract such as urinary incontinence. Urodynamic investigation provided the means for objective measurement to aid diagnosis and monitor the results of treatment.

The Urodynamic Service

The place of urodynamic techniques in the assessment of patients, not only with urinary incontinence but also with the wider spectrum of micturition disorders, needed careful evaluation. Many patients with urinary symptoms had no obvious anatomical or pathological cause that could be demonstrated on the conventional investigations and certain diagnoses, such as bladder neck obstruction, were based more on speculation than on objective measurement. Since that time, the demand for these investigations has increased far beyond the original expectations and now over 6000 patients have been studied in the Unit. During the evolution of the established service in Bristol, many relevant practical issues have arisen. These include problems of staffing, financial support and data collection. Such matters are discussed in Chap. 6.

The studies which are performed in the Bristol Unit are simple, basic investigations of bladder and sphincter function of the lower urinary tract. The tests consist of urine flow measurements, filling and voiding cystometry and urethral pressure profiles. Urodynamic investigations and their interpretation are described in Chap. 3. Sophisticated techniques using EMG recording of pelvic floor activity and synchronous video-cystourethrography, may need to be employed for selected problems, but the equipment is costly and the discriminating clinician needs to consider both the type and the organisation of the urodynamic service that is required before such equipment is purchased. There is a risk, as Hinman (1979) suggested that too many expensive instruments will be purchased by urologists and gynaecologists, who do not have the time either to learn basic urodynamics or to perform the tests in a reproducible manner. It is essential that the urodynamic service should be developed in relation to the clinical demand. Various levels of investigation are possible, but the most important factors are the competence and enthusiasm of the staff. The setting up of a urodynamic service will be considered in Chap. 6.

Patient Assessment

No investigation is relevant to the individual patient unless the results can be related to the patient's particular problem. In this respect the time spent in elucidating and discussing the patient's symptoms is most important. Symptoms may vary with time, and the patient may find it difficult to communicate, especially in a busy clinic. We consider that one of the great advantages of the Bristol Unit is that adequate time is available for close questioning, unhurried investigation and practical advice. This approach alone serves to 'cure' a proportion of patients with incontinence. The analysis of symptoms is discussed in Chap. 2. The interrelation of symptoms with urodynamic results and the role of those results in management, are considered in the various clinical sections (Chap. 5).

Communication

The meaning of words in communication needs some consideration. Professional communication on an international level needs accepted definitions. To facilitate this the International Continence Society (ICS) set up a Standardisation Committee in 1973. This Committee has produced four reports on the terminology of lower urinary tract function. The subjects covered are:

Urinary incontinence
Procedures related to the evaluation of urine storage
  Cystometry
  Urethral closure pressure profile
Units of measurement
Procedures related to the evaluation of micturition
  Flow rate
  Pressure measurement
  Pressure/flow relationships
  Residual urine
Neuromuscular dysfunction of the lower urinary tract

These standards are proposed to facilitate comparison of results by investigators who use urodynamic methods. It has been recommended that the acknowledgement of these standards in written publications be indicated by a footnote stating: 'Methods, definitions and units conform to the standards proposed by the International Continence Society except where specifically noted.' We have accepted their standards, and used them in this book. They are repeated and explained in the relevant chapters, and the reports are published in full in App. 1.

The manner in which investigation results are communicated to physicians who are not personally involved in urodynamic assessment is of significance and is discussed further in Chap. 6. Sending polygraph tracings, or lists of figures derived from them, may not be very helpful. We consider an informed comment is an important part of the report; however, the value of this depends on the calibre of the reporter. The review of urodynamic parameters with synchronous video-cystourethrography allows clinicians to relate functional values to a more traditional and acceptable radiological image, and may help to bridge this gap.

The Objectives of This Book

Urodynamics can be complicated, and it has not yet achieved the acceptance in urology, gynaecology and allied subjects that has been awarded, for instance, to catheter studies in cardiology. One of the objectives of this book is to put the subject over simply, but in enough detail to allow urodynamic investigation to be accepted, on its own merit, as a fundamental contribution to the management of many patients. To do this means not only describing the tests but also showing in which clinical areas they help management and in which they are pointless. It means concentrating on the common clinical problems and on the presenting symptom complexes, not the diagnoses; and it means pointing out the inadequacies and artifacts of investigation.

We hope that a clinician with no previous experience in urodynamics, after reading this book, will appreciate the value and limitations of the subject, and will have obtained the necessary practical advice on the use of the appropriate equipment in the correct situations. Because this book is based on personal experience, references in the text are relatively few. To compensate for this, and to help readers elucidate a particular subject, an extensive bibliography is provided in App. 4.

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Chapter 2

Patient Assessment

Introduction

As the subject matter of this book is confined to the lower urinary tract, the patients for assessment will usually be complaining of lower urinary tract symptoms. Emphasis is given to these, though silent presentation, for example uraemia, is possible. Since we have had the facility to check objectively patients' assessment of themselves, we have been impressed by the unreliability of even a careful history. This is one reason for the use of urodynamic tests, but we commend any approach that lends objectivity to diagnosis, and in particular the use of frequency/volume charts (see 'Frequency/Volume Charts', p. 15).

During discussion of the patient's presenting complaints the clinician should seek information on both the filling and the voiding phases of the micturition cycle. If the symptoms are interpreted in the context of the normal function of the lower urinary tract, it may be possible to produce a provisional, symptomatic diagnosis. Urodynamics and other investigations then become a test of a clinical hypothesis. If these steps are undertaken consciously, then there is a feedback from functional urodynamic information which helps to improve symptomatic diagnosis.

Although symptoms have been considered individually in this section they may be grouped together in symptom complexes. These have more diagnostic significance (Whiteside 1979), and therefore will be considered in Chap. 5.

Analysis of Symptoms

In this section each symptom will be defined and explained in functional terms. The object is to provide a pathophysiological understanding of the patient's complaints. Such an approach requires some conceptual thinking, and the conclusions written here may need to be changed as new facts are revealed.

The interpretation of a patient's symptoms is modified by many factors, not least by the time available to be spent with him or her. The limits of normality are not defined adequately, and in an individual case may be what the patient, rather than the doctor, considers to be normal. The adequacy of communication is important, as are any preconceived ideas held by the medical staff.

Frequency of Micturition

Abnormalities of urinary frequency are changes from that to which any particular patient is accustomed. The distribution of urinary frequency in the patient population of Bristol is shown in Fig. 2.1. The conclusions that can be drawn from the patient group are that there is little increase in frequency with age and little difference between the sexes (Table 2.1). The mean frequency in patients is about

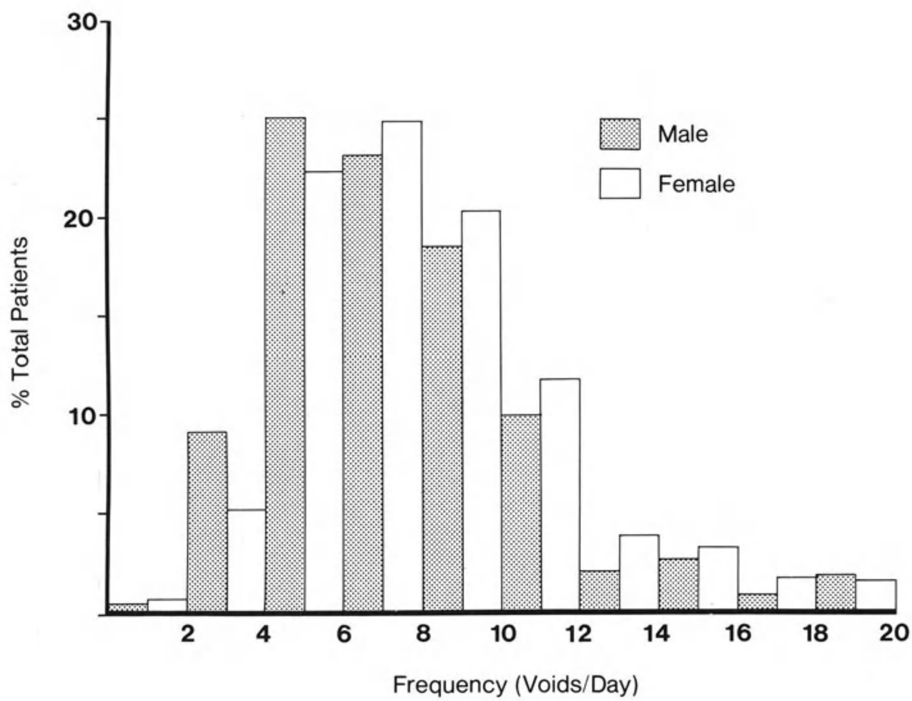

Fig. 2.1. Histogram showing the distribution of urinary frequency (voids/day) in the patient population attending the Bristol Unit.

Table 2.1. Diurnal urinary frequency in patients vs age

Age	Male		Female	
	Mean frequency	Approx. modal frequency[a]	Mean frequency	Approx. modal frequency[a]
5–14	7.76	5	8.00	5
15–24	6.22	5	7.95	5
25–34	7.78	6	8.99	7
35–44	7.84	7	8.91	7
45–54	8.28	6	8.82	8
55–64	8.67	8	8.92	8
65–74	7.78	7	8.32	7
75–84	7.71	7	7.98	6
	n = 1152		n = 2124	

[a]The distribution of urinary frequency is skew with a bias towards higher frequency (Fig. 2.1). The mean values are therefore higher than the 'peak' of the graphical distribution (the modal value). The modal value may be nearer to the mean value in normal patients.

eight times per day, slightly lower in males than females. Normal diurnal frequency probably lies in the region of four to eight per day, the day lasting between rising from bed in the morning and falling asleep at night.

Increased urinary frequency is seldom a primary complaint—it is usually the consequence of some other symptom such as urgency. Frequency itself is tolerable up to 10–12 times per day; above this it may be socially embarrassing. Its main use is as an objective index of the severity of other symptoms. In this context it must be recognised that patients are notoriously inaccurate in the assessment of their frequency and some objective means such as a frequency/volume output chart or urinary diary is needed (see 'Frequency/Volume Charts', p. 15).

Mechanisms of Increased Urinary Frequency

1. *Normal bladder capacity*. This is represented by volumes voided within the normal range, 300–600 ml for an adult. Increased frequency may be due to an increased input and output secondary to: (a) an osmotic diuresis, e.g. in diabetes mellitus; (b) an abnormality of antidiuretic hormone production, e.g. in diabetes insipidus; or (c) polydipsia, which may occasionally be psychotic, but is more usually because the patient enjoys a favourite beverage, be it tea, water or beer.
2. *Reduced functional bladder capacity*. This term implies that the bladder capacity under a general or regional anaesthetic would be normal, but the volumes voided are consistently small, less than 300 ml. A small functional bladder capacity can be secondary to: (a) inflammatory causes of increased bladder sensation, e.g. acute cystitis; (b) non-inflammatory causes of increased bladder sensation, e.g. anxiety or the idiopathic hypersensitive bladder (see 'Hypersensitive Cystometrogram', p. 68, and 'Increased Sensitivity', p. 115); (c) motor hyperactivity, as in the unstable bladder (see 'Overactive Bladder', p. 70, and 'Overactive Detrusor Function', p. 110); (d) a significant residual urine resulting from detrusor underactivity or bladder outflow obstruction, or a combination of both; (e) a fear of going into urinary retention, especially in older male patients who experience increasing hesitancy as the bladder becomes full, and who compensate by voiding frequently; or (f) habit, or fear of incontinence.

3. *Reduced structural bladder capacity*. In this instance the bladder capacity will be smaller than normal under general or regional anaesthesia. The reduced capacity may be due to: (a) muscle hypertrophy, as in longstanding motor hyperactivity; (b) postinfective fibrosis, e.g. tuberculosis; (c) non-infective cystitis, e.g. interstitial cystitis (Hunner's ulceration), carcinoma; (d) postpelvic irradiation fibrosis, e.g. for bladder or cervical cancer; or (e) surgery, e.g. after partial cystectomy.

Mechanism of Decreased Urinary Frequency

Infrequent voids of large volumes of urine usually provoke admiration rather than complaints. The end stage of the following forms of bladder hypoactivity may produce increased frequency or retention with overflow: (a) hypocontractility in the absence of obstruction, and (b) impaired bladder sensation.

Nocturia

This complaint is extremely dependent on age in both sexes (Table 2.2). We have defined nocturia as being woken from sleep each night by the need to urinate. It is not abnormal for men over 65 and women over 75 to be woken once a night in this way. The frequency of nocturnal voiding in relation to age needs to be considered when judging the significance of the symptom.

Unless the clinician's definition of nocturia is made clear, the patient may include a void before going to sleep or the first void in the morning. Other patients will attempt to include all voiding during the hours of darkness. It is also important to be sure that the patient sleeps well and does not drink during the night. Some patients sleep poorly, some for no apparent reason and some because of chronic painful conditions, such as arthritis. These patients are often unable to settle until they have emptied their bladders, thus producing apparent nocturia. However, most such patients have no increase in daytime frequency.

Table 2.2. Nocturia in patients vs age

Age	Male		Female	
	% Nocturia	Mean voids per night	% Nocturia	Mean voids per night
5–14	16	1.20	38	1.57
15–24	26	1.47	45	1.53
25–34	52	1.69	56	1.72
35–44	48	1.55	59	1.68
45–54	66	2.10	67	1.84
55–64	84	2.20	78	2.05
65–74	88	2.82	78	2.34
75–84	92	2.95	81	2.79
		n = 1152		n = 2124

Mechanisms of Nocturia

The majority of the causes of increased diurnal frequency of micturition also cause nocturia. In addition, there may be increased nocturnal production of urine. Often this is due to the reabsorption of oedema fluid in mild congestive cardiac failure. It is therefore important to examine the ankles and sacrum of all elderly patients. However, increased nocturnal urine production may be seen in the absence of demonstrable oedema. Thus, nocturia may still be due to subclinical oedema as it is difficult to detect oedema unless at least 1 litre of fluid lies in the interstitium. Nocturia may also be due to loss of antidiuretic hormone production at night, or reversal of diurnal pituitary rhythm.

Nocturia is likely to be due to motor hyperactivity of the bladder (instability) when there is concurrent diurnal frequency and urgency.

Premicturition Symptoms

Normal premicturition symptoms are hard to describe as they differ from patient to patient. They are usually judged by questioning the patient while doing a cystometrogram, for the patient's memory may otherwise be vague and inaccurate. The first desire to void is usually felt in the deep perineal or retropubic region at approximately half functional bladder capacity. In everyday life the earliest feelings are usually ignored and are not felt again until the bladder approaches capacity. The desire to void then gradually increases and although voiding can be delayed the feelings eventually become a continuous discomfort. Some patients complain of a constant or fluctuating awareness of their bladder which does not amount to urgency, and from which it must be distinguished. It is very difficult to judge the significance of this symptom.

Urgency

The term 'urgency' should be used when there is a strong desire to void and a feeling that micturition is imminent. This sensation is usually felt in the perineum or penis and often provokes a contraction of the pelvic floor to avoid potential incontinence. If this symptom is felt more than occasionally, perhaps once a week, then it should be considered abnormal.

Mechanism of Urgency

Urgency is more of a proprioceptive sensation and requires cystometry to elaborate fully its cause, which may be (a) increased bladder sensation, e.g. acute cystitis or the idiopathic hypersensitive bladder, or (b) increased motor bladder activity, as in bladder instability. The latter is more likely to result in urge incontinence.

Bladder Pain

Although this symptom may share the same causes as urgency it is experienced differently. Bladder pain is felt suprapubically and increases slowly and gradually with bladder filling. This pain leads to frequency not because of a fear of incontinence, but due to a fear of increasing pain and discomfort. Bladder pain, although often relieved by micturition, may persist after voiding.

Mechanism of Bladder Pain

Bladder pain may be due to (a) inflammatory conditions of the bladder, e.g. acute cystitis or interstitial cystitis, or (b) certain types of increased bladder sensation without inflammation as in the idiopathic hypersensitive bladder.

Hesitancy

This symptom is defined as a delay in the onset of micturition when the patient wants to void and is ready to do so. The complaint of hesitancy should be assessed in terms of the volume voided. It may be normal for a patient to have hesitancy when trying to void with less than 100 ml of urine in the bladder. Conversely, a patient may complain of hesitancy only with a very full bladder, which is often a sign of impending retention, although if a normal person's bladder gets exceptionally full then he may have trouble initiating voiding.

Mechanism of Hesitancy

Hesitancy may be due to (a) over- or under-distention of the bladder; (b) psychological inhibition of bladder contraction, as seen in patients who cannot void except when alone; (c) lack of voluntary initiation of detrusor contraction, or detrusor sphincter dyssynergia seen in neurological disease, especially multiple sclerosis; or (d) poor and slow detrusor contraction.

Urinary Incontinence

Incontinence is a condition in which involuntary loss of urine is a social or hygienic problem, and is objectively demonstrable. Loss of urine through channels other than the urethra is extra-urethral incontinence. Strenuous efforts should be made on history taking to decide which type of incontinence the patient presents.

Stress Incontinence

Stress incontinence denotes either a symptom, a sign or a condition. The symptom indicates the patient's statement of involuntary loss of urine during any physical exertion which tends to elevate intra-abdominal pressure. The sign denotes the observation of involuntary loss of urine from the urethra synchronous with physical exertion (e.g. coughing). The condition has been defined by the International Continence Society as 'genuine stress incontinence'. This condition may be defined as involuntary loss of urine when the measured intravesical pressure exceeds the measured maximum urethral pressure, but in the absence of detrusor contraction. This implies that the intra-abdominal pressure is also being measured in order to prove that no detrusor contraction is taking place.

Mechanism of Stress Incontinence

The first line of continence is normal closure of the bladder neck. The second line is a competent distal urethral sphincter mechanism. It follows that stress incontinence must involve a degree of inadequacy of both these mechanisms. The physiology of the urethral competence is discussed in Chap. 4.

The clinical situations in which bladder neck and urethral incompetence occur include (a) a weakened pelvic floor, especially in obesity and multiparity; (b) a paralysed pelvic floor in lower motor neurone lesions; (c) abnormally high pressure in a distended bladder, the distension presumably tending to open the bladder neck; (d) operative damage to the posterior urethra, e.g. extensive prostatectomy; and (e) congenital short urethra.

Urge Incontinence

This symptom is defined as involuntary loss of urine associated with a strong desire to void.

Mechanism of Urge Incontinence (see also 'What Causes Incontinence?', p. 143).

Urge incontinence may, as in the case of urgency, be associated with (a) increased motor activity of the detrusor, as in the unstable bladder (motor urge incontinence); or (b) increased bladder sensation (sensory urge incontinence). It may be difficult to understand why increased sensation should provoke loss of urine. For incontinence to occur it is necessary also that the bladder neck and urethra are incompetent and the mechanism of this requires further investigation. It may be that inappropriate bladder neck and urethral relaxation (unstable urethra) is responsible.

Giggle Incontinence

This type of incontinence is usually a complaint of younger women. The history is clear and not associated with other urinary disturbance. Because of the problems of reproducing this symptom whilst the patient is under investigation the mechanism is not understood. The definition is implicit in the name.

Postmicturition Dribble

It is important to distinguish between terminal dribble and postmicturition dribble. Terminal dribble is continuous with the main flow of urine. Postmicturition dribble is defined as leakage occurring after voiding has been completed. It usually occurs as or after the patient has dressed and is seldom associated with a demonstrable abnormality. These types of urinary leakage more commonly occur in men.

Mechanism of Postmicturition Dribble

This symptom may be due to (a) failure of the bulbocavernosus and spongiosus muscles to empty the penile urethra as micturition ends; or (b) failure of the normal milk-back mechanism by which the urine trapped between the distal urethral sphincter mechanism and the bladder neck at the end of micturition is returned to the bladder. Leakage occurs later as the distal sphincter relaxes and the urine passes into the anterior urethra.

Enuresis

Strictly speaking, enuresis can refer to any incontinence day or night. However, the term is most often used to mean a normal act of micturition occurring during sleep, i.e. nocturnal enuresis. Enuresis may be divided into primary, when the patient has never been dry at night and secondary, when enuresis follows a period of night-time continence. Nocturnal enuresis is often a significant factor in the past history of young adults with nocturia. A family history should be sought and the presence or absence of concurrent diurnal symptoms noted.

Mechanism of Enuresis

Enuresis, the pathophysiology of which is discussed later (see 'Decreased Sensation', p. 116; 'Enuresis', p. 122), is fundamentally a disturbance of brain function whereby bladder distension for one reason or another cannot elicit normal cortical arousal. Various other factors can exacerbate the situation, including (a) increased nocturnal secretion of urine; (b) inadequate bladder or urethral sensation; (c) increased motor activity of the bladder; and (d) inappropriate cerebral sedation.

Reflex Incontinence

Reflex incontinence is involuntary loss of urine caused by detrusor hyperreflexia or involuntary urethral relaxation and in the absence of the sensation usually associated with the desire to micturate. This type of incontinence only occurs in cases of neuropathic dysfunction.

Unconscious Incontinence

Rarely, patients complain of incontinence which occurs without urgency or other sensation, in the absence of raised intra-abdominal pressure or increased detrusor pressure, and with no obvious neurological abnormality. In these cases a fistula or ectopic ureter must be excluded. In patients without an obvious pathophysiological explanation, the condition needs to be investigated by urodynamic studies.

Urinary Stream

The following facts should be established: is the stream continuous or interrupted, does the patient relax to void or does he strain, does the stream vary through the day and, in particular, is it forceful first thing in the morning? As the urine flow rate is dependent on volume voided, the patient should be asked about the quantities he passes, although the frequency/volume chart gives this information more accurately. The quality of the stream should be determined: is it single or multiple, weak, or thin and forceful? The last mentioned type indicates meatal or submeatal stenosis.

Mechanism of Decreased Urinary Stream

A reduced urine flow may be due to (a) any cause that reduces the volume voided and therefore any cause of frequency; (b) bladder outflow obstruction at any level from the bladder neck to the external meatus; or (c) decreased bladder contraction. This may be neuropathic (lower motor neurone lesions) or myopathic. Myopathic abnormalities may be any primary disturbance of bladder muscle, any toxic influence upon bladder muscle, or secondary to overstretching.

Postmicturition Symptoms

The normal patient, after micturition, completely loses any awareness of the bladder. Persistence of symptoms is usually felt as incomplete emptying or sometimes as a persistent desire to void. These symptoms may often be misleading, as the patient may be shown to have emptied the bladder completely.

Mechanism of Postmicturition Symptoms

As is the case with premicturition symptoms, the causes of postmicturition symptoms are inadequately understood. The reasons include: (a) increased sensation, e.g. cystitis or the idiopathic hypersensitive bladder, urethritis and prostatitis. (b) Persistent bladder contraction. The bladder has been observed to continue contracting after it is empty, producing a high postmicturition pressure (after contraction). This phenomenon is not correlated with bladder instability, it is not always felt and it is not always abnormal. However, it does on occasions give rise to postmicturition symptoms. (c) Residual urine. Many patients are unaware of the fact that they have failed to empty their bladder, but others do have a feeling of incomplete emptying.

Other Symptoms

Haematuria

In almost every instance this symptom is an indication for further urological investigation and should never be ignored. The investigation of haematuria will usually take precedence over the investigation of other lower urinary tract dysfunction.

Loin Pain

Loin pain to the urologist presents the same problems as low back pain does to the orthopaedic surgeon. It is unusual for the complaint of loin pain to be directly related to lower tract dysfunction, although it can be secondary to vesico-ureteric reflux or have an infective origin (pyelonephritis), and these conditions may occur in outflow tract obstruction. Similarly, occlusion of the lower end of the ureter may present with a combination of upper and lower urinary tract dysfunction.

Dysuria

This term tends to be used in different ways. Some clinicians mean difficulty in voiding. We reserve the term dysuria for the urethral pain typically felt in acute urethritis. Dysuria may be secondary to infection at any level in the urinary tract, but usually is indicative of urethritis, prostatitis or cystitis. Some patients with increased bladder sensation without infection, for example, hypersensitive cases and those with the 'urethral syndrome', also report dysuria.

It is appropriate to note here that there is a need for accuracy in the diagnosis of urinary infection. The condition is often diagnosed from symptoms and an inadequate mid-stream specimen of urine (MSU). There is a need for an MSU to be properly supervised, or for a dipstick inoculum plate to be taken. If there is any doubt the situation should be checked with a suprapubic aspiration of urine into a sterile syringe. It is appropriate for a catheter specimen of urine to be taken for culture at each urodynamic investigation.

Sexual History

In the absence of previous surgical intervention, for example surgery of the rectum, psychogenic factors are the most common cause of impotence. However, these symptoms in the male patient may accompany demonstrable neurological disease, for example after spinal cord injury or in multiple sclerosis, or may be the first indication of a peripheral neuropathy, as in diabetes mellitus or alcoholism. Such pathological processes may of course also lead to lower urinary tract dysfunction.

It should be determined whether erection is absent, reflex or psychogenic. If ejaculation is present, is it forceful and clonic, or weak (emission)? Is there evidence of retrograde ejaculation? What is the character and acuity of orgasm, if present? Reflex erection is mediated by sacral roots and pelvic nerves, whereas psychogenic erection may occur through the cholinergic sympathetic fibres of hypogastric nerves. Ejaculation depends on the co-ordinated action of the somatic musculature of the pelvic floor and therefore the pudendal nerves. Orgasmic sensation is a combined afferent bombardment through the hypogastric (sympathetic) input and through the pudendal nerves.

It must also be recognised that incontinence can have a profound effect on the sexual activity of patients and is frequently a cause of marital disharmony. Because of the profound psychological repercussions this can have, it is important that this aspect of the history should be explored in every relevant case in order that the proper practical advice may be given.

Incontinence may be related specifically to sexual activity. The commonest problem is leakage from the female during intercourse. Penetration may precipitate involuntary bladder contractions, and an unstable cystometrogram is a frequent finding in such cases. Occasionally ejaculation of urine occurs, and the interrelation of sexual activity and lower urinary tract dysfunction in males is an area that requires more research. Bladder neck 'obstruction' and postmicturition dribbling are two conditions that might be elucidated in such a way.

Frequency/Volume Charts

The clinician has to deal with a range of urinary symptoms, many of which are variable in nature. It may be unnecessary to proceed to urodynamic investigation because the basic abnormality in many patients may not be related to detrusor or sphincter dysfunction, but to alterations in renal excretion, circadian rhythms and the psychological control of micturition. In addition, minor abnormalities of bladder dysfunction may be exacerbated by alterations in renal function and it is important to identify such alterations before instituting major surgical treatment. Over a period of 6 years we have obtained considerable experience in the use of frequency/volume charts completed by the patient (Fig. 2.2). We have found these a useful additional method of investigating the function of the male and female

D E P A R T M E N T   O F   U R O L O G Y

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FREQUENCY VOLUME CHART

Please complete the confidential form overleaf as accurately as possible and bring it with you when you come to Ham Green Hospital.

Please note the time you pass your water, and the volume passed. Any measuring jug will do for this purpose. Obviously at work, for example, it may be inconvenient to measure the volume; in this case record only the time. However, at other times please try to record both.

If you wet yourself at any time record the time and underneath the letter "W".

Day-time means when you are up: Night-time when you are in bed.

An example is provided below to help you.

EXAMPLE

DAY	time / volume (mls) DAY-TIME				NIGHT-TIME	
1	7am / 200	1pm / –	6pm / 400	11pm / 300	3am / 200	6am / W
2						
3						

at work, couldn't measure volume

wet at 6 a.m.

Fig. 2.2. One side of the frequency/volume chart showing the simple instructions and example provided for the patients.

lower urinary tracts. The charts were developed originally as part of a research project evaluating the response to treatment (Torrens 1974).

For a period of 7 days prior to an outpatient appointment the patient is requested to record as accurately as possible the time and volume of successive urinary voids. In addition, any episode of urinary incontinence is recorded on the chart. The patient is not instructed to 'hold on' until the bladder is very full, as suggested by some authorities (Turner-Warwick and Milroy 1979), but told to void as normal. The patient's fluid intake is not assessed accurately as it has been found that such additional measurements are too complex. Therefore, the patient is simply asked to estimate average daily intake in cups.

We have found that these charts are well accepted, even by elderly patients and, in the majority of cases, are completed with enthusiasm. Such a chart facilitates history taking and avoids exaggeration of the patient's symptoms. By examination of the chart the clinician is able to obtain accurate information of the degree of frequency and nocturia and the average volume of urine excreted with each episode of voiding. Such a method is the only way of obtaining a value for the average functional bladder capacity, which is important if sensitive urodynamic studies are to be undertaken.

From the frequency/volume charts abnormalities in the fluid balance rhythms may be detected and psychogenic voiding patterns identified. In addition, it has been shown that patterns suggestive of a particular type of bladder and urethral pathology may be demonstrated at a relatively early stage in the investigation.

Alterations in Fluid Excretion

The normal daily fluid output from the kidneys varies between 1 and 3 litres per 24 h. Approximately 80% of this volume is excreted during the waking hours and, therefore, in the normal condition it is not necessary to empty the bladder at night. Abnormalities of renal excretion may be induced by a sudden increase in the volume of fluid ingested, or by an alteration of the normal circadian rhythm.

Alterations in the quantity of fluid imbibed may occur at times of stress and during periods of social change, for example, at times of redundancy or retirement. An example is shown in Fig. 2.3, where a sudden change in life-style has resulted in a dramatic increase in the patient's fluid intake, leading to frequency and nocturia with large volumes voided on each occasion. (The subject had become the tea-boy in a prison.)

Abnormalities of the normal circadian rhythm may be induced primarily by disease itself, such as renal or heart failure, or secondarily due to the drugs used in the treatment of such conditions, for example, diuretic therapy. It is important to identify such abnormalities of renal excretion at an early stage as they may exacerbate minor abnormalities of bladder function. Lastly, alterations in circadian rhythms may be due to a primary defect in posterior pituitary function. Although such abnormalities are easily identified by examining the frequency/volume charts, they may be resistant to treatment. Antidiuretic hormone (DDAVP) administration may be helpful.

Name ______________________ Date of appointment ____________

DAY	time/volume (mls) DAY-TIME	NIGHT-TIME
1	10.30/500, 11.09/450, 2.17/375, 4.37/400, 8.15/450, 9.43/300	12.40/400, 5.00/450.
2	6.00/200, 9.17/350, 11.05/450, 1.57/350, 4.24/350, 6.31/400, 8.14/200, 9.41/350	12.00/300, 5.11/450
3	9.00/250, 11.34/325, 2.26/400, 4.02/300, 6.08/350, 7.59/450, 9.36/300, 11.00/500	4.50/200, 6.15/150
4	9.34/325, 11.00/400, 2.15/300, 4.00/350, 6.51/400, 9.23/400, 10.11/300	1.00/400, 4.23/200, 5.45/150
5	10.45/300, 12.25/250, 1.40/250, 2.21/350, 4.34/400, 6.40/350, 9.25/300.	1.15/200, 4.05/300, 5.45/250
6	10.30/350, 11.26/375, 12.33/300, 1.22/400, 3.13/700, 4.56/350, 9.04/400	1.12/300, 4.00/200
7	6.00/200, 10.37/400, 12.27/350, 4.22/400, 6.09/350, 8.23/350, 9.32/350, 10.30/250	3.04/400, 5.25/300

AVERAGE DAILY FLUID INTAKE (in cups) = 12

Fig. 2.3. The recording chart for frequency/volume assessment showing an alteration in frequency due to excessive intake.

Name ______________________ Date of appointment 4.6.80

DAY	time/volume (mls) DAY-TIME	NIGHT-TIME	
1	7.30/200, 9.45/110, 10.45/110, 12.30/150, 2.30/110, 5.15/100, 7.0/80, 10.00/100	2.0/150	Mon
2	6.30/180, 9.15/110, 2.0/100, 5.0/100, 7.45/100, 10.0/100	12.30/100, 3.0/150	Tues
3	6.30/200, 9.30/100, 11.0/110, 2.0/110, 3.15/–, 5.30/100, 7.45/100, 10.0/150	1.0/180, 3.15/150	Wed
4	6.0/180, 9.0/110, 10.30/–, 12.30/100, 3.15/100, 6.30/100, 10.0/110	3.30/190, 5.15/150	Thurs
5	7.45/150, 9.15/100, 10.45/180, 12.15/100, 1.30/100, 3.30/100, 6.45/150, 9.30/150, 11.30/100	2.30/200, 5.0/150	Fri
6	8.0/100, 11.0/125, 3.30/110, 6.45/100, 10.30/100		Sat
7	8.45/200, 10.15/100, 2.15/150, 5.0/130, 10.30/100	1.30/150	Sun

AVERAGE DAILY FLUID INTAKE (in cups) = 6

Fig. 2.4. Frequency/volume chart showing excessive frequency during periods at work.

Psychogenic Voiding Patterns

The bladder has often been referred to as the mirror of the mind and it is common for psychological problems to manifest themselves initially as urological symptoms. Such psychogenic voiding patterns are often diagnoses of exclusion following persistently negative urological studies. However, the frequency/volume chart may identify such abnormalities at any early stage. Such alterations in voiding patterns are those of frequency and nocturia occurring at times of social and mental stress. In Fig. 2.4 it is shown that frequency is occurring during periods at work, but disappears at the weekend. We have also found that patients may be able to interpret these findings themselves and make a self-assessment of their condition if they are given the opportunity of completing a frequency/volume chart.

Intravesical Pathology

Although serious bladder pathology (e.g. infiltrating carcinoma or carcinoma in situ) is usually associated with other urinary symptoms, including haematuria, such individuals may only present with symptoms of frequency and nocturia. These cases are often diagnosed at cystoscopy at the final stage of a urological investigation. It has been found that such patients frequently demonstrate a fixed bladder capacity with relentless frequency and nocturia. For example, in Fig. 2.5 a patient exhibiting such characteristics on his frequency/volume chart commonly has a serious bladder or prostatic pathology. These patients require urgent cystoscopy to confirm the diagnosis at an early stage of their investigations.

Name ____________________ Date of appointment 20·8·80

DAY	time/volume (mls) DAY-TIME	NIGHT-TIME
1	11·30AM/100, 12·00/100, 12·30/100, 12·55/100, 1·20/100, 2·00/100, 2·55/100, 3·50/50, 4·45/50	
	6·45/50, 7·45/75, 8·45/25, 9·45/25, 10·15/25	12·30/50, 2·55/25, 2·10/25, 2·40/25, 3·45/25, 4·40/25
2	6·30/50, 7·20/50, 8·00/25, 8·50/100, 9·25/50, 10·10/50, 11·10/50, 11·45/50, 12·30/50	
	3·15/50, 4·20/25, 6·00/25, 6·50/25, 7·30/25, 8·30/50, 9·10/25	9·50/25, 12·20/25, 1·00/25, 3·50/25, 4·10/25, 5·40/25
3	5·50/25, 6·30/25, 7·50/25	

AVERAGE DAILY FLUID INTAKE (in cups) = 4

Fig. 2.5. Frequency/volume chart showing frequency due to fixed bladder capacity in a patient with bladder carcinoma.

Frequency/Urgency Syndrome

Following the exclusion of the abnormalities above, there remains a group of patients in whom the basic pathology is still unclear. From the clinician's point of view the most important factor to consider is whether the patient's symptoms are related to outflow obstruction or due to a primary abnormality in detrusor function not related to obstruction of the lower urinary tract.

These patients often display a regular frequency pattern on their charts with low diurnal volumes voided and larger volumes at night and especially the first void on waking in the morning. It is impossible to differentiate obstructed from unobstructed cases on the basis of frequency/volume charts alone, but with the use of a urine flow meter a differentiation can be made in the majority of cases.

Past Medical History

Obstetric History

It is known that weakness of the pelvic floor is associated with stress incontinence. It is also apparent that the incidence of stress incontinence increases with the number of pregnancies and the difficulties of parturition. Particular factors which may affect the pelvic floor are the number of pregnancies, the length of labour, the size of the baby, any episiotomies or tears and the use of forceps during delivery. The use of postpartum exercises designed to improve pelvic floor tone may help to prevent stress incontinence.

Gynaecological History

The relationships of the urinary tract to the hormonal status of the patient are significant. It is important to enquire into the patient's menstrual cycle and her menopausal status. Operations on the uterus may interfere with the innervation of the bladder or may lead to distortion of the lower urinary tract. Denervation, more properly termed decentralisation, is most likely after a radical hysterectomy for neoplasm and may act at both the bladder and the urethral levels. Any history of vaginal or suprapubic operation for prolapse or incontinence may be relevant, as such procedures can produce urethral or bladder neck distortion or narrowing.

Urological History

The significance of urological symptoms has already been discussed. Enquiry should be made concerning past urological operations. All operations on the lower urinary tract have their complications, of which obstruction and sphincter damage are the most common.

Surgical History

The operations most relevant to lower urinary tract function are those on the lower large bowel where dissection at the side wall of the pelvis may result in nerve damage, especially during abdominoperineal resection of the rectum.

Trauma History

Trauma to the urethra resulting in obstruction, or trauma to the spinal cord leading to an upper or lower motor neurone lesion, are the accidents most relevant to the lower urinary tract. Trauma to the urethra may be severe and obvious, as in a fractured pelvis with disruption of the pubic symphysis, but problems may follow the apparently trivial perineal injury from which the patient appears to recover in minutes or hours.

Other Significant Conditions

Systemic disease processes which influence the lower urinary tract may do so by affecting the innervation. Diabetes mellitus and multiple sclerosis are two common conditions. Infections such as tuberculosis and schistosomiasis must be remembered. Degenerative disease of the cervical and lumbar spine, spinal tumours and many cerebral conditions may present as incontinence. Pelvic radiotherapy may produce a post-irradiation cystitis with limitation of the bladder capacity, frequency and sometimes pain. Mucosal telangectasia following radiotherapy may cause haematuria.

Drug Therapy

Enquiries should be made as to which drugs the patient is, or has been, taking and whether these drugs had any effect on bladder function or produced side effects. Drugs may be taken intentionally to modify urinary function, or the urinary symptoms may be a side effect of the drug taken for another purpose. All drugs with enhancement or blocking effects on cholinergic, alpha adrenergic and beta adrenergic receptors have a potential influence on lower urinary tract function. Some of these drugs are listed in Tables 2.3 and 2.4.

Drugs Enhancing Bladder Emptying

Bladder emptying may be improved by giving drugs either to increase bladder contractility or to decrease bladder outlet resistance. Cholinergic drugs increase bladder contractility and may produce frequency, whilst alpha adrenergic blockers decrease outflow resistance and may precipitate or exaggerate stress incontinence.

Table 2.3. Drugs improving bladder emptying[a]

Increased detrusor contractility	Decreased outlet resistance
Cholinergic agents	*Alpha sympathetic blocking agents*
Carbachol	Phenoxybenzamine
Bethanecol	Phentolamine
Anticholinesterase	*Striated muscle relaxants*
Distigmine	Baclofen
	Dantrolene
Prostaglandins	Lisidonal
E_2	Diazepam
$F_2\alpha$	
Beta sympathetic blocking agents	
Propranalol	

[a]N.B. These drugs are not all of proven therapeutic efficacy.

Table 2.4. Drugs enhancing urine storage[a]

Detrusor relaxation	Increased outlet resistance
Anticholinergic agents	*Alpha sympathomimetic agents*
Propantheline	Ephedrine
Oxybutinin	Phenylpropanolamine
Dicyclomin	Phenylephrine
Empromium	Imipramine
Imipramine	
	Alpha sympathetic enhancement effect
Beta sympathomimetic agents	Oestrogens
Isoprenaline	
Orciprenaline	
Salbutamol	
Prostaglandin synthetase inhibitors	
Indomethacin	
Smooth muscle relaxants	
Flavoxate	
Oxybutinin	
Dicyclomin	
Dopamine receptor stimulators	
Bromocriptine	

[a]N.B. These drugs are not all of proven therapeutic efficacy.

Drugs Enhancing Bladder Storage

Drugs that in cases of bladder hyperactivity help to achieve continence and increased bladder capacity may provoke retention of urine in normal or borderline obstructed patients. Anticholinergic drugs relax the bladder whilst alpha adrenergic stimulating drugs increase bladder outlet resistance.

A full discussion of the actions of drugs on the lower urinary tract is beyond the intentions of this book. Further information is provided in the section on neurotransmitters and receptors (see 'Receptor Sites and Neurotransmitters', p. 101).

It is suggested that, if a patient is on a drug prescribed to influence lower tract function, or on a drug with urinary side effects, the investigator should interpret the urodynamic findings in the light of the known drug effects. It is preferable to withdraw relevant drugs 1 week before urodynamic testing or before filling in a frequency/volume chart.

General Patient Assessment

Whilst discussing the presenting symptoms with the patient the clinician will have made a subjective assessment. It is clear that there is considerable interaction between the patient's personality and mood and the urinary symptoms. It is a common experience that anxiety leads to urinary frequency and even urgency. Such factors as a patient's age, degree of stoicism, degree of neuroticism, and mood should be assessed. Some patients are extremely tolerant of symptoms that other patients would refuse to accept, and the presence of nocturia is a good example. Whilst the factors mentioned above cannot be quantified easily, they remain important when the clinician comes to interpret the patient's symptoms and urodynamic findings, particularly with respect to proposals for treatment. It will be necessary occasionally to seek a psychiatric opinion where the clinician is uneasy about a patient's mental state, but cannot define the abnormality and its relation to urinary symptoms.

In addition to the mental state, the mobility and dexterity of patients have a profound influence on management. Are they well motivated? Can they manage an appliance? Would they be continent if more mobile and able to reach a toilet? Will they co-operate with follow-up or take drugs reliably? Often the fact that these aspects of assessment are overlooked prevents the subsequent urodynamic diagnosis and efforts at management from achieving an optimal result.

Physical Examination

It is assumed that a general examination of the patient has been undertaken already. This section will note only aspects of examination that are of special relevance to lower urinary tract function.

Abdominal Examination

It is appropriate that the lower abdomen should be palpated and percussed in an attempt to demonstrate the bladder. Large, 'floppy' bladders are difficult to palpate, although they should be demonstrated readily by percussion. Pressing on the suprapubic region and asking if the patient feels the need to void, if positive, is a good indication of a full or enlarged bladder. Examination also reveals the degree of sensitivity of the bladder in some cases where bladder pain is a symptom. The degree of obesity of the patient should be noted.

Examination of the External Genitalia

In the female, abnormalities such as meatal stenosis or fusion of the labia are found occasionally. In male patients, phimosis should be excluded, the external meatus should be examined carefully for stenosis and the urethra felt for fibrous thickening which might indicate a stricture.

Vaginal Examination

Initially the introitus should be viewed with the patient lying on her back with legs flexed and abducted. The position and appearance of the meatus should be noted. The patient is then asked to cough and any cystocoele, rectocoele, cervical descent or urinary leakage recorded. A further assessment of uterine descent should be made with the examining fingers in the vagina. The effect on continence of elevating manually the vaginal fornices can be assessed (Bonney's test). The patient should be asked to contract the pelvic floor on the clinician's fingers as an assessment of the voluntary contractile ability of the perivaginal muscles. This is an appropriate moment to explain to the patient what is meant by the command to squeeze or hold during the later performance of a urethral pressure profile. The activity of the pelvic floor can be assessed more accurately by the use of a perineometer (see 'Use of the Perineometer', p. 148).

Rectal Examination

Both resting anal sphincter tone and voluntary anal contractility should be assessed. As in a vaginal examination, an attempt should be made to exclude any pathology such as neoplasm. In males the prostate is felt for size, shape, consistency and abnormal tenderness.

Neurological Examination

All patients must have a simple neurological examination which should include a gross assessment of sensation, reflexes and muscle function in the legs. In particular, special attention should be paid to the sacral dermatomes, the motor divisions of which supply the bladder. In patients found to have, or known to have, neurological abnormalities a full neurological examination should be performed. In injuries to the spinal cord, the level of the lesion and whether or not the lesion is complete, should be documented.

Certain reflex responses are described in the assessment of sacral function. The anal reflex is elicited by pricking the perianal skin and watching to see if the anal sphincter contracts reflexly. This is quite easy to do at the time of rectal examination. The second reflex often described is the bulbocavernosus reflex. This involves digital squeezing of the glans penis (or clitoris) and the observation of contraction in the anal sphincter or bulbocavernosus muscle. This procedure may provoke a certain amount of discontent in the patient and perhaps encourage him or her to become less co-operative. In any case, a positive response is present only in 70% of normal people. If the reflex is considered to be important it should be demonstrated electrophysiologically [see 'Sacral Evoked Responses (SER)', p. 92).

Investigations

Urine Analysis

The opportunity should be taken to obtain a catheter specimen of urine at each urodynamic investigation. Urodynamics should not be performed in patients who are known to have a urinary tract infection because of the risk of provoking bacteraemia and septicaemia. Patients who have a past or present history of infection, or have a condition such as a residual urine, which predisposes to infection, should have the urine cultured well before any urodynamic investigation is contemplated. If infection is present investigation should be avoided. If investigation is essential in a patient in whom infection cannot be eradicated then an appropriate dose of the correct antibiotic must be prescribed in order to produce an adequate blood level at the time of the investigation.

Cytology

Cytological studies of urine, vagina or cervix may be indicated. Patients with widespread vesical carcinoma in situ, of the type carrying a poor prognosis, may present with the symptoms of bladder hypersensitivity or of cystitis. In these patients the urine specimen usually shows white cells, and an early morning urine, on cytological examination, shows malignant cells. In female patients with lower urinary tract symptoms the hormonal status may be assessed by lateral vaginal wall cytological smear. It has been shown that the urinary symptoms of patients whose vaginal cells show signs of oestrogen deficiency often improve with oestrogen therapy.

Radiology

Non-contrast Radiology

A plain x-ray of the abdomen and pelvis should always be inspected to exclude diagnoses such as stones. Observe the skeleton for abnormalities as well (spondylosis, spina bifida, metastases).

Intravenous Urography

Many patients will have had intravenous urography (IVU) performed before referral. While this may be appropriate for other indications, an IVU gives no information concerning lower urinary tract function that cannot be obtained more adequately in other ways. If an IVU is available, the bladder image should be inspected to assess the shape, size and wall thickness; the presence of trabeculation, sacculation or diverticulae; and the postmicturition residual urine. Static films give very little idea of function. Bladder shape may alter during contraction and diverticulae may appear. In particular, the evaluation of residual urine volume is notoriously inaccurate. Whilst the presence of such a residual urine needs further investigation, it does not necessarily imply obstruction; the patient may not be able to initiate a satisfactory void under the conditions of the test. Equally, the absence of a residual urine, or of a basal prostatic filling defect, may not exclude serious obstruction. Each patient must therefore be questioned personally to check that the void was normal and easily initiated. The volume voided should be within that individual's normal range. The postmicturition film must be taken immediately after voiding, before the bladder refills.

Video-cystourethrography

The conventional video-cystourethrogram (VCUG) consists of the visualisation by a radiologist of one abnormally fast filling and one emptying of the bladder with a number of spot films at appropriate occasions. This can be the most valuable assessment of lower urinary tract structure as it changes during the micturition cycle. It is appropriate to make the most of the investigation and to provide the maximum amount of information for the referring clinician. To do this the events should be recorded on videotape. The use of synchronous video-pressure-flow studies will be discussed in detail later (see 'Synchronous Uro-video-cysto-urethrography', p. 83).

The indications for VCUG are:

1. Recurrent upper urinary tract infections to exclude ureteric reflux
2. Inadequate voiding in women or younger men
3. Complicated stress incontinence
4. Neuropathic bladder disorders
5. Locating the site of a urodynamically proven obstruction

The observations that are appropriate on a VCUG are those relating changes of structure to time and micturition events. Much care should be exercised in making functional interpretations.

Full, at rest	Capacity, shape, outline Reflux at rest
Strain, cough	Degree of bladder base descent Bladder neck competence

Voiding	Reflux and diverticula Speed and extent of bladder neck opening Calibre and shape of urethra Site of urethral narrowing
Stop voiding	Speed and adequacy of voluntary urethral closure mechanism Milk back from posterior urethra Trapping of urine in prostatic urethra
Empty	Residual urine

Endoscopy

Visualisation of the bladder and urethra is a necessary part of the investigation of haematuria, chronic infection, suspected stone and radiographic filling defects. All of these may present with symptoms of lower urinary tract dysfunction and the place of endoscopy must not be overlooked. Urodynamics cannot identify these situations.

Endoscopy should always consist of urethroscopy followed by cystoscopy. It is particularly important that urethral inspection should not be omitted, as it may show inflammation or structural causes of obstruction (stricture, neoplasia, prostatic hypertrophy). If the obstruction is functional rather than structural, for example, detrusor/bladder neck dyssynergia or a detrusor/sphincter dyssynergia, then the site of obstruction will not be demonstrated by endoscopy. Bladder neck hypertrophy does not indicate obstruction and neither does trabeculation of the bladder wall. If urethroscopy is normal and the urodynamic assessment shows obstruction, then a VCUG is the investigation of choice. The correlation between endoscopy and urodynamic findings is discussed further in Chap. 5, 'Urodynamics and the Adult Male'.

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Chapter 3

Urodynamic Investigations

Principles of Urodynamic Investigation

Indications for Investigation

Urodynamic investigations are indicated whenever the results may improve the management of the patient. In Chap. 2 it has been shown how the same lower urinary tract symptoms may be indicative of a variety of pathophysiological processes. It therefore follows that assessment by symptoms alone has a high rate of error. Similarly, the shortcomings of endoscopy and intravenous urography in the investigation of voiding disorders have been discussed.

It is therefore necessary to make objective observations that allow an accurate diagnosis. As micturition is a dynamic event these observations must be dynamic and not static as are the x-ray films of an intravenous urogram. It is appropriate to make an objective assessment of patients prior to any surgical procedure designed to modify the function of the lower urinary tract. The possible exceptions to this dogmatic statement are women with the symptoms of pure stress incontinence who are seen to leak immediately on coughing. Urodynamic investigations are also unnecessary, indeed most are not possible, during acute urinary retention.

Although many of the larger urology and gynaecology units have active urodynamic units, not all clinicians have the facilities for full urodynamic testing. Fortunately, in many instances, especially in males, uroflowmetry is sufficient to allow a confident urodynamic diagnosis to be made. There is now sufficient evidence to state that prostatic surgery should not be practised by surgeons who do not use a urine flowmeter. Obviously it is not practical for all urologists and gynaecologists to perform pressure/flow studies of micturition. Where there appears to be diagnostic doubt, patients should be referred to a centre where such investigations are possible. The groups of patients most likely to fall into this category are men with symptoms of outflow obstruction and borderline urine flow rates, women with incontinence that is not pure stress in type and patients with voiding disorders thought to be secondary to neurological disease.

Urodynamic investigations are also useful in the evaluation of drugs, of surgical treatment and of persistent problems following lower urinary tract surgery. The indications in specific clinical situations will be noted in the text below, particularly in Chap. 5.

Fig. 3.1. The investigation area for routine urodynamics showing, *from left to right,* the urethral pressure profile withdrawal apparatus and syringe infusion pump, investigation couch, the commode and urine flow transducer, the transducer stand (with a calibration system, infusion fluids, peristaltic pump and warming system) and finally the polygraph recorder.

Extent of Investigation

It is convenient to have a basic routine urodynamic assessment. This makes it easier for the staff to work efficiently. It should not, however, allow a rigid attitude towards investigation to develop. The basic system of investigation that has evolved in Bristol is as follows. The investigation area includes a couch for examination, catheterisation and testing (Fig. 3.1), which is attached to an adjacent commode situated over the flowmeter. The transducer stand for pressure measurement is situated beside the commode and the various transducers are connected to the recording apparatus which is in the room with the patient. In addition there are equipment storage areas, sluicing facilities and a catheterisation trolley.

Investigation starts by explaining the environment to the patient and reassuring him or her about any unusual noises from equipment. The first test is a free urine flow rate undertaken in as much privacy as possible. This is followed by urethral catheterisation and assessment of residual urine, if any. Urethral pressure profiles are then performed with the bladder empty, being repeated if necessary with the bladder full and the patient in various positions. Following profilometry the patient is catheterised for filling cystometry and then moves across into a sitting position over the commode (see 'Patient Position During Cystometry', p. 66). The bladder is filled at the rate of 50 ml/min and at a temperature of 37°C using physiological saline. When the patient is as full as they would be when they normally void they are encouraged to micturate, the filling catheter having first been removed from the urethra. After voiding, residual urine is again assessed.

Such a routine range of urodynamic studies is not indicated for each patient. The clinician should decide the extent of the investigations after listening to the patient's symptoms and performing a physical examination. Urine flow studies alone may help to decide which further investigations are most likely to be helpful. Occasionally it is appropriate to employ additional tests. It is therefore desirable to have a flexible system with adequate time to extend the investigations, if indicated. The indications for the specific tests are discussed in detail in this Chapter and Chap. 5.

The Conduct of Investigation

The investigations must be carried out in a safe and scientific manner. Each investigator needs to develop techniques which are adapted to fulfil the particular local diagnostic requirements. The best results will occur when the doctor in clinical charge of the patient is involved with the urodynamic unit. Considerable insight and understanding are needed by the investigator to obtain the best value from urodynamic tests. He or she needs to be familiar with the clinical problems and satisfactory results will not be obtained if the work is delegated to a junior doctor or to any disinterested party.

Terminology

It is important to describe any abnormality precisely and in terms of the techniques used. The limitations of urodynamic investigations should be appreciated. They are discrete functional studies and therefore the results should not be used as a pathological or clinical diagnosis. For example, if a high bladder pressure and low urine flow rate are measured during voiding it is possible to say that outflow obstruction exists, but not what causes the obstruction or where it is. It follows that the urodynamic diagnosis should be discussed in terms that implicate neither clinical disorders, nor ideas about pathophysiology. The terms used should be objective, definable and ideally should be applicable to the whole range of an abnormality. They should also be agreed generally. It is preferable then to speak in terms of normality, overactivity or underactivity of a particular functional measurement, rather than to introduce special new words for observed disorders. The value of the standardisation of terminology elaborated by the International Continence Society has already been mentioned.

Urine Flow Studies

Introduction

Urine flow studies are the simplest of urodynamic techniques, being non-invasive. Furthermore, the equipment needed is simple and relatively inexpensive. Before reliable recording apparatus was commercially available some clinicians made a habit of watching the patient void. Any such semi-objective observation is valuable. However, for flow rate assessment to be meaningful the bladder should be reasonably full, an uncommon event in the out-patient clinic. Also, the patient may find it embarrassing to have the void observed. In women it is not practical in most circumstances. The advantage of modern urine flowmeters is that a permanent graphic recording is obtained. Urine flow rates have been measured for 40 years, but not until Von Garrelts developed his flowmeter in 1956 has equipment been sufficiently accurate for the recordings to be clinically useful. If, despite the availability of commercially produced apparatus, the clinician has no flowmeter, the patient can be asked to time his urinary stream with a stop watch and record the voided volume to calculate the average flow. In the normal patient average flow is approximately half the maximum flow, although in patients with obstruction the average flow may almost equal the maximum flow.

Definitions

Flow rate is defined as the volume (ml) of urine expelled from the bladder each second (s). When recording flow rate the position of the patient, i.e. standing, sitting or supine, whether or not the flow study was part of another investigation, e.g. a pressure flow study or a cystogram, and what volume of urine was voided, should be stated. The method of filling affects the subsequent flow. Filling should be natural, but if a forced diuresis is used or filling by catheter for a prior cystometrogram, this fact must be stated and taken into account.

Continuous Flow (Fig. 3.2). Flow time is the time over which measurable flow occurs. Time to maximum flow is the elapsed time from onset of flow to maximum

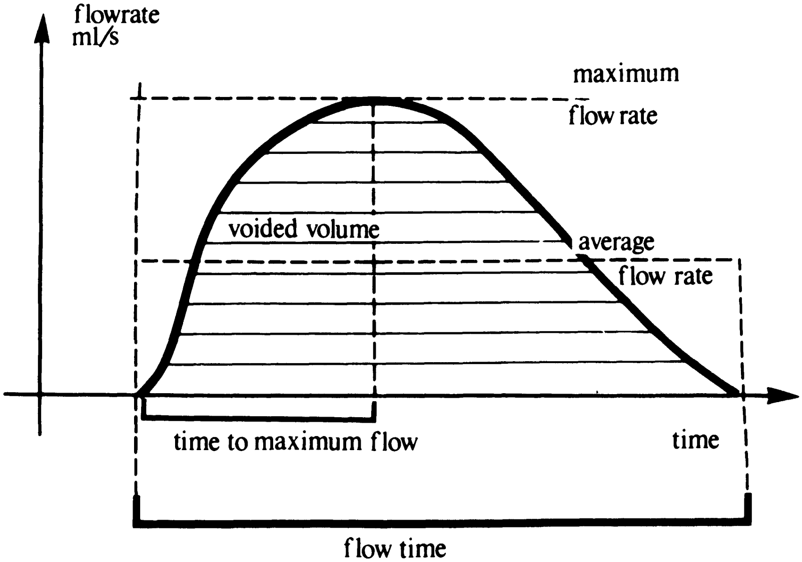


Fig. 3.2. The terminology relating to the description of urinary flow (International Continence Society Second Report on the standardisation of terminology of lower urinary tract function, see App. 1).

flow. Maximum flow rate is the maximum measured value of the flow rate. Voided volume is the total volume expelled via the urethra. Average flow rate is voided volume divided by flow time.

Intermittent Flow or Continuous Flow with Substantial Terminal Dribbling (Fig. 3.3). The same parameters are applicable as to continuous flow if care is exercised in measuring flow time, as previously described. Time intervals between flow episodes are disregarded and the duration of a very low terminal flow is also

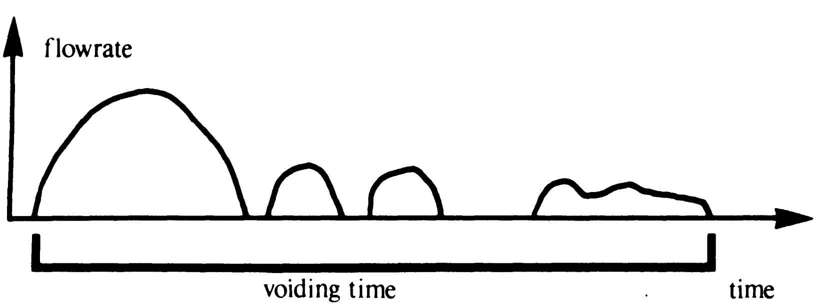


Fig. 3.3. The terminology relating to an intermittent flow rate tracing (see App. 1).

disregarded. Voiding time is the total duration of micturition, including the interruptions. In a continuous flow situation voiding time is equal to flow time. The area beneath the curve or curves represents the volume voided.

Technique and Equipment

Urine flow studies should be performed when the patient has the normal desire to void, and in a condition of privacy. If flow studies are to be made in the out-patient clinic it is particularly important to ensure that the bladder is adequately full. If a sterile urine sample is required for bacteriology a separate void is necessary. This means that the patient has to remain in the out-patient department for 2–3 h to perform two or more voids. It may therefore be found appropriate for the patient to attend on another occasion for urine flow studies. If possible, several flow traces should be obtained for each individual.

The available flowmeters use several different principles. One type of flowmeter has a disc onto which the urine falls. This disc is kept rotating at the same speed by a servomotor, in spite of changes in urine flow rate. The inertia of the urine tends to slow the rotation of the disc. The differing power needed to keep this rotation constant is proportional to the urine flow rate. The flow signal is electronically integrated to record the volume voided. Another variety, the dipstick (capacitance) flowmeter, has a metal strip capacitor attached to a plastic stick which is inserted into the urine collection vessel. This dipstick is held vertically in the straight-sided container. The solutes in urine conduct electricity across the capacitor. As the urine level rises the effective area of the capacitor decreases and the capacitance falls. The change in capacitance gives the volume voided. This signal is electronically differentiated and the rate of change of volume gives the urine flow rate. The third main group of flowmeters involves weight transducers which measure the mass and hence the volume of urine voided. They also, by differentiation with respect to time, calculate urine flow rate. An insignificant error may be produced by this type of flowmeter because of the inertia of the urine falling into the container. It is also possible to 'weigh' urine by measuring the hydrostatic pressure exerted by a column of urine using an ordinary pressure transducer. This is no cheaper and somewhat more difficult to manage.

Most commercially available flowmeters have acceptable accuracy. However, the buyer should always seek independent information on the machine's performance and, in particular, the accuracy (error should be less than 5%), the linearity of response over the range 0–50 ml/s, the reliability of the apparatus, the compatibility with any existing equipment, the safety of the flowmeter and its ease of cleaning.

Many manufacturers also produce a chart recorder marketed as a package with a flowmeter. Because changes in flow rate are relatively slow, in electronic terms, an inexpensive pen recorder is adequate for uroflowmetry.

It is likely that in the future more information will be obtained from non-invasive investigations of urinary flow. Current research projects include drop spectrometry of the urinary stream (Ritter et al. 1977), and the recording of momentum flux (Meyhoff et al. 1977). Such techniques are unlikely to become generally useful in the immediate future. However, with the advances in micro-electronic technology it is quite possible that they will be the primary investigations of the next decade.

Normal Values

When considering the normality of flow rates, the patient's age and sex and the volume voided should be taken into account. As well as the numerical data derived from any flow trace, the shape of the trace is also important. The normal flow curve is almost symmetrical with the maximum flow rate being achieved in 3–5 s. The appearance of the trace depends on the paper speed of the recorder. If this is very slow, flow will appear as a vertical line; if faster, it will be elongated. A paper speed of 0.25 cm/s is practical and allows the easiest interpretation of shape.

Urine flow rate is highly dependent on the volume voided. Bladder muscle when stretched achieves an optimal performance, but if stretched further it become inefficient (Fig. 3.4). Flow rates are highest and most predictable in the volume range 200–400 ml. Through this range the flow tends to be more constant. Above 400 ml the efficiency of the bladder muscle begins to decrease. This is exemplified in Fig. 3.5.

In practice the definition of normality can be considered in two ways. The simplest way is to have a minimum acceptable flow rate for any given sex and age group. Because of the dependence on volume voided this is relatively inaccurate, but may be acceptable provided that the volume voided is in the range 200–500 ml.

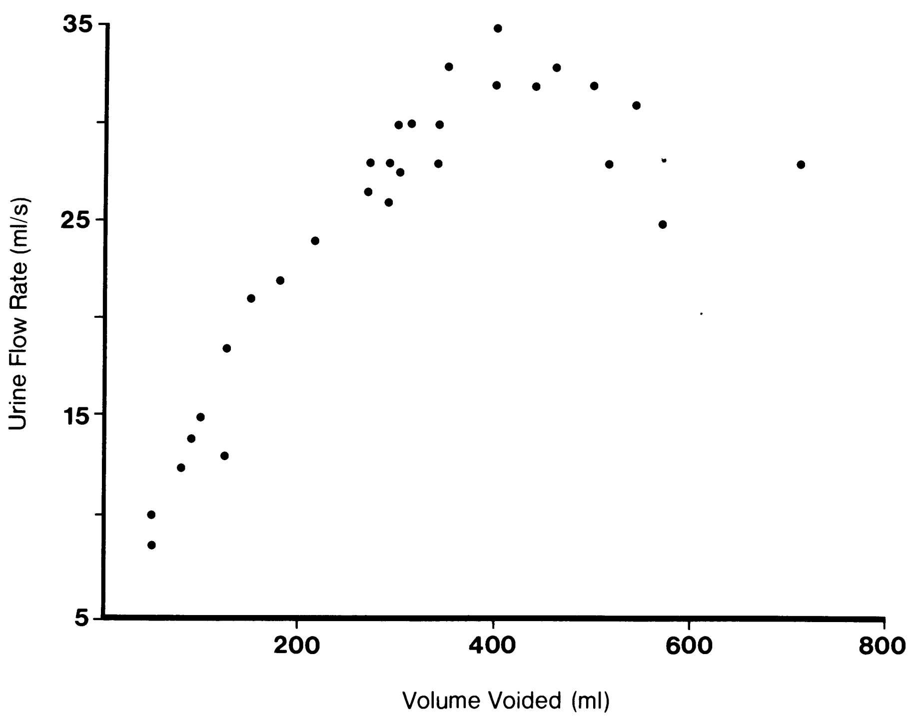


Fig. 3.4. Maximum flow rate plotted against the volume voided for a large number of voids in one individual normal case.

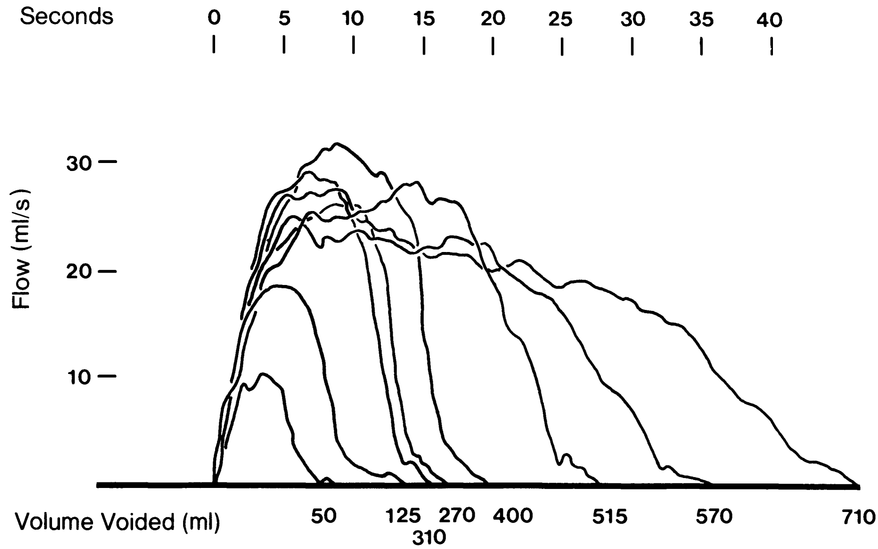


Fig. 3.5. The superimposition of various flow rate tracings, examples taken from the same case as Fig. 3.4. This is a very useful way to display multiple flow rate tracings.

Table 3.1. Minimum acceptable maximum urine flow rates[a]

Age	Minimum volume (ml)	Male (ml/s)	Female (ml/s)
4– 7	100	10	10
8–13	100	12	15
14–45	200	21	18
46–65	200	12	15
66–80	200	9	10

[a]Values given are taken from personal experience and relevant literature. In general the values are one standard deviation below the mean for the maximum flow. Values below those given may not be abnormal, but need further consideration.

Such values are given in Table 3.1. In equivocal cases greater accuracy can be obtained by using a nomogram of maximum flow vs. voided volume, taking sex and age into account. Various authorities have produced such nomograms (Von Garrelts 1958; Backman 1965; Gierup 1970; Siroky et al. 1979).

If the values for maximum flow in Fig. 3.4 are plotted on semi-logarithmic paper the values between 50 and 500 ml are seen to be approximately linear (Fig. 3.6). This may facilitate the construction of nomograms. Von Garrelts (1958) found the square root of the volume to be more accurate for the construction of linear nomograms.

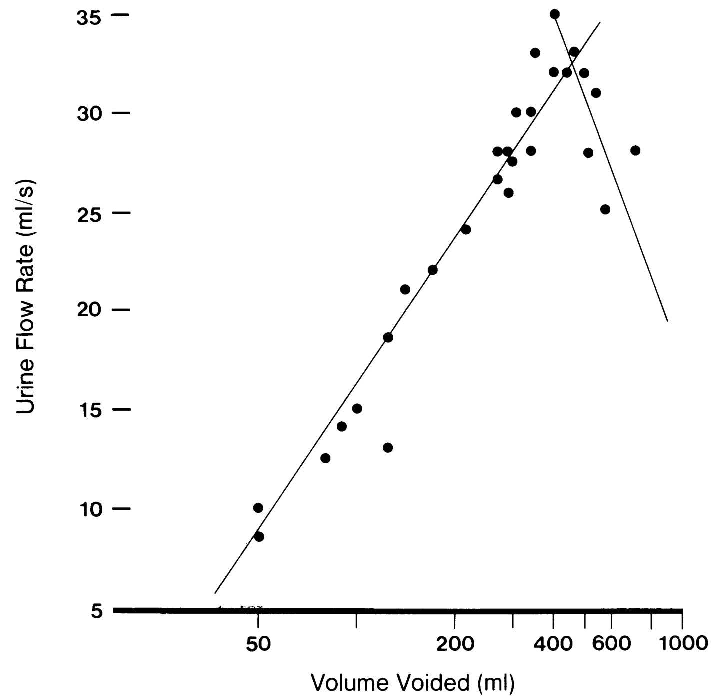


Fig. 3.6. Maximum urine flow plotted against the logarithm of the volume voided. It seems that there is an almost linear relationship between the figures, both in the normal part of the curve (50–400 ml) and in the decompensating phase where the bladder muscle is slightly over-stretched.

In children and in older subjects who are obstructed, the voided volume is frequently less than 200 ml, often because of detrusor overactivity. It is in these cases that flow rate assessment may be most important. We recommend that in any equivocal case the data should be related to an established nomogram (Fig. 3.7). When a flow rate is found to be abnormally low, the next procedure is to repeat the recording to check its accuracy. If necessary a pressure/flow study should be undertaken.

Classification of Abnormal Urine Flow Patterns

Detrusor Overactivity (Unstable Bladder; see 'Overactive Detrusor Function', p. 110)

Normal or supranormal maximum flow is reached almost instantly (Fig. 3.8). This is because detrusor contraction has already occurred and opened the bladder neck. Continence is maintained by the voluntary distal urethral sphincter. When this relaxes, maximal flow is established at once.

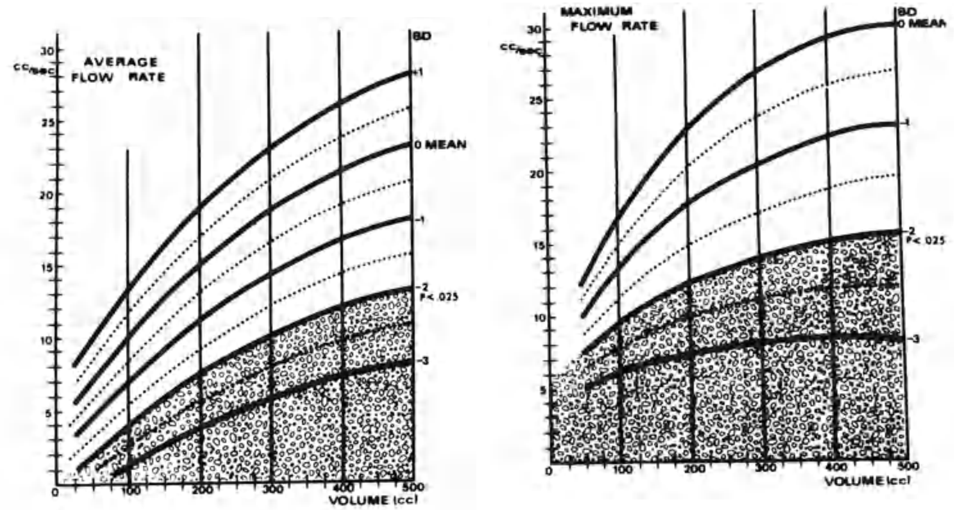


Fig. 3.7. A nomogram for flow rate in male subjects, allowing an estimate for the probability of normality. Three standard deviations below the mean are plotted. The *stippled zone* indicates flow rates that occur in less than 2.5% of the normal male population. (Siroky et al. 1979).

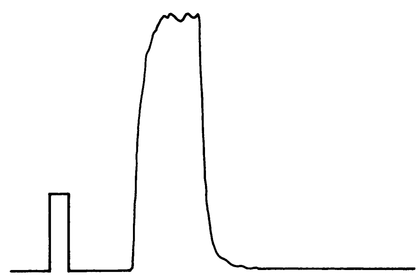


Fig. 3.8. The flow trace in a case of detrusor overactivity. In this and subsequent figures the height of the calibration mark indicates 10 ml/s flow rate and the width of the mark is 2 s. In this case supranormal flow is established almost immediately and cessation of flow is equally rapid as the bladder neck closes suddenly.

Outflow Tract Obstruction

Flow curves in obstructed patients are characterised by a low maximum and average flow, although the average flow is greater than half the maximum flow. Maximum flow is usually obtained relatively quickly (3–8 s), but the flow rate then slowly decreases (Fig. 3.9).

Fig. 3.9. The flow trace in a case of outflow tract obstruction. Maximum flow is established soon after the onset of voiding.

Underactive Detrusor

This diagnosis will be discussed later (see 'underactive Detrusor Function', p. 112) and may be suspected if a symmetrical trace of low maximum flow rate is seen (Fig. 3.10). However, there is a considerable overlap between the flow traces of the obstructed and the underactive detrusor group and therefore the diagnosis should not be made without a pressure/flow study.

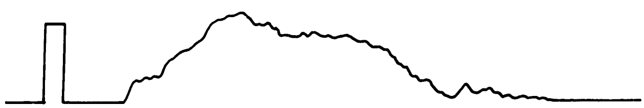


Fig. 3.10. The flow trace in a case of detrusor underactivity. Maximum flow is established near the middle of the voiding time.

Irregular Tracing Secondary to Straining

Some patients may need to use their diaphragmatic and abdominal muscles to produce urine flow and other patients may merely be assisting their detrusor to increase the flow. Straining makes the flow trace irregular (Fig. 3.11). With straining the changes in flow tend to be relatively slow and the stream is usually continuous at first. Straining flow traces are very variable in appearance as they may occur in the presence or absence of obstruction and in the presence or absence of a detrusor contraction. The situation often needs further elucidation by a pressure flow study that includes a subtracted (detrusor) pressure (see 'Abdominal Straining', p. 80).

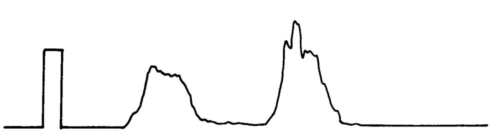


Fig. 3.11. Irregular urinary flow due to straining.

Irregular Tracing Secondary to Detrusor/Sphincter Dyssynergia

In neurologically abnormal patients involuntary contraction of the distal urethral sphincter mechanism is termed dyssynergia. Such a voluntary contraction of the pelvic floor, including the distal urethral sphincter mechanism, is seen in normal individuals who may be made anxious by their investigations. As with straining, the appearances are variable, but in general flow changes are faster than those due to straining (Fig. 3.12).

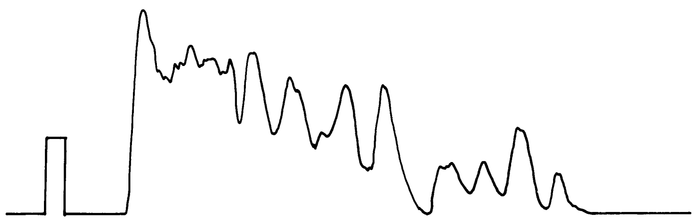


Fig. 3.12. Irregular urinary flow due to detrusor/sphincter dyssynergia. The alterations in flow rate are relatively rapid.

Irregular Tracing Secondary to Fluctuating Detrusor Contractions

This abnormality is generally seen in patients who have a neurological problem, for example, multiple sclerosis. It may also be seen when a detrusor muscle is failing. The detrusor contraction, instead of producing an approximately constant pressure during voiding, may fluctuate. This produces either a continuous but varying flow or, more commonly, an interrupted flow (Fig. 3.13).

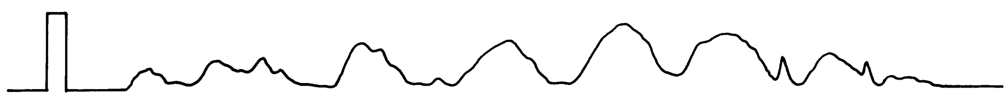


Fig. 3.13. Intermittent flow due to fluctuating detrusor contraction. The changes in flow rate are relatively slow.

Irregular Tracing Secondary to Flow Recording Artifacts

The most potent cause of artifacts is seen when the urinary stream moves in relation to the collecting funnel. If a male patient directs the stream across the funnel from side to side a tracing similar to the one shown in Fig. 3.14 will be produced. Certain funnels are now available which have a built-in baffle to minimise this effect.

Fig. 3.14. Irregular flow rate due to recording artifacts. The changes in flow rate tend to be rapid and biphasic.

Flow vs. Volume Assessment

More valuable than the analysis of a single flow rate is the correlation of a number of flow rates with voided volumes in an individual case. Patients, usually males, are admitted for the weekend whilst the ward is quiet. On Friday a history is taken and they are taught to use the flowmeter. On Saturday the patients void with their normal frequency. On Sunday they are asked to refrain from voiding for as long as possible. This may sometimes precipitate an episode of retention.

A graph of flow against volume is plotted, as in Figs. 3.4 and 3.5. This, together with clinical observation of the patient, gives valuable additional information on the severity of the problem, the likelihood of retention and the state of compensation or decompensation of the detrusor.

Indications for Uroflowmetry

1) Investigation of dysfunctional voiding
2) Suspicion of outflow tract obstruction
3) Before and after any procedure designed to modify the function of the outflow tract

Pressure Measurement and Recording

Introduction

The electronic equipment required for basic urodynamic monitoring can be divided into three units: transducer, conditioning unit and recorder. The transducer can be either a pressure sensor or a flowmeter, any apparatus that produces an electrical signal which may be amplified and conditioned before it is output on to some form of hard copy recorder. This general section is concerned with the various pressure transducers and chart recorders that are available. The terminology and techniques related to pressure measurement are described. The relative advantages and disadvantages of the recording media, fluid and gas, are also considered.

Definitions

Zero reference for all pressure measurements is the level of the superior margin of the symphysis pubis. All pressures are expressed in centimetres of water (cmH_20).

When describing the results of pressure measurement the technique and the position of the patient must be stated. The type and size of any measuring catheters must be specified and the details of the measuring equipment given.

The various pressures measured are denoted by the site of measurement (intravesical, abdominal, urethral), the derivation (detrusor pressure, urethral closure pressure) and by the point at which they occur in the micturition cycle.

Further details of this nomenclature will be found in 'Definitions', pages 48, 61 and 73.

In Table 3.2 are listed the acceptable abbreviations in common usage in urodynamics for pressure and other measurements.

Table 3.2. Acceptable urodynamic abbreviations

Parameter[a]	*Basic symbol*	*Acceptable unit*	*Abbreviation*
Pressure	P	centimetres of water	cmH_2O
Volume	V	millilitre	ml
Time	t	second	s
Flow rate	Q	millilitres/second	ml/s
Temperature	T	degrees celsius	°C
Length	l	metre or submultiples	m, cm, mm
Urological qualifiers[b]		*Values*[b]	
Intravesical, bladder	ves	Maximum	max
Urethral	ura	Minimum	min
Ureteral	ure	Average	ave
Detrusor	det		
Abdominal	abd		

[a]For other parameters see ICS report on standardisation of terminology in Appendix 1
[b]Examples: maximum urine flow rate, Qmax; maximum intravesical pressure, P_{ves}, max

Pressure Transducers

There are three main varieties of transducer appropriate for urodynamics: external units mounted on an adjacent stand, external units mounted on the patient and internal catheter-tip transducers.

External Stand-Mounted Pressure Transducers

These are the conventional type of strain gauge unit, often cylindrical with a transparent dome at one end, which are suitable for most urodynamic applications. The advantages are that the units are relatively cheap, easy to handle and of robust construction. The disadvantages are that a long fluid-filled connection to the patient is required, and if this is moved or knocked artifacts are produced. A further disadvantage is that zero errors occur if the patient moves in height in relationship to the transducer. Continual re-adjustment of zero with reference to the symphysis pubis may be necessary.

External Patient-Mounted Transducers

Types include small 'luer fitting' units and others that are flat and conveniently fixed to a belt or strap. These tranducers are useful for ambulatory studies. The advantages are that shorter fluid-filled lines are required for connection and artifacts are therefore reduced. Some artifacts will be reduced still further if air can be used rather than fluid in these transmission lines. Because the transducer is fixed to the patient there are many fewer zero errors. The main disadvantage is that they are more complicated to fix on to the patient. The smaller varieties are also more expensive and less robust, but in general these are not appropriate for urodynamics anyway.

Catheter-Tip Transducers

These are strain gauges located on the catheter at the site of recording, and they can be made especially to suit particular applications. The catheter size is dependent on the number of transducers needed and whether or not a channel for bladder filling is required. A catheter with one channel for infusion and two pressure transducers can be made with a size of 8 or 10 FG. The transducer should be flush with the catheter surface and is connected to its conditioning unit by an insulated cable. The advantages of catheter-tip transducers are the elimination of zero errors and fluid-filled connecting lines. Their disadvantages are that they are expensive to purchase, relatively fragile and more difficult to handle and calibrate. They are especially useful if rapid changes in pressure are to be compared accurately, e.g. stress urethral profiles (see 'The Stress Urethral Profile', p. 54).

Design and Specification

Various factors in the design and specification of any transducer need to be checked before it is considered acceptable.

Is a mounting for the transducer supplied?

Are the cables long enough?

Can new domes be fitted easily? (Sterile disposable domes are not usually appropriate.)

Is the transducer able to withstand rough handling?

Does the transducer meet the required safety standards?

Is the transducer sufficiently stable?

Is the pressure range of the transducer appropriate (0–300 cmH_20)?

Is the mechanical construction, especially the mounting of the diaphragm, sufficiently robust?

Does the transducer require special care and attention when being cleaned? Can it be autoclaved and are the domes re-usable?

Once calibrated, how long will the transducer remain accurate?

Has the transducer an electronic calibration facility?

Calibration

There are three main sources of error when using pressure tranducers. The zero point may drift, the amplification factor needed may change and the patient may move in relation to the established zero level (taken from the upper margin of the symphysis pubis).

With external transducers zero drift may be checked by opening a tap on the transducer itself to atmospheric pressure. Correction amplification or gain must be checked initially by submitting a correctly zeroed transducer to the pressure of a column of water of a known height, e.g. 20 cmH_20. Some transducers have an internal electronic re-calibration facility which makes the maintenance of correct recording easier. Calibration is required every day and more often if the stability of the transducer has shown it to be required. It is important to keep the system free of all air bubbles.

Catheter-tip transducers are automatically at atmospheric 'zero' pressure when in air. Calibration is achieved by placing the strain gauge in question at a known distance under the surface of the water. As these units are temperature sensitive the calibration bath should be at 37°C, simulating the environment of the body. Zero drift when in situ is difficult to check with catheter tip transducers. This does not matter except during a long recording of several hours. If the transducer is not stable for at least an hour, it should be returned.

Sterility of Transducers and Tubing

It is not necessary to change all the tubing or re-sterilise external transducers for each test. Initial sterilisation can be performed with Cidex, used for at least 3 h (preferably overnight). Make sure the cable connection socket is covered and watertight. If tubing and transducers are kept filled with an antiseptic solution they may continue to be safe for several weeks. Re-sterilisation with Cidex is recommended weekly. The antiseptic solution used must not allow a deposit to form on the diaphragm of the transducer. We have found that 0.01% benzalkalonium chloride or 0.02% aqueous chlorhexidine gluconate are suitable. Figure 3.15 shows a system allowing flushing and calibration of the transducers. Sterility is not required in the rectal line, but it is convenient for both to be connected to the same calibration system. The manometer connection tube between the bladder catheter and the transducer should be changed after each test.

Catheter-tip transducers can be kept sterile by storing them in Cidex. Do not let fluid get into the plug.

Abdominal Pressure Measurement

The purpose of measuring abdominal pressure simultaneously during bladder or urethral pressure recording is to aid interpretation of observed pressure changes. If pressure rises the increase may be due to contraction of the musculature of the bladder or urethra or due to additional extravesical pressure. In the normal person abdominal pressure is transmitted to the whole of the bladder and the part of the proximal urethra which lies above the pelvic floor. It is a standard urodynamic procedure to record rectal pressure as an approximation to intra-abdominal

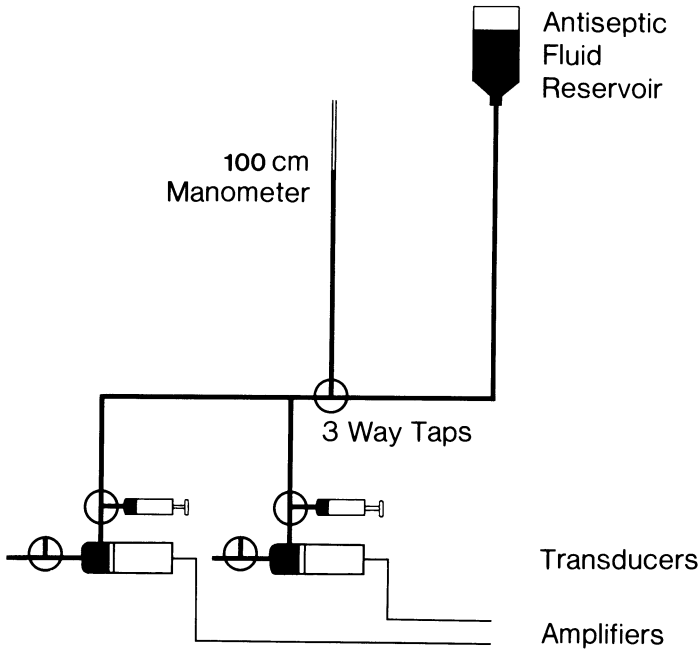


Fig. 3.15. An appropriate system for flushing and calibration of external transducers.

pressure. Intra-abdominal pressure can also be recorded from the stomach or from the pre-peritoneal space via the supra-pubic route. Figure 3.16 illustrates the importance of measuring intra-abdominal pressure. The procedure assists in understanding the tracings, in identifying artifacts due to extravesical pressure, in diagnosing small spontaneous detrusor contractions (unstable waves; see 'Over-active Bladder', p. 70) and in assessing the contribution of abdominal straining to the process of voiding. It is also useful to ensure that the patient does not strain during the recording of urethral pressure profiles, thus producing an abnormally high urethral pressure. It is regarded widely as being an obligatory method if the optimal interpretation of traces is to be made.

Certain artifacts may arise as a direct result of rectal pressure recording and these must be excluded. The rectal pressure may be higher than the intravesical pressure and fluctuations may occur. Even in the presence of these artifacts, the rectal pressure can help the qualitative interpretation of tracings.

The rectal recording line, which can be a piece of manometer tubing cut short, must be filled with the same medium as the intravesical pressure recording line. To avoid blockage with faeces and leakage of fluid per rectum it is advisable to cover the end of the rectal line with one of the fingers cut from a thin, disposable plastic glove, tied on securely. This 'balloon' should not be distended, indeed, it may be helpful to puncture it, allowing excess air to escape.

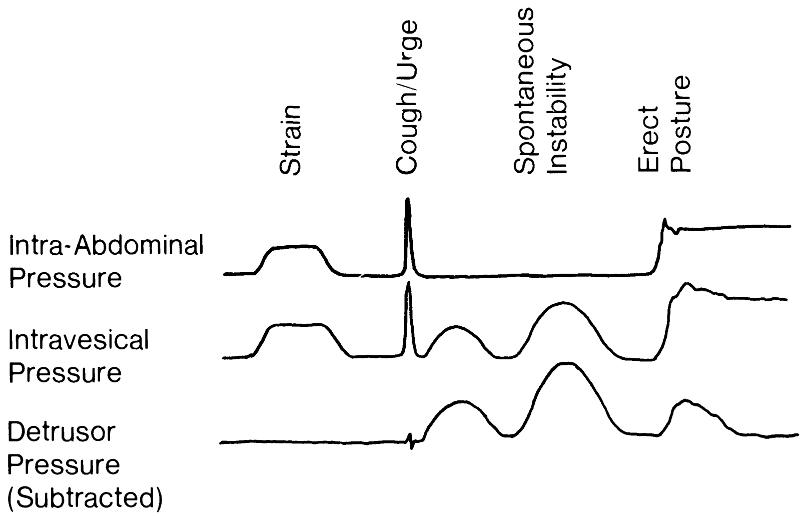


Fig. 3.16. The importance of measuring intra-abdominal pressure in order to derive the true detrusor pressure.

Electronic Subtraction

In addition to the display of abdominal (P_{abd}) and intravesical (P_{ves}) pressure, it is helpful to display the derived or subtracted detrusor pressure ($P_{ves} - P_{abd} = P_{det}$). Several commercial concerns produce 'subtraction units'. These can also be made very cheaply by a medical physics department. There are also differential or subtracting transducers available. These should never be used. They work by applying the two pressures to be subtracted to either side of the strain gauge diaphragm. The resulting pressure will be the detrusor pressure, but neither of the primary pressures can be recorded and without them the detrusor pressure cannot be interpreted. To avoid biphasic subtraction artifacts it is necessary to have bladder and rectal recording lines and catheters that are exactly the same calibre and length.

Conditioning Units

Conditioning units or pre-amplifiers interface the often low-level signal produced by the transducer to the appropriate level for input to the driver amplifier of the recorder. The pre-amplifier can stand alone or be part of a multi-channelled recording system. Several manufacturers now produce a composite amplifier/ recorder system. As with transducers, there are certain points to check when acquiring a system:-

Make sure your transducer and amplifier are compatible.

Make sure all inter-connecting cables are supplied with the correct plugs and sockets.

Check the technical specification of the pre-amplifiers with respect to zero drift, linearity and frequency response.

Make sure the amplifier controls are easy to operate and understandable.

Check that the amplifier has the output capacity to drive the recorder.

If you have any doubts about the system, ask the supplier to loan the equipment for a few days' test and consult your friendly local medical physicist.

Recording Equipment

Chart recorders come in a variety of specifications and it is often a difficult job to decide which is the most suitable for a particular urodynamic recording situation. The most important factors are related to the mechanism of write out and therefore the paper required. In addition, it is important to consider the number of channels needed and, if these overlap, whether they require special identification. When channels overlap the pens may well be offset and lead to inaccuracies. It is also necessary to ensure that the frequency response and the paper speed of the recorder are appropriate for the particular recording needs. From the electronic point of view it is essential that the sensitivity of the apparatus is appropriate to the range of input signals. There is no point in having a machine which is more expensive and complex than necessary. The suitability of the main groups of commercially available recorders is considered below.

Four channels is the minimum required for most urodynamic applications; abdominal pressure, intravesical pressure, detrusor pressure and urinary flow rate. Additional channels may be required for measuring bladder volume, EMG, urethral pressure and urethral closure pressure. If all these parameters were to be required simultaneously, for research, then an eight-channel recorder would be needed. In practice, six channels are more than adequate as a selector unit can be built, or acquired commercially, which will allow presentation of any six channels from eight recorded parameters.

Heated Stylus Recorders

In this system a metal wire pen is heated and writes on heat-sensitive paper. This system is robust and generally trouble free, although the paper is moderately expensive. The frequency response of the writing system is up to about 50 Hz and therefore is suitable for all urodynamic applications except qualitative EMG. The channels do not usually overlap. The paper stores moderately well, but marks easily if folded or scratched. There is good contrast for photography.

Ink Stylus Recorders

Either metal pens with ink reservoirs or felt tip pens are used. This system behaves in a similar way to the heated stylus system. The advantage of any ink pen system is in the low cost of the writing paper. The disadvantage of the ink reservoir system is that the pens may clog up if not used regularly. With the felt tip system the traces can be identified by using different colours. Systems are available where each trace runs the full width of the chart. This means that the pens are offset and this introduces errors of correlation between different traces. There is one circumstance in which this offset can be an advantage; it may be desirable to advance the write out of the urinary flow trace by about 1 s to compensate for the delay taken for the stream to pass from the urethral meatus into the recorder. If an ink stylus system is chosen it may be appropriate to note whether the write out is curved or in a straight line. A curved system may be cheaper and intrinsically more accurate, but it is sometimes more difficult to interpret.

Ink Jet Recorders

In this system a very fine jet of ink is squirted under high pressure directly from the driving galvanometer block on to the paper. The jet is so thin that it is invisible to the naked eye and when it has reached the paper it is blotted by a roller. This system is more expensive, but reliable and does not seem to block up. It has the advantage of using cheap paper, of a high-frequency response (up to 700 Hz) and of the traces being able to cross one another with minimal offset (1–2 mm). The disadvantages of the system are its cost and the fact that the paper speed cannot be very slow or the trace becomes blotchy. As with all ink systems, the records are durable and easily photographed.

Ultraviolet Recorders

This system gives the highest frequency response, up to 5000 Hz. The galvanometer block reflects a beam of UV light, using a small mirror, onto the light-sensitive paper. A few seconds later, when the UV paper has been exposed to light, the tracing appears. As well as a fast frequency response, this system has the advantage of relatively low capital cost and the possibility of having a very large number of channels on relatively narrow paper. The traces can cross without any offset at all and this may produce difficulties with identification. Most recorders have a built-in identification system whereby each trace is interrupted regularly with an identification mark. The disadvantages are the high cost of the light-sensitive paper, the relatively poor quality of the tracings and the fact that the tracings fade on storage, particularly if they are exposed to light. The UV light source is expensive and needs replacing quite frequently. When buying such a recorder one should check whether the galvanometers require an extra conditioning unit, because they are current driven. UV recorders are therefore not appropriate for routine urodynamic applications, but are best reserved for specific research projects where a high-frequency response is required, e.g. electromyography.

XY Plotters

This form of write out can use ordinary graph paper of a convenient size to fit in the notes or reproduce by photocopying. XY plotters are most useful where parameters other than time can be represented graphically, e.g. pressure against urethral length for urethral profiles and pressure against volume during a cystometrogram. Abrams et al. (1977) have described how bladder function can be displayed as a pressure/volume loop incorporating both filling and emptying phases. This system has been modified further so that a free flow rate, urethral pressure profile, inflow cystometrogram and pressure/flow study of micturition can be recorded (Abrams et al. 1981). One particular advantage is that several urethral profiles can be superimposed and compared directly.

Urethral Pressure Measurement

Introduction

The analysis of urethral pressure changes has in some ways superseded the use of EMG in the analysis of urethral 'sphincter' function. Its advantage is that direct quantitative measurements are made which include most of the elements contributing to urethral closure. There are two types of urethral pressure measurements. 'Static' assessment implies that measurements are taken at all points of the urethra during a steady-state period and reproduced in the form of a functional profile. 'Dynamic' assessment means that recordings are taken from one part of the urethra over a period of time, during which events related to micturition may occur.

Definitions

The urethral pressure profile (UPP) indicates the intraluminal pressure along the length of the urethra with the bladder at rest. Figure 3.17 shows the ICS terminology for urethral pressure measurement. The zero pressure reference point is again taken as the superior edge of the symphysis pubis. When describing the method, it is necessary to specify the catheter type and size, the measurement technique, the rate of infusion (if the Brown and Wickham technique is used), the rate of catheter withdrawal, the bladder volume and the position of the patient.

Maximum urethral pressure is the maximum pressure of the measured profile. Maximum urethral closure pressure is the difference between the maximum urethral pressure and the intravesical pressure. Functional profile length is the length of the urethra along which the urethral pressure exceeds intravesical pressure.

Techniques and Equipment

Three main methods for urethral pressure measurements are currently used; the resistance to fluid or gas perfusion (Brown and Wickham 1969), small intraluminal balloons (Enhorning 1961) and catheter tip transducers (Asmussen and Ulmsten 1975).

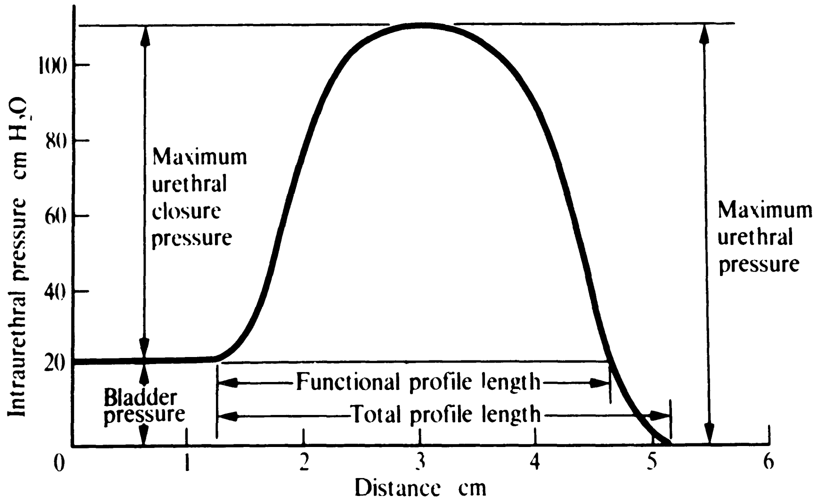


Fig. 3.17. A schematic representation of the urethral pressure profile giving the terminology recommended by the International Continence Society's First Report (see App. 1).

Fluid Perfusion Profilometry

This is probably the best known method. The basis of the technique is the measurement of the pressure needed to perfuse a catheter at a constant rate. The catheter is passed into the bladder and withdrawn slowly through the urethra. The catheter has eye holes 5 cm from its tip through which the perfusion fluid escapes into the bladder or urethra. The constant infusion is maintained by a syringe pump. The technique has been shown experimentally to be measuring the occlusive pressure of the urethral walls. Figure 3.18 illustrates the equipment required for urethral closure pressure profile measurement using this technique.

Catheter Size. There is no appreciable difference in pressure measurements provided the catheter is between sizes 4 and 10 FG. It seems likely that the sizes above 10 FG may record urethral elasticity as well as urethral closure pressure and therefore give falsely high readings. The comparison of pressure between smaller and much larger catheters may provide a basis for measuring urethral elasticity.

Catheter Eye Holes. A single end hole or side hole is known to be inaccurate, the first because of the lack of adequate mucosal contact and the second due to specific orientation. A catheter with two opposing side holes set back from the catheter tip is known to be of adequate accuracy. The presence of more than two holes does not improve the accuracy significantly. If the holes are 5 cm from the tip recatheterisation is facilitated.

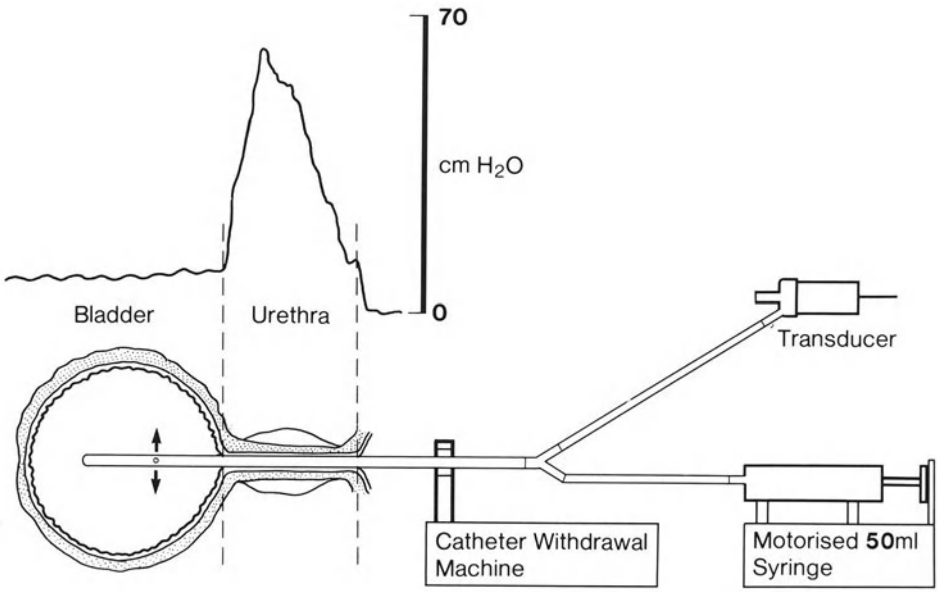


Fig. 3.18. Equipment necessary for a fluid perfusion urethral pressure profile. If the urethral closure pressure is required then a double lumen profile catheter is required, together with an extra transducer, in order to measure concurrently the intravesical pressure.

Rate of Perfusion. It is desirable that the catheter is perfused at a constant rate. This necessitates the use of a motorised syringe pump and excludes the use of a peristaltic pump. A perfusion rate of between 2 and 10 ml/min gives an accurate measurement of closure pressure. Perfusion rates of less than 2 ml/min usually fail to record the true urethral pressure unless an extremely slow withdrawal rate is used. The reason for this is outlined below. Perfusion rates in excess of 10 ml/min are likely to lead to falsely high readings as the fluid cannot escape from the catheter eye holes along the urethra fast enough.

Rate of Catheter Withdrawal. It is most satisfactory to withdraw the catheter mechanically at a constant speed using a motorised system. Speeds of less than 0.7 cm/s are satisfactory when used with perfusion rates of 2 to 10 ml/min. The catheter withdrawal machine can be fitted with a potentiometric device which measures catheter position. If required, this device can be connected to one axis of an XY plotter or to one channel of a moving chart recorder.

Response Time. The attention to technique is vital and the methods discussed above should allow the investigator to measure pressure profiles accurately. However, it is still essential to assess each individual measurement system for its recording accuracy. The response time of the system should be calculated. In a

Brown and Wickham system this is most easily done by occluding the eye holes of the perfused catheter whilst recording. A graph of pressure against time will be obtained (Fig. 3.19). The slope of the line will give the maximum response at that perfusion rate as centimetres of water per second, for example, if the system has a maximum response at a given perfusion rate of 50 cmH_2O per second and the urethral pressure rises by 100 cmH_2O in the proximal 2 cm of the urethra, it follows that the catheter must not be withdrawn faster than 1 cm/s at the test infusion rate or the pressure will be under-estimated. The response time of the system is determined by three factors: the length and diameter of the tubing from the patient to the external pressure measuring transducer, the rate of catheter perfusion and the speed of catheter withdrawal. In practice a 100-cm length of manometer tubing is a satisfactory means of connecting the profile catheter to the pressure transducer and to the syringe pump.

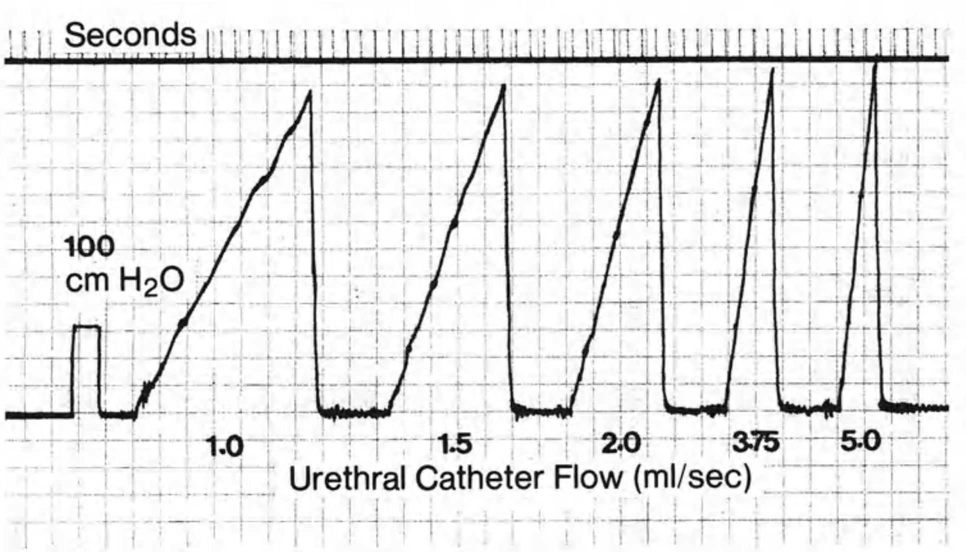


Fig. 3.19. The varying response times for a urethral pressure profile catheter system, showing the pressure response to catheter occlusion at different infusion rates.

By studying the shape of the urethral pressure profile it is relatively easy to decide whether the response time has been adequate to obtain an accurate profile. The tracing we describe as a 'saw tooth' profile (Fig. 3.20) is diagnostic of an inaccurately measured maximum urethral pressure. The upstroke of the profile is smooth and straight and looks unphysiological. The downstroke is usually faster than the upstroke and more irregular. If such a profile is recorded the perfusion rate should be increased or the withdrawal rate decreased. Other factors influencing the response time of the system are air bubbles or fluid leaks.

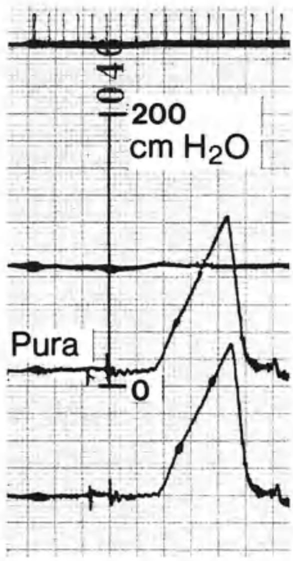


Fig. 3.20. The artifactual 'saw tooth' urethral pressure profile, with a straight ascending limb which underestimates the actual urethral pressure. Abbreviations in figures correspond to those suggested by the International Continence Society, App. 1.

Gas Perfusion Profilometry

Gas, usually carbon dioxide, may be used as a perfusate instead of water. The technique is similar in principle and if used correctly the readings of gas and water are comparable (Fig. 3.21). The technique is full of hazards and needs very careful analysis beforehand. Because gas is compressible, very high perfusion rates are needed to obtain the same pressure response time as with water. If the technique employed above is used to test response time, it will be found that a perfusion rate of 2 ml/min of water is approximately equivalent to 150 ml/min of gas. It may also be found that the infusion rate of gas is not constant and decreases when intraluminal pressures are high. Gas pressure profiles are not recommended unless the investigators think they know exactly what they are doing.

Balloon Catheter Profilometry

Enhorning in 1961 described the measurement of urethral pressure using a small soft balloon mounted on a catheter. Pressure is transmitted by a fluid column to the external pressure transducer. Several balloons can be mounted on the same catheter. This system is undoubtedly capable of measuring urethral pressure very accurately and the response time is more rapid than with the perfusion method. However, the system is more difficult to use. The balloon membrane introduces inaccuracies due to its physical characteristics. These factors can be eliminated by frequent and careful calibration. It is particularly important to remove all air bubbles from this system or pressure transmission will be damped.

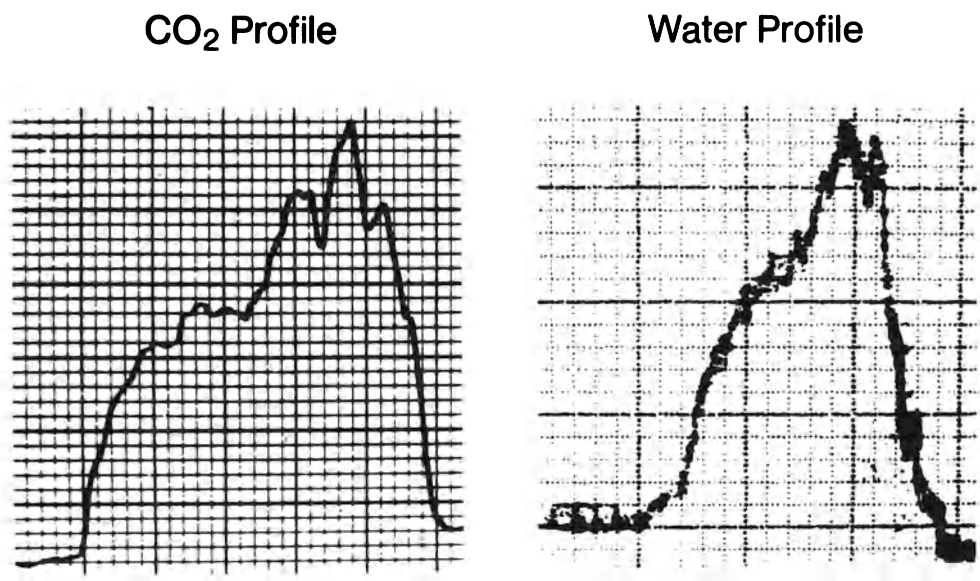


Fig. 3.21. A comparison of carbon dioxide and water perfusion pressure profiles in the same patient.

Catheter-Tip Transducers

This method allows a pressure transducer to be sited at the point of measurement rather than relying on pressure changes being transmitted to an external transducer along lengthy tubing. The artifacts produced by response time variations are therefore eliminated as are problems due to leaks and air bubbles. The absence of any zero errors means that the transducer readings remain correct when the patient changes position and this facilitates the measurement of urethral pressure in the sitting and standing positions, which are perhaps more physiological. These advantages, combined with the rapid response time of such transducers, mean that it is easier to record dynamic pressures such as the stress urethral profile described below.

Simultaneous Recording of Bladder Pressure During Urethral Pressure Measurement

It has been argued that the bladder pressure should always be measured during profilometry (ICS first report 1975). This is because a detrusor contraction, perhaps with reciprocal urethral inhibition, might occur undetected as the pressure sensor is withdrawn through the urethra. However, in practical terms the profiles must be recorded several times until a constant pattern emerges. In our opinion, this eliminates the possibility of such an artifact. It is probably more important to record rectal pressure and analyse the transmission of abdominal pressure to the urethra. When there are only two transducers in the system it is appropriate to use the bladder (sterile) pressure line for recording urethral pressure.

The 'Stress' Urethral Profile

The concept of the 'stress' profile has recently been introduced (Asmussen and Ulmsten 1976). Bladder pressure measurement can be made simultaneous with urethral pressure if a suitable catheter is used. For accurate measurement the catheter-tip transducer system is recommended. The measuring catheter is withdrawn very slowly through the urethra (1–2 mm/s), as described above, with the patient coughing at regular intervals. An alternative method is to hold the measuring catheter stationary at 0.5-cm intervals down the urethra while the patient performs a Valsalva manoeuvre to a pre-determined pressure. This method

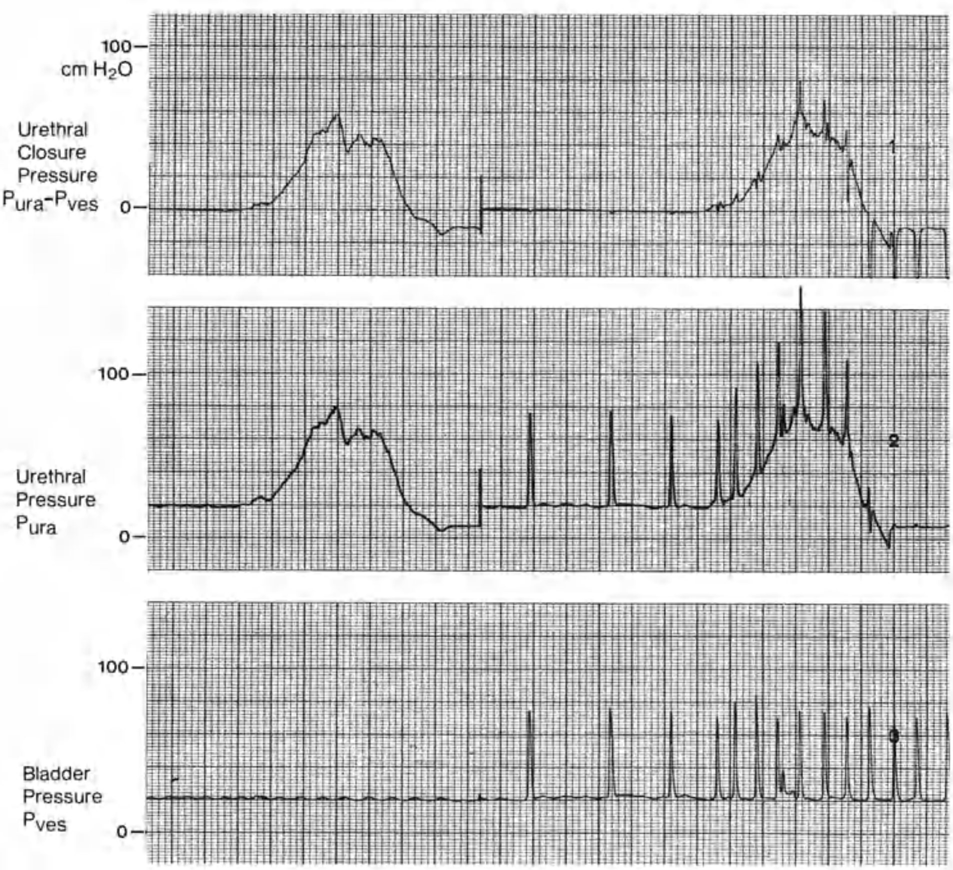


Fig. 3.22. A 'stress' urethral profile. On the *left* there is a conventional urethral pressure profile and on the *right* there is the same profile performed with the patient coughing regularly. If the urethral closure pressure (*upper trace*) becomes negative in the earlier part of the profile then stress incontinence is likely to occur. In this example the situation is equivocal. The urethral closure pressure at rest is 60 cmH_2O. The functional profile length is 2.7 cm, but the general amplitude of the profile drops on coughing and the urethral closure pressure just becomes negative. The patient did have stress incontinence.

measures the efficiency of pressure transmission into the proximal urethra from the abdominal cavity. It is now well known that decreased conduction of increased intra-abdominal pressure is associated with genuine stress incontinence. The transmission may be expressed as the closure pressure, which is the urethral pressure minus the intravesical pressure. If the closure pressure becomes negative on coughing, leakage is likely to occur. Closure pressure may be derived electronically by subtracting intravesical pressure from intra-urethral pressure and this may be displayed on the chart recorder (Fig. 3.22).

Reproducibility of the Urethral Pressure Profile

Provided that suitable attention to details of technique has been paid, the results are highly reproducible. Certain 'normal' variations in the urethral pressure profile have been described. The most common reason for pressure fluctuation is voluntary contraction of the urethral or peri-urethral musculature. It seems likely that the majority of the maximum urethral pressure of the resting profile is produced by the intramural urethral striated muscle described by Gosling (1979). If the patient is not relaxed during urethral pressure profile measurement then the pelvic floor, which lies in close proximity to the urethra may, by its contraction, produce a pressure increment along the urethra. This can be recorded deliberately by asking the patient to contract voluntarily the pelvic floor as if they were holding on when desperate to pass urine. If the urethra is sensitive it is not uncommon for the first urethral profiles to be of a higher pressure because of the failure of the patient to relax. As Plevnik and Janez (1978) have pointed out, some individuals have greater variability of urethral pressure than others. If reproducible profiles cannot be obtained in any particular case then this is an indication for the performance of a dynamic profile, recording the maximum urethral pressure with a stationary catheter over a longer period of time. Sometimes vascular pulsations are seen on such recordings; this is not abnormal.

Effect of Posture on the Urethral Pressure Profile

From the technical point of view it is easier to perform urethral profiles if the patient is supine. Most tests are performed in this position. The posture of the patient does have a considerable influence on urethral muscle tone. George and Feneley (1978) have described the sort of pressure changes that can occur. The normal response to the assumption of a more upright posture is an increase in the maximum urethral closure pressure of about 23%. In some abnormal patients this increase may not occur and in others, some neuropathic, the increase in pressure may be excessive (greater than 100%). The absence of an increase in pressure on standing may be a diagnostic test for genuine stress incontinence (Tanagho 1979).

The Normal Urethral Pressure Profile

The figures for normal urethral pressures in the available literature are all taken from very small series. The figures in Table 3.3 below are taken from a large number of our patients who have been assessed and considered to be both clinically

Table 3.3. Values for urethral pressure in patients in whom no abnormality has been found

	Maximum urethral pressure (cmH_2O)			
	Male		Female	
Age	Mean	Range	Mean	Range
<25	75	37–126	90	55–103
25–44	79	35–113	82	31–115
45–64	75	40–123	74[a]	40–100
>64	71	35–105	65[a]	35–75

[a]Edwards (1973) quotes figures for normal urethral pressure in the over 45 age groups that are much lower than this, in the range of 20–50 cmH_2O.

and urodynamically normal. The figures are for patients who are in a supine position with the bladder empty. Adequate information on normal pressures in other postures and for other bladder volumes is not available. This does limit the value of urethral pressure profile measurement, for it is the urethral response to bladder filling and postural change which may be most important in diagnosis.

There are certain sex differences. In the male, the maximum urethral pressure does not decline significantly with age, whereas in the female, particularly after the menopause, the maximum urethral pressure is lower. Similarly, in the male, the prostatic length tends to increase with age and in the female the functional urethral length tends to decrease (see Figs. 5.11, 5.12).

It is evident that there is a wide overlap between the range for normal urethral parameters and for abnormal situations, e.g. stress incontinence. There is a better correlation between normality and abnormality if an index is used. This is most commonly some estimate of total urethral muscle function such as maximum urethral closure pressure × functional length or, alternatively, a measurement of the area beneath the urethral pressure profile curve.

The shape of the urethral profile is of diagnostic importance. In the normal male the most important part of the profile, from a functional point of view, is that between the bladder neck and the membranous urethra. The distal bulbar and penile urethra are very variable in length and not usually described. Certain constant features are seen in male profiles. The presphincteric part of the trace shows, even in boys, a pressure increase due to prostatic tissue (Fig. 3.23). The presphincteric pressure area blends with the pressure zone attributed to the distal urethral sphincter mechanism which in itself should be more or less symmetrical. As the male patient gets older the length of the presphincteric profile (prostatic length) increases and the pressure within this area may become higher. This is not necessarily abnormal within certain limits.

The normal female urethral pressure profile is symmetrical in shape (Fig. 3.24) and asymmetry is generally due to a faulty measurement technique, e.g. the sawtooth profile.

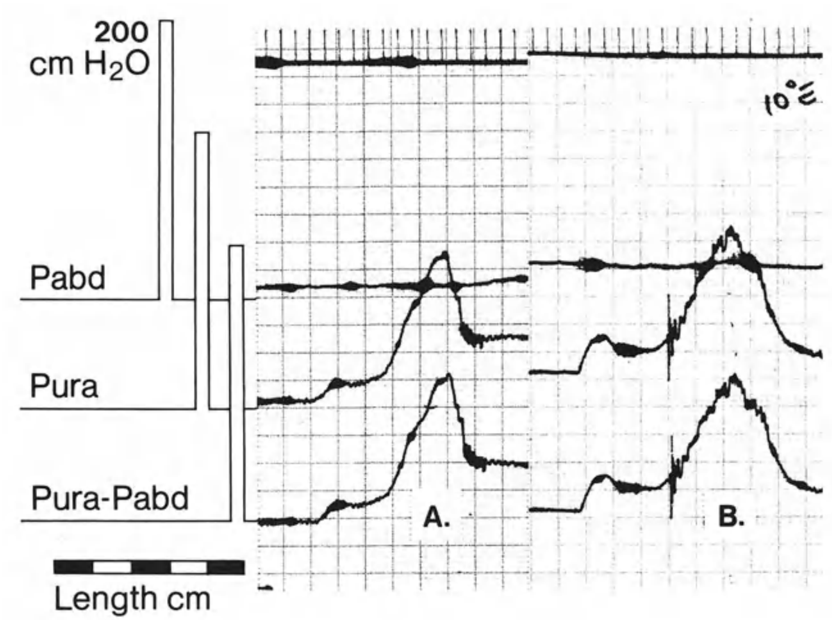


Fig. 3.23. Urethral pressure profiles in normal males aged 14 (**A**) and aged 50 (**B**).

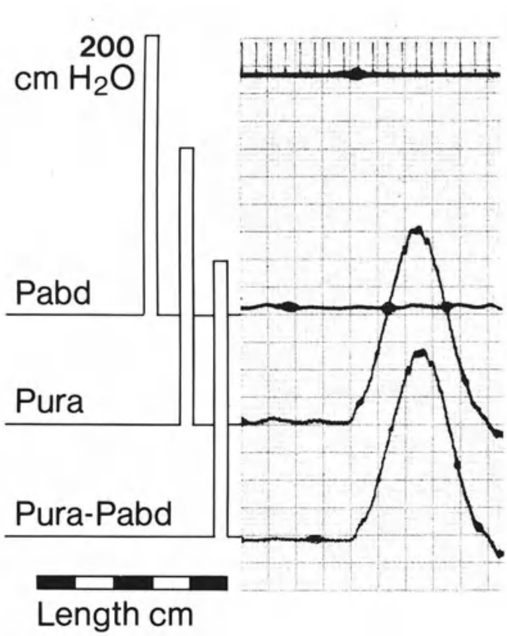


Fig. 3.24. The urethral pressure profile in a normal female.

Classification of Urethral Pressure Profile Abnormalities

Abnormalities may be classified according to the part of the urethra affected and the sex of the patient.

Presphincteric abnormalities are usually seen in male patients with bladder neck or prostatic problems. Commonly, the prostatic plateau may be elevated or elongated. This plateau may be flat (Fig. 3.25) or there may be a prostatic peak (Fig. 3.26). The position of the prostatic peak is variable and can appear anywhere between the bladder neck and the distal urethral sphincter mechanism. The significance of this peak is uncertain. If it is at the region of the bladder neck then it is sometimes due to bladder neck hypertrophy. A bladder neck peak may also occur on penile erection. A peak in the mid-prostatic region may be related to the meeting of the lateral lobes of a hypertrophied gland. Presphincteric abnormalities in the female are usually produced by surgery where an elongation is related to operations which suspend the bladder neck.

Sphincteric abnormalities are confined to the area of the main urethral pressure peak; mid-urethra in the female and just near the prostatic apex in the male. The pressure here is either too low or too high and may be assessed either at rest or during voluntary contractions, as well as in relation to postural and bladder volume changes. Low pressure is related to damage, atrophy or denervation (Fig. 3.27).

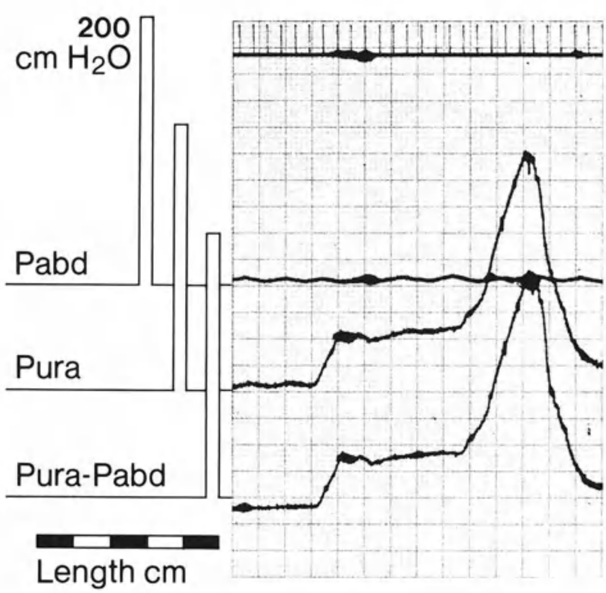


Fig. 3.25. Urethral pressure profiles showing a prostatic plateau and some elongation of the prostatic urethra in a male aged 38.

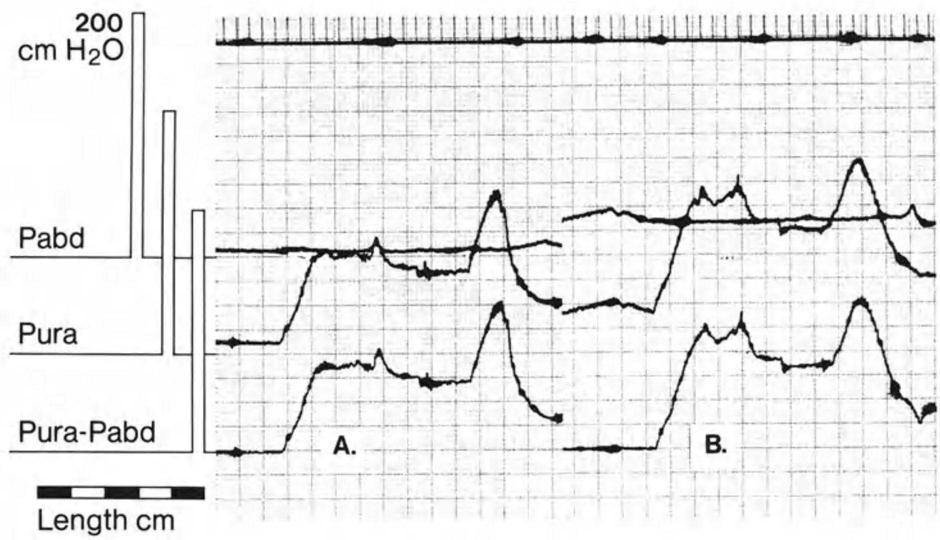


Fig. 3.26. Urethral pressure profile showing a bladder neck and prostatic peak in a man aged 60. These peaks are not so prominent in the supine position (**A**) as they are in the erect position (**B**).

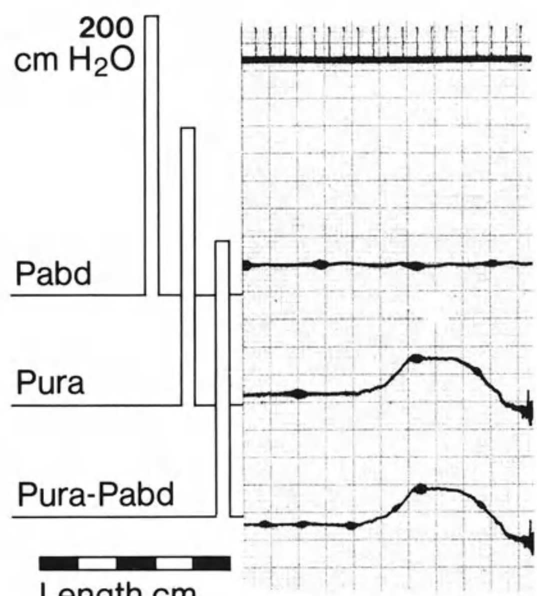


Fig. 3.27. An abnormally low urethral pressure profile in a female aged 84.

An abnormally high pressure is usually related to involuntary sphincter spasticity or sphincter hypertrophy. In the latter case the high pressure is only seen on voluntary contraction when the pressure may reach above 300 cmH_2O and this is most commonly encountered whilst investigating adult enuretics of both sexes with unstable bladders.

Post-sphincteric abnormalities are less common. Rigid urethral strictures are not well demonstrated by the profile technique. Adequate demonstration of a stricture depends on the recording catheter being exactly the same gauge as the stricture, or slightly larger. A small peak, because of meatal stenosis, is not uncommonly seen in females. Occasionally, the urethral pressure from the bulbocavernosus muscle in the male will be greater than that at the region of the distal urethral sphincter mechanism. The significance of this and changes with age and sexual activity have not been investigated.

Urethrocystometry

Synchronous measurement of intravesical pressure and of urethral pressure at one or more points during bladder filling and the initiation of voiding may be termed urethrocystometry (Enhorning 1961; Asmussen and Ulmsten 1975). The technique is similar to the measurement of the urethral closure pressure profile by balloon, perfused catheters or catheter tip transducers. The measuring point is located either at a fixed distance from the bladder neck or at the level of the maximum urethral pressure.

Urethrocystometry is regarded by many investigators as the ideal way to assess the activity of the lower urinary tract. It is particularly relevant in neuropathic bladder disorders and more complex female incontinence. The main disadvantage is that the size of the catheters necessary may lead to obstruction during voiding. Anyone setting up a new service would be well advised to consider becoming equipped for synchronous bladder and urethral pressure studies.

The normal urethral response to bladder filling is an increase in the maximum urethral pressure. This is not always as much as the increase in electromyographic activity would lead one to suspect. Indeed, some workers have shown a decline in pressure in normal subjects (Awad et al. 1978). At the initiation of voiding various changes may occur. The urethral pressure may fall either before or at the same time as the intravesical pressure rises. There may also be a fall in urethral pressure with no increase in intravesical pressure.

Inappropriate responses of the urethral musculature include involuntary relaxation (unstable urethra; see 'Urethral Incompetence', p. 105) sometimes associated with an involuntary bladder contraction, and also failure of the urethra to relax appropriately. Further work is needed to define the relative contributions of smooth and striated muscle elements to these dynamic urethral pressure changes.

Indications for the Measurement of Urethral Pressure

1) Assessment of prostatic obstruction, especially in cases where the volume voided is low and flow rates therefore difficult to interpret.

2) The assessment of postprostatectomy problems.
3) The assessment of genuine stress incontinence in the female with special emphasis on the transmission of pressure to the proximal urethra and the ability of the urethra to react to postural change.
4) The assessment of the adequacy of external sphincterotomy in cases of detrusor sphincter dyssynergia.
5) The analysis of the effects of drugs on the urethra.
6) The analysis of the effects of stimulation on urethral function.
7) The assessment of the adequacy of, and pressure produced by, implanted artificial urethral sphincter devices.

Filling Cystometry

Introduction

This section should be read in conjunction with the discussion on 'Detrusor Function', p. 107. Cystometrograms have been performed for many years using incremental filling and intermittent pressure measurement by water manometer. However, since reliable pressure transducers have been introduced and continuous filling and recording is more feasible, new cystometric patterns have been recognised.

Although cystometry seems to be a simple and well-recognised technique there are a number of areas of controversy. It will be shown later that the understanding of the physiology of bladder filling is very inadequate. In the practical sphere there are problems relating to terminology, to the definition of normality and to the accuracy and repeatability of cystometrograms. The clinical relevance of these filling studies has also been questioned recently. Emphasis has moved away from the assessment of bladder sensation and capacity to the consideration of bladder contractility.

Definitions

Cystometry is the method by which the pressure/volume relationship of the bladder is measured. Zero reference for all pressures is the level of the superior edge of the symphysis pubis.

Intravesical pressure (P_{ves}) is the pressure measured within the bladder. *Abdominal pressure* (P_{abd}) is the pressure surrounding the bladder and this is usually measured as rectal pressure. *Detrusor pressure* (P_{det}) is that proportion of the intravesical pressure produced by active and passive bladder wall properties. Detrusor pressure is calculated by electronically subtracting the abdominal pressure from the intravesical pressure. *Empty resting pressure* is the pressure (intravesical and detrusor) when the bladder volume is zero. *Full resting pressure* is the pressure recorded at maximum cystometric capacity, but in the absence of bladder contraction.

In addition to measuring pressure there are certain defined volumes in cystometry. The volume at the *first desire to void* (FDV) is a rather variable event, not always reported accurately by the patient. The *maximum cystometric capacity* is the volume at which the patient has a normal, strong desire to void. It must be appreciated that the maximum cystometric capacity has little relationship to either functional capacity or structural capacity. The *average functional capacity* was defined earlier (see 'Frequency/Volume Charts', p. 15) as the mean of the volume recorded on the frequency/volume chart. It has been shown that maximum cystometric capacity is only about 60% of the average functional capacity (N. George and P.A. Lewis, unpublished work). *Maximum functional capacity* is the largest volume voided on the frequency/volume chart and this is appreciably greater than the maximum cystometric capacity. The *maximum structural bladder capacity* can only be assessed when the contractility of the bladder is abolished by deep general anaesthesia or by regional anaesthetic block. *Effective cystometric capacity* is the maximum cystometric capacity minus the residual urine.

Compliance indicates the change in volume for a change in pressure. It is defined as $C = \Delta V/\Delta P$ where ΔV is the volume increment and ΔP is the change in pressure associated with this volume increment. It can be calculated for any volume increment, but at maximum cystometric capacity compliance equals that capacity divided by full resting pressure minus empty resting pressure. The concept of compliance is illustrated in Fig. 3.28.

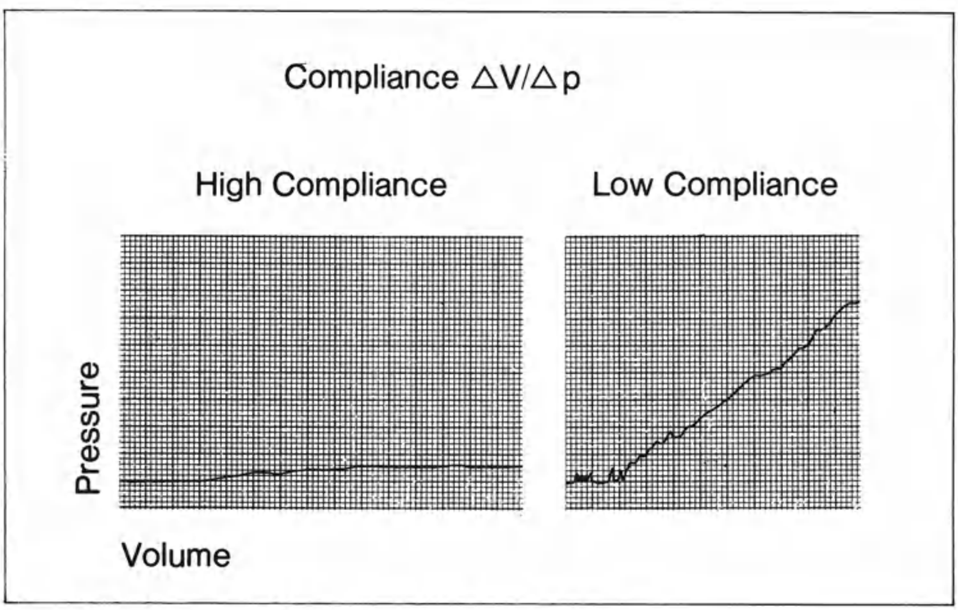


Fig. 3.28. The concept of compliance.

Technique and Equipment

The following points are important in the technique of cystometry and should be specified in any report.

Access for bladder filling and for measurement of bladder and intra-abdominal pressure.
Anaesthesia used for catheterisation.
Types of catheters used for pressure measurement and bladder filling.
Medium used for bladder filling.
Rate of bladder filling.
Temperature of filling agent.
Position of patient during filling and voiding.
Measurement techniques, i.e. type of pressure transducer and recording apparatus.
State of consciousness and medication of the subject.

Access for Measurement of Intravesical Pressure

Catheters may be passed suprapubically (transcutaneously) or transurethrally. In the adult patient the bladder rises to the upper border of the pubis when the bladder volume is approximately 300 ml and only becomes easily palpable in the thin patient when the bladder volume is approximately 500 ml. Therefore the routine use of the suprapubic route may present practical difficulties and can only be used when the bladder is full. The suprapubic route is contra-indicated in the presence of lower abdominal scars which may tether intraperitoneal contents to the lower part of the abdominal wall. It is also impractical in obesity. However, the suprapubic route for intravesical pressure measurement remains the ideal because it avoids the unphysiological effects of a catheter in the urethra and of urethral anaesthesia.

The presence of an intra-urethral catheter during voiding may not only alter neurological control of the bladder, but may also obstruct urinary flow when the urethra is narrow, as in a child. In children, suprapubic catheterisation is technically easier as the bladder tends to be more of an intraperitoneal structure. However, in children it may not be possible to obtain adequate co-operation for suprapubic catheterisation. Should the child require a general anasesthetic then the tube can be introduced at the same time and urodynamic studies performed 1 or 2 days later. As has been implied above it is more convenient, in the urodynamic laboratory with service commitments, to use a narrow transurethral catheter for intravesical pressure measurement.

Anaesthesia for Urethral Catheterisation

In female patients who have a short, straight urethra, local anaesthetic is probably unnecessary, adequate lubrication being all that is needed to ensure patient comfort. Occasionally the urethra may be extremely sensitive and it is better to use local anaesthetic than to upset the patient and risk unusual stimulation of the bladder. Some investigators would agree that male patients also require only adequate lubrication, although it is the current practice of the authors to use a local anaesthetic gel containing an antiseptic agent. It has been shown that such an anaesthetic has no effect on the urethral pressure profile measurements (Edwards et al. 1972). Investigations in our unit have shown that urethral anaesthesia has no effect on measurements recorded during cystometrograms and pressure flow studies, provided that the patient is not obstructed. In the presence of outflow tract obstruction the bladder capacity may be increased, as may the volume of residual urine. Micturition may be difficult to initiate, but once voiding has commenced the values for pressure and flow are not altered by urethral anaesthesia (P.H. Powell, personal communication).

Catheter Types

It is desirable that catheters used for pressure measurement should have the smallest calibre possible if the catheter remains in the urethra during voiding. Larger catheters may obstruct micturition. Von Garrelts (1958) showed that catheters varying between 1.09 mm and 4.9 mm diameter had no effect on intravesical pressure, though larger catheters had an effect on flow rates. However, Bryndorf and Sandøe (1960) showed that intravesical pressure was less when suprapubic recording was used than when a urethral catheter was in place. Gleason et al. (1967) showed that catheters of 5 FG had no effect on flow until the flow was greater than 16 ml/s. At this level of flow, obstruction is unlikely. Backman et al. (1966) showed that a catheter of external diameter 1.55 mm had no effect on either pressure or flow in female subjects.

The catheters should be flexible enough to allow easy passage into the bladder. A catheter that is too soft may curl up in the urethra, particularly in the male and catheters that are too hard may cause urethral trauma. For the measurement of bladder pressure a disposable epidural catheter (Portex) of outside diameter 1.1 mm is recommended. This catheter is very flexible, but can be passed into the bladder by locking it into the eyehole of a 10 FG filling catheter and passing the two catheters together. Once inside the bladder the filling catheter is held fixed and the epidural catheter withdrawn until it is felt to slip out of the eyehole. The epidural catheter can then be advanced well into the bladder. The epidural catheter has convenient markings on the side to show the amount that has been inserted. It is equally satisfactory to use the pressure profile catheter for bladder filling. Incidentally, the presence of an epidural recording catheter in the urethra does not interfere with pressure profile recordings.

A number of catheters have been developed especially for urodynamic studies. The Buzelin 10 FG double lumen catheter (Porges) may be used for bladder filling and pressure recording. The calibre is likely to obstruct the urethra during flow. The Rossier 10 FG catheter (Portex) has a triple lumen for bladder filling, bladder recording and measurement of urethral pressure by the infusion technique. In practice these larger catheters are only useful in circumstances where pressure flow studies are not required, but when repeated investigations are needed such as neurological problems.

Medium Used for Bladder Filling

Water or physiological saline are the most commonly used media in the United Kingdom. Since Merrill (1971) introduced the concept of gas cystometry the use of carbon dioxide as a filling medium has gained in popularity. Water or saline have the obvious advantage that they mimic urine more closely. Carbon dioxide can have no such pretension.

Gas cystometry has been evaluated objectively (Torrens 1977; Wein et al. 1978). CO_2 cystometry underestimates the maximum cystometric capacity when compared with filling with saline by an average 20%. The variability of maximum cystometric capacity on repeated testing with gas infusion is about 30% and pressure on testing on different occasions varies by about the same amount. Bladder overactivity (instability) is quite easy to see on CO_2 infusion, but high CO_2 infusion rates may inhibit instability rather than provoke it. Carbon dioxide causes pain in hypersensitive bladders.

Because CO_2 is compressible the speed and amplitude of pressure registration depends on the volume of CO_2 in the measuring system. To reduce this to a minimum, narrow tubing is essential. A 100-cm disposable manometer tube is an appropriate connecting unit. It is a good idea to have a three-way tap in the system which is turned off except during the test to prevent reflux of urine up the tube. The CO_2 cystometer should be above the patient to reduce the risk of urine damaging the transducer. Because the CO_2 has no weight the transducer need not be level with the patient.

There are therefore various good reasons why gas cystometry should *not* be used:

Gas is an unphysiological medium.

Measurement of capacity is inaccurate because gas is compressible and dissolves in urine.

CO_2 in solution (carbonic acid) is an irritant and may cause inflammation of the mucosa which can be seen on subsequent cystoscopy.

Following gas cystometry no pressure flow analysis of micturition can be made.

Although gas is a negative contrast medium, it is not possible to obtain adequate sychronous video-cystourethrography.

When filling with gas there is no increase in bladder mass during distension. The increase in bladder weight during filling may have some physiological importance.

On the other hand, gas cystometry does have certain advantages which make it suitable for use as a screening test, particularly in an 'office' environment, provided that its limitations are appreciated.

It is quick, simple and free of mess.

No sterilisation is required; the filling catheter and connecting link can be disposable.

Only one catheter is required.

If the patient is catheterised with a full bladder at the beginning of the study an approximate pressure/flow study is possible using the urine already present. A very small calibre catheter is necessary to avoid obstruction.

Movement artifacts from tubing are minimal.

Rate of Bladder Filling

The ICS has defined three categories of filling: slow fill cystometry up to 10 ml per minute, medium fill cystometry between 10 ml and 100 ml per minute, and fast fill cystometry when the rate is greater than 100 ml per minute.

The rate of bladder filling has considerable influence on the resulting measurements. The faster the bladder is filled, the lower the bladder compliance, as defined above. A series of cystometrograms repeated one after the other with a medium or rapid filling rate will show a gradually increasing capacity, the phenomenon of hysteresis. This has been shown not to occur at more physiological rates of filling (Klevmark 1974). The rate of filling that is chosen depends on whether the investigator is attempting to reproduce normal physiological events or provoke the bladder into involuntary contraction whenever possible. Often the filling rate chosen will be a compromise between these two extremes and a convenient rate, which does not prolong the test unduly, is 50–60 ml per minute. In patients with neurological abnormalities and particularly patients with reflex bladders secondary to spinal trauma the bladder should be filled very slowly (less than 10 ml per minute) because faster flow rates may produce artifactual bladder activity (Thomas 1979). This is discussed further in 'Modification of Urodynamic Technique', p. 166.

Temperature of Filling Fluid

Temperature sensation is present in the bladder and if the aim of the investigator is to mimic the physiological situation then the fluid used for bladder filling should be warmed to 37°C. If provocative cystometry is being undertaken this does not matter so much and fluid at room temperature can be used. Occasionally, ice-cold saline is injected as a test of reflex contractility. Except in cases of spinal cord injury this test is seldom used in practice.

Patient Position During Cystometry

It is most convenient to catheterise the patient when he or she is supine. However, the supine position does not reflect the everyday stresses to which the bladder is subject. Many patients complain of bladder symptoms only when they are active. Whether or not it is agreed that fast filling with room temperature fluid is an acceptable technique, it is certainly appropriate to test the patient with normal and changing posture. Investigators who use simultaneous urodynamic and video studies tend to fill the patient's bladder in the supine position and then tilt the x-ray table so that the patient stands to void. When the cystometrogram is performed without synchronous video then it is convenient to fill the patient's bladder whilst the patient is sitting on the commode. The sitting position results in the same increase in intravesical pressure as standing and can be maintained for voiding. This is the natural position for females. Male patients, in our experience, have had no problems voiding in this position. Patients who are severely disabled by neurological disease have to be investigated in the lying position on a couch, or on the x-ray table. Whatever the posture, it is an advantage to have the patient positioned over the flowmeter. This allows the detection and quantitation of urine leakage during bladder filling and testing by stress. It is easier to arrange in the sitting position.

Equipment

The equipment necessary for pressure measurement and recording has already been dealt with (see 'Pressure Measurement and Recording', p. 40). In addition, it is useful to measure the volume infused. This can be done by attaching the bag with the sterile infusion to a strain gauge which measures its weight. Alternatively, an infusion pump can be used which delivers the filling medium at a known rate. The volume infused is then determined from the infusion time. This has the advantage that infusion is constant and does not slow down when the bladder pressure rises. Sometimes, when patients are incontinent it is difficult to know exactly what the bladder volume is. We have used a technique whereby the volume voided is automatically subtracted from the volume infused and the bladder volume thereby calculated (Abrams et al. 1977).

Normal Filling Cystometry

It is appropriate to describe cystometrograms in terms of *capacity*, *compliance*, *contractility* and *sensation*.

The quoted values for maximum cystometric capacity vary considerably. The range of normal in men may be anywhere between 350 and 750 ml and for women rather less, 250–550 ml. As a cystometrogram is such a bad way of measuring bladder capacity there is no great point in putting reliance on the measurement except to show that it falls within the normal range for the unit concerned. The assessment of bladder capacity depends upon when the investigator stops the infusion. If a subsequent pressure/flow study is to be undertaken it is better not to over-distend the bladder. George and Lewis (1978, Personal communication) concluded that the ideal capacity for filling before a pressure/flow study was between 50% and 90% of the average functional capacity. It is our practice to stop infusion at the point when the patient says they would normally be obliged to void.

The pressure change on bladder filling (compliance) is a more relevant observation. The intravesical pressure when the bladder is empty varies according to patient position and factors such as obesity, but it is usually less than 40 cmH_2O. The detrusor pressure is independent of posture and should be less than 10 cmH_20 at zero volume. Most bladders are very compliant (accommodate well), even to fast-fill cystometry. Pressure increases are small; less than 10 cmH_2O at 300 ml and less than 15 cmH_2O at capacity (Fig. 3.29a). However, some bladders do appear to be less compliant (Fig. 3.29b), especially when filled fast. It must be realised that this low compliance may be artifactual (Klevmark 1974). If this situation of relatively low compliance is found during testing then the cystometrogram should be repeated at a slow fill rate or, alternatively, the flow may be stopped and the detrusor pressure observed. If the pressure falls (Figs. 3.29c) then the low compliance is a phenomenon caused by the fast filling. Not enough work has been done on the assessment of compliance during infusion at different rates and it may be that this will prove an additional means of evaluating bladder wall function.

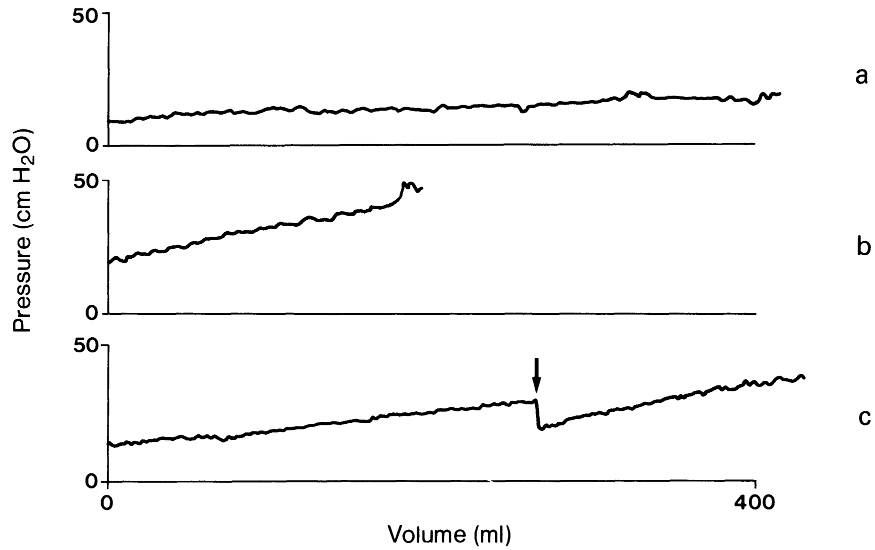


Fig. 3.29a–c. Various responses to filling. **a** Normal cystometrogram. **b** Constantly reduced compliance. **c** Reduced compliance due to fast filling. When infusion is stopped (at the *arrow*) the pressure falls immediately, to increase again when infusion is restarted.

The normal bladder does not contract during the filling phase, but can of course contract on volition. It follows that to categorise a detrusor as normal it must be observed during both the filling and the voiding phases.

Sensation, being subjective, is very difficult to judge. A normal bladder produces little significant sensation of distension until 150 ml and will accept 300 ml or more with no appreciable discomfort or strong desire to void. If sensation is normal there should be distinct discomfort by the time 600 ml capacity is reached.

Classification of Abnormal Filling Cystometrograms

When describing the result of urodynamic investigation the abnormalities should be qualified by the test in question. It is therefore appropriate to refer to an abnormal cystometrogram rather than to an abnormal bladder. In practice, as everyone knows, the distinction becomes blurred. However, it is important to bear this thought in mind when writing urodynamic reports.

Hypersensitive Cystometrogram

As the tracing shows (Fig. 3.30a) the hypersensitive cystometrogram is normal apart from the reduction of maximum cystometric capacity. The patient will not tolerate a greater volume of infusion because of extreme discomfort. The feeling of pain may be referred to the perineum or to the abdomen, but the patient is usually most emphatic about his or her unwillingness to continue the test.

Hypocompliant Cystometrogram

Low compliance is of two types. The pressure rise shown in Fig. 3.30b may be continuous, or it may be more rapid after a period of relatively normal accommodation. It is assumed that these forms of reduced compliance represent

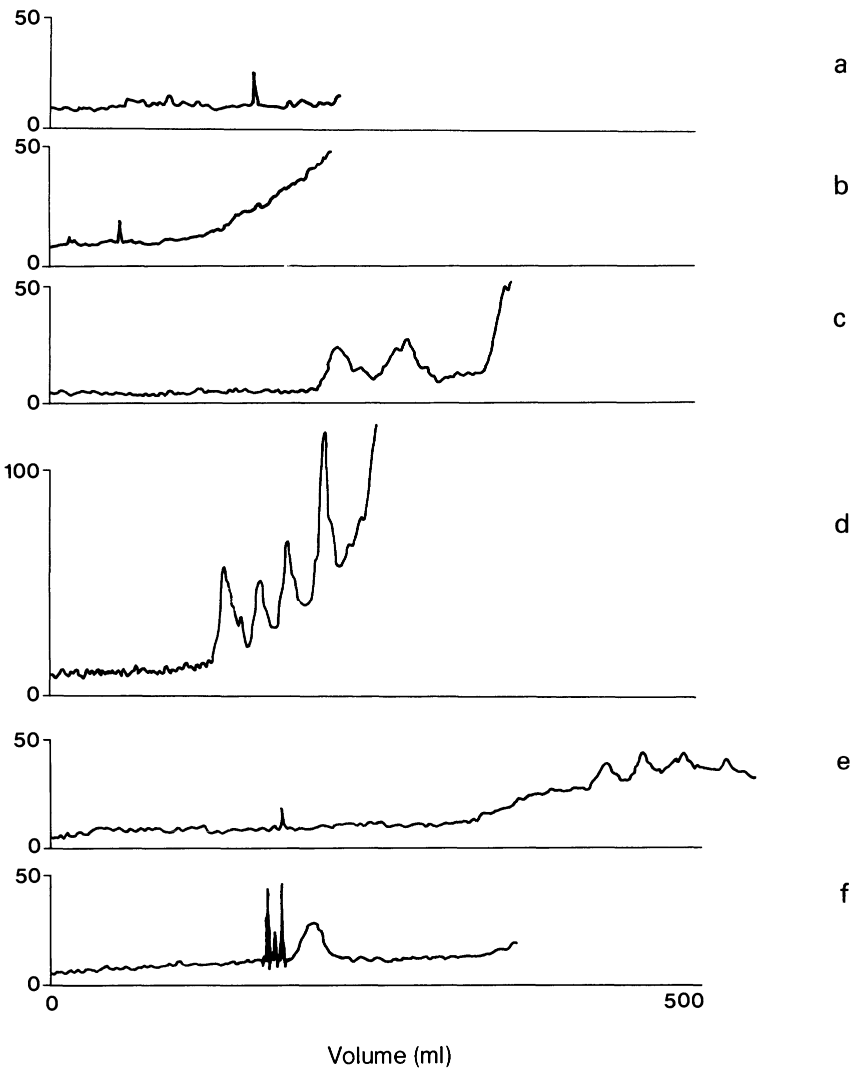


Fig. 3.30a–f. Various types of filling cystometrograms. **a** Hypersensitive cystometrogram. **b** Cystometrogram with decreased compliance in the terminal phase, described by some workers as 'unstable' and by others as 'hypersensitive'. **c** The commonest form of unstable cystometrogram with overactivity occurring as capacity is reached. **d** Unstable cystometrogram with decreased compliance in the overactive phase due usually to muscle hypertrophy. **e** Cystometrogram with an abnormally large capacity and with unstable activity occurring only in the terminal phase, associated often with a neurological deficit. **f** An unstable contraction occurring after stress, in this case coughing.

bladder wall indistensibility, but the understanding of the physical characteristics of the bladder wall which contribute to this picture is by no means complete. The hypocompliant bladder may have a small, normal or large capacity.

Hypercompliant Cystometrogram

This term may be used when a bladder fills normally with regard to pressure, but accepts a capacity above normal limits, i.e. greater than 750 ml. It is not appropriate to describe this as a non-contractile, or underactive, bladder unless it has been shown during the attempted voiding phase that contraction cannot be initiated under any circumstances.

Overactive Bladder

The term most commonly used in the United Kingdom to denote increased contractility during bladder filling is 'instability'. The definition of this and its counterpart 'stable' is discussed further in 'Detrusor Function', p. 109. Unstable contractions on the cystometrogram may be seen with normal or reduced compliance and bladder capacities ranging from small to large. Unstable contractions occurring at low volumes and not re-appearing as the bladder fills may indicate artifactual instability due to the presence of the catheter unless there is an overt neurological problem. In the most frequently occurring type of instability the contractions become more frequent and stronger as the cystometric capacity is approached (Fig. 3.30c). Unstable contractions may or may not be associated with urinary leakage, depending upon the reaction of the urethra. Should leakage occur the event should be marked on the cystometrogram. If the patient is sitting over the flowmeter during the cystometrogram the incontinence will then be noted on the flow rate tracing.

In cases of life-long bladder instability there is often a decrease in the compliance of the bladder wall as filling progresses, producing a high baseline pressure (Fig. 3.30d). We believe that this is associated with bladder wall hypertrophy and therefore indistensibility because of the high pressure of the contractions and the increased detrusor work. There is often associated sphincter hypertrophy as well. Very occasionally, in neurological cases, there is a long period of increased bladder compliance and a high volume results. At the end of this a few unstable contractions may occur (Fig. 3.30e).

To exclude the presence of instability, provocative activities must be employed during the filling cystometrogram. These should mimic the strains that the bladder undergoes in normal life. Coughing (Fig. 3.30f) or change of posture may result in an unstable contraction. Fast filling, low temperature fluid, standing and jumping may also be used. The use of subtracted (P_{det}) recordings is essential under these circumstances. We have described contractions occurring under these circumstances as provoked instability to distinguish them from spontaneous instability.

Examples

Some of the more common cystometrogram types are described above. It is important to recognise that urodynamic results do not fall conveniently into categories and that many of the types can co-exist. This is why it is preferable to describe the observations made at each cystometrogram separately to avoid categorising patients using words that are equivocal in their understanding, and to avoid implying functional correlations on insufficient evidence.

It is emphasised once again that each cystometrogram should be described in terms of *capacity, compliance, contractility* and *sensation.* Each of these may be increased, normal or decreased and for a full evaluation needs to be linked with activity in the voiding phase. Various examples of mixed categories are given in Fig. 3.31.

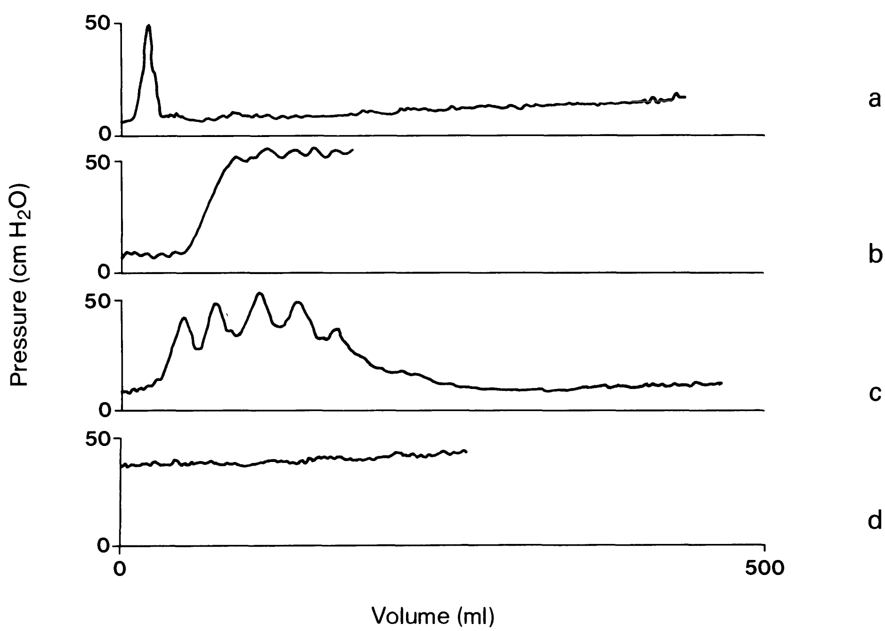


Fig. 3.31 a–d. Cystometrograms that are difficult to classify. **a** Unstable contraction occurring soon after the onset of filling. This is usually considered to be an artifact related to the unusual conditions of the test. **b** Persisting high pressure following an early bladder contraction without incontinence. This is an example of bladder overactivity and is sometimes related to obstruction. **c** A cystometrogram which is overactive in the initial phase and underactive in the terminal phase, again often associated with neurological disorders. **d** A persistently high pressure bladder often associated with stress incontinence and obesity.

Drug Administration During Cystometrograms

It is useful to be able to distinguish between underactivity due to muscle failure and underactivity associated with denervation. This may be possible by using the denervation supersensitivity test. This has been described by Lapides et al. (1962) and Glahn (1970). Some experience of the test and a degree of standardisation is necessary for reliable interpretation. It is appropriate to fill the bladder either with a constant volume or with a volume just below capacity; 0.25 mg carbachol is then injected subcutaneously and the bladder pressure observed for a period of 30 min. A rise in bladder pressure of more than 20 cmH_20 indicates that denervation is likely. Carbachol may be given intramuscularly to speed up the response, but often produces cramping pains in the abdomen. Administration of carbachol is contra-indicated in patients with asthma and hypertension.

Some workers have given anticholinergic drugs as a test in cases of bladder overactivity. There is no proven difference in response between neuropathic and non-neuropathic bladders in this category and therefore the test is of no particular diagnostic use other than confirming that the bladder can respond to the drug in question.

Isotonic Bladder Volume Registration

This form of cystometry has been employed by Sundin et al. (1977). Bladder pressure measurements do not always show when the bladder relaxes. A more accurate way of assessing bladder contraction and relaxation is by measuring the bladder volume under isotonic conditions. The changes in bladder volume are recorded as the weight of a liquid-filled vessel of large cross-sectional area which is placed on an electronic balance at the same height as the patient's bladder. This vessel is connected to the bladder by a large-bore catheter. When the bladder contracts or relaxes there is an exchange of volume between the vessel and the bladder. An increase in weight on the balance indicates a bladder contraction and a decrease in weight, a bladder relaxation. It has been shown to be a very sensitive way of detecting spontaneous, unstable bladder contractions.

A convenient method for performing this test is to place a partly filled 1-litre plastic intravenous fluid bag on a flat plate which rests on a weight transducer type of flowmeter and to connect this bag to the urethral catheter. Do not allow the bag to become full or the recording will be incorrect.

Indications for Filling Cystometry

1. To elucidate the cause for frequency and urgency, especially before surgery on the outflow tract.
2. As part of the evaluation of:
   Incontinence
   Persistent residual urine
   Vesico-ureteric reflux
   Neurological disorders
   Sensory disturbances
   The effect of drugs on bladder function

Pressure/Flow Studies of Voiding

Introduction

The improved electronic equipment that led to the increased acceptance and practice of cystometry was essential in the development of techniques for accurate measurement of intravesical pressure and urine flow rate during voiding. These studies represent a natural progression from urine flow studies. As will be discussed in Chap. 5, urine flow studies can only provide limited information. Flow rate is dependent on the outflow resistance and the contractile properties of the detrusor. A low flow rate may be associated with a high voiding pressure, or with a voiding pressure that is below normal. Similarly, normal flow rates may accompany a high voiding pressure or normal voiding pressure. In the female normal flow may occur despite no increase in intravesical pressure. Pressure/flow studies are essential for a complete functional classification of the lower urinary tract and personal experience of the test allows greatly improved interpretation of isolated urine flow rate tracings.

Definitions

During a pressure/flow study of voiding, intravesical pressure and flow rate are measured continuously. The various terms applied are illustrated in Fig 3.32.

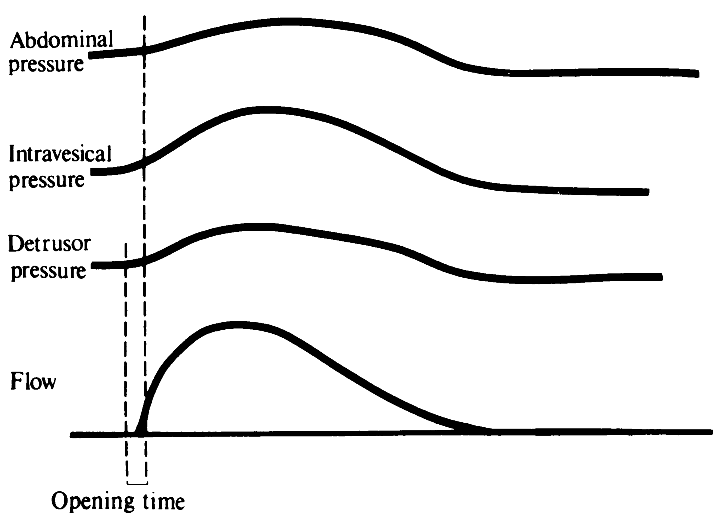


Fig. 3.32. The corresponding tracings of pressures and flow rate during micturition. The order of presentation of curves as shown is recommended (International Continence Society Second Report — Appendix 1).

Opening time is the elapsed time from the initial rise in detrusor pressure to the onset of flow. This is the initial isovolumetric contraction period of micturition. The *premicturition pressure* is the pressure recorded immediately before the initial isovolumetric contraction. It will be the same as the full resting pressure if the patient has not moved following the filling cystometrogram. *Opening pressure* is the pressure recorded at the onset of measured flow. Any delay in the recording of flow because of the passage time of urine to and through the flow meter must be allowed for in interpretation. *Maximum voiding pressure* is the maximum value of the measured pressure. *Pressure at maximum flow* is the pressure recorded at the time of maximum flow rate. Again, any delay in the recording of flow rate must be allowed for. *Contraction pressure at maximum flow* is the difference between the pressure at maximum flow and the premicturition pressure. An *after-contraction* is represented by a pressure increase after flow ceases at the end of micturition. The significance of this event is not understood.

The bladder and urethra have independent functional properties and in combination these characteristics determine the *pressure/flow relationships of micturition*. By knowing both factors and relating them to the normal values of each it is possible to ascertain whether voiding function itself is normal. This can be done more accurately than from either measurement alone.

To formalise the relationship of pressure and flow, various *urethral resistance factors* have been elaborated. The commonest relates intravesical pressure to the square of flow at maximum flow. This expresses minimal resistance ($Rmin = P_{ves}/Qmax^2$). This derivation depends on the hydrodynamic laws of flow through rigid tubes. The urethra is both irregular and distensible. Furthermore, in the same way that flow depends upon the volume voided, so also does the minimal resistance. For a while we recorded the resistance factor directly by using an analogue computation unit and writing out the resistance graphically on the chart recorder. The shape of the resistance curve is quite characteristic (Fig. 3.33). However, it is not easy to produce a nomogram of normal and abnormal resistance factors. The practical considerations have been discussed by Gierup (1970).

The ICS has recommended that pressure/flow data should be presented graphically by plotting one against the other (Fig. 3.34). We would agree with this view and would emphasise the importance of studying the characteristics of the pressure and flow tracings rather than reducing the information to a single index. Nevertheless, urethral resistance is an important concept. For voided volumes between 200 ml and 400 ml, and using intravesical pressure, the highest acceptable value for urethral resistance in men is 0.6 and in women, 0.2 ($Rmin = P_{ves}/Qmax^2$). The values for pressure and flow in normal subjects are summarised in Table 3.4.

Technique and Equipment

Techniques and equipment used in pressure/flow studies are essentially the same as those used for inflow cystometry and urine flow studies. Several additional points are important in order that accurate tests may be performed.

The investigation environment is particularly significant during voiding. In centres where urodynamic studies are performed simultaneously with video-cystourethrography it is found that up to 30% of female patients and a smaller percentage of male patients cannot void on command. Every effort should be made to maximize the patient's feelings of privacy. Many women find voiding in the standing position difficult and undignified. It is possible to modify the x-ray apparatus to allow the sitting position. By using increased density of contrast in the bladder a lateral visualisation in the sitting position is possible. This is not only better for the patient, but also gives more information about bladder neck anatomy than an antero-posterior or oblique view.

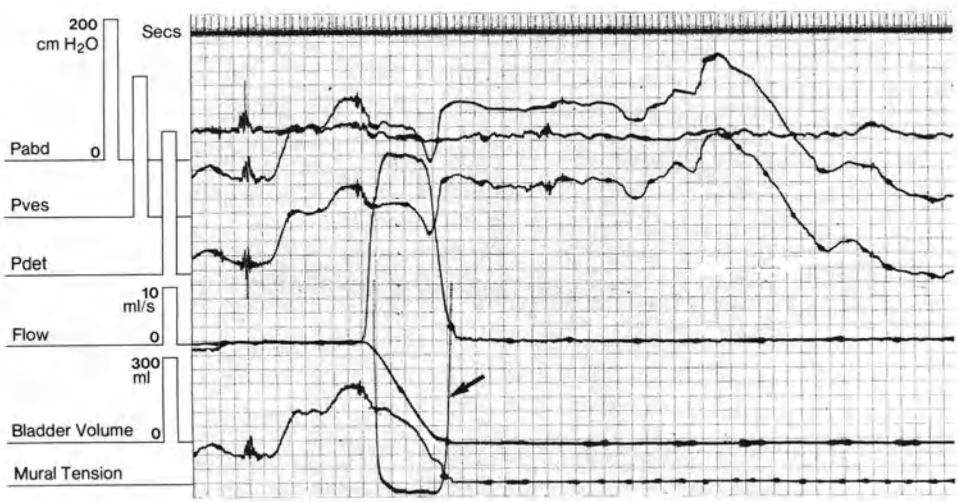


Fig. 3.33. A pressure flow study of micturition showing the plotting out of a resistance tracing (*arrow*). This is a patient with bladder overactivity, supranormal flow rate and a with very low resistance.

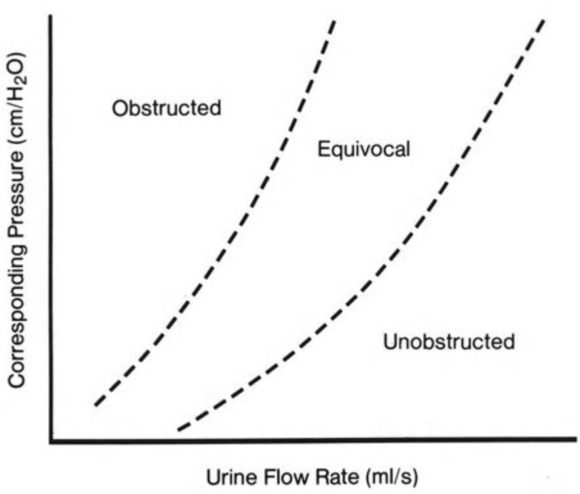


Fig. 3.34. Pressure/flow relationships. The exact position and width of the equivocal zone will depend on many factors especially age, sex and urinary volume voided.

It is useful to test the effect of interruption of micturition. Virtually all men and many women can interrupt the stream suddenly by closing the urethral sphincteric mechanism. Some women can only inhibit the detrusor; this takes place over several seconds. If the patient can close the urethra voluntarily, or indeed if the urethra is manually occluded, the detrusor contraction becomes isovolumetric as it continues (Fig. 3.35). The detrusor pressure increases to a maximum ($P_{det}iso$), and this represents the power of the detrusor muscle. This is of research interest, for example, in the assessment of the response of the detrusor to an obstructing lesion. In addition there are certain instances where it is of practical value. The most important of these is in the assessment of detrusor power prior to stress incontinence surgery. Operations designed to suspend or elevate the bladder neck increase bladder outflow resistance and give rise to voiding difficulties in some patients. It is now accepted that those patients with a small isometric rise on interruption of voiding may have problems with voiding after surgery. These cases in which the test is important may be exactly those in which the patient cannot interrupt her own stream. Under these circumstances some mechanical form of interruption is appropriate.

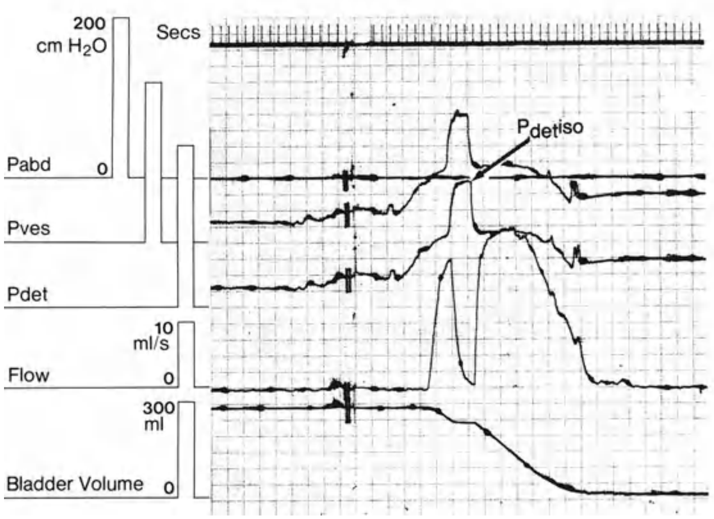


Fig. 3.35. A pressure/flow study of interrupted micturition showing the isovolumetric pressure increase generated by a normal bladder on cessation of flow. In this case the pressure increase is 66 cmH_2O.

Normal Values

Relatively few pressure/flow studies have been performed on normal people, but those series that do exist show results that are quite closely comparable. The normal values, separated by sex, are shown in Table 3.4.

Table 3.4. Pressure and flow during micturition in normal subjects under the age of 45 years

	Mean intravesical pressure at maximum flow (cmH_2O)		Mean maximum flow rate (ml/s)	
	Male	Female	Male	Female
von Garrelts (1958)	78	57	23	28
Arbuckle and Paquin (1963)	–	55	–	21
Smith (1968)	76	64	19	24
Frimodt-Møller and Hald (1972)	71	55	20	25

The definition of normality in girls and women is somewhat easier than in men. This is because there is less dependence of urodynamic parameters on age. In normal men the prostate gland grows steadily throughout the middle years of life and may become hypertrophied in old age. The growth of the prostate gland, with the consequent increase in urethral resistance, leads to progressively lower maximum urine flow rate and higher voiding pressures. The definition of normality becomes somewhat arbitrary.

A normal pressure/flow study is shown in Fig. 3.36. Various features of nomenclature are noted in the legend to this figure. We have not discussed the normal values of opening pressure as their clinical significance is unclear. More

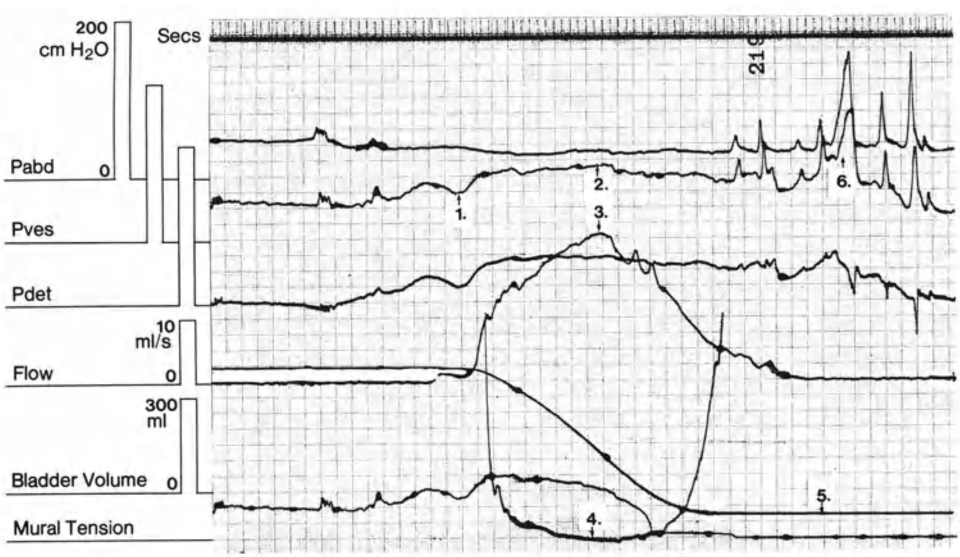


Fig. 3.36. A normal pressure flow study of micturition. *1*, Intravesical opening pressure. *2*, Intravesical pressure at maximum flow, in this case the same as maximum intravesical pressure (92 cmH_2O). *3*, Maximum urine flow rate (23 ml/s). *4*, Urethral resistance at maximum urine flow. *5*, Urinary volume voided (480 ml). This is greater than the volume infused because of urine secretion during the cystometrogram. *6*, Voluntary straining at the end of micturition.

interest centres on the assessment of bladder contractility by measuring the isometric pressure generated on interruption of the urinary stream ($P_{det}iso$), as discussed above. The derivation of this is discussed by Griffiths (1980), who puts the normal range between 50 and 100 cmH_20 in adults of both sexes. Following micturition, residual urine should be negligible. The presence of an after-contraction (Fig. 3.37) is of uncertain significance. There is no evidence to show that it is abnormal.

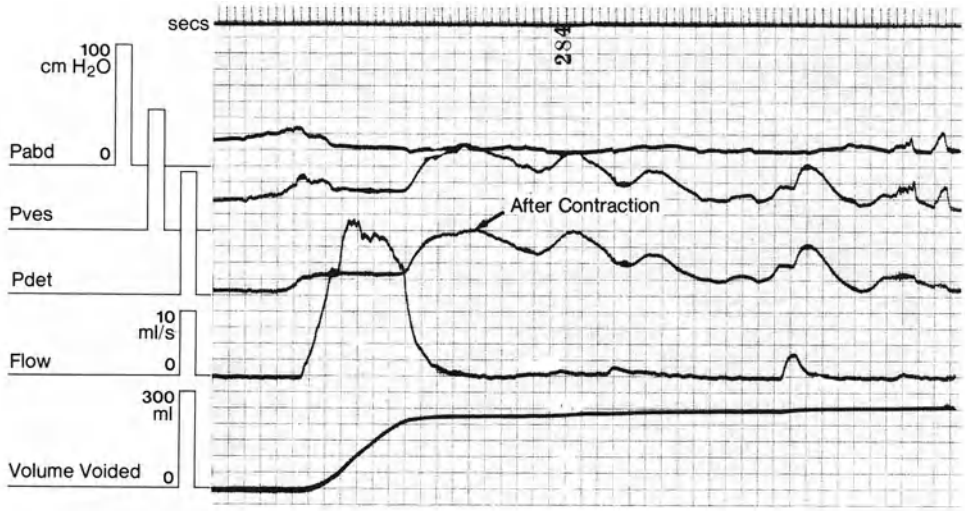


Fig. 3.37. Pressure/flow study of micturition demonstrating the phenomenon known as an after-contraction. This is sometimes associated with detrusor overactivity but has not been shown to be abnormal.

Abnormal Pressure/Flow Patterns

Abnormal pressure/flow studies may most easily be discussed in terms of the flow rate patterns seen on voiding. This section should be read in conjunction with the relevant discussion of flow rate (see 'Classification of Abnormal Urine Flow Patterns', p. 36).

Normal Urine Flow Rates

Normal flow rates are most usually produced by a normal detrusor contraction emptying the bladder through a normal urethra. However, normal flow may also occur when a powerful detrusor contracts against an obstructed urethra. Also, and most commonly in women, normal flow may occur in the apparent absence of a detrusor contraction. Under the latter circumstances the detrusor may be proved to be contracting by measuring the isometric pressure on interruption of flow (Fig. 3.35).

Low Urine Flow Rate

Low flow most commonly indicates bladder outflow obstruction in male patients (Fig. 3.38), though this is not necessarily so in female patients. The finding of a high or normal detrusor pressure with a low flow rate would indicate outflow obstruction. However a low flow rate associated with a low detrusor voiding pressure may not indicate obstruction, but rather an abnormality of detrusor contractility. In cases with outflow tract obstruction the detrusor pressure may not be very well sustained. The pressure, and consequently the flow, fall off gradually during micturition and maybe this is related to a failing detrusor muscle. It has been observed that the isometric pressure generated ($P_{det}iso$) may also fall off at the end of micturition and this is further evidence for the inadequacy of muscle contraction. An unsustained contraction is likely to lead to a residual urine.

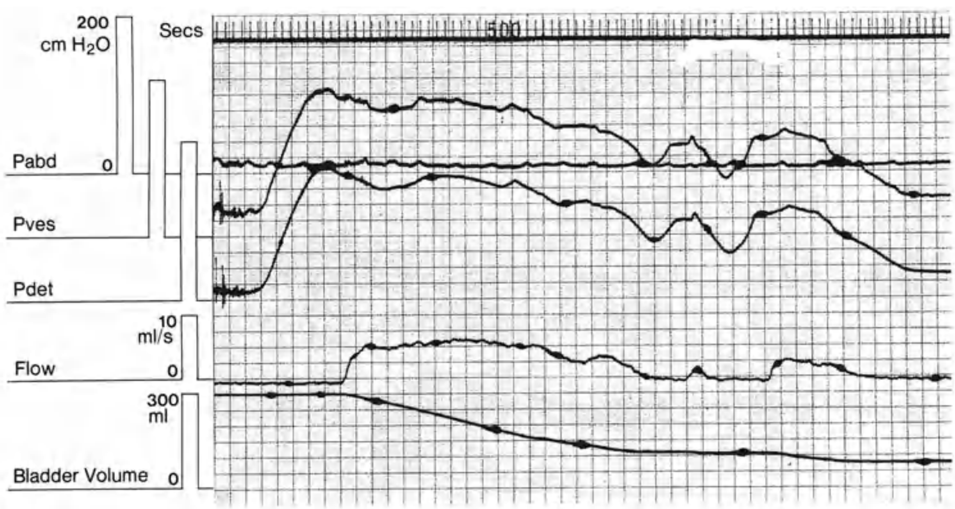


Fig. 3.38. A pressure/flow study in a male aged 62 with outflow tract obstruction.

High Urine Flow Rate

In both men and women high flow rates in excess of 40 ml/s may be associated with exceptionally powerful detrusor contraction with higher than normal voiding pressure. This is seen most often in patients with long-standing bladder overactivity and detrusor hypertrophy, but no outflow obstruction.

Pressure/Flow Patterns Associated with Bladder Instability

In patients with instability the bladder is often contracting before the patient is ready to void. The contraction is isometric, but usually pulls open the bladder neck, continence being maintained by the distal urethral sphincteric mechanism. If the patient can remain continent until he or she is ready to void, the flow will start immediately the urethra is voluntarily relaxed. The detrusor may already be contracting at maximum force and therefore maximum flow rate is achieved almost immediately. The detrusor pressure usually falls as flow commences (Fig. 3.39).

Irregular Micturition

As discussed earlier (see 'Classification of Abnormal Urine Flow Patterns', p. 36) an interrupted stream is usually associated with abdominal straining, intermittent detrusor contraction or detrusor/urethral dyssynergia.

Abdominal Straining

Patients may strain during voiding for several reasons: because of poor detrusor contraction, as a habit, and as a reaction to the strange circumstances of the investigation. Patients should always be requested to void 'naturally' during pressure/flow studies and not to assist voiding by straining. However, abdominal straining during voiding is easily detected on the abdominal pressure trace (Fig. 3.40). In females a normal or supranormal flow rate can be achieved by straining, provided that the urethra relaxes normally. Indeed the void by strain may not be abnormal in women. In men, however, the situation is almost always abnormal and will be associated with a low urine flow rate.

Fluctuating Detrusor Contraction

Detrusor contraction may fluctuate and this results in an interrupted or irregular flow trace (Fig. 3.41). This situation occurs most often in neurologically abnormal patients, particularly those with multiple sclerosis. It can also occur with non-neuropathic outflow tract obstruction. These changes in flow rate tend to be less rapid than are those associated with straining or detrusor/urethral dyssynergia. The abdominal pressure trace should show no change in pressure.

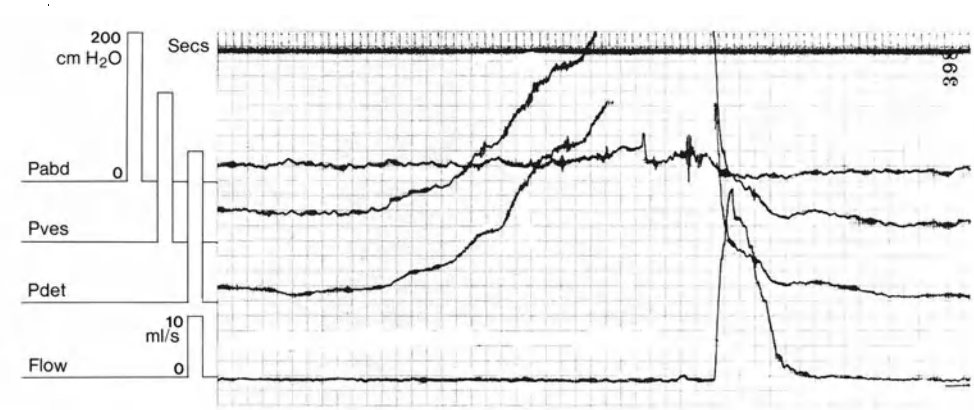


Fig. 3.39. A pressure/flow study in a case of bladder instability in a male aged 28. Involuntary contraction of the bladder is producing a pressure of more than 260 cmH_2O; this pressure falls suddenly as soon as flow starts. The voided volume on this occasion was only 150 ml; the flow rate being achieved was 33 ml/s.

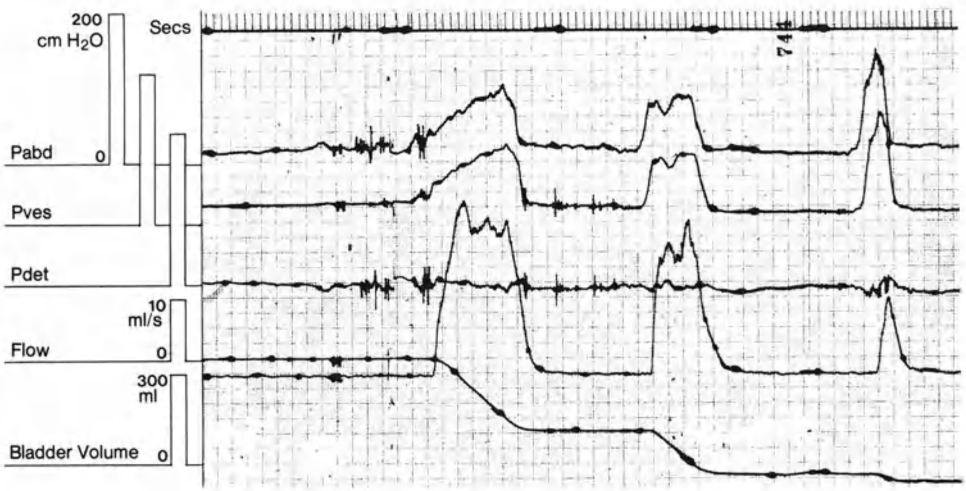


Fig. 3.40. Pressure/flow study in a female patient voiding only by straining. There is no intrinsic detrusor activity whatsoever.

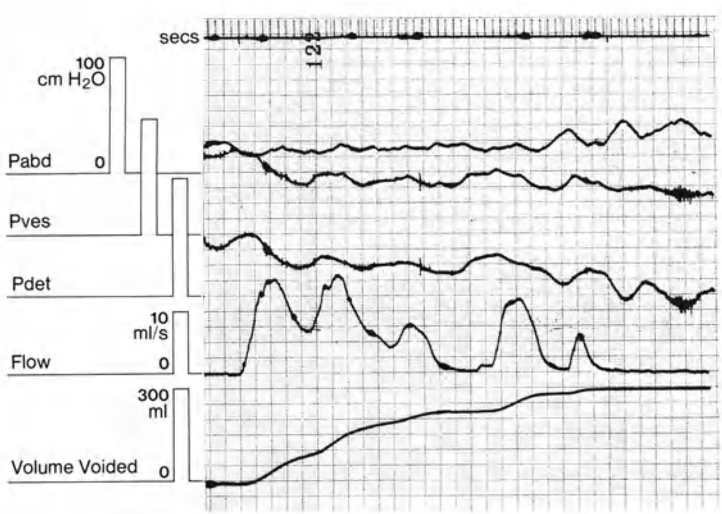


Fig. 3.41. A pressure/flow study demonstrating a fluctuating detrusor contraction and a correspondingly variable flow rate. The detrusor appears to be overactive and the premicturition pressure is high; nevertheless the pressure is inadequately sustained during voiding.

Detrusor/Urethral Dyssynergia

This concept is discussed and defined in a later section (see 'Urethral Overactivity and Obstruction', p. 105). The commonest variety occurs between the detrusor and the striated muscle of the urethral sphincter. This is termed detrusor/sphincter dyssynergia. It is seen most commonly in the neurologically abnormal patient with an upper motor neuron lesion, but is also seen in patients who appear to be neurologically intact. Instead of relaxing, the urethral sphincteric mechanism remains closed or closes irregularly during detrusor contraction. This produces a flow trace showing rapid rates of change occurring as the sphincter opens and closes (Fig. 3.42a). Alternatively there may be a sustained elevation in bladder pressure with urine flow occurring only when the sphincter relaxes (Fig. 3.42b). Sometimes the urinary flow cannot be initiated despite a high bladder pressure. This occurs particularly in high complete spinal cord lesions (Fig. 3.42c). The sphincter may remain contracted for many minutes at a time.

Indications for Pressure/Flow Studies

1. The identification of obstruction in cases where flow rate alone is equivocal.
2. The assessment of detrusor contractility. A detrusor cannot be defined as normal on the basis of a filling cystometrogram. The distinction between outflow obstruction and an underactive detrusor cannot be made on the basis of flow rate alone.

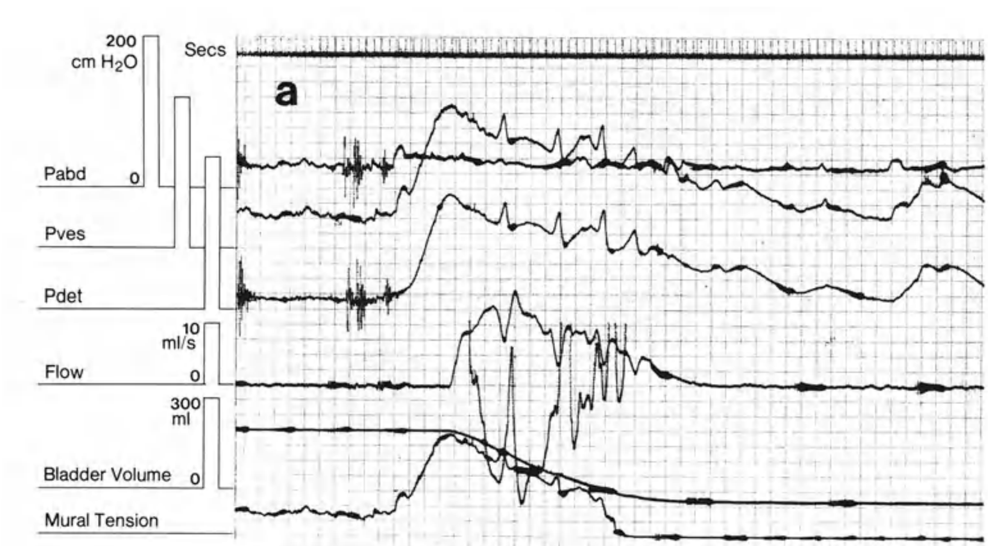
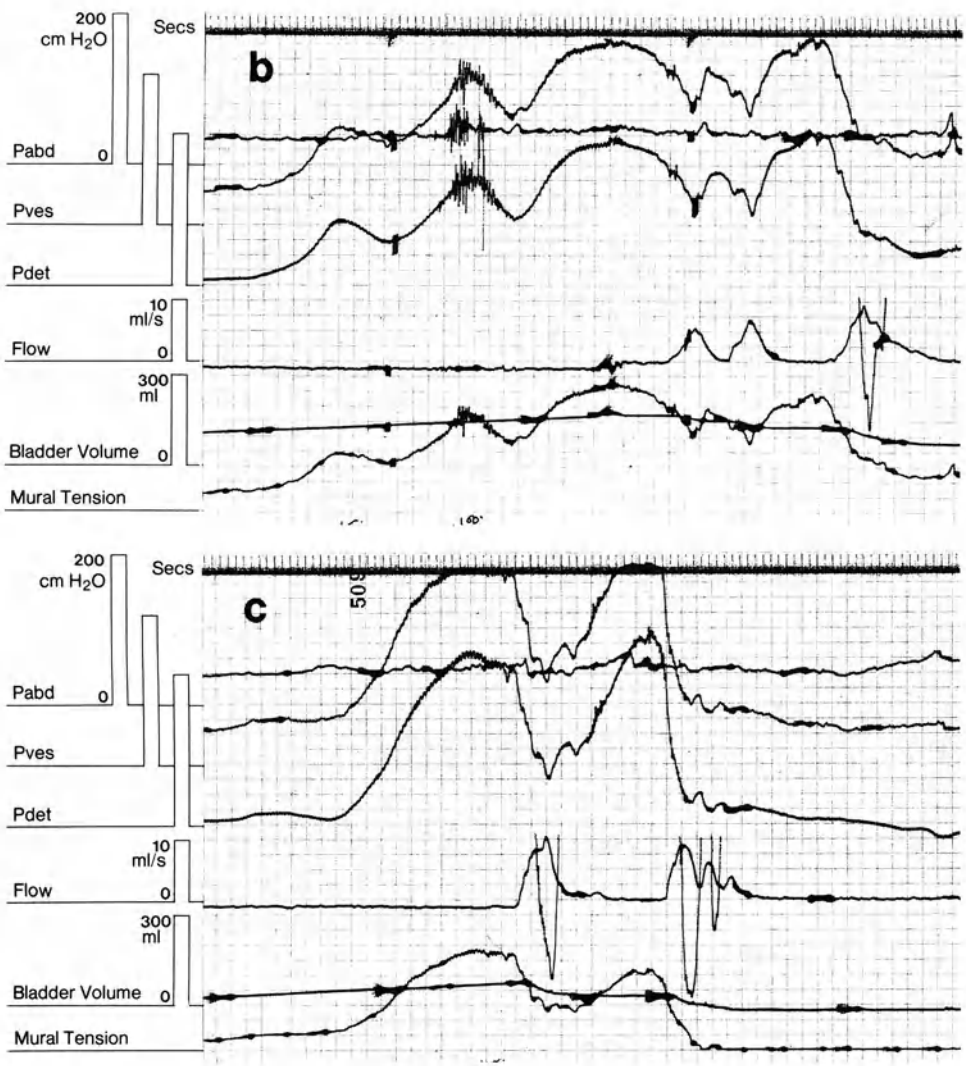


Fig. 3.42. Various examples of detrusor/sphincter dyssyneria. **a** A mild form showing rapid fluctuations in urine flow rate, and resistance, at times of sphincter closure. Each decrease in urine flow is accompanied by an increase in isometric detrusor pressure. **b** Sustained elevation of detrusor pressure. Urine flow occurs only occasionally when the sphincter relaxes. **c** Despite a very high detrusor pressure urine flow is not established for sometime.



Synchronous Uro-video-cystourethrography

The advent of cinefluoroscopy of the bladder in the early 1950s was a major stimulus to the development of a more functional view of lower urinary tract disorders. In the early 1960s pressure studies were synchronised with video-cystograms (Enhorning et al. 1964), providing further information, and this technique has been developed in certain larger urodynamic centres over the last decade. Some investigators regard these synchronised studies as the single most helpful means of functional assessment. Others, notably ourselves, have argued that almost all the information can be derived from urodynamic tests alone, combined with a non-synchronous video-cystourethrogram when necessary. In this section we hope to place this argument in a proper perspective.

Equipment

The technique of video-cystourethrography (VCUG) is universal and the appropriate urodynamic methods have been described above. The synchronisation of recording and display is achieved by various methods which are similar in principle — the urodynamic tracings need to be visualised in an interpretable form on the television screen, together with the image of the bladder. There are three main ways by which this can be achieved (Fig. 3.43).

The *first* method uses a closed-circuit television camera to view the output either of the polygraph or, preferably, of a 'memory' oscillosope. The latter gives better contrast to the tracings. The image from this camera is mixed with that from the image intensifier and displayed on a single monitor (Fig. 3.44). The two cameras must be compatible and synchronised. The advantage of this system is its relatively low cost, but the video images may not be very clear.

The *second* alternative is a purpose-made analogue-to-video converter (Fig. 3.45). This can be designed and built on a one-off basis or obtained commercially. A digital output is an advantage and allows the display of a longer section of the investigation on the screen by slowing down the tracings. A dedicated, purpose-built system is the easiest to operate and gives the best image, but it is expensive commercially.

The *third* possibility is the use of a small computer, available now at a competitive price. The system must include an analogue-to-digital converter. This method involves the generation of appropriate software, but allows the computer

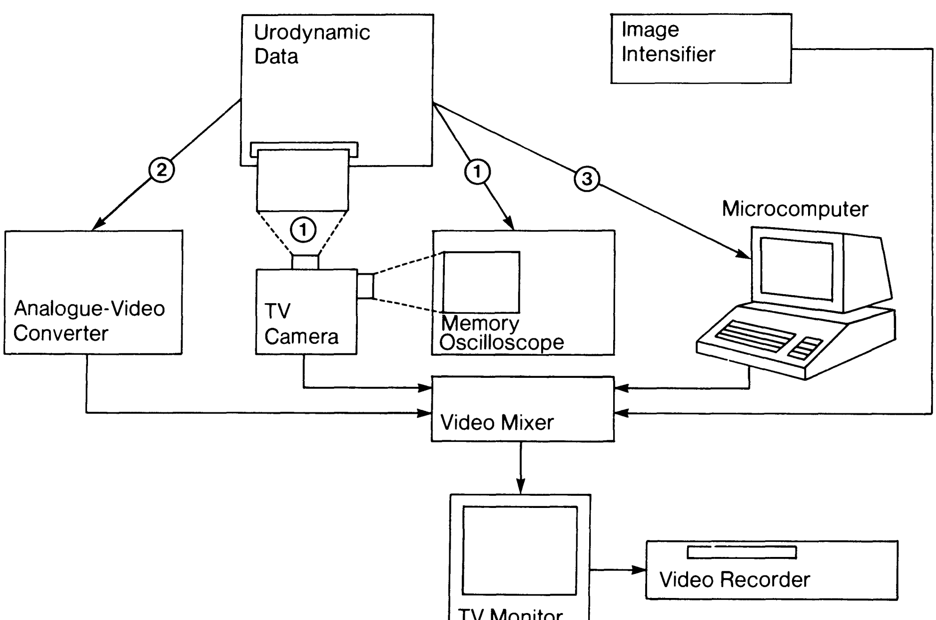


Fig. 3.43. Three of the methods whereby analogue and video information can be mixed. See text for details.

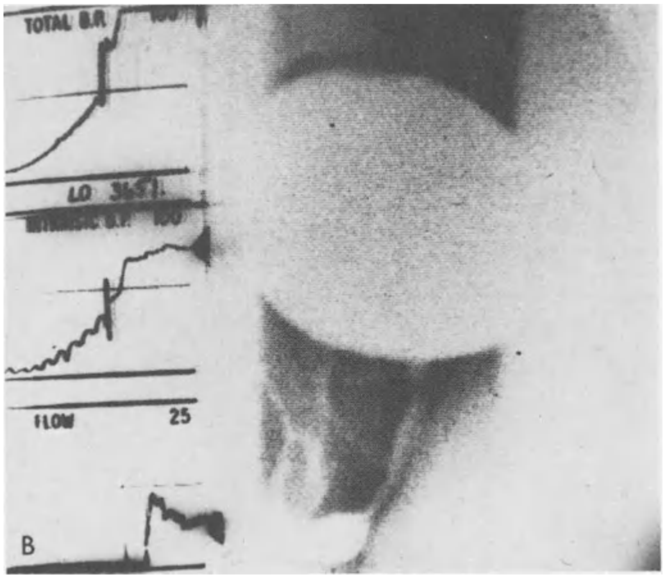


Fig. 3.44. Synchronous uro-video-cystourethrography using a split screen system and a television which views the output of the chart recorder. (Whiteside and Bates 1979).

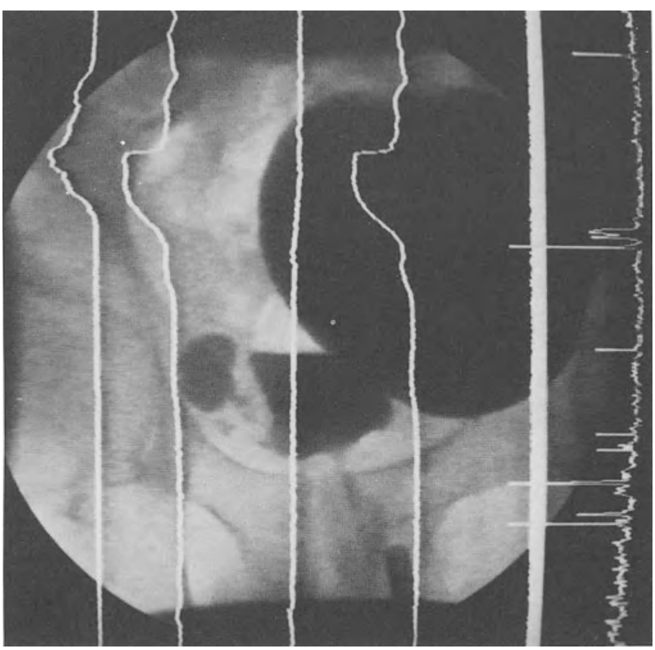


Fig. 3.45. Synchronous uro-video-cystourethrography using an analogue to video converter with a digital output. The X-ray shows a bladder with one large and one small diverticulum. The urodynamic traces (from right to left) are flow, vesical pressure, abdominal pressure, detrusor pressure, a blank trace and on the right the integrated EMG. On attempting to void there is a slight elevation of detrusor pressure for a considerable time while the diverticulum fills up. Only then can the pressure rise further, the bladder neck opens and the flow starts.

to be used for analysis of urodynamic results. This system is more complicated, but much more versatile. The price would be comparable with that of a commercial analogue-to-video converter, but a medical physicist is likely to be required to run the system.

Modifications of urodynamic methods

Certain changes in urodynamic technique are necessary to accommodate to the radiological environment. The first is that the contrast medium used for visualising the bladder is of a different density to urine. This means that adjustments may have to be made to the flowmeter which would otherwise record an artifactually high reading because of the greater weight of the voided fluid.

If it is necessary for women to void in the standing position a specially shaped funnel system needs to be used to collect the voided urine and pass it on to the flowmeter. This may delay further the registration of the flow tracing on the polygraph, relative to the pressure. However, as long as this potential problem is recognised it is unlikely to cause any practical difficulties.

Modifications of X-Ray Technique

If the patient is to void in the sitting position some further modification of technique may be required. The simplest way to provide a radiotranslucent commode seat is to construct a thick foam cushion, cut to the shape of a toilet seat, and cover it with a hygienic material. Certain x-ray manufacturers have this equipment available.

It is useful to be able to visualise the bladder neck in the straight lateral projection. This may mean an increase in the radiation exposure, but is facilitated by the use of special high-density contrast (260 mg I/ml). Such constrast has a higher density and viscosity, though this is less significant if the contrast is heated to 38°C. The effect on flow is not as great as might be expected because the flow is less turbulent.

Normal Results

Certain of the observations appropriate to VCUG have been noted earlier (see 'Video-cystourethrography', p. 26). Here the considerations relevant to synchronous uro-video studies will be discussed, stating how the urodynamic measurements amplify the x-ray interpretation.

The normal sequence of events on voiding is as follows:

1. Bladder base descent
   Urethral pressure decrease
   Reduced sphincter EMG activity

2. Bladder neck opening
   Detrusor pressure increase
   EMG silent
3. Flow in progress
   Detrusor pressure maximal
   EMG silent
4. Urethral pressure increases
   Flow ends, no residual urine
   Detrusor pressure usually decreases, but may increase (after contraction)
   EMG transiently increases

If urine flow is voluntarily interrupted in 'mid stream' the cut off starts at the level of the distal urethral sphincter mechanism. The proximal part of the stream is milked back into the bladder and the bladder base is elevated. When the pelvic floor and urethral sphincter are strong, which often happens with bladder overactivity, as noted above, this bladder base elevation may appear quite forceful and has been described as a 'kick'. Under these circumstances the isometric detrusor pressure usually reaches a high level.

Abnormal Results

There is no satisfactory way of measuring the function of the bladder neck during micturition. Apart from electromyographic analysis of striated peri-urethral muscle, the same reservation applies to the rest of the urethra. At present, intra-urethral pressure measuring devices are large enough to produce an element of obstruction. It follows that the major indications for synchronous uro-video studies are in cases of bladder neck or urethral dysfunction.

The bladder neck should remain closed until the subject voluntarily initiates micturition. If it is seen to open either spontaneously or during stress or postural change, this is abnormal. Such an opening may be due to intrinsic incompetence of the bladder neck or because the bladder neck is being opened actively in association with a detrusor contraction. Without measuring detrusor pressure it may be impossible to distinguish between these causes.

Equally, the bladder neck should open adequately during voiding. If it is seen to remain closed this may be because the detrusor is not contracting strongly enough (low P_{det}) or because the bladder neck itself is failing to relax and so producing obstruction (high P_{det}). Again, detrusor pressure must be measured to distinguish the cause. The latter situation is bladder neck obstruction or, preferably, detrusor/bladder neck dyssynergia. A clue to its existence is the presence of 'trapping' of contrast in the posterior urethra, proximal to the distal urethral sphincter mechanism, due to failure of retrograde emptying of the urethra.

A common urethral problem occurs in overactive bladders in both sexes. This is characterised by a constriction at the level of the distal urethral sphincter mechanism, proximal to which the posterior urethra is distended by the force of the detrusor pressure. This subvesical distension emphasises the bladder neck which appears as a bar or ring on x-rays or endoscopy. This situation can arise in two ways. The high-pressure overactive detrusor may be associated, in neuropathic states, with a hyperactive distal sphincter which is dyssynergic and obstructive (see

'Urethral Overactivity and Obstruction', p. 105). Alternatively, it may be associated with voluntary hypertrophy of the distal sphincter which is not obstructive but is needed to maintain continence after the bladder neck has been opened by the detrusor contraction. Pressure/flow studies are needed to decide whether obstruction actually exists.

We have suggested above how urodynamics may amplify video studies. The converse occurs when urodynamics show outflow tract obstruction and the site of this cannot be localised. Radiology during voiding is the easiest way to assess this and may be indicated in any type of urethral obstruction, including dyssynergic states, prostatic obstruction, strictures and urethral valves. When the patient has a uniform and repeatable voiding pattern the majority of the necessary information can be obtained from studies that are not synchronised. However, synchronisation does have other advantages, outlined below, which may make it convenient.

The Choice of Investigation

Urodynamic testing and VCUG therefore complement one another. The advantages and disadvantages of synchronisation of these studies are tabulated below.

Advantages

1. Combined studies offer the most comprehensive means of assessment. Radiology is the best way to localise urethral obstruction.
2. Videotape recording improves case review sessions. Teaching promotes a greater interest and understanding of urodynamics over a wider area. It allows clinicians to relate the measurements to familiar structural and radiological entities.
3. Sound recording on the tape adds another dimension to assessment as well as allowing more spontaneous recording of incidental observations.
4. The tilting radiological table facilitates the assessment of the effects of postural change on the behaviour of the bladder and urethra.

Disadvantages

1. Not all patients need radiology and some may get unnecessary x-ray exposure. Clinicians may not select out those that do not need x-rays.
2. Expensive urodynamic equipment may be lying idle in the x-ray department for 4 days a week unless part of it can be made portable.
3. The unnatural environment for voiding leads to psychological suppression of micturition in some cases. Women especially dislike voiding when standing.
4. The busy atmosphere of a radiology department may mean there is less time for the clinician to spend with the patient in history taking and discussion. We have found that the overall benefit of assessment depends very much on the time allowed to understand the patient's problem and to set the patient at ease.

Many of the disadvantages can be avoided with appropriate organisation. In the end, the value of the investigation depends not so much on the technique or the equipment, but on the presence of an experienced enthusiast. There can be no substitute for this and it is important that such a person with clinical insight into the particular patient's problem should be present at the investigation. Bearing in mind how infrequently the patient's consultant can attend a radiology investigation, it is fair to comment that synchronised studies recorded on videotape provide the maximum amount of information for consultant review at a later date.

Indications for Synchronous Uro-video-cystourethrography

1. Atypical outflow tract obstruction:
   Neuropathic bladders
   Children (avoids repeating investigations)
   Bladder neck dysfunction
   Distal urethral obstruction
2. Complicated female incontinence:
   Failed repair operations
   Voiding difficulties
   Symptomatic stress incontinence that cannot be demonstrated clinically
3. Neurological problems (better than sphincter EMG)
4. Anything that cannot be explained easily on simple urodynamic assessment.

Electromyography

All muscles produce an electrical potential when contracting, but only striated muscle activity can be measured easily in the lower urinary tract.

Technique

Two electrodes are required with a third independent 'ground' electrode, usually on the thigh. Recording may be either from a surface or by needle electrodes within the muscle.

Surface electrodes need to be adjacent to the muscle studied. Skin pickup has not been effective in the perineum. Anal sphincter recording can be made from electrodes mounted on an anal plug and urethral recordings from a catheter electrode. The recorded potential represents the local mass contraction. The presence of an anal plug could, in theory, modify function in the lower urinary tract. It is also argued that the anal sphincter does not always act synchronously with the urethral sphincter (Vereecken and Verduyn 1970), though this is usually a minor variation in timing except in certain neuropathic states.

When urethral sphincter activity is recorded from two ring electrodes mounted on a urethral catheter, the same catheter can be used to record urethral pressure. Care must be taken to avoid movement artifacts due to a change in catheter position. Catheter movement may stimulate sphincter contraction.

Needle electrode insertion is only slightly uncomfortable to the patient, but adds to the unnatural circumstances of the investigation. The needles are usually concentric electrodes inserted blind, but guided by a finger in the rectum or vagina when the urethral sphincter is sought (see below). The position is adjusted to obtain a good recording which is represented by an appropriate sound on a loudspeaker. While the anal sphincter can be sampled accurately it is likely that an approach to the urethral sphincter ends up in the peri-urethral striated muscle of the pelvic floor (see 'Anatomy and Innervation', p. 99). The potentials picked up by needle electrodes represent only the few motor units around the end of the needle. These are usually representative of the whole muscle unless there is denervation. Motor unit activity can be used as an aid in diagnosis in neuropathic and myopathic states.

Artifacts will be less if an amplifier designed specifically for EMG work is used. This will contain filters to remove unwanted activity. The type of write-out will depend on the desired interpretation. Judging the 'quantity' of mass contraction is best done on an integrated trace and for this a chart recorder of low-frequency response is satisfactory. Evaluation of the 'quality' of motor units requires an oscilloscope and a high-frequency write-out (UV recorder). The frequency response of most pen recorders is limited to 75 Hz.

Electrode Insertion into the Para-urethral Area

In the female the bipolar needle is inserted through unanaesthetised skin adjacent and lateral to the external urethral meatus. Guided if necessary by a finger in the vagina, the needle is advanced about 1.5 cm and positioned where individual motor units from muscle in that area can be recorded.

In the male the electrode is inserted in the midline of the perineum, just behind the bulbar urethra and, with a finger in the rectum for orientation is advanced towards the apex of the prostate. If the bulbocavernosus muscle is being sought the needle is inserted lateral to the bulbar urethra and a shorter needle is appropriate. Despite care in insertion, no reliance can be placed on the exact anatomical position of the electrode.

Normal Responses

In normal subjects and, indeed, in the majority of non-neuropathic cases, the EMG signal builds up during bladder filling and ceases promptly on voluntary micturition, remaining silent until the pelvic floor contracts at the very end of voiding.

The individual responses from a motor unit occur four to ten times a second during a weak voluntary or postural contraction. As activity increases adjacent motor units are recruited and the rate of firing increases until so many units are active that individual potentials cannot be identified. This is the so-called interference pattern.

Abnormal Responses

Increased Activity

If EMG activity persists during voiding the condition known as detrusor-sphincter dyssynergia (see 'Urethral Overactivity and Obstruction', p. 105) may exist. This may reveal itself as persistent EMG discharge during a sustained detrusor contraction leading to very high bladder pressures. Alternatively, the EMG activity may be intermittent, leading to intermittent spurts of voiding. Sometimes the sphincter contraction leads to detrusor inhibition and relatively low-pressure retention. Apparent dyssynergia in non-neuropathic cases is likely to have a psychogenic basis.

Decreased Activity

Lack of response with technically satisfactory electrode placement probably means denervation or damage and may be confirmed by altered potentials (see below). It should be remembered that normal muscle is silent at rest.

Involuntary inhibition of EMG activity may occur in non-neuropathic cases as well as in diseases such as multiple sclerosis. Such inhibition may either precede or occur during an involuntary or unstable detrusor contraction, despite attempts by the patient to remain continent by sphincteric occlusion. This can be termed an unstable urethra (see 'Urethral Incompetence', p. 105).

Altered Activity

If the potentials are viewed on an oscilloscope or fast UV recorder certain qualitative changes may be observed. These need to be interpreted by an expert. Analysis of EMG activity can be performed automatically by microprocessors and frequency/power spectra produced. These may reveal a 'profile' of muscle activity, but are not a substitute for an experienced observer working with raw data. Recent techniques such as single-fibre EMG are giving new information on the state of denervation or re-innervation of muscle. It is likely that unsuspected neuropathic and/or myopathic factors may be found in conditions such as stress incontinence.

Indications for Electromyography

The main clinical indication for EMG studies is as an adjunct to videocysto-urethrography to distinguish between striated and smooth muscle in distal urethral obstruction of a neuropathic type. Otherwise EMG studies provide information that is interesting rather than essential and it follows that they are not of fundamental importance. Surface electrode recording from catheter electrode or anal plug is quite adequate for general urodynamic purposes.

Since it has become more apparent that there is a feedback between bladder and sphincter with urethral contraction provoking bladder inhibition, the use of EMG to investigate 'functional' or psychological disturbances of voiding may be appropriate. EMG also allows a more dynamic evaluation of urethral function when synchronous video studies are not employed, though the yield of abnormalities is minimal.

In the research sphere EMG may well become more significant, especially in relation to biofeedback. Recently described methods of EMG analysis by computer may allow muscle contractions to be classified.

If diagnostic analysis of motor unit patterns is thought necessary, expert advice should be sought. The amount of precise information that can be gained from conventional EMG tracings is limited and diagnosis depends largely on clinical features and other investigations.

Sacral Evoked Responses (SER)

The object of sacral evoked responses (SER) is to measure the integrity of the sacral reflex arc. Clinical observations such as the bulbocavernosus reflex are most inaccurate and may not detect minor degrees of dysfunction.

Technique

The method measures the conduction time (latency) between a stimulus to a peripheral nerve and an evoked neurological event, usually a muscle contraction. A large number of potential responses can be elicited and some are tabulated below.

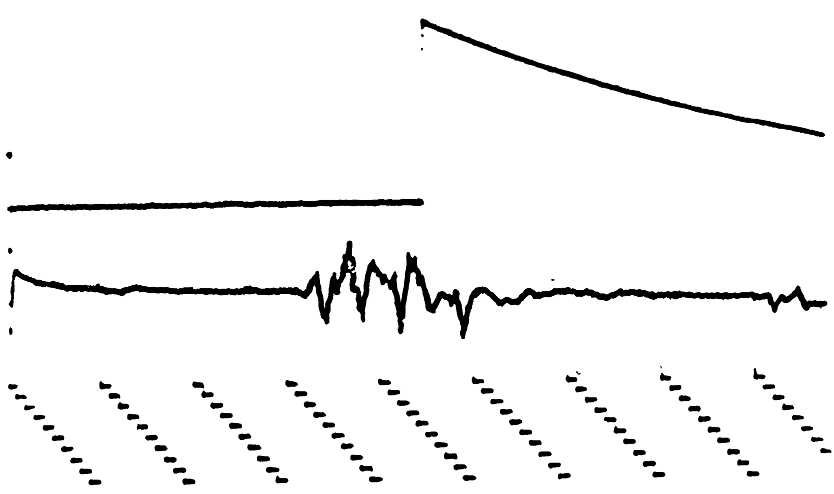


Fig. 3.46. A normal sacral evoked response. Stimulation on the dorsal nerve of the penis, recording in the bulbocavernous muscle. *Upper trace* — calibration 1 mV, *middle trace* — evoked response with a latency demonstrated on the lower trace to be 32 ms. Each *dot* on the time base is 1 ms.

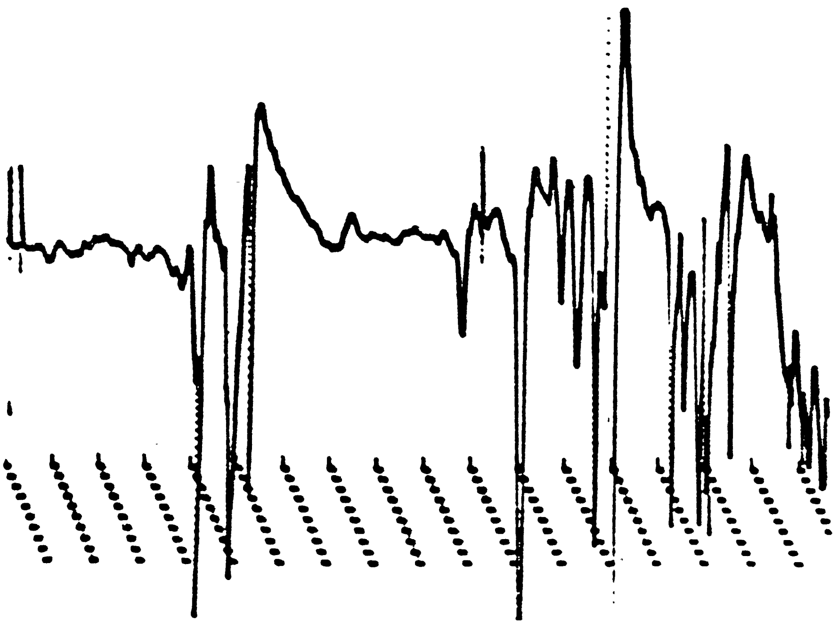


Fig. 3.47. Sacral evoked response in an undiagnosed myelopathy. There is a large positive component at normal latency with an after-discharge and a prominent second component.

Sites of stimulation	Dorsal nerve of penis/clitoris Perianal skin Urethral mucosa Bladder mucosa Cutaneous nerves in leg
Sites of recording	Anal sphincter Urethral sphincter Bulbocavernosus muscle Levator ani Cerebral cortex (scalp)

For the purposes of illustration only the bulbocavernosus reflex will be described. It has a more stable latency than recordings involving the 'sphincters'.

Square wave stimuli (1 Hz, 1 ms) are delivered to the skin over the dorsal nerve of the penis, using a block electrode taped in place. A concentric needle electrode is inserted into the bulbocavernosus muscle. A ground electrode is placed on the groin or thigh. The signals are monitored on an oscilloscope, the sweep being trigged by the stimulator and the sweep velocity set to allow analysis of 100–200 ms. A signal averager may be useful, but if the latency is stable it is not essential.

Stimulation intensity is gradually increased to determine sensory threshold, reflex threshold and threshold for minimum latency (the latency tends to decrease to a limit as the stimulus intensity increases).

Normal Results

The normal response is shown in Fig. 3.46. The average latency in normal subjects is 35 ms with a range of 27–42 ms. The sensory threshold occurs at about 25 volts, but to achieve minimum latency may require 50–60 volts, which can be rather uncomfortable. The response may have two components, the earlier appearing at a lower threshold.

Abnormal Results

Lesions of cauda equina, conus and peripheral nerve prolong the latency and increase the sensory threshold. The longer the latency, the more variable it becomes. The latency may be 40–50 ms or even longer. It may not necessarily be outside the normal range (up to 42 ms) quoted above. The second component of the response may become more prominent, giving the appearance of a prolonged latency.

Suprasacral cord lesions do not affect latency so much, though it may be shortened slightly. The reflex threshold may be lower. The response may be abnormal with positive waves and after discharges (Fig. 3.47).

Indications for Evoked Responses

The sacral evoked response is a more sensitive indication of deneryation or neuropathy than the analysis of EMG potentials unless the single-fibre EMG technique is used.. Studies are indicated to distinguish between neuropathic, myopathic and functional bladder disorders and between neuropathic and functional impotence.

Other Types of SER

The latencies of anal sphincter contraction following bladder and urethral stimulation are much longer, about 60–80 ms. This suggests that the reflex is polysynaptic. The anal sphincter response can be abolished in normal subjects if they relax the pelvic floor. The absence of the ability to abolish this response may indicate a suprasacral lesion and may be associated with detrusor overactivity (Anderson et al. 1976).

An electroencephalographic response can be obtained following stimulation of the urethra (Gerstenberg et al. 1980). The latency is quite short, about 65 ms with an amplitude of only 5 μv. Specialised equipment is needed to average many responses. The relatively fast speed of conduction suggests the response may be related to proprioceptive afferents from the pelvic floor rather than truly representing bladder sensation.

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Chapter 4

The Interpretation of Urodynamic Findings

Introduction

This chapter considers the various urodynamic results in the light of current thoughts on lower urinary tract function. A working hypothesis about physiology is needed to rationalise diagnosis and treatment. The following accounts must be regarded not as definitive statements of fact, however didactic they may sound, but as a physiological stimulus to more appropriate therapy. Perhaps the greatest single contribution urodynamics has made is to provoke thought about therapeutic dogma. Although the bladder and urethra are described separately below, it should be remembered that they act normally as a reciprocal functional unit.

Urethral Function

Very often the urethra is considered only as a passive conduit for urine, the bladder being the more important and more active part of the lower urinary tract. One of the reasons for this may have been the observation of Lapides that continence was maintained in the isolated bladder even when most of the urethra had been cut off. Urethral function is discussed first in an attempt to redress this balance. Indeed it would be possible to argue that the urethra is the controlling agent in the micturition cycle.

The urethral closure mechanism, and hence urinary continence, depends on active and passive factors. Its function may be classified as normal, overactive or incompetent.

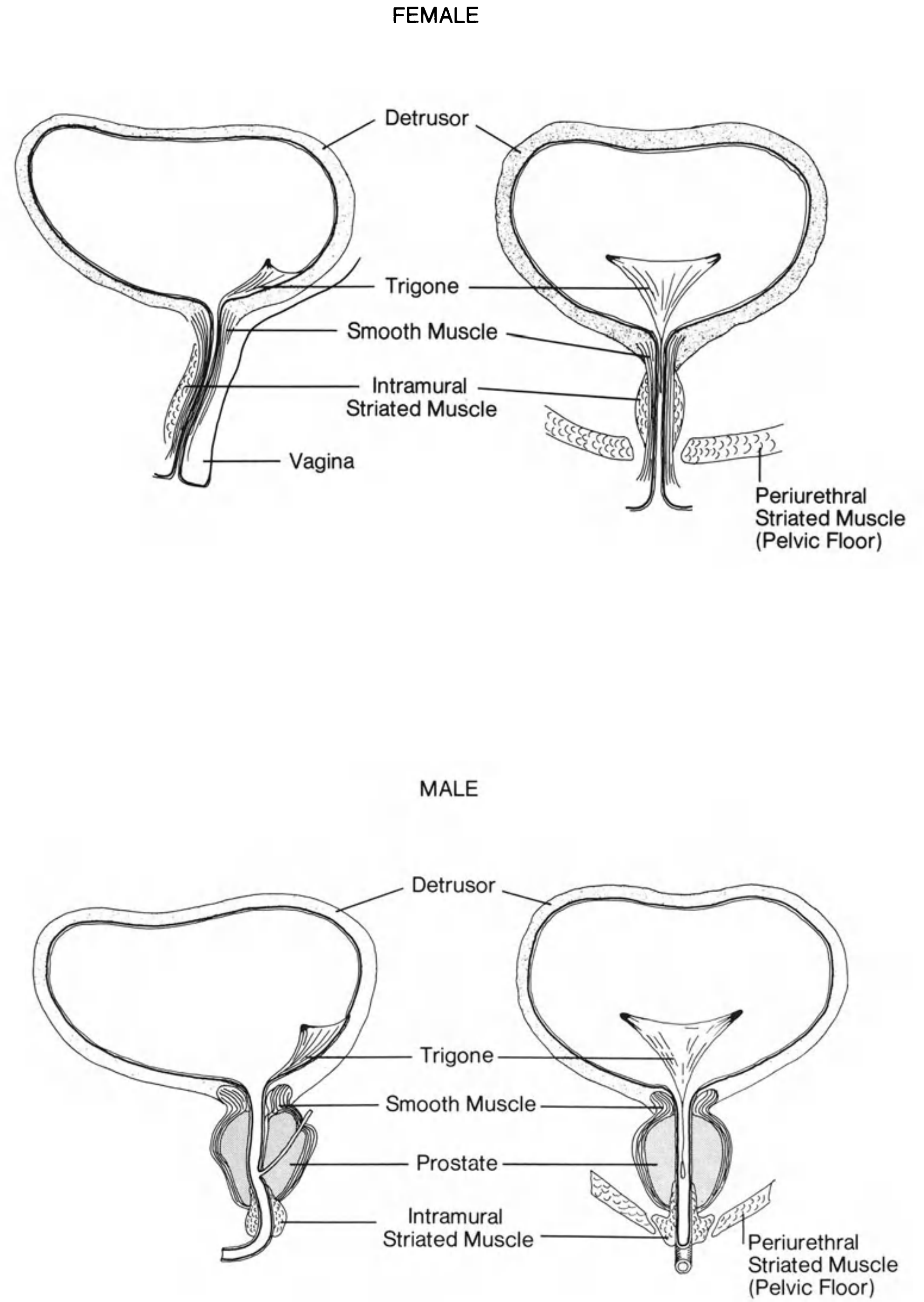

Fig. 4.1. The structural relationships in the lower urinary tract. The various layers are described in the text. (Modified from Gosling 1979).

Anatomy and Innervation

It is always tempting to infer function from structure. In general the following comments on anatomy are intended to give more perspective to the functional urodynamic observations. The terminology and general arrangement of the lower urinary tract is shown in Fig. 4.1

Mucosa

In both sexes the mucosa is organised in longitudinal folds giving the urethral lumen a stellate appearance when closed. This arrangement allows considerable distensibility. The surface tension may be a factor in urethral closure.

Submucosa

The submucosal layer is a vascular plexus. Zinner et al. (1976) discuss the role of this layer in relation to inner urethral wall softness. Their suggestion is that the submucosa acts in a passive plastic way to 'fill in' between the folds of mucosa as the urethra closes. This is said to occur as the tension increases in the muscular wall of the urethra and its effect is to improve the efficiency of the seal of the urethral lumen.

The vascular plexus may be more than passive. Huisman (1979) has suggested that there are myoepithelial cells to be found in association with arteriovenous shunts. This would provide a means of controlling submucosal pressure. M. Asmussen (personal communication) suggests that the vascular element may be an important factor in urethral closure in females where it is difficult to attribute all the occlusive forces to urethral muscle. This also explains the presence of urethral pressure changes synchronous with the arterial pulse, and may be the reason for some postural and menstrual pressure changes. J.A. Gosling (personal communication) cannot confirm the anatomical basis for this vascular control.

Urethral Muscle in Females

The smooth muscle of the female urethra is arranged longitudinally. Acetylcholinesterase analysis suggests that the dominant innervation is cholinergic (Gosling et al. 1977). Virtually no noradrenergic nerves are seen. This may appear confusing at first because the majority of the measurable resting urethral pressure depends on alpha-adrenergic activity, if studies using alpha-blocking drugs are to be believed (Donker et al. 1972). This leads to a choice of conclusions:

1) There are alpha receptors on smooth muscle but no nerves to produce the transmitter (noradrenaline); this seems illogical.
2) The urethral smooth muscle does not produce the urethral pressure. This is not so improbable as it sounds for the fibres are not circular but longitudinal, and not very prolific.
3) The alpha-adrenergic effects occur not on the muscle but at the level of the pelvic ganglia. This is the currently popular explanation.

4) Alpha blocking drugs have effects on neuromuscular transmission that are not conventionally recognised.

There are two groups of striated muscle fibres in relation to the urethra, called intramural and peri-urethral by Gosling (1979).

Intramural striated muscle bundles are found close to the urethral lumen, sometimes interdigitating with smooth muscle. In the female these fibres are found in the greatest frequency anteriorly and laterally in the middle third of the urethra. They do not surround the urethra posteriorly to form a circular sphincter as in the male. The muscle is of a 'slow twitch' type rich in myosin ATPase, and adapted to maintain contraction over a relatively long period of time. No muscle spindles have been seen. The intramural striated muscle is supplied by myelinated fibres from S2–4 running with the pelvic nerve. This explains why they are not affected by either pudendal block or neurectomy.

The peri-urethral striated muscle is part of the pelvic floor, and is separated from the urethra by a layer of connective tissue. This muscle is a mixture of slow and fast twitch fibres and is supplied by the pudendal nerve (S2–4).

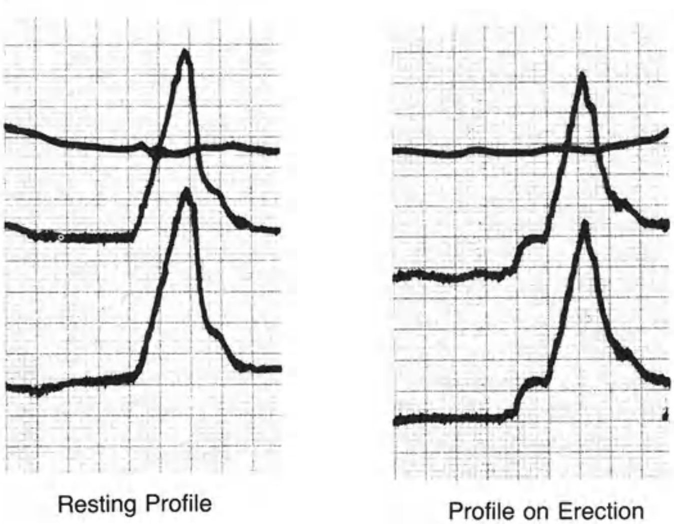

Fig. 4.2. Urethral pressure profile demonstrating elevation of pressure in the region of the bladder neck/preprostatic sphincter during penile erection.

Urethral Muscle in Males

The smooth muscle of the preprostatic urethra in males is histochemically distinct from that of the detrusor and from urethral muscle in females. This muscle also forms the prostatic capsule. It is richly provided with noradrenergic terminals and little acetylcholinesterase has been found. It is agreed generally that this well-defined muscle represents a 'genital sphincter' designed to prevent reflux of ejaculate. Certainly we have observed changes in pressure in this part of the urethra during penile erection (Fig. 4.2), and these do not seem to occur during any part of the micturition cycle.

The striated muscles in the male can be divided into the same two groups described above for the female. The innervation is similar. The intramural striated muscle is orientated circularly around the postprostatic 'membranous' urethra as a distinct sphincter.

Receptor Sites and Neurotransmitters

Much recent effort has been directed towards the analysis of receptors in the urinary tract. The distinction between experimentally demonstrable alpha- and beta-adrenergic receptor sites and innervation is not always made clear. Alpha-adrenergic receptors, causing smooth muscle contraction when stimulated, produce their effects mainly in the region of the bladder neck and proximal 3 cm of the urethra in both sexes. Beta-receptor activity is very weak in this area, being present mainly over the bladder dome. Beta stimulation encourages bladder relaxation. Appreciation of these functions aids the understanding of the action of drugs on the urinary tract. However the appropriate sympathetic nerves may not even be present anatomically in the areas where receptors have been demonstrated.

The complex interrelation of nerves, transmitter substances and receptor sites has been the subject of controversy for years. Some of the reasons why progress is slow in this field are outlined below.

1) Individual nerves may produce more than one neurotransmitter.
2) Neurotransmitters may act on more than one type of receptor producing different actions.
3) Neurotransmitters may act in different ways at the same receptor site depending on their concentration.
4) Neurotransmitters may interact with one another.
5) There are considerable species differences in both neurotransmitters and receptors.

An example of fundamental controversy is the question of the identity of the principal neurotransmitter to the detrusor muscle. The postganglionic parasympathetic fibres are presumed to be cholinergic in that they are associated with identifiable acetylcholinesterase. However if the transmitter is acetylcholine it should be blocked by atropine. Although some species are atropine sensitive the majority are not. This has led to the suggestion that another substance may be the principal neurotransmitter. Alternatively the receptors on bladder muscle may have more nicotinic characteristics than muscarinic. Perhaps some receptors are not accessible to freely circulating atropine. Suggestions for alternative transmitters include 5-hydroxytryptamine, purine nucleotides such as ATP, and prostaglandins. The problem has been reassessed recently by Nergardh (1981), who used field stimulation to activate muscle strips in vitro. As far as the cat bladder is concerned it would appear that atropine does not inhibit contraction; rather, it enhances it, which makes acetylcholine an improbable neuromuscular transmitter. Quinidine, which is said to block receptors to ATP, had no effect, which suggests that purinergic nerves in the cat bladder are unlikely to be significant. On the other hand indomethacin, which blocks prostaglandin synthetase, inhibited the effect of field stimulation. Selective antagonists of 5-hydroxytryptamine also produced inhibition of contraction. A great deal of parallel work is currently being performed on human muscle preparations, and a more reliable understanding of bladder neuropharmacology should soon emerge. Meanwhile the unpredictable response to the pharmacotherapy of detrusor overactivity becomes less surprising.

Central Nervous Activity

As can be seen in Fig. 4.3, the organisation of central control is a rather complex business. It can however be reduced to several relatively simple concepts.

Sensation from the lower urinary tract must be appreciated centrally and consciously if the normal cerebral control is to work. Sensation of bladder fullness and contraction ascends in the anterior half of the spinal cord and may be affected by damage there (anterior spinal artery thrombosis, bilateral spinothalamic tractotomy) as well as other spinal cord lesions. Sensation of activity in the pelvic floor ascends in the posterior columns.

Sensation must not only reach the conscious level when the subject is awake, it must also, by its collateral effects on the reticular formation perhaps, be able to wake the subject from sleep or otherwise subconsciously to inhibit micturition. This may be the fundamental problem in nocturnal enuresis.

Assuming sensation is normal, the brain acts by balancing the various facilitatory and inhibitory effects suggested by Fig. 4.3 and the final common efferent pathway

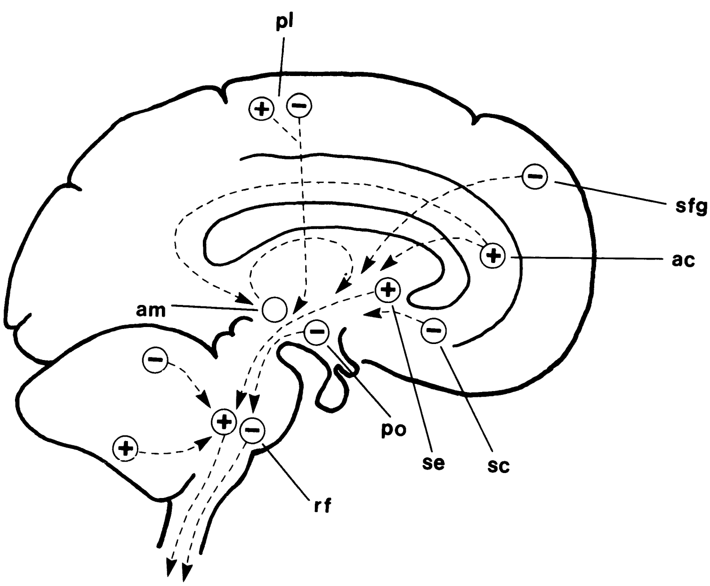

Fig. 4.3. A simplified representation of the cerebral areas involved in micturition. The multiplicity of interactions makes it easy to appreciate why the subject should be left to the research physiologist. +, facilitation; −, inhibition; *ac*, anterior cingulate gyrus; *am*, amygdala; *pl*, paracentral lobule; *po*, preoptic nucleus; *rf*, pontine recticular formation; *sc*, subcallosal cingulate gyrus; *se*, septal area; *sfg*, superior frontal gyrus. (Torrens 1982).

is through the 'bladder centre' in the pontine reticular formation. This centre is essential for normally coordinated micturition. It acts on the sacral micturition centre in the conus medullaris where the final integration of bladder and urethral activity takes place.

Since the usual response of a bladder liberated from cerebral control is one of reflex overactivity, it is assumed that the major cerebral output is one of tonic inhibition, hence the term 'uninhibited bladder'. However this is only an assumption, and prejudging the activity of the nervous system can only slow down the understanding of it. We suggest that terms which imply specific pathophysiology should be avoided as much as possible.

The neurological control of the bladder is reviewed elsewhere (Nathan 1976; Fletcher and Bradley 1978; Torrens 1982).

Normal Urethral Function

The normal urethral closure mechanism maintains a positive urethral closure pressure during bladder filling even in the presence of increased abdominal pressure. Continence can be seen to be maintained at the bladder neck in normal persons. This can be regarded as the proximal urethral closure mechanism. If this vesico-urethral junction is incompetent, continence may still be maintained at the high pressure zone in the urethra about 2–3 cm distally. This zone corresponds to the maximum condensation of muscle, both smooth and striated, and may be regarded as the distal urethral closure mechanism. Whether it is really valid to separate two parts of the urethra in this way from a physiological point of view is debatable; the normal urethra probably works as one unit. However from a practical standpoint it is useful because the two urethral areas may not be abnormal simultaneously.

Many factors have been thought to contribute to urethral closure; some are obvious, some equivocal. They are listed below.

1) Muscular occlusion
2) Transmission of abdominal pressure to proximal urethra
3) Mucosal surface tension
4) Anatomical configuration at the bladder neck
5) Submucosal softness or vascularity
6) Longitudinal tension
7) Inherent elasticity
8) Urethral length

While the relative importance of these various factors remains unknown, it is better to consider and describe only those that can be observed objectively: urethral closure pressure, EMG and the videoscopic appearance of the urethra. Mechanical and hydrodynamic analogies, such as those quoted by Zinner et al. (1976), serve only to demonstrate how complicated the situation is.

Typically, the urethral closure pressure decreases at or before the onset of micturition. This is synchronous with bladder base descent on fluoroscopy and reduction of EMG from local striated muscle. The pressure changes during a normal micturition are shown in Fig. 4.4 and are explained in the legend.

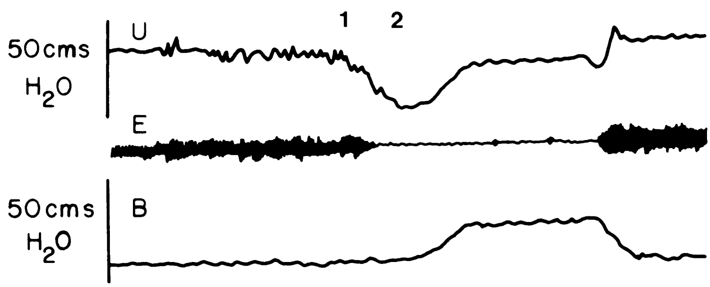

Fig. 4.4. Intravesical (*B*) and urethral (*U*) pressure and striated sphincter EMG (*E*) during volitional voiding. At the initiation of voiding (*1*) the urethral pressure falls to a minimum before the intravesical pressure starts to rise. Flow is initiated at (*2*), before an appreciable intravesical pressure has been generated. Flow is therefore a consequence of urethral relaxation in this female subject. At cessation of flow EMG activity returns after a period of silence, and the urethral pressure transiently rises while the proximal urethra is emptied back into the bladder. (McGuire 1978).

It is a fallacy to consider that the urethra is forced open by a head of detrusor pressure. Micturition quite often occurs at a voiding pressure less than the maximum resting intraurethral pressure. It seems that the decrease in urethral closure pressure represents an active relaxation process. Part of the pressure decrease can be attributed to the relaxation of the striated muscle of the pelvic floor, but part seems to be due to active urethral inhibition. This can be reproduced by stimulation of the sacral nerves, especially S4 (Torrens 1978). Some women have been observed to void by relaxation and urethral opening only; no detrusor pressure rise is necessary.

Abnormal Urethral Function

The urethra actively contracts and relaxes. Its passive properties include its elasticity and, like the bladder, it may exhibit high or low compliance. Compliance may be modified by the characteristics of the urethral wall, or by structures outside the urethra such as the prostate. Any one of these factors may be abnormal.

In general there has been less attention paid to the testing of urethral function, partly because it seems more difficult and, mistakenly, because it was felt to be less relevant. More interest is now being shown and perhaps new investigations will be introduced.

No one test can evaluate the urethra fully. Urethral hypercontractility, impaired relaxation and low compliance tend to produce outflow tract obstruction. Pressure/flow testing is the best overall assessment in this group. Impaired contraction, inappropriate relaxation and high compliance are associated with urethral incompetence and evaluation of urethral pressure is most useful. However, as in many urodynamic situations, a composite evaluation by several methods is often necessary to get an overall view, and this will naturally include testing the bladder as well.

Urethral Incompetence

This may be passive (structural) or active.

Passive urethral incompetence is associated with 'genuine stress incontinence' and with various measurements that have been noted earlier. These include:

1) Low urethral closure pressure
2) Shortened profile length
3) Decreased area under profile curve
4) Less increase in urethral closure pressure on assuming upright posture
5) A urethral closure pressure that becomes negative on coughing or straining

This syndrome occurs in both sexes in relation to urethral trauma, especially iatrogenic, and with denervation. In females it may be associated with increasing age, parity and decreased urethral support. R. Anderson (personal communication) has discovered, by using single-fibre EMG, that the majority of females with stress incontinence have evidence of pelvic floor denervation.

Decreased urethral support, which seems to be a feature of the 'developed' world, acts in two ways. It is well recognised that downward displacement of the bladder neck is associated with incompetence and a measurable reduction of the transmission of intra-abdominal pressure to the urethra. It is perhaps less well recognised that the urethra also becomes 'baggy' and highly compliant. In this condition it is physically less able to seal. In the light of excellent anatomical work on the urethra recently, the time is ripe for a reappraisal of the urethral pathology on ageing.

Active urethral incompetence means inappropriate relaxation. This is the functional counterpart to the inappropriately contracting 'unstable' bladder and has therefore been termed the *unstable urethra*. As is the case with the detrusor, urodynamic observations show the functional changes of a normal micturition event occurring when the patient does not wish to void. This means, in the case of the urethra, that the intraluminal pressure falls. This is commonly, though not invariably, associated with an unstable detrusor contraction, especially in women. Such a pressure decrease can occur occasionally in the absence of detrusor activity, and this may explain some cases of urge incontinence where the bladder seems to behave normally (McGuire 1978).

To avoid confusion it should be pointed out that one of the first workers to use the term 'unstable urethra' (Asmussen 1975) did so in a different, though related, context. He used the words to describe the behaviour of some female urethras where considerable pressure fluctuation occurs during periods of urgency. This has also been described as the 'holding pattern' (Bradley and Timm 1976) when it is associated with suppression of detrusor contraction (see 'Underactive Detrusor Function', p. 112).

Urethral Overactivity and Obstruction

Urethral obstruction may also be active or passive. An overactive urethral closure mechanism contracts involuntarily against a detrusor contraction or fails to relax on attempted micturition. Synchronous detrusor and urethral contraction of this type is termed detrusor/urethral dyssynergia. When this involves the striated muscle of the distal urethral closure mechanism it may be called by the more familiar name detrusor/sphincter dyssynergia. Otherwise the condition should be qualified by stating the location and type of urethral muscle involved (see Table A.1.3). Persistent urethral contraction can reflexly inhibit the contraction of the detrusor even to the point of producing retention.

The smooth muscle around the bladder neck may be unable to relax, thus producing bladder neck obstruction. It is important to distinguish between bladder neck obstruction and bladder neck hypertrophy. The latter, a greatly thickened bladder neck, may coexist with detrusor overactivity as a form of work hypertrophy. It does not necessarily cause obstruction and may even be the result of functional obstruction more distally in neuropathic disorders. Videoscopic or cystoscopic appearances need to be checked by pressure/flow studies.

Bladder neck obstruction may be of two types. There may be active, inappropriate contraction of the bladder neck, or there may be fibrosis causing physical indistensibility. The relative roles of these two factors have not been distinguished fully. The former would better be termed detrusor/bladder neck dyssynergia. In addition apparent failure of opening, or premature closure, of the bladder neck may be related to an inadequate detrusor contraction, though whether this means that the bladder neck has to be 'pulled open' by the detrusor can be disputed.

It is tempting to correlate the role of the bladder neck in males as an adrenergic genital sphincter with its potential to obstruct urinary outflow. Sometimes the static urethral closure pressure profile in bladder neck obstruction shows the changes of Fig. 4.2 but alpha adrenergic blocking drugs do not produce a therapeutic effect. However pressure profiles are an inadequate means of diagnosis, and this is one instance where synchronous video pressure/flow studies are essential.

In the female, bladder neck obstruction is seldom a problem, though bladder neck hypertrophy can occur. The compliance of the bladder neck and urethra can be adversely affected by an inappropriately tight suspension operation, and also occasionally by the fibrosis induced by repeated radical urethral dilatation.

Conditions which passively reduce urethral compliance and produce obstruction, such as strictures and prostatic hypertrophy, usually generate more uniform and repeatable urodynamic results than active obstruction, which varies from time to time.

Detrusor/sphincter dyssynergia denotes inappropriate contraction of the striated muscle of the distal urethral sphincter mechanism. This may occur in nervous individuals, but in its true form it is always associated with neurological disorders of an upper motor neurone type. The urodynamic findings have already been illustrated (see 'Detrusor/Urethral Dyssynergia', p. 81) and the videoscopic appearance is also characteristic (Fig. 4.5). As noted above (see 'Abnormal Results', p. 87) the main distinction is from voluntary hypertrophy of the distal sphincter, and this requires pressure/flow studies.

A further form of dyssynergic urethral contraction may occur, especially in children. This involves the smooth muscle of the distal urethral sphincter in both sexes. It occurs particularly in cases where the parasympathetic and sacral somatic pathways are ablated by a lower motor neuron lesion, but the sympathetic outflow supplying the urethra from a higher level (T10–L2) remains intact. Contrary to dyssynergia of the striated sphincter, where the nerve supply to the bladder is intact, this disturbance leads to a relatively low-pressure retention with an acontractile bladder and a funnelled urethra proximal to the constriction.

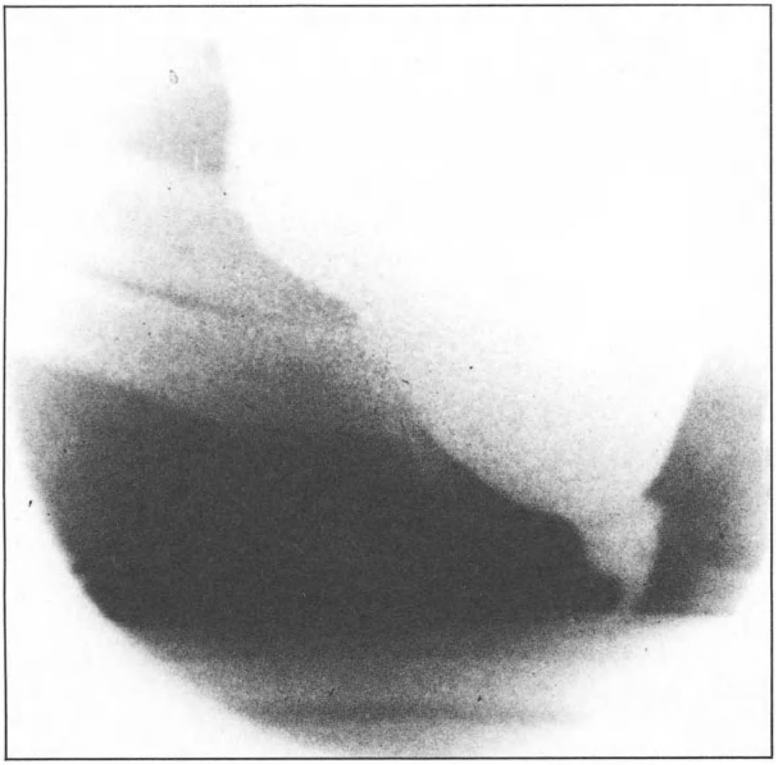

Fig. 4.5. Part of a cine-cystogram in a male patient with detrusor/sphincter dyssynergia. The proximal urethra is distended with the bladder neck still visible as a ring, producing a characteristic radiological appearance.

As will be described in Chapter 5 ('The Neuropathic Bladder', p. 164), certain of these abnormalities may coexist, making both diagnosis and management difficult.

Detrusor Function

Anatomy

The urinary bladder is not a sphere even when contracting, and calculations of tension based on that premise can only be erroneous. Its shape is more of a three-sided pyramid, base posterior and apex at the urachus. The superior surface is covered by peritoneum and is pressed upon by the other viscera. The two inferior surfaces are supported by the pelvic floor and connected to the pelvic fascia by various condensations of fibro-areolar tissue. The functional adequacy of the bladder does depend on its correct anatomical position, so heavy viscera or inadequate pelvic support cause functional problems.

The detrusor is composed of an interlacing network of smooth muscle bundles. These are not layered as has sometimes been described and as is the case in the intestine. The detrusor muscle around the bladder neck is arranged in various loops and slings. These may be involved in the mechanisms of closure and opening of the bladder neck. However the various mechanical theories of function that have been elaborated are presumptive and should be interpreted with great caution.

The detrusor muscle is relatively rich in acetylcholinesterase. This is evidence for a dominant cholinergic innervation (see 'Receptor Sites and Neurotransmitters', p. 101). Very little nor-adrenergic activity can be demonstrated histochemically.

Innervation

Efferent motor nerves to the detrusor arise from the parasympathetic (cholinergic) ganglion cells in the pelvic plexus. The preganglionic fibres run in the sacral roots 2–4. The third sacral root is the dominant nerve in most cases. The parasympathetic supply is excitatory.

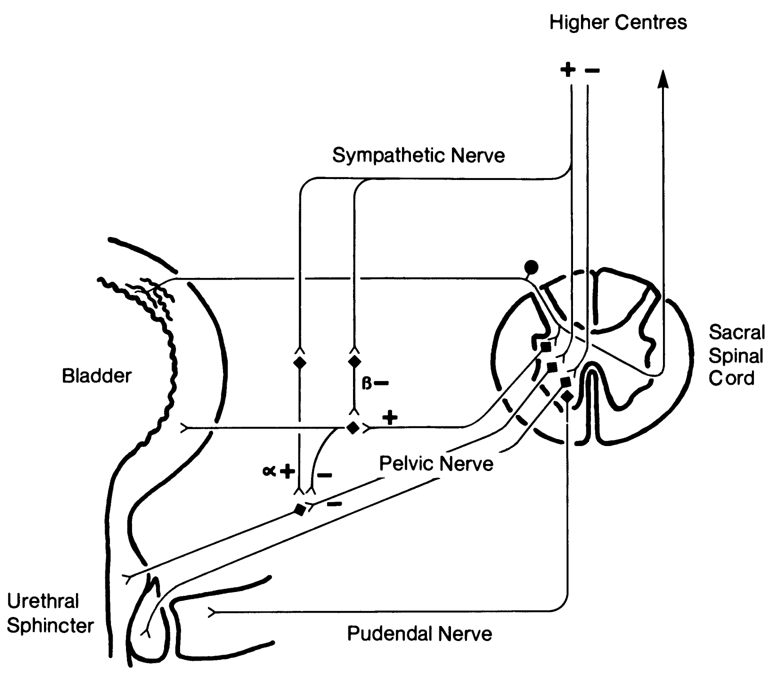

Fig. 4.6. Summary of the possible organisation of the peripheral nervous supply to the lower urinary tract. Preganglionic parasympathetic fibres and postganglionic sympathetic fibres both synapse with ganglion cells close to, and within, the bladder wall. The arrangement in relation to the urethra may be morphologically similar but functionally different. The periurethral striated muscle (pelvic floor) is supplied by the pudendal nerve. The somatic nerve supply to the intramural urethral striated muscle runs with the pelvic nerve and is vulnerable during pelvic surgery. (Torrens 1982).

Nerve-mediated detrusor inhibition has been described, occurring after stimulation of the pelvic floor or perianal area. It is suggested that such relation may be mediated by the sympathetic nervous system (Sundin and Dahlstrom 1973). Bladder relaxation evoked by bladder wall stretch (accommodation) may be similarly mediated. Gosling (1979) has shown that little significant sympathetic innervation reaches the bladder dome in humans, and so it is suggested that this inhibition occurs at the neurones in the pelvic ganglia where noradrenergic axosomatic terminals have been observed. The sympathetic supply to the pelvic ganglia arises at the T10–12 level and runs in the presacral nerves and hypogastric plexus. The muscle around the bladder neck in both sexes is similar to that of the rest of the bladder. Most nerve terminals are acetylcholinesterase positive and almost no noradrenergic terminals are seen. This is in contradistinction to certain species of animals.

The sensory nerves from the bladder run with the motor supply. In general the proprioceptive afferents related to tension enter the sacral segments, as do the greater proportion of enteroceptive afferents related to pain and temperature. Poorly localised sensations of pain and distension enter with the sympathetic fibres at a higher level. The innervation of the bladder and urethra is summarised in Fig. 4.6.

Normal Detrusor Function

Detrusor function may best be considered, and described, using the measurements that are made during cystometry — sensation, capacity, compliance and contractility. All these may be normal, increased or decreased. Using unequivocal terms that do not require special definition lessens misunderstanding.

During the filling phase the bladder contents increase in volume without a significant rise in pressure (accommodation). The bladder is therefore compliant. No involuntary contractions occur. Normal voiding is achieved by a voluntarily initiated detrusor contraction that is sustained until the bladder is empty. A normal voiding contraction can be suppressed voluntarily. It is evident that normality cannot be defined without assessing activity during both filling and voiding phases.

A supine cystometrogram does not test the reactivity of the bladder to the stress of normal daily activity. With this in mind the concept of provocation cystometry has been elaborated to prove that the bladder does not contract involuntarily under *any* circumstances. Provocations include fast filling, change of posture from supine to erect, coughing, jumping and perhaps the sound of running water. A bladder that does not contract on provocation cystometry may be described as '*stable*'.

At this point some terminological confusion must be noted. A 'stable' bladder defined only by a filling cystometrogram includes the categories of normal and reduced contractility. It was our understanding that this definition was acceptable as the obvious opposite to 'unstable' (see below). It has been agreed more recently (ICS 4th report, 1980, Appendix 1) that 'stable' is synonymous with normal as defined above. This means that for a bladder to be designated stable it must be shown to contract on voiding. R. Turner Warwick (personal communication) has pointed out that in his opinion the term 'stable' does not mean that contractility during voiding is always normal, though the bladder must be shown to be capable of contraction. If 'stable' means normal there seems no benefit in using the term. If 'stable' is used in contradistinction to unstable, to describe the results of provocation cystometry, then it would seem to be acceptable, easy to understand and is in common usage. Regrettably it seems necessary to clarify what each individual means by the term; it has not been used in this book.

The normal detrusor contracts at will on voiding. Such a contraction does not necessarily produce an increase in intravesical pressure, especially in females. If a high flow rate occurs and keeps pace with detrusor muscle shortening the contraction may be isobaric. Alternatively the bladder dome may invaginate itself into the bladder base without so much shortening of the detrusor fibres in the bladder wall.

Abnormal Detrusor Function

Any one of the factors noted above may be abnormal, either in the filling or voiding phase. It is always helpful to obtain an overall picture of the whole micturition cycle, and this is one reason why a sequence of urodynamic studies designed to provide such an assessment may be preferable to, for example, an isolated cystometrogram.

Overactive Detrusor Function

Increased Contractility. Detrusor overactivity exists when, during the filling phase, there are involuntary detrusor contractions that the person cannot suppress. These contractions may be spontaneous or occur only on provocation as described above. Detrusor overactivity during voiding may be indicated by an involuntary voiding contraction, or by the inability to suppress a voluntary contraction. At present this last category, impaired suppression, is not commonly recognised. Various special terms have been used to describe these features and they are defined as follows:

The *unstable detrusor* is one that is shown objectively to contract, spontaneously or on provocation, during the filling phase while the patient is attempting to inhibit micturition. The unstable detrusor may be asymptomatic and its presence does not necessarily imply a neurological disorder. *Detrusor hyperreflexia* is defined as overactivity due to disturbance of the nervous control mechanisms. It must be confirmed by objective evidence of a neurological disorder. Other conceptual and undefined terms should be avoided. These include hypertonic, systolic, spastic, automatic and uninhibited.

The whole of this concept of detrusor overactivity has been built up on the basis of medium or fast fill cystometry. There are those who would argue that fast filling of the bladder is so unphysiological that it will give an unrepresentative record of detrusor activity (Klevmark 1974). It may be that fast filling of the bladder 'excites' the detrusor into artificial hypercontractility. Thomas (1979) states that this is especially likely in neuropathic bladders (see 'Modification of Urodynamic Technique', p. 166). However Jensen (1981) in a small series of normal and neuropathic bladders found that varying filling rates did not affect intravesical pressure, and Ramsden et al. (1977) also found that the filling rate did not influence capacity or the incidence of instability. There is a need for basic research in this area.

Detrusor hypercontractility leads to work hypertrophy of the muscle and so to trabeculation, especially if there is a high pressure due to obstruction of the outflow tract or due to a powerful voluntary urethral sphincter. Trabeculation is related more significantly to detrusor overactivity than it is to obstruction.

Since the limits of normality cannot be defined, can it be stated when hypercontractility is unequivocally abnormal? When the patient's symptoms are reproduced exactly during an objectively demonstrated unstable contraction it is reasonable to implicate the detrusor. Otherwise interpretation requires discretion.

Decreased Compliance. In addition to increased contractility bladder pressure may be elevated progressively on filling because of low compliance (indistensibility). There are two elements contributing to this low compliance: the active and the passive characteristics of the bladder wall. It may be possible to distinguish between these two by removing some nervous influences by epidural anaesthesia. Then the residual compliance, which approximates to the passive element, can be assessed.

Low compliance may be due to fibrosis (infection, radiotherapy), and in such cases the pressure rise on cystometry is usually constant (Fig. 3.30). When the indistensibility is due to muscle wall hypertrophy associated with detrusor overactivity the cystometrogram is flatter initially and the compliance later decreases progressively (Fig. 3.33).

It is essential to recognise that the apparent compliance may depend on the filling rate (Klevmark 1974). The faster the bladder is filled, the steeper the slope of the cystometrogram. This is yet another reason why the average medium-fill cystometrogram must not be expected to reveal the true physiological activity of the bladder. If low compliance is due to fast filling, but the pressure falls when filling is stopped (Fig. 3.31), what does this mean? Has the fast filling induced a contraction or is the phenomenon due to the passive properties of the bladder wall? The situation is unclear.

What Is Instability?

According to definitions of the term 'unstable' which use any pressure rise during filling of more than 15 cmH_2O as their criterion for abnormality, any bladder of low compliance is unstable. This further confusion tends to complicate understanding. We have tried to resolve the problem by regarding bladder pressure change as either *phasic* or *tonic*. A phasic change tends to occur more rapidly, perhaps over 5–10 s, and the pressure increase is frequently followed by a decrease. This is what we mean by a *contraction*. A tonic pressure increase occurs more slowly, over minutes, and decreases only after micturition. This is what we have regarded as the active element in lowered compliance and corresponds to what has been described as *tone*. It may be that this concept will allow a mathematical definition of detrusor contraction. If compliance is represented as the change in volume for a given change in pressure (dv/dp), then contraction can be represented as the rate of change of compliance (d^2v/dp^2).

It has become evident that, from a clinical point of view, it is not the presence of detrusor overactivity which is significant but the severity. This is why the use of 'provocative' cystometry requires reappraisal. Some provocation may be extreme and some investigational circumstances inappropriate. The object should be to reproduce the patients symptoms and then analyse what causes them. The more relaxed and normal the environment the better. Some way of expressing the severity of detrusor overactivity, in relation to the type of test employed, might be useful. In practice, if the intravesical pressure is high, if the maximum cystometric or functional bladder capacity is low and if incontinence occurs during involuntary detrusor contractions, then there is significant overactivity.

Underactive Detrusor Function

In the underactive detrusor there are no contractions during filling, and during voiding the contraction may be absent or inadequately sustained. Such a bladder will often accommodate a large volume on filling at a low pressure and may be termed a *high compliance bladder*. However not all underactive detrusors will accommodate normally to stretch and some may be of low compliance. Some bladders may exhibit longstanding underactivity with no obvious symptoms until some complication, such as obstruction, supervenes. A *non-contractile detrusor* is one that does not contract under any circumstances. *Detrusor areflexia* exists where underactivity is due to a proven abnormality of nervous control and denotes the complete absence of centrally coordinated contraction. In detrusor areflexia due to lesions of the conus medullaris or sacral nerve outflow, the detrusor should be described as *decentralised* — not denervated, since the peripheral ganglionic neurones remain intact. In such bladders pressure fluctuations of low amplitude may occur because of uncoordinated bladder contraction. This aspect of bladder function may be described as *autonomous contractility*. The use of terms such as atonic, hypotonic, autonomic and flaccid should be avoided.

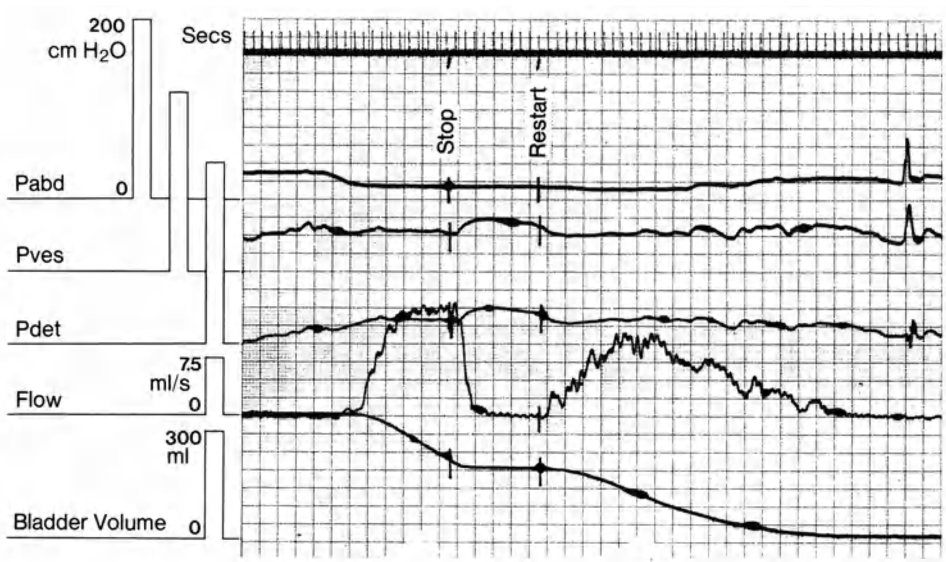

Fig. 4.7. The interruption of an equivocal flow (17.5 ml/s) in a female, produces only a small increase in pressure (20 cmH_2O) which indicates that the detrusor is able to contract but not very powerfully (normal 50–100 cmH_2O; see 'Normal Values' p. 76).

Detrusor underactivity cannot be diagnosed from a filling cystometrogram alone; a voiding study is necessary as well. Problems arise when the patient cannot initiate micturition and it is unclear whether this inhibition is psychogenic or neurogenic. If synchronous urethral pressure or sphincter EMG is being recorded it may be evident that the urethra cannot, or will not, relax. In such a case the inability to void is either psychogenic or, if neurogenic, due to a lesion above the sacral spinal cord. Psychogenic suppression of detrusor contraction is less common if the patient is put at ease by the investigator and the investigation environment.

In other cases it may be difficult to distinguish between neuropathic and myopathic causes for detrusor underactivity. If the urethral function is quite normal then neuropathy is unlikely; if urethral function is abnormal then the sacral reflex arc can be tested using an evoked response (see 'Sacral Evoked Responses (SER)', p. 92) and a denervation supersensitivity test may be performed (see 'Drug Administration During Cystometrograms', p. 71).

In those cases where voiding can be initiated the typical urodynamic findings have been described above. These include low pressure/low flow, poorly sustained pressure, intermittent pressure and micturition assisted by voluntary effort. In an equivocal situation (low pressure/near normal flow) a 'stop test' should be performed to determine the power of isometric contraction (Fig. 4.7).

The Effect of Performing a Cystometrogram

The interpretation of detrusor function depends largely on cystometrograms. It is fair to ask 'how physiological is a cystometrogram?'. Very little attention has been paid to this question. Indeed the demands for convenience and the concept of provocation have led to exceptionally rapid infusion of alien gases and solutions.

N.J.R. George and P.A. Lewis (unpublished material) analysed cystometrograms performed at a continuous filling rate of 50 ml/min using saline at 37°C and with the patient sitting. Maximum cystometric capacity was compared with average functional capacity (see 'Frequency/Volume Charts', p. 15). Of 38 patients studied, 37 had a reduced maximum cystometric capacity compared with the average functional capacity. The mean reduction was by 41%. Cystometry therefore tends to underestimate capacity, especially when there is hypersensitivity.

Cystometry also affects the residual urine. The residual volume after cystometry can only be compared with that after the initial pretest void prior to catheterisation. Of 38 patients, 22 had some residual urine after the pretest void, and in 18 of 22 this was reduced or abolished after the cystometrogram. The reduction was greater than that to be expected if capacity decreases. In 9 of 22 the residual urine was abolished. Those in whom the residual increased (3 of 22) all had residual volumes greater than 500 ml. In only one patient was the residual unchanged. In other patients whose pretest void was must greater than the average functional capacity (and who were not included above) residual urine was the rule, present in 22 of 25. In only 3 of 22 did this persist after cystometrography.

George and Lewis concluded that the ideal pretest capacity for cystometric analysis is between 50% and 90% of the maximum functional capacity. On analysis only 26% of patients presenting to the Bristol unit fall within this range. If the artificial infusion alters the results of filling cystometrograms, it may also affect contractility and hence the results of pressure/flow studies.

The conclusion from this is that cystometric capacity is unreliable and residual urine measurements after cystometry are suspect. The bladder must not be allowed to get overstretched at any stage of the proceedings or contractility will be affected. Patients are often asked to attend for urodynamic investigation with a 'full' bladder, but this may compromise the results of testing if the bladder becomes overdistended.

Sensation

Balanced bladder and urethral function are dependent on the integrity of various sacral and the suprasacral reflexes. Each of these reflexes needs an intact sensory system and without it function becomes deranged. The sensory system has been relatively neglected, partly because it is difficult to evaluate. Sensation may be classified as normal, increased or decreased.

Normal Sensory Function

The presumed sensory receptors in bladder and urethra are unspecialised. They relay information related to pain, temperature and touch (exteroceptive) and also to muscle tension in the bladder wall, sphincters and pelvic floor (proprioceptive). Although in general proprioceptive information travels in the posterior column of the cord and is accompanied by touch, whilst the sensations of pain and temperature travel in the spinothalamic tract, the location of afferent bladder sensation in the spinal cord does not seem to be as predictable as this. Studies of patients who have undergone anterolateral cordotomy for pain seem to show that the majority of bladder afferents travel with the spinothalamic tract but that sometimes they lie as a group elsewhere in the spinal cord. Certainly any pathological process affecting the anterior sections of the spinal cord is likely to abolish the central conduction of sensation.

The tension receptors have been shown in experimental animals to have a firing rate proportional to both the volume and pressure within the bladder. This explains why the first desire to void and the sensation of fullness may occur without an appreciable rise in bladder pressure.

The Evaluation of Sensation

Subjective evaluation of sensation is possible in relationship to distension either of the bladder or urethra, and to touch and temperature. It is certainly valuable to record the reaction of the patient to catheterisation and to take this into account when interpreting urodynamic observations.

It is possible to produce a semi-objective assessment of sensation by measuring the threshold to constant current electrical stimulation (Powell and Feneley 1980). In this technique a urethral catheter, with two platinum electrodes mounted 1 cm apart and 1.5 cm below the catheter balloon, is inserted into the bladder. These electrodes are connected to a constant current stimulator producing square wave impulses at a rate of 20 Hz. When the balloon is inflated and withdrawn against the bladder neck a standard urethral sensitivity can be obtained, particularly if the readings for threshold are repeated on several occasions. Using this method a normal electrosensitivity threshold of 6 mA has been obtained. Unipolar stimulation using an electrode within the bladder lumen surrounded by saline may also give an estimate of bladder electrosensitivity. For obvious reasons this is a somewhat less reliable measurement. Powell and Feneley (1980) have shown a good correlation between urethral electrosensitivity threshold and the first desire to void on cystometrogram and also with cystometrogram capacity.

Increased Sensation

The characteristics of the cystometrogram in hypersensitive bladders have been described previously (see 'Hypersensitive Cystometrogram', p. 68). Similar hypersensitivity has been recorded in the urethra and correlates well with bladder hypersensitivity syndromes. Indeed it is not always easy to decide whether the symptoms arise from the bladder or urethra. Cystoscopy, with careful urethroscopy, is always indicated for many of these cases may be associated with inflammation. In other cases where no inflammatory pathology can be found the situation is less easy to understand, and the effect on bladder and urethral function is only just beginning to be understood. Although there is markedly increased sensation in many cases this does not seem to lead to reflex facilitation of motor activity. Instability associated with hypersensitivity is uncommon. Indeed we have observed more frequently an inhibition of detrusor contraction with a poor urine flow rate. It may be that urethral pain exerts an effect similar to anal pain in this respect, predisposing towards retention.

Increased urethral sensitivity is also associated with outflow obstruction due to prostatic hypertrophy. The reason for this is not clear but again there may be a dynamic relationship between urethral sensation and the inhibition of detrusor contractility. This would mean that the 'decompensation' of the detrusor in chronic retention was not necessarily just due to physical overdistension.

Klevmark (1980) describes two types of sensory urgency or hypersensitivity. In one group the average volumes at first desire to void, urgent desire to void and maximum cystometric capacity were 60 ml, 110 ml and 205 ml respectively. Bladder filling under anaesthetic showed a normal capacity. He describes these as 'idiopathic sensory urgency' and a few of the cases were later shown to be due to interstitial cystitis. This group of patients tended to have nocturia and incontinence and frequency/volume charts showed small volumes day and night. This group could never be distracted from their symptoms and the cystometric capacity was always small. A second group he describes as 'psychosomatic sensory urgency.' In this case the first desire to void, urgent desire to void and maximum cystometric capacity occurred at average volumes of 115 ml, 210 ml and 500 ml respectively. The patients could always be distracted from their symptoms to accept a normal bladder capacity. This group of patients would usually sleep through the night, had little or no incontinence and the frequency/volume charts showed extremely variable capacities. It was felt that this second group of patients should be treated by psychotherapeutic methods.

In relation to this rather ill-defined group of hypersensitive patients pathological changes within the sacral nerve roots have been reported. Bohm et al. (1959)

described fibrosis, myelin degeneration and round cell infiltration in the majority of human sacral nerve specimens taken from patients complaining of severe pain syndromes in the lower urinary tract.

Decreased Sensation

If lower urinary tract sensation is sufficiently decreased then continence is compromised and detrusor contractility may be impaired. It is likely that objectively demonstrated hyposensitivity will be related to some identifiable neurological disorder. Two other groups of patients with decreased urethral sensitivity have been determined by Powell and Feneley (1980). In one group the hyposensitivity is associated with longstanding bladder instability. It may be that the inadequacy of urethral sensation predisposes to the impairment of maturation of bladder control. If sensation is not conducted up to the brain then neither conscious nor unconscious control of the micturition reflex can develop. The other group of patients with hyposensitive urethras complain of hesitancy of micturition, a variably slow stream and recurrent urinary tract infections. A few cases present with recurrent episodes of acute retention in the absence of apparent obstruction. It is likely that intensive investigation of this group would reveal an occult neuropathic state, but as yet the studies have not been performed.

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Chapter 5

The Clinical Contribution of Urodynamics

Introduction

The purpose of this chapter is to show how urodynamic tests can help the clinician to improve diagnosis and treatment. There are four main ways in which this is possible. Firstly, the investigations may assist in the evaluation of an individual case, providing objective evidence on which to base decisions. Secondly, the analysis of groups of patients may, over a time, improve both the understanding of pathophysiology and the selection of patients for treatment. Thirdly, urodynamics may provide objective information before and after therapeutic intervention, allowing the clinician to monitor the results of treatment more accurately and, lastly, they assist the continuing education of clinicians themselves.

As the clinician becomes more experienced in the urodynamic investigation of patients his confidence in his diagnostic ability as to the significance of symptomatic complaints increases. This increase in confidence is only partially justified. We shall refer to the study in which the diagnostic ability of the urodynamic investigators was tested. The computer proforma (App. 2) contains a question asked of the investigator at the end of the symptomatic enquiry. The investigator is asked to predict the urodynamic findings from the symptomatic complaints. Even for the experienced investigator the results are salutary!

The urodynamic diagnosis is used by us as the 'arbiter of truth'. This statement assumes that the explanation for the patients' symptomatic complaints must unfold as the urodynamic investigations proceed. If the symptomatic history and the urodynamic investigations are at variance then the studies should be repeated or extended.

The appropriate distribution of referred patients by sex, age and urodynamic diagnosis is given in Table 5.1. The specific interests and responsibilities of the urodynamic unit have influenced the proportions in each group. However, the investigation of incontinence forms a large proportion of the work of any urodynamic unit. Incontinence is one of the symptomatic complaints of 52% of male patients and 78% of female patients referred to the unit (Table 5.2). Of all patients referred for investigation, 34% were women with stress or urge or stress/urge incontinence. However, the prevalence study conducted in the community demonstrates the real extent of the problems of incontinence (Table

Table 5.1. The urodynamic diagnosis of 1002 male patients and 1901 female patients referred for investigation

Urodynamic diagnosis	Males%	Females%
Normal unobstructed	14	26
Unstable unobstructed	20	19
Hypersensitive unobstructed	6	12
Stress incontinent unobstructed	1	20
Unstable, weak sphincter unobstructed	2	6
Normal obstructed	10	2
Unstable obstructed	16	1
Hypersensitive obstructed	6	1
'Neuropathic'	15	8
'Others'	10	5

Table 5.2. The types of incontinence categorised by symptoms

Incontinence (types)	Men % (576 patients)	Women % (791 patients)
None	47.5	22.3
Stress	1.0	19.0
Stress/urge	0.7	25.1
Urge	22.7	14.4
Urge/enuresis	3.3	5.1
Enuresis	5.7	2.9
Postmicturition dribble	13.0	0.8
Continuous	4.2	6.4
Other	1.9	4.0

Table 5.3. The prevalence of incontinence in the community

	Men %		Women %	
Incontinence	15–64 yrs	over 65 yrs	15–64 yrs	over 65 yrs
Recognised	0.1	1.3	0.2	2.5
Unrecognised	1.6	6.9	8.5	11.6

5.3). The recognised group consists of those patients who are known to the various health and social service agencies participating in their management. The 'unrecognised' group consists of patients who suffer incontinence and who have not sought medical advice, but were identified by the study.

In this chapter lower urinary tract problems are discussed. They are presented as they were referred to the clinician, that is, according to their symptomatic complaints. The accuracy of diagnosis from the patients' symptoms is also discussed.

The presenting clinical problems have been arranged by age and sex, partly because this is the way they present and partly because such factors modify management. The exception is the section on the neuropathic bladder which is sufficiently homogeneous to stand alone. The section dealing with geriatric patients has been approached slightly differently. The unit in Bristol has developed a particular interest in the voiding problems of the elderly, stemming from urodynamic investigations, and encompassing extensive nursing care.

Urodynamic investigation is placed in the context of the overall management of the problem and, to simplify the understanding of this, flow diagrams have been used[1]. We also describe the way in which urodynamic tests may be modified to suit particular clinical problems. In general, the advisability or otherwise of particular forms of treatment has not been discussed unless urodynamics has a special relevance.

Children

Urodynamic studies are more complicated in children than in adults for several reasons. The size of the urethra may lead to technical difficulties in catheterisation and the catheters are more likely to obstruct urinary flow. The co-operation of a child may be difficult to obtain. There is a natural reluctance among clinicians to investigate children because of the possible emotional trauma. It is therefore necessary to be certain that investigation by urodynamics is appropriate and that the results are likely to be clinically useful.

There are three clinical areas in which functional assessment may be of value:

Congenital and anatomical abnormalities include urethral valves and defects of development or fusion of the bladder, urethra and anterior abdominal wall. Urodynamic investigation is seldom necessary for diagnosis though a flow rate may be helpful in excluding obstruction. Functional measurements may be useful in the assessment of treatment (Cromie and Duckett 1979).

Neurological disorders in children are most commonly related to dysgenesis of the spine and the associated nervous system. The neurological deficit is frequently more complicated than that in acquired neurological problems and this makes the interpretation of bladder dysfunction more difficult. However, the comments made in the later section on neurological disorders (see 'The Neuropathic Bladder', p. 164) are equally relevant to children and should be read in conjunction with the paragraph below, relating to paediatric neuro-urology.

Dysfunctional voiding problems are where urodynamic assessment of children and young adults is most relevant. These include enuresis, the diurnal frequency/urgency syndrome, some cases of so-called occult neuropathic bladder and also some cases of recurrent urinary tract infection.

Modification of Investigation Techniques

If urodynamic studies are to be of diagnostic importance then it is justifiable to introduce the filling and pressure measuring catheters by the suprapubic route under a general anaesthetic, perhaps at a prior cystoscopy (see 'Access for Measurement of Intravesical Pressure', p. 63). This route of catheterisation is preferable in boys below the age of puberty and girls below the age of about 8 years. This approach is recommended because of the importance of obtaining reliable and repeatable measurements for diagnostic purposes. The transurethral introduction of catheters is far more likely to disturb the responses obtained or to prevent investigation altogether.

Various investigators have described the use of sedation and even general anaesthesia before investigation, but this need not be necessary provided that sufficient time is spent obtaining the confidence of the child. In general it is preferable to exclude the parents from the investigation and with the prior placement of the recording catheters the whole investigation can be performed with the child sitting on the commode over the flowmeter. Synchronous radiological studies may well be helpful, but the presence of the x-ray apparatus tends to disturb the children in the same way that it does adult patients.

Children under the age of 4 years are unlikely to be able to co-operate with any investigation more complicated than a flow rate. Few children are therefore investigated below this age and there are good reasons for investigations of young children being carried out only in units with special expertise and experience. Older (post-pubertal) children and adolescents can be investigated in the same way as adults.

If the results of initial urodynamic investigation are abnormal the studies should be repeated until the investigator is sure that the child is relaxed and the voiding pattern is reproducible. This requirement is facilitated by the presence of suprapubic catheters. It is important not to label a child who has intermittent sphincter contractions during voiding on a first urodynamic test as a 'dysfunctional voider'. It should be remembered that the child's bladder accommodates less than the adult's and the filling rate should be adjusted accordingly. In most cases a filling rate of 15 ml/min is optimal. The parameters of normal must also be judged in relationship to those worked out for children of a comparable age. This is particularly true of the flow rate (Gierup 1970). The minimum acceptable maximum urine flow rates are given in Table 3.1. To be more accurate, the flow rate should be assessed in relation to the volume voided, as in adults (see Fig. 3.4).

Enuresis

Nocturnal enuresis has been the commonest reason for the urodynamic assessment of young persons in Bristol. Enuresis is defined as a reflex act of normal micturition, occurring during sleep. A total of 259 patients have been investigated and most of them are being followed up to determine the natural history of adolescent enuresis (Table 5.4).

Table 5.4. The urodynamic analysis of 259 enuretics

Age	Male	Female	Total	Unstable
Under 10	19	8	27	22 (81%)
10–19	66	67	133	71 (53%)
20–29	43	56	99	62 (62%)
Total	128	131	259	
Obstructed	10 (7.8%)	1 (0.7%)		
Unstable	85 (66%)	70 (53%)		

Since urodynamic studies are not required in the diagnosis of enuresis their relevance has been mainly to the understanding of pathophysiology and in the selection of patients for treatment. They have as yet contributed little to the management of the condition.

As is shown in Table 5.4 the incidence of bladder instability in enuresis is high. Ellison Nash (1949) related the prognosis for childhood enuresis to the severity of the bladder instability. He also found that the degree of instability was closely related to the diurnal symptomatology. He interpreted enuresis as a delay in the normal maturation of urinary control. However, it is obvious that the basic problem in enuresis is the inability to wake up even when the bladder is full and starts to contract. The observations of Torrens and Collins (1975) and of Powell and Feneley (1980) have shown that there is a deficiency of sensation in the lower urinary tract of some enuretics. It may well be that this contributes both to impaired arousal during sleep and to the defective maturation of bladder inhibition. Certainly, the further understanding of enuresis will require the combined analysis of central neurological and peripheral urological function.

Urodynamics has contributed a little to the management of this syndrome, particularly in abolishing the idea that obstruction is an important cause of enuresis. In our series obstruction was only significant amongst males where 7% of cases showed increased urethral resistance. Half of these cases were borderline and did not warrant outflow tract surgery. Functional investigation has shown that the combination of trabeculation, a prominent bladder neck and a subvesical posterior urethral pouch indicate only detrusor hypertrophy because of instability. There is no correlation with obstruction.

It would be useful if selection for treatment could be based on urodynamic results. For example, it would be logical to treat the unstable cases with anticholinergic drugs and the cases with no bladder instability with drugs that increase urethral tone. However, little useful correlation between urodynamics and successful treatment has been found. It is apparent that the more unstable the bladder, the more difficult it is to treat by any means, and the less likely it is to resolve spontaneously. It is significant that the most useful treatments in enuresis are those which act centrally on the nervous system, and those that act both centrally and peripherally are especially effective (e.g. Imipramine and Ephedrine). The most effective treatments of all would seem to be either conditioning by enuretic alarm or the use of an antidiuretic agent such as DDAVP (Desmopressin).

The main clinical use for urodynamics is therefore in the exclusion of obstruction and it is likely that this can be achieved by a flow rate. Those centres which maintain a special interest in the subject and can assess large numbers of patients as part of a research project must continue to do so in the hope that a more rational explanation for the syndrome can be elaborated.

Symptoms of Bladder Overactivity in Children

Diurnal symptoms of frequency, urgency and urge incontinence are not uncommon among children and may be associated with nocturnal enuresis, as described above. These symptoms of bladder overactivity decrease with age so that few young adults have significant problems, though the symptoms may return in late middle age. Where symptoms of overactivity are not associated with urinary tract infection it is uncommon to find any anatomical abnormality, though the presence of bladder instability is predictable. Some authors have related the high pressure within the unstable bladder to the incidence of recurrent urinary tract infection in women (Lapides et al. 1968).

In children with bladder overactivity we would suggest that obstruction should be ruled out by doing a urine flow rate and that pressure flow studies should be performed in equivocal cases only. It appears that full urodynamic investigations do not improve the management of the patient and symptomatic treatment should be given whilst waiting for the condition to improve spontaneously.

Recurrent Urinary Tract Infections

After proven urinary infections most children will be referred for excretion urography and micturating cystourethrography. These investigations will demonstrate the majority of pathological problems, the most important of which is vesico-ureteric reflux. Urodynamic investigations do not identify other causes for recurrent urinary infection in these children.

Voiding Difficulties

Voiding difficulties are unusual in the neurologically intact child. Occasionally children present with infrequent or difficult voiding, or perhaps with recurrent infections. Radiology in such patients may show a bladder which is emptying poorly and no structural reason for this, such as urethral valves, can be found. In these cases urodynamic studies are necessary to identify the functional cause of the voiding problem.

One reason for failure to void may be a long-standing inadequacy of bladder contraction. Alternatively, there may be a functional failure of co-ordination between detrusor contraction and sphincter relaxation. This syndrome, described in detail by Allen (1977), consists of high detrusor pressures in large trabeculated bladders, associated with a persistently contracting sphincter. In some of these cases voiding is possible when the very high detrusor pressure overcomes the urethral sphincter contraction. However, residual urine is universal, infection and reflux are common and incontinence is also common. Many of the children also exhibited bowel dysfunction, especially chronic constipation. Allen has emphasised the role of bladder re-training in treatment. Others might resort to sphincterotomy or perhaps to primary treatment of the constipation.

Neurological Disorders

The largest group of children with neuropathic bladders is those with myelodysplasia. It is important to recognise that the level of the neurological lesion does not correlate with the functional classification of the bladder. This is true in many types of neurological disease, but is particularly evident in these children, most of whom have spina bifida in addition to their neurological lesion.

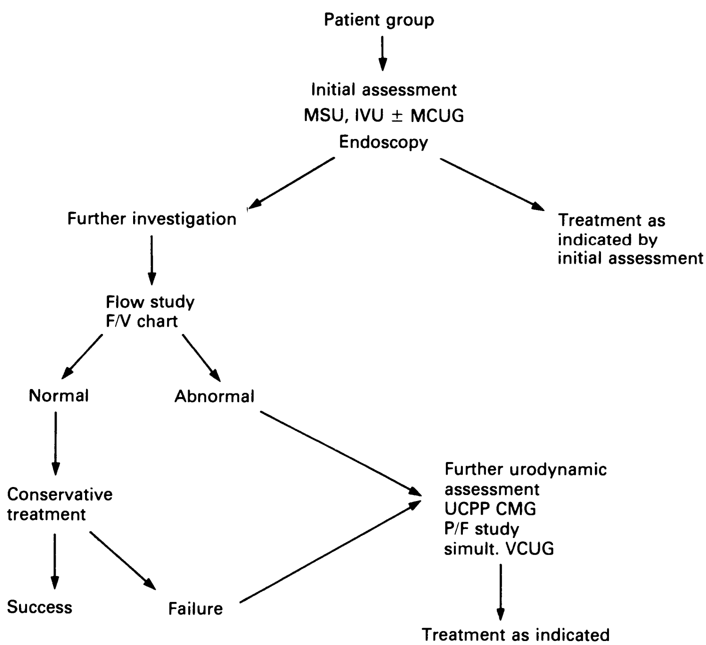

Fig. 5.1. Suggested management of children with voiding disorders.

In the flow diagrams the following abbreviations are used: CMG, inflow cystometrogram; F/V chart, frequency/volume chart; IVU, intravenous urogram; MSU, midstream specimen of urine; P/F study, pressure/flow study of micturition; PUT, plain urinary tract x-ray; UCPP, urethral closure pressure profile; VCUG, video-cystourethrography.

The crucial functional distinction is between a high-pressure and a low-pressure bladder, the former being associated with the worse prognosis. Blaivas et al. (1977) emphasised that there was no statistical correlation between the pressure generated in the bladder and the level of the neurological lesion. They noted that detrusor/sphincter dyssynergia can occur in both high- and low-pressure bladders, but that only in the high-pressure variety does the dyssynergia commonly lead to a significantly increased residual urine.

It must be emphasised again that a slow rate of filling is necessary in neurologically abnormal patients. Since the problems are usually complicated it is also appropriate to perform synchronous video-cystography and/or EMG recording.

The principles of management are threefold:

1. To reduce the bladder pressure, if high, with drugs or by sphincterotomy
2. To counteract infection by urinary acidification and antibiotics, in low dosage if necessary, and by keeping the bladder empty either by expression or by intermittent catheterisation
3. To promote continence either by drugs to combat the demonstrated functional abnormalities, or by keeping the bladder empty using intermittent catheterisation or by encouraging voiding by the clock

Figure 5.1 presents a suggested line of management for children with voiding disorders.

The Adult Male

The prostate gland has been held responsible for many of the symptomatic complaints of male patients, particularly amongst those of the older age group. There has been the tendency to use prostatectomy as a panacea for lower urinary tract symptoms. The need for objective evaluation of these symptoms was answered by the introduction of pressure/flow analysis of micturition. Urodynamic studies have provided alternative explanations for certain symptoms and they have contributed to our understanding of some of the common disorders. However, they have not in any way superseded the importance of a careful and a methodical clinical assessment. The history and clinical examination, followed by the routine urine and appropriate radiological investigations, remain the basis for urological management. This section outlines the ways in which urodynamic studies can improve this management in male patients.

Symptomatic Groups

Symptoms give a poor indication of the diagnosis in patients with lower urinary tract disorders. Urinary symptoms tend to be emotive, causing distress and embarrassment to many patients, with the result that the problem is often exaggerated when medical advice is first sought. The value of the frequency/volume chart, recording the micturition pattern, has been a notable success in our experience. The complaints of frequency every half hour, or nocturia disturbing sleep three or four times every night are often not confirmed when the patient maintains a chart over a period of 3 days.

Incontinence of urine occurs throughout the age span of the adult male. Out of a total of 1002 male referrals to our Unit between 1975 and 1980, 587 patients were incontinent, but they tended to have a minor degree of disturbance compared to the women: 33% had urge incontinence, 29% had postmicturition dribble, 25% had enuresis and 10% had continuous incontinence; 43% of young adult males presenting to our Unit complained of urgency, urge incontinence and enuresis. Similarly, 44% of 318 older men referred with symptoms considered to be attributable to prostatic obstruction, complained of incontinence. A careful history should make it possible for the clinician to decide what type of incontinence the patient is experiencing (see 'Urinary Incontinence', p. 00). In the male patient with no evidence of any neurological abnormality, incontinence is associated with a high incidence of bladder instability. Stress incontinence is very unusual, but it may follow prostatic surgery or occur in high-pressure chronic retention when intravesical pressure exceeds intra-urethral pressure.

A postmicturition dribble is a common complaint in all age groups and occurred in 27% of our male patients. It is not associated with objective evidence of bladder outflow obstruction, but with the trapping of urine that may occur between the bladder neck and the distal sphincteric mechanism, or with failure of the bulbospongiosus muscle to empty the urethra at the end of micturition. It is a condition that is not treated by operation, but by perineal muscle exercises and manual compression of the urethra at the end of micturition.

Recurrent Urinary Tract Infections

Patients presenting with frequency, urgency and dysuria are commonly labelled with the diagnosis of a urinary tract infection. The history may consist of one or more episodes and the patient may already have been treated empirically with antibiotics. Symptomatic complaints suggestive of a lower urinary tract infection must always be confirmed by accurate diagnosis. Examination of a fresh midstream specimen of urine by microscopy and culture is essential. Irritative symptoms may arise from other pathological conditions in the urinary tract such as calculi or neoplasms, but the routine urological screening (midstream urine and plain urinary tract x-ray) should identify such abnormalities. A relatively unusual predisposing factor in the aetiology of a recurrent urinary tract infection is infrequent voiding. This is much more common in women, but does occur occasionally in male patients. Such patients can hold urine 8 h or more during the day and void 800 ml or more on micturition. This will be evident from the frequency/volume chart. It is considered that such infrequent voiding may allow the colonisation of the bladder by bacteria, as even a small residual urine (less than 50 ml) may lead to a clinical urinary tract infection (Mackintosh et al. 1975). By advising the patient to void more frequently, every 2 or 3 h, recurrent infection may be prevented.

In the presence of urinary infection and/or calculi the question of an associated bladder outflow tract obstruction does arise. The intravenous urogram is a poor method of diagnosing obstruction, whereas urodynamic studies can be helpful. If endoscopy is indicated on clinical grounds it is preferable to undertake urodynamic studies before this examination is performed. Urine flow studies are the simplest routine urodynamic investigations and if these are normal further urodynamic investigations are unlikely to be helpful.

If the urine flow rate is reduced, or in an equivocal range, further urodynamic studies may be indicated. Urethral pressure profilometry may reveal the presence of a bladder neck, prostatic or urethral abnormality which predisposes to the problem. Catheterisation after urodynamic studies allows the accurate measurement of residual urine. As the bladder and urethra work as a single unit during voiding, a residual urine may result from abnormal bladder behaviour, abnormal urethral behaviour or both. Poorly sustained detrusor contractions may occur with or without neurological abnormality. Incomplete emptying due to detrusor underactivity becomes a more potent factor with age as outflow obstruction becomes more common. Detrusor contraction may be adequate, but emptying is prevented by outflow obstruction. Most commonly the obstruction is anatomical, such as a bladder neck stenosis, prostatic hypertrophy or a urethral stricture. However, the obstruction may be functional, as in the neurologically abnormal patient with detrusor/sphincter dyssynergia or those younger male patients with detrusor/bladder neck dyssynergia.

Figure 5.2 summarises the investigation of patients with proven urinary tract infections. In this group of patients it is advisable to give the patient a prophylactic antibiotic prior to and after the urodynamic investigation.

Symptoms of Bladder Overactivity

The diagnosis of bladder overactivity is suggested by the symptoms of frequency, nocturia, urgency, urge incontinence and enuresis. These symptoms may be produced by a reduced bladder capacity or an excessive output of urine in a patient with a normal bladder capacity. The bladder capacity may be reduced as a result of a functional or a structural cause. Patients with a reduced functional bladder capacity form the largest group and the common causes are a residual urine occurring with outflow obstruction, bladder instability and bladder hypersensitivity.

Symptomatic Diagnosis

The crucial question is how to distinguish between the various causes of the symptoms of overactivity.

As we have discussed previously, bladder instability is associated with the symptoms of frequency, nocturia, urgency and urge incontinence: bladder hypersensitivity with frequency, nocturia, bladder discomfort and, less commonly, urgency. Outflow obstruction leads to frequency and nocturia if there is a large residual urine. The problems in diagnosing the cause of bladder overactivity from the symptomatic complaints are due to the high incidence with which two conditions coexist (Abrams 1977) as shown below, the data being derived from a series of 319 men with symptoms suggestive of outflow obstruction (Table 5.5).

Various studies have shown that the symptoms of overactivity noted above are of doubtful diagnostic use when considered alone. The more complete the symptom complex is, i.e. the more of the symptoms that occur together, the greater is the likelihood of bladder instability.

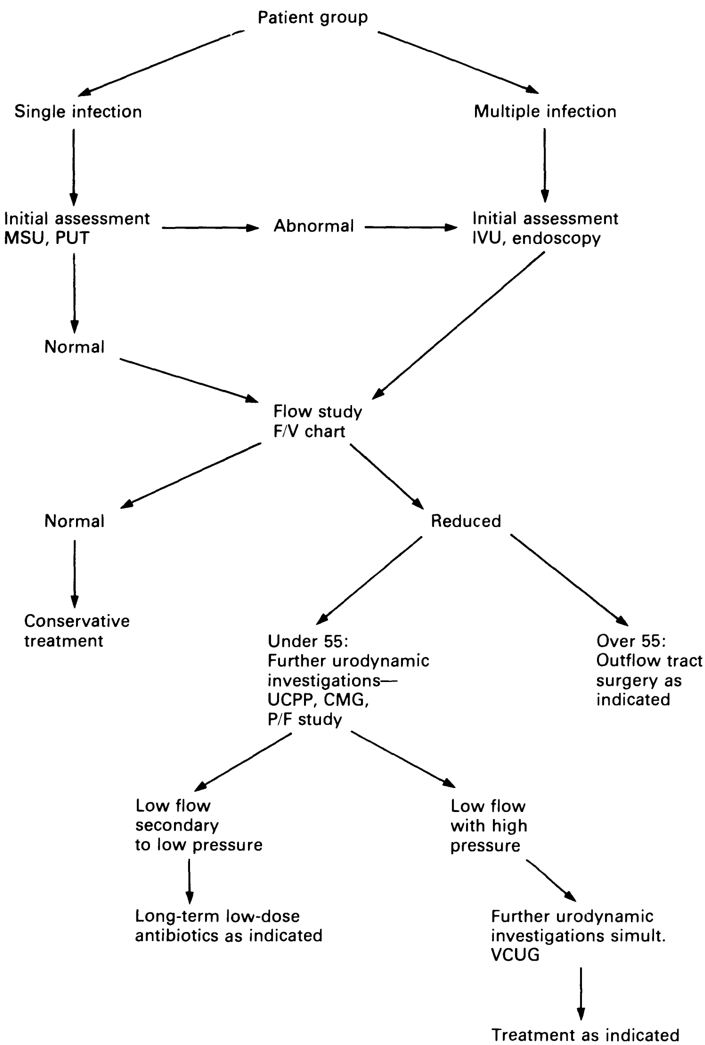

Fig. 5.2. Suggested management of male patients with urinary tract infections.

Only hesitancy and a slow urinary stream have significance in the diagnosis of obstruction. Unfortunately their diagnostic usefulness is reduced in the group we are currently considering. Because of the reduced functional bladder capacity the voided volume in these patients is small. The small volume is associated with a slower stream and hesitancy whether or not there is obstruction.

The confusion engendered by the symptoms variously attributed to bladder overactivity and obstruction can be illustrated by the example of two unobstructed patients voiding 1 litre urine per 24 h (Table 5.6, data from Siroky et al. 1979). It is clear from the example that by reducing the functional bladder capacity, bladder

Table 5.5. The filling and voiding urodynamic diagnoses in men with instability, hypersensitivity and obstruction

Urodynamic diagnosis		
Filling	Voiding	
Unstable	Unobstructed	14%
Hypersensitive	Unobstructed	4%
Normal	Obstructed	17%
Unstable	Obstructed	40%
Hypersensitive	Obstructed	7%

Table 5.6. The effect of bladder instability on the micturition symptoms for a daily voided volume of 1 litre

	Frequency	Nocturia	Average void (ml)	Patient's description of stream	Maximum flow rate
No instability	4	0	250	Normal	25 ml/s
Instability	8	2	100	Slow	13 ml/s

instability is responsible not only for the symptoms of overactivity, that is, frequency, nocturia and urgency, but also the complaint of slow stream.

Although both bladder instability and bladder hypersensitivity may be found in the presence of outflow obstruction, their relationship has yet to be established. For example, instability is said by some workers to be due to obstruction yet instability is found in the same percentage of unobstructed as obstructed patients (Abrams 1977).

Bladder overactivity due to bladder instability may continue from childhood into adult life. Our study of 212 adult male patients aged 20–45 years showed that 76% of patients complaining of frequency, nocturia, urgency and urge incontinence had bladder instability. In the younger male patient with this symptom complex the finding of coexisting obstruction was uncommon (4%). Bladder instability becomes more common with age in the patient population. In the 20–30 age group instability was seen in 33% of patients and in the 45–85 age group in 54% of patients, when instability was seen frequently in association with obstruction (Abrams 1977). Bladder hypersensitivity is seen in 10%–15% of the patient population in all age groups from 10-78 years (Abrams 1977, Abrams et al. 1981).

In our study of clinical diagnostic efficiency it was found that the chance of predicting correctly the presence of an unstable bladder before urodynamic studies was 53%. However, a very poor predictability of only 13% was found for the hypersensitive bladder.

Urodynamic Diagnosis and Management

The ability of a flow study to distinguish between hyperactivity alone and hyperactivity with obstruction is good provided the patient can pass a sufficient volume for proper analysis. Our study of 212 young men with voiding problems showed that of 116 presenting with symptoms of overactivity, pressure flow studies demonstrated obstruction in 8. In all these patients the diagnosis of obstruction could have been made on the flow studies alone.

We would argue that once coexisting pathology has been excluded, by an MSU, plain urinary tract radiology and endoscopy, then the only remaining question of therapeutic importance is, does outflow obstruction exist? If no obstruction exists then it is reasonable to treat the patient empirically with an anticholinergic such as Imipramine or Emepronium Bromide. If the patient fails to respond to drug treatment then full urodynamic studies should be performed, in order to define precisely the extent of the abnormality of bladder activity producing the patient's symptomatic complaints, before any other definitive treatment is instituted. The baseline urodynamic studies may then be repeated after therapy to assess its effect.

The possible organisation of management is shown in Fig. 5.3.

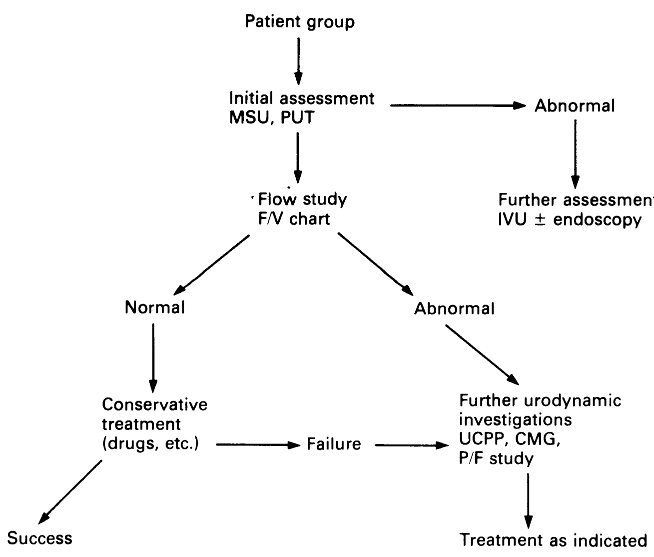

Fig. 5.3. Suggested management of male patients with symptoms suggestive of bladder overactivity.

Voiding Difficulties

The distribution of voiding difficulties is dependent on age, there being a high incidence of outflow obstruction in patients over 55. In a study of 318 patients over the age of 55 we assessed the relevance to the urodynamic findings of the presenting symptoms listed below:

Frequency
Nocturia
Urgency
Incontinence
Slow stream
Hesitancy
Postmicturition dribble

Of this symptom complex, known collectively as 'prostatism', only the complaints of slow stream and hesitancy were shown to be associated with the proven presence of outflow obstruction (Abrams and Feneley 1978). From the discussion in the previous pages it is clear that the greater number of these symptoms, that is, frequency, nocturia, urgency and incontinence, may be attributed to bladder overactivity. The complaint of postmicturition dribble, as has been discussed in Chap. 3, has no association with either overactivity or obstruction.

We feel strongly that the term 'prostatism' should be abandoned and the patient's symptoms enumerated. This has the dual role of making the clinician decide from the history the likely cause of the patient's symptoms and to avoid the tendency for the patient with 'prostatism' to proceed automatically to prostatectomy.

Although it is possible to associate certain symptoms with either overactivity or with obstruction, patients often present with a mixture of symptoms. Table 5.7 shows the ultimate urodynamic diagnosis of 318 Bristol patients with lower urinary tract symptoms. It is clear that the largest group of patients will present with the symptoms of both overactivity and obstruction. Table 5.7 shows that 13% of all patients presenting with symptoms thought to be due to obstruction were found to have no urodynamic abnormality either on inflow or on outflow cystometry.

The urine flow study was a reliable indicator as to the presence or absence of obstruction. If the flow study is normal then, if the patient has symptoms of overactivity, the plan of treatment should follow that outlined in this chapter, 'Symptoms of Bladder Overactivity'. If the flow rate is definitely reduced then, taken with the symptomatic complaints, the surgeon has adequate evidence to

Table 5.7. The urodynamic diagnosis of 318 male patients (aged 45–85) referred with symptoms suggestive of outflow obstruction

Urodynamic diagnosis	
Normal	13%
Unstable unobstructed	14%
Hypersensitive unobstructed	4%
Obstructed	17%
Unstable obstructed	40%
Hypersensitive obstructed	7%
'Others'	5%

proceed to outflow tract surgery in the over-55-years age group. Standard urodynamic tests may be desirable if the results of the urine flow studies are equivocal for the diagnosis of obstruction. A patient over 55 years of age with a low flow, particularly if he has a significant residual urine demonstrated by postflow catheterisation, will be improved by outflow tract surgery, in terms of increased

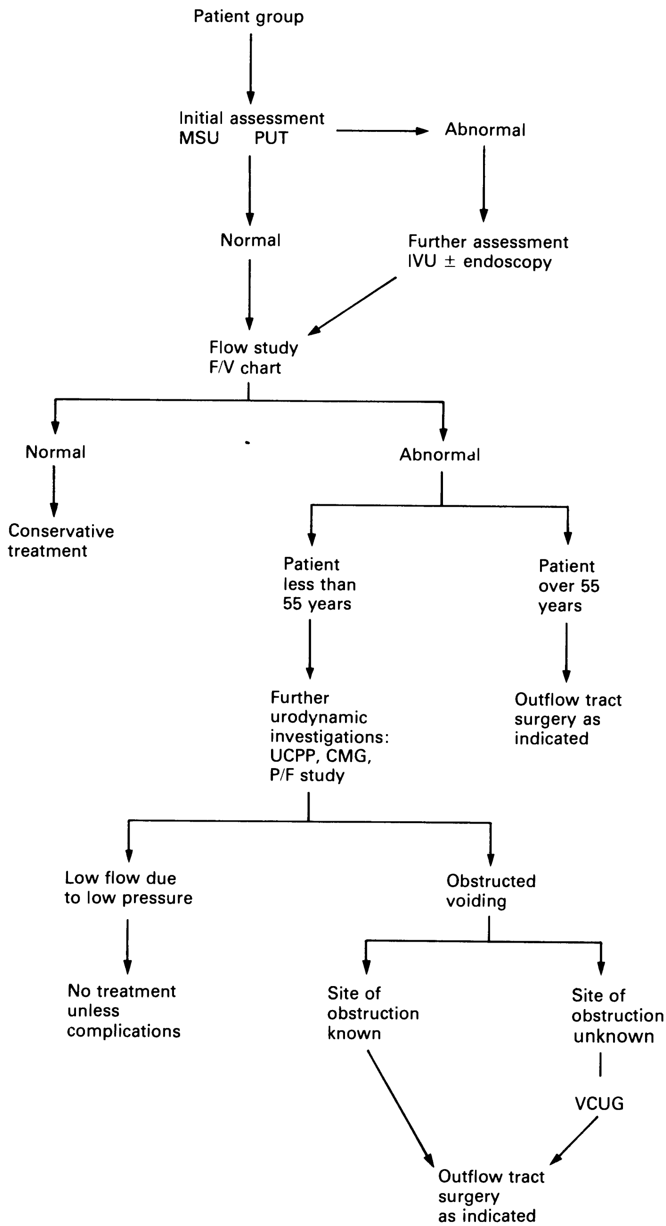

Fig. 5.4. Suggested management of male patients with symptoms suggestive of outflow obstruction.

flow and decreased residual urine. The evidence for this view comes from a study of 100 patients investigated by standard urodynamic studies before and after operation. Of 13 patients with low flow and normal voiding pressures, 11 were urodynamically improved by prostatectomy (Abrams 1977). The suggested management is shown in Fig. 5.4

From the former series of 318 patients 107, who had not proceeded to elective surgery on clinical grounds at the time of first assessment, were reviewed after an interval of 5 years (Ball et al. 1981). Fifty three of the 107 patients had originally been shown to be obstructed by urodynamic techniques. Ten patients had subsequently required surgery, 2 because of acute retention and 8 because of deteriorating symptoms; all of these patients had been classified as obstructed. Of the remaining 97 patients the symptoms in 81 were unchanged or slightly better. Most had no evidence of progression of the disorder on clinical or urodynamic assessment. Leaving 'prostatism' untreated did not lead to many problems and the urine flow rate was shown to be the best test to monitor the progress of the condition. No patient with a flow rate within 2SD of normal required surgery within the review period.

Readers may note the omission of comments on the benefits to lower urinary tract investigation of intravenous urography. In our opinion the indications for urography are symptoms suggestive of neoplasia, stone or upper tract disease such as pyelonephritis. In addition, urography may be indicated if the plain urinary tract x-ray is abnormal, or if the urine specimen shows microscopic evidence of pyuria or haematuria. Urography has little part to play in the investigation of functional lower tract problems. This opinion was reached as a result of reviewing 202 urograms from patients with symptoms thought to be due to prostatic enlargement, and who had been investigated using standard urodynamic tests (Abrams et al. 1976). This study showed that the only radiological signs that could be associated with obstruction were the size of the basal prostatic filling defect and bladder size, but only if the bladder size was comparable on both the control film and the postmicturition film. Several other radiological features have been attributed to outflow obstruction. Of these trabeculation, the presence of diverticula and upper tract dilatation were associated with a high intravesical pressure. The value of urography is further diminished by the unreliability of its ability to show residual urine accurately, as discussed in Chap. 2, 'Intravenous Urography'. There is now much evidence to show that urography is an unnecessary investigation in the assessment of bladder outflow obstruction (Marshall et al. 1974; Abrams et al. 1976; Gammelgaard et al. 1976).

Postprostatectomy Problems

Patients with postprostatectomy problems present as three main symptomatic groups:

Persistent symptoms of bladder overactivity

Persistent symptoms suggestive of obstruction

Incontinence

Therefore, several symptom complexes are seen which may suggest a single disorder or, as in the non-operated patient, a combination of symptoms suggesting, for example, overactivity and obstruction. The symptoms of frequency, nocturia, urgency, urge incontinence and bladder discomfort are suggestive of persistent bladder overactivity. The symptoms of slow stream and hesitancy and the occurrence of proven urinary tract infections are suggestive of persistent obstruction. The symptom of incontinence is likely to be regarded even more seriously by the patient after surgery than before operation. The patient should be asked the frequency and severity of his incontinence and whether or not he suffers social restriction or has to take protective measures to safeguard his clothes. It is also important to establish whether or not the incontinence was present before operation and then to determine what kind of leakage the patient suffers. The incidence of postprostatectomy incontinence has been estimated at 3% (Powell 1980).

The standard urodynamic studies are adequate for the investigation of almost all this group of patients. As we shall describe, the urethral pressure profile and the voiding study are particularly useful.

Abrams (1980) reported the urodynamic findings in a group of 60 patients with postprostatectomy problems. Table 5.8 shows the symptomatic complaints of the patient group.

Table 5.8. The symptomatic complaints of 60 patients with postprostatectomy problems

Symptoms	No. of cases
Incontinence:	
Urge	19
Stress	8
Unclassified	6
Slow stream, hesitancy, straining to void	14
Frequency, nocturia, urgency	11
Postmicturition dribble	2

Those patients with persistent symptoms suggestive of bladder overactivity are shown by the cystometric findings to have a high incidence of bladder instability and bladder hypersensitivity. The symptoms of bladder instability are known to improve after prostatectomy and 62% of unstable bladders revert to normal on postoperative cystometry (Abrams 1978). However, 19% of patients continue to show bladder instability after an adequate prostatectomy. Price et al. (1980) have shown that those patients with the symptoms of urgency and urge incontinence and with demonstrable severe bladder instability before operation are more likely to have persistent problems after operation. The reason for the conversion of bladder instability to normal detrusor behaviour on cystometry is unclear. It has been suggested that lower voiding pressures after prostatectomy, or the denervation of the bladder neck and posterior urethra resulting from surgery may be important factors.

The postoperative complaints of slow stream and hesitancy have in the past led to repeated transurethral resections with the increased likelihood of damage to the intrinsic urethral sphincter mechanism. The urodynamic results of this group of patients clearly show that the minority of such patients with reduced flow have persistent outflow obstruction. A higher proportion of patients have a slow stream due to an underactive or acontractile detrusor. If urethral pressure profilometry shows no residual prostatic tissue (Fig. 5.5), then a second prostatectomy will not help the patient. However, should profilometry show the presence of residual prostatic tissue (Fig. 5.6) then transurethral resection of the remaining prostatic tissue may be expected to improve voiding, even when the detrusor is underactive.

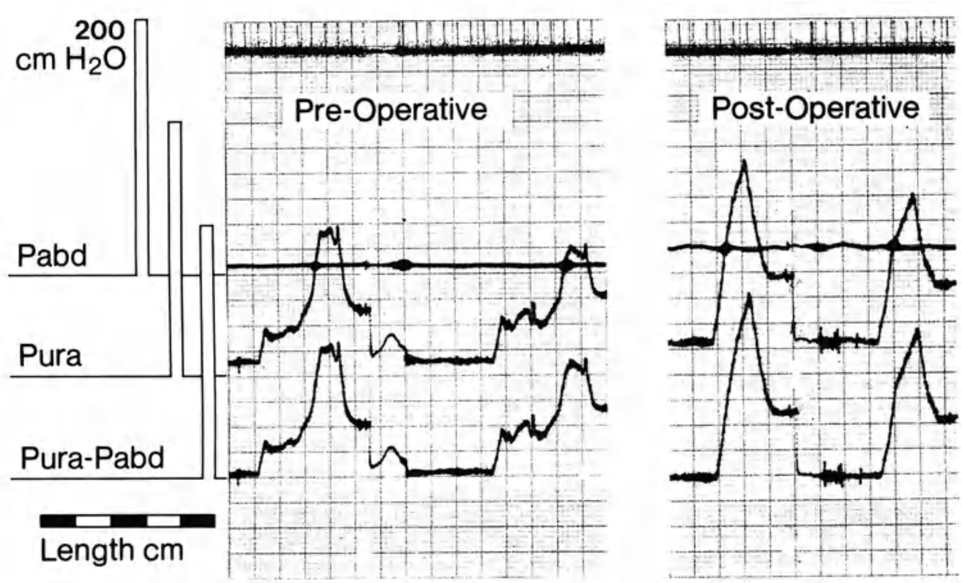

Fig. 5.5. Urethral pressure profiles before and after prostatectomy. There is no residual prostatic pressure area postoperatively.

When assessing postprostatectomy problems a reasonable time interval following the operation should be allowed for the gradual improvement of symptoms, which can be expected to occur for 6 months following surgery. The appearance of new complaints after surgery suggests a change has occurred in the lower urinary tract. Symptoms of overactivity may be due to a urinary tract infection and those of obstruction to a developing stricture. If a patient complains of urge incontinence following prostatectomy then he will have had the symptoms of urgency and possible urge incontinence prior to operation. Our experience of the failure of these symptoms to improve after operation has led us to counsel our patients with urgency prior to operation, explaining that although we would anticipate an improvement in urine flow rate, we cannot be similarly confident with the symptoms of overactivity.

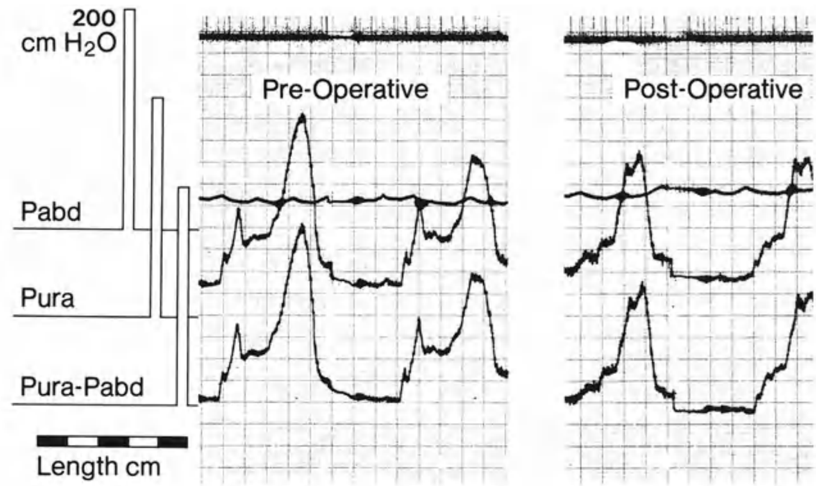

Fig. 5.6. Urethral pressure profiles before and after prostatectomy. In this case enough prostatic tissue remains to produce a presphincteric pressure rise.

Incontinence following prostatectomy is either urge incontinence, stress incontinence or very occasionally a mixture of the two types. The symptom of stress incontinence in neurologically normal male patients does not occur in the unoperated case. Therefore, the appearance of this symptom following surgery implies per-operative damage to the distal urethral sphincteric mechanism, or possibly the weakening of the pelvic floor support to the sphincter mechanism by removal of a large adenoma at open operation. In urological practice it is relatively common to see transient stress incontinence following open prostatectomy. Persistence of stress incontinence, in our view, indicates per-operative sphincteric damage. In male patients stress incontinence is a difficult symptom to treat, but if severe the insertion of some form of artificial sphincter may have to be considered.

Our approach to postprostatectomy problems is outlined in Fig. 5.7.

Patients with normal flow rates who fail to respond to symptomatic treatment such as anticholinergic drugs for bladder overactivity, should be referred for standard urodynamic tests so that the pathophysiology may be more completely understood. Should standard urodynamic tests show that low flow is due to poor detrusor activity with a consequent residual urine after voiding, then the effect of a cholinergic drug such as distigmine bromide or bethanecol may be tried.

Our experience gained by investigating postprostatectomy problems indicates that these symptoms are best investigated by urodynamic means. Then a rational treatment plan encompassing no treatment, medical therapy and surgical treatment can be devised.

The Adult Female

Incontinence in women forms a large part of the workload of any urodynamics unit. Two-thirds of the women referred to the Bristol unit fall into this category. Stress

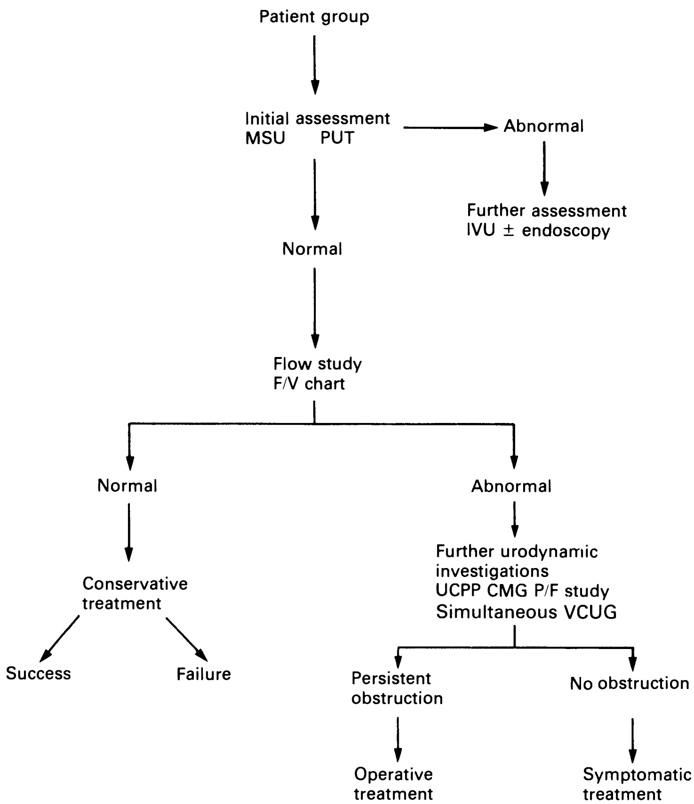

Fig. 5.7. Suggested management of postprostatectomy problems.

incontinence is almost entirely a female problem which may occur alone or be associated, to a variable extent, with urgency. Leakage associated only with urgency is also a common problem. The symptom complex allows an index of suspicion about the nature of the functional disorder, but it is not entirely reliable. One of the principal roles for urodynamics is the identification of the main cause of incontinence, detrusor or urethral, in any particular case.

Table 5.9 shows the distribution of the different types of incontinence among patients referred to our unit. Sixty-four percent complain of either stress or urge incontinence. The reason why female incontinence is more frequent, and more troublesome, than in males is that the predisposing factors work together to compound the problem. While there is a natural tendency for the bladder to become overactive with advancing age, there is also a tendency for the urethra to become less competent. The pattern of presentation therefore varies with age (Table 5.10) and the overall prevalence increases with age.

Table 5.9. The different types of female incontinence categorised by symptoms

Incontinence (types)	%
None	22.3
Stress	19.0
Stress/urge	25.1
Urge	14.4
Urge/enuresis	5.1
Enuresis	2.9
Postmicturition dribble	0.8
Continuous	6.4
Other	4.0

Table 5.10. Percentage of female patients presenting with incontinence according to age

Age	Stress	Stress/urge	Urge
20–30	14%	15%	15%
40–50	30%	34%	16%
60–70	12%	32%	20%

Mixed Stress and Urge Incontinence

This is the most frequent reason for a female referral. It is now well recognised that one of the dominant reasons for the failure of surgery in this group is the presence of significant overactivity of the bladder. So what is 'significant' overactivity?

Symptomatic Diagnosis

The symptoms have been defined in Chap. 2. Close questioning reveals a variety of possible symptomatic combinations in these patients. Pure stress incontinence and pure urge incontinence may coexist in one patient and occur at different times. Others may get a sense of urgency only following a stress such as coughing or sport. Some may have a mixed symptom pattern that is impossible to categorise. Although the existence of urgency should make one suspicious of a diagnosis of pure stress incontinence, it is not an absolutely reliable indicator of bladder overactivity. Table 5.11 relates the presenting type of incontinence to the final urodynamic diagnosis in a series of 679 patients. Whilst the relative incidence of instability of the bladder increases with the prominence of urgency the correlation between the two never reaches even 50%. The correlation of stress incontinence as a symptom with incontrovertible genuine stress incontinence is slightly better, but still inaccurate. It follows that objective studies are necessary for proper diagnosis.

Table 5.11. The urodynamic diagnoses in the four commonest groups of incontinence, categorised by symptoms

Types of incontinence (No. of patients)	Final urodynamic diagnosis %				
	Normal	Unstable bladder	Hypersensitive bladder	Genuine stress incontinence	Other[a]
None (176)	42	13	11	4	30
Stress (150)	35	7	4	39	15
Stress/urge (199)	21	20	7	19	23
Urge (154)	16	29	5	12	38

[a]Includes obstructed, neuropathic, and unclassified cases

Urodynamic Diagnosis

The functional observations made in cases of pure stress and pure urge incontinence will be described later. Certain additional comments are appropriate to the mixed type. The first is one of terminology. To some clinicians the term stress/urge means only urgency provoked by stress. To others it means any combination of the two symptoms. The former category is also described as cough/urge and is exemplified in Fig. 5.8. Certainly the aetiological significance of stress in provoking

Fig. 5.8. Part of a filling cystometrogram showing an unstable contraction provoked by coughing.

bladder instability must be recognised and the patient should be subjected during urodynamic testing to whatever factors predispose to incontinence in her particular case.

The important aspect of investigation is the cystometrogram, and to a lesser extent the voiding study. Filling in the sitting position allows leakage to be noted on the flow trace. The patient should cough during filling. When full, more coughing is encouraged and a Valsalva manoeuvre performed. If the examination is visualised on x-ray synchronously or subsequently the bladder neck function is better displayed. Pressure recording is essential to be sure of the reason for bladder neck opening. If no leakage occurs when sitting, the patient should stand (not forgetting to level the transducers), cough whilst standing and jump up and down if necessary. If no instability is demonstrated after these manoeuvres and leakage does occur on stress, then treatment directed towards the urethral incompetence is appropriate without further investigation of the bladder.

The only relevant part of the voiding study is the response to the command to 'stop' in midstream. The adequacy of the urethral sphincter can be judged by the speed of cessation of urine flow, or by visualising the 'milk back' of contrast into the bladder. If the stream can be interrupted quickly this suggests that the sphincter should be able to withstand the pressure of normal daily stress. If the stream can be interrupted and the isometric contraction pressure observed, an assessment of detrusor strength may be made.

Assessment of urethral function may be important, especially in the absence of video studies and in equivocal cases. A low resting urethral pressure, absent voluntary squeeze and decreased transmission of abdominal pressure to the urethra all suggest incompetence, as is discussed in 'Urethral Incompetence', p. 105.

Management

It is necessary to decide whether bladder instability or urethral incompetence is the most significant cause for incontinence, or that some other cause is responsible. The factors influencing this decision are summarised below (Table 5.12). Having

Table 5.12. Clinical and urodynamic features of urethral incompetence and detrusor instability

In favour of urethral incompetence	In favour of detrusor instability
Low resting urethral pressure	
Inability to increase urethral pressure voluntarily	Numerous high pressure unstable contractions
Inability to stop in midstream	Ability to stop in midstream
Decreased transmission of abdominal pressure to urethra	Ability to voluntarily increase urethral pressure
	Presence of P_{det} iso
Larger volumes passed on frequency/volume chart	Low volumes passed on frequency/volume chart
An incompetent bladder neck may occur in either situation and its presence does not help diagnosis	

decided on the dominant pathology the appropriate treatment should be instituted. The simple management plan is shown in Fig. 5.9. Surgical repair in moderate or severe stress incontinence is not contra-indicated by a mild degree of bladder instability. Meyhoff et al. (1980) describe a series of 41 patients where a conventional colpo-suspension or anterior repair was performed in the presence of detrusor instability. The overall cure and improvement rate was 73% and 30% had their instability abolished.

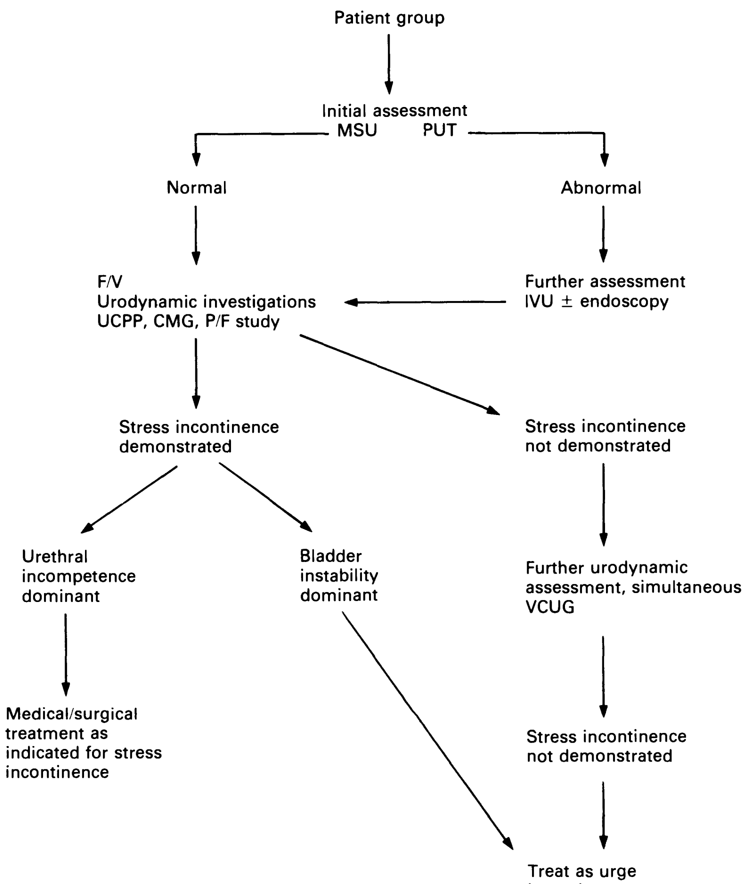

Fig. 5.9. Suggested management of female patients with mixed stress/urge incontinence.

Frequency, Urgency and Urge Incontinence

This symptom complex presents commonly when incontinence begins, the other symptoms having been present for a longer time, perhaps even lifelong. The mechanism of these symptoms was discussed earlier (see 'Frequency of Micturition' p. 7; 'Urgency' p. 10; 'Urinary Incontinence', p. 11) and the main distinction to be made by urodynamics is whether the symptoms are due to increased motor activity of the detrusor, or to increased sensory input. However, in the present state of our inadequacy in treating this syndrome the functional diagnosis may not have much importance.

Symptomatic Diagnosis

It is difficult to distinguish between overactivity and hypersensitivity from symptoms. Frequency in unstable cases is the same as for patients with normal cystometrograms (modal value 7–8 — see 'Frequency of Micturition', p. 7). Hypersensitive bladders have a slightly greater tendency to frequency (modal value 10–11). Urgency occurred, in our series, in 70% of patients with normal cystometrograms, 61% of hypersensitive cases and 85% of unstable cases. However, if frequency, nocturia and urge incontinence occur together then 89% of patients will have unstable bladders.

In our study of diagnostic efficiency it was found that the accuracy of prediction of an unstable cystometrogram, from the symptoms and signs, ranged between 31% and 48%. The predictability of a hypersensitive cystometrogram was even less, 22% to 25%. Even though it might appear possible to be more accurate than this, in practice it is not easy even for experienced investigators.

Some further diagnostic help may be available from analysis of the frequency/volume charts. If the voided capacity is variable a diagnosis of instability is likely, whereas if it remains fixed a sensory problem is to be expected.

Urodynamic Diagnosis

Again the cystometrogram is the more important investigation and the comments in the previous section apply. There should be no difficulty in distinguishing between an unstable and hypersensitive cystometrogram, except in one respect. Some workers describe a bladder of limited capacity, where the difference between full and empty resting pressure is greater than 15 cmH_2O, as unstable, even though there is no obvious evidence of contraction. We would regard this type as hypersensitive if the capacity is limited by increased bladder sensation and would look for sensory impairment if the capacity was limited by incontinence without the sensation of fullness.

A more significant conclusion to elicit from the urodynamic results is the reason for the occurrence of incontinence. We noted above that this is usually the reason for referral, some of the other symptoms being of longer standing. It may be found that the urethral mechanism is no longer able to withstand the detrusor pressure because of the development of active or passive incompetence. This means that investigation of these cases by urethrocystometry is appropriate (see 'Urethrocystometry', p. 00).

When this entire clinical group is reviewed in the light of urodynamic findings it is obvious that bladder instability is not the whole explanation for incontinence that is associated with urgency.

What Causes Incontinence?

Provided sensation allows the unstable contraction to be felt a normal urethral sphincter should maintain continence in most cases. If it does not:

1. The bladder pressure may be too high.
2. The urethral sphincter may fatigue.
3. The sphincter may not contract because of damage.
4. The sphincter may be inhibited or may relax.

The significance of the urethra in motor urge incontinence may be greater even than this. Urethral contraction promotes bladder inhibition as do other afferent influences from the pelvic floor. It could be that the loss of the ability to contract the urethral and peri-urethral muscles promotes bladder instability. In this respect the urethra deserves more attention.

If incontinence occurs in a hypersensitive bladder (sensory urge incontinence) then it is necessary to postulate spontaneous opening of the urethra, for there is no significant increase in bladder pressure to expel the urine. This area of urodynamic investigation requires more basic research.

Management

The interrelation of bladder and urethral function is also most important in treatment. Drugs alone have not been successful. The effects of distension and denervation are usually transient. More useful are methods which retrain the pelvic floor. These include 'bladder' training which, by use of a urine volume output chart, makes the patient more aware of her voiding pattern and how it can be modified by voluntary, mostly pelvic floor, activity. Methods which use some form of electrical stimulation may work in the same way. Certainly, the response to treatment should be analysed in relation to urethral function. This may allow more rational selection of treatments for patients in the future.

The significance of urodynamics in management has been related more to the evaluation of treatment than to selection of patients for specific therapy. There is a certain logic in distinguishing between leakage due to instability and that due to hypersensitivity because the pharmacotherapy of the two conditions should be different. In practice, however, the results of the different drug trials are at variance with one another and almost any treatment, be it by drugs or otherwise, produces a 50% 'improvement' initially.

The management flow chart (Fig. 5.10) emphasises the role of conservative treatment in this condition. Until the aetiology is more clearly understood radical measures are not appropriate except in a controlled experimental situation.

Stress Incontinence

Cases of uncomplicated 'pure' stress incontinence are rarely referred for urodynamics and this is as it should be. If a woman has no symptoms of urgency and

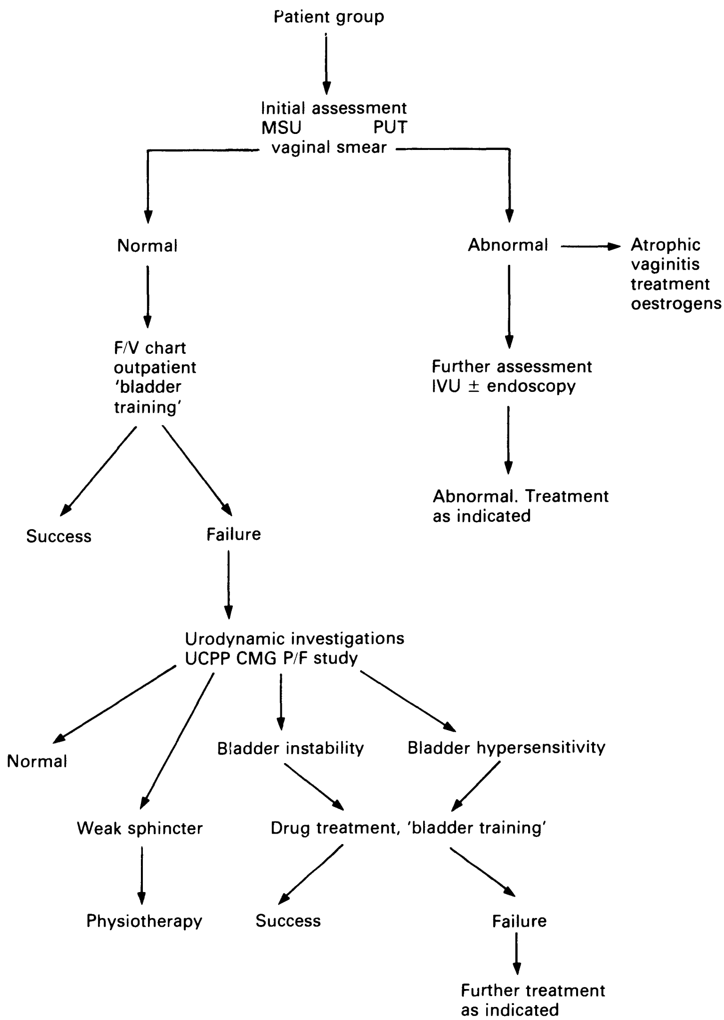

Fig. 5.10. Suggested management of female patients with symptoms of bladder overactivity.

incontinence is observed to occur instantly on coughing then no further functional testing is necessary. There may be patients however where the diagnosis remains equivocal and incontinence cannot be demonstrated clinically.

Symptomatic Diagnosis

The accuracy of clinical diagnosis in this group is the best of our series: 87% were selected correctly before any urodynamic tests. Diagnostic quality can be improved by getting the patient to cough on a full bladder. Since the bladder seems to be emptied invariably in the out-patient clinic for urine sampling before the patient is examined this is rarely practical, but perhaps clinic routines could be changed.

Urodynamic Diagnosis

Urodynamic investigation is indicated when there is a good history of stress incontinence, but it cannot be demonstrated by other means. It should be noted here that the condition 'genuine' stress incontinence can only be defined by urodynamic tests showing involuntary loss of urine when the measured intravesical pressure exceeds the measured maximum urethral pressure in the absence of detrusor activity.

For stress incontinence to occur it is necessary for there to be incompetence of the bladder neck *and* the distal urethral mechanism. The appropriate tests are those which analyse the function of both areas. A video-cystourethrogram may be adequate to resolve the problem, but more accurate analysis can be made by measuring urethral pressure.

The urethral closure pressure profile represents the pressure exerted by the urethra and can be performed at rest, during voluntary activity and during postural change (see 'Urethral Pressure Measurement', p. 48). There is a tendency for the maximum urethral pressure in females to decrease with age and this regression is accentuated in stress incontinence (Fig. 5.11). The urethral length also tends to be

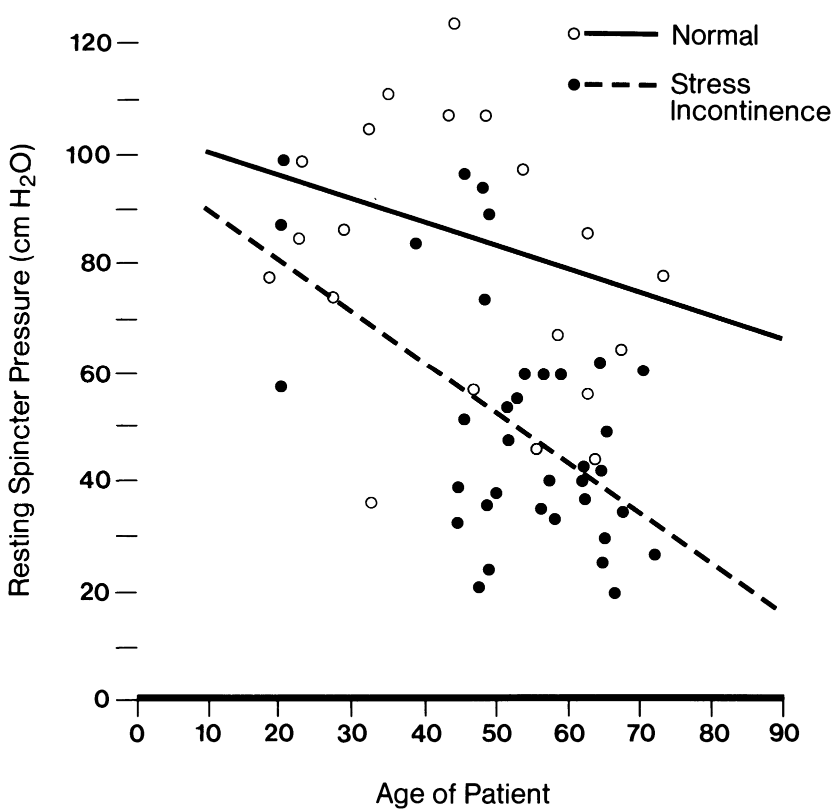

Fig. 5.11. Resting maximum urethral pressure plotted against age in normal and stress incontinent patients, with regression lines calculated statistically.

shorter in cases of stress incontinence (Fig. 5.12) and voluntary contraction is impaired. Due to the overlap with normal values these facts cannot be used for accurate diagnosis and anyway, do not assess the bladder neck for competence. If an index of urethral length times maximum urethral pressure is used then stress incontinent cases can be distinguished from normal with an 86% accuracy, which is no better than clinical assessment.

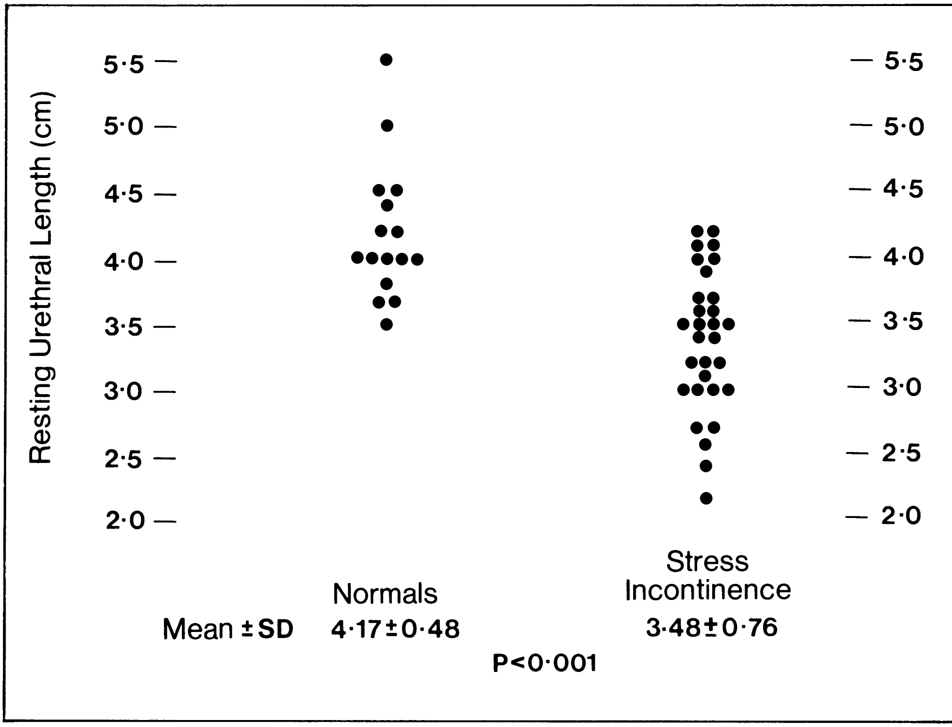

Fig. 5.12. A comparison of urethral length in normal and stress incontinent females.

Tests have therefore been used to measure the transmission of pressure from the abdominal cavity to the urethra (see "The 'Stress' Urethral Profile", p. 54). In normal cases a high proportion of the pressure due to a cough should be recordable from the proximal urethra up to the point of maximum urethral pressure and the urethral closure pressure on coughing does not become negative until this point is reached (Fig. 5.13). In stress incontinence this pressure transmission, which is thought to help keep the normal urethra closed during stress, is inadequate. The urethral closure pressure becomes negative on coughing (Fig. 5.14). This may occur even when the urethral pressure profile appears quite normal in other respects (Fig. 5.15).

A related, but slightly different, test of bladder neck competence, has been described by Sutherst and Brown (1980). This has been called the fluid bridge test and relies on the fact that bladder neck incompetence allows continuity of fluid between the bladder and urethra. This fluid will transmit bladder pressure and so, if urethral pressure becomes the same as bladder pressure during a cough, there may

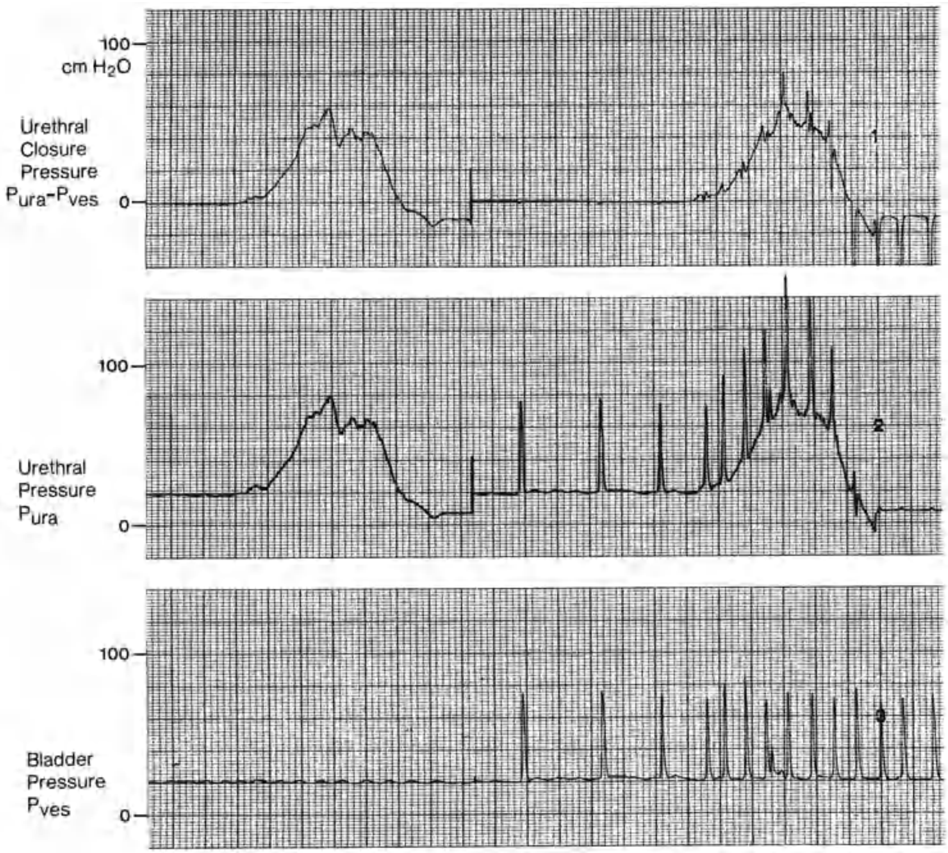

Fig. 5.13. A urethral closure pressure profile (*left*) and 'stress' urethral profile (*right*) in a continent female patient. The urethral closure pressure (*upper trace*) does not become negative until the point of maximum urethral pressure has been passed.

be incompetence. The pressure can *only* be measured in this test by an open perfusion system (see 'Fluid Perfusion Profilometry', p. 49) but with the infusion pump switched off. The catheter is shown in Fig. 5.16, and typical results in Fig. 5.17. The urethral recording point is located 0.5 cm distal to the location of the bladder neck on the urethral closure pressure profile. It is still not entirely clear whether this technique measures only bladder neck incompetence, or whether bladder base descent on a fixed catheter, without incompetence, will give a positive result as well.

Management

The flow chart for management of stress incontinence is represented in Fig. 5.18.

It is not appropriate to comment here on the surgical management of stress incontinence, which is treated more fully elsewhere (Stanton and Tanagho 1980). Urodynamic tests after successful operation may show no change in urethral closure pressure or urethral length though, if the stress urethral profile is measured,

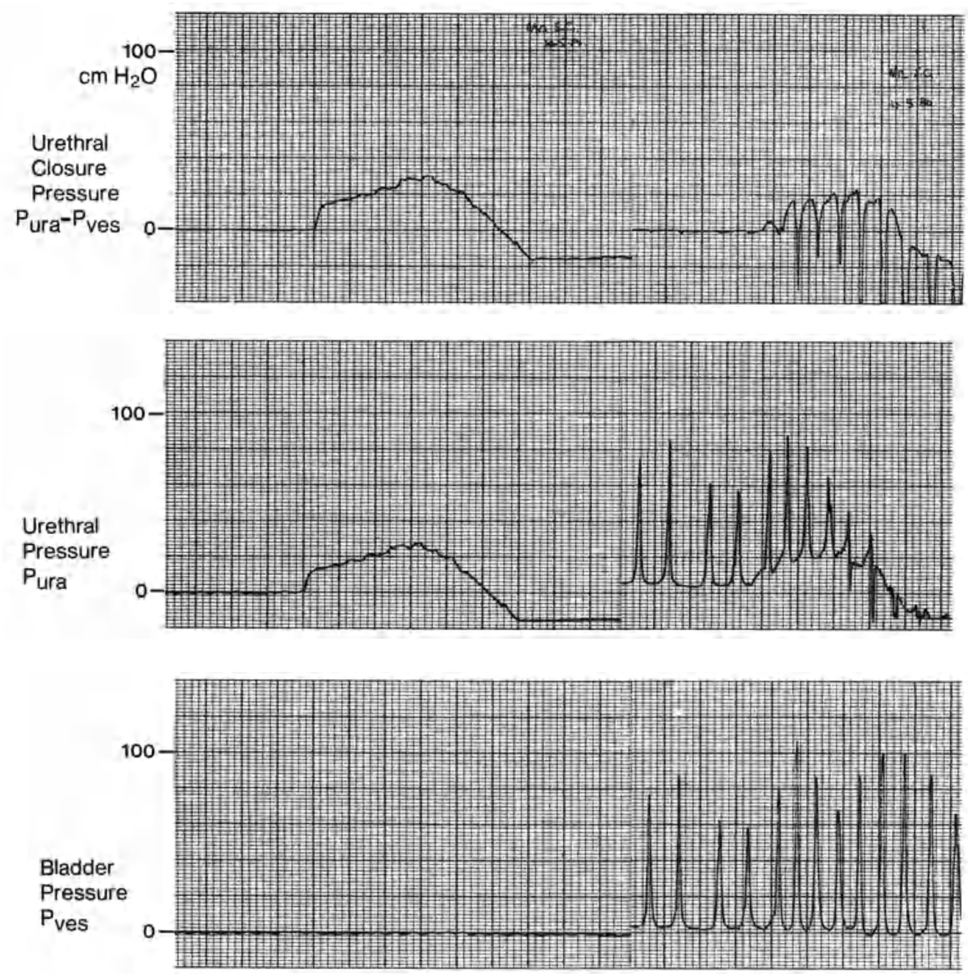

Fig. 5.14. A similar test to Fig. 5.13 in a patient with a low urethral closure pressure, and poor transmission of cough pressure to the urethra. The urethral closure pressure becomes negative on coughing.

there will be an improved transmission of intra-abdominal pressure to the urethra.

It is perhaps appropriate to mention conservative treatment of stress incontinence and one method is described below in particular detail. The concept incorporates ideas derived from urodynamics and from biofeedback techniques and could be applied more widely.

Use of Perineometer to Treat Stress Incontinence

Kegal (1948) published the details of a piece of equipment designed to measure the strength of the muscles of the pelvic floor. This he called a perineometer. He

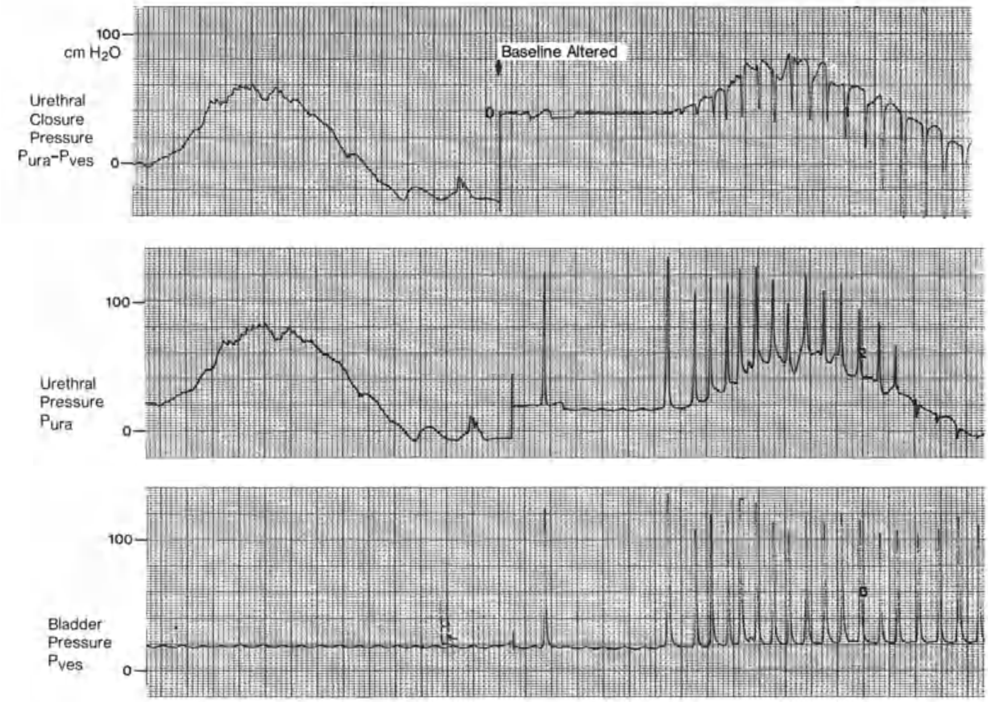

Fig. 5.15. A case illustrating the occurrence of a negative urethral closure pressure on coughing despite a relatively normal conventional urethral pressure profile.

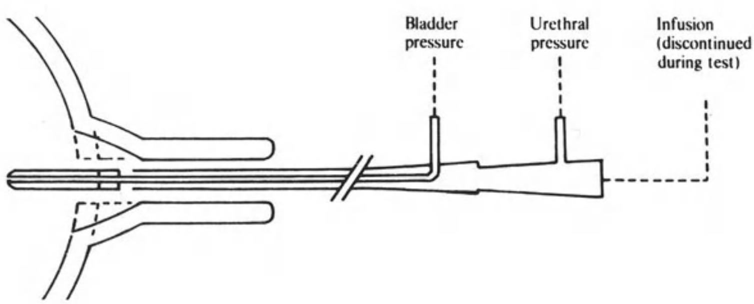

Fig. 5.16. The arrangement of infusion and pressure lines in the catheter used for the fluid bridge test. During a cough the urethra may open to allow fluid to surround the catheter side holes (as in the diagram). (Sutherst and Brown 1980)

advocated its use for women of any age who complained of stress incontinence with absence of gross anatomical deformity. After an initial measurement had been made the patient was instructed by a physiotherapist in the use of the perineometer, both as an exerciser and for measuring improvement in muscle efficiency. A few of these instruments still exist, but until recently no attempt has been made to introduce a modern equivalent.

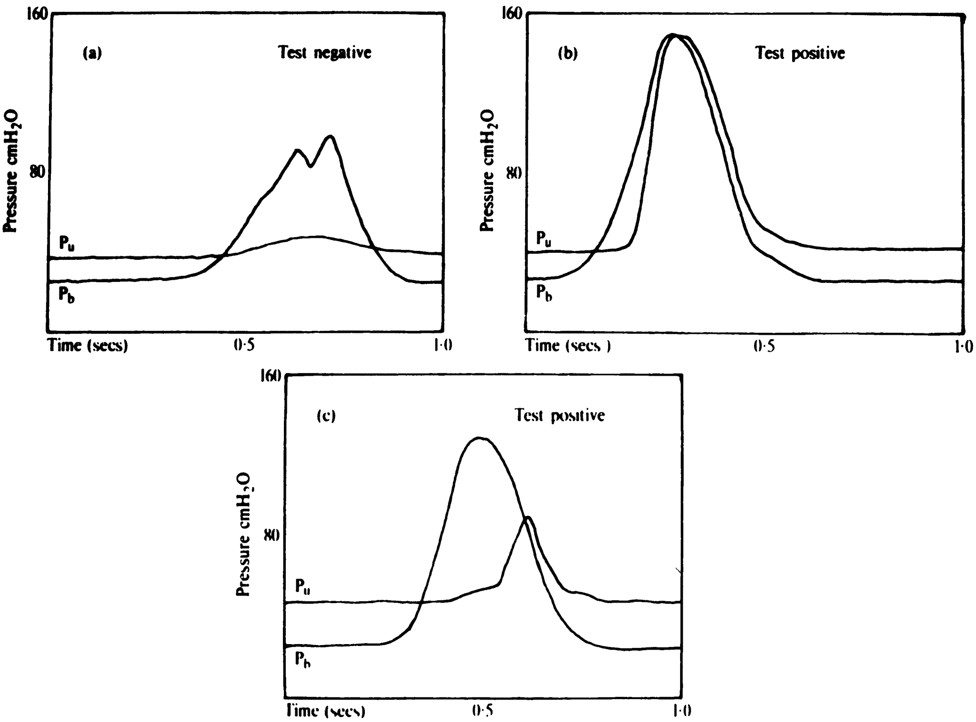

Fig. 5.17. Pressure tracings of cough taken from polaroid photographs of CRT screen recordings: (*a*) the proximal urethra remains closed: (*b*) the proximal urethra opens to the test point immediately: (*c*) the urethra opens to the test point late in the cough cycle. (Sutherst and Brown 1980)

Table 5.13. The increase in intravaginal pressure achieved by normal parous women on voluntary contraction of the pelvic floor

Name	Age	Parity	Increase in pressure (cmH_2O)
B.T.	50	3	5
E.M.	56	2	8
P.L.	30	2	6
S.H.	25	2	7
P.D.	26	2	5
J.B.	40	4	6
J.P.	45	1	3
B.S.	60	3	6
H.D.	42	2	4
J.M.	35	5	5
Average	40.9 yrs	2.6	5.5 cmH_2O

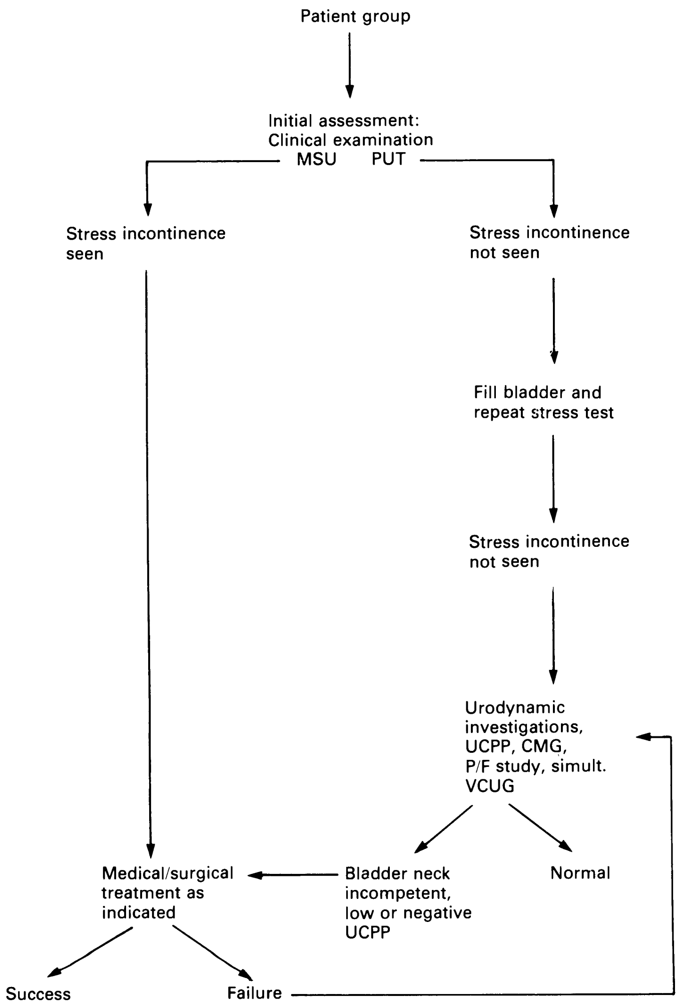

Fig. 5.18. Suggested management of female stress incontinence.

In 1977 the Medical Physics Department at the Bristol General Hospital produced a simple piece of equipment based on Kegal's design. This consisted of a hollow, firm, latex rubber probe 12 cm long with a 3-cm diameter, attached to a pressure gauge, recording pressure in the range of 0–25 cmH_2O.

The probe was inserted into the vagina as far as it would go comfortably and then withdrawn 2 cm. The patient was then asked to contract her perineal muscles and the resultant increase in pressure was recorded. Readings taken from ten 'normal' parous women, i.e. no stress incontinence, with an age range 25–60 years are given in Table 5.13.

In a small trial involving 22 patients, all of whom were found to have either demonstrable stress incontinence or a weak sphincter mechanism on urodynamic studies, the perineometer was used to make an objective assessment of improvement. The results are recorded in Table 5.14.

Treatment included vaginal faradism, together with exercises taught by a skilled and enthusiastic physiotherapist and ranged from a single attendance to a maximum of eight attendances at weekly intervals, with an average of 4.8 visits per patient. A follow-up performed 18 months after the end of treatment on a larger series of 54 patients suggested that 13 (24%) patients were completely dry and 30 (56%) patients thought that they were more than 75% improved, while the symptoms in the 11 remaining patients were the same.

The subjective results were reflected by the alteration in perineometer readings. Before treatment the range was from 0 cmH_2O to a maximum of 3 cmH_2O, with an average of 1.1 cmH_2O. After treatment the range was between 1 and 7 cmH_2O

Table 5.14. The effect of physiotherapy on the intravaginal pressure increase (cmH_2O) achieved by voluntary contraction in incontinent women

		Pressure increase	
Name	Age	Before trt.	After trt.
E.C.	59	1	7
M.H.	32	1	4
H.W.	49	0	4
E.B.	38	3	3
M.J.	47	0	4
P.C.	35	0	3
M.B.	61	2	5
D.W.	45	0	2
E.R.	48	0	3
A.B.	52	3	4
A.F.	62	2	3
G.K.	45	0	3
S.C.	45	3	5
B.N.	24	2	4
A.S.	42	1	1
T.B.	32	0	3
F.N.	47	0	2
A.L.	35	1	4
B.C.	52	0.3	
T.A.	26	2	5
L.B.	58	1	4
C.C.	26	0	4
Average	43.8 yrs	1.1 cm H_2O	3.5 cm H_2O

with an average of 3.5 cmH_2O. In this trial the perineometer proved its usefulness as an objective method of assessing improvement in function of the muscles of the pelvic floor.

Currently a further modification is being considered. Figure 5.19 shows the development of this piece of equipment, which it is hoped will be marketed. With its inflatable balloon this probe has the advantage that it can be adjusted to fit snugly within the vaginal introitus and the pressure is then brought to zero before the patient contracts her muscles. Not only is it designed to be used as a method of assessing initial muscle function and subsequent improvement, but also as an exerciser. Patients can be instructed and then use the exerciser at home between hospital attendances. We believe that efficient pelvic floor function is essential for urinary control in those men and women who have suffered some interference with the primary mechanism maintaining continence and who complain of troublesome stress incontinence in the absence of gross anatomical deformity.

The equipment may also have some value in prophylaxis, for example, after childbirth. If only a small proportion of patients can avoid surgery the technique is still very well worthwhile. The indications for its use are:

1. Mild or moderate stress incontinence
2. No gross anatomical defect (prolapse)
3. Low maximum resting urethral pressure
4. Inability to contract pelvic floor
5. Inability to interrupt the urinary stream

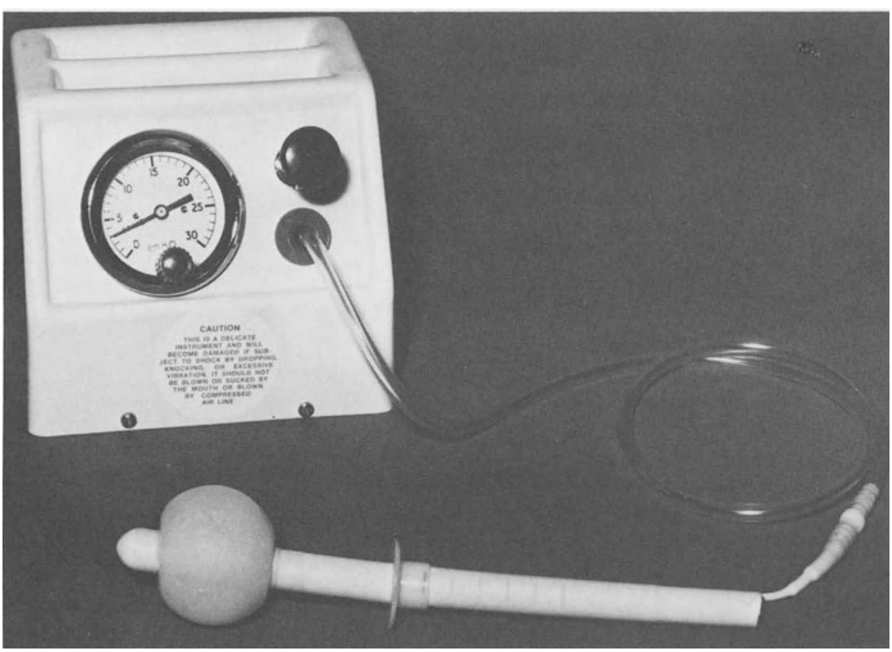

Fig. 5.19. The perineometer used for pelvic floor exercises and assessment.

Voiding Difficulties

Problems with voiding may be due to bladder underactivity or to obstruction. In a series of 2124 female patients 8.1% had an underactive detrusor. In contrast to the pattern in male voiding difficulties, only 3.7% of female patients were urodynamically obstructed.

Detrusor underactivity may be secondary to drugs such as the tricyclic antidepressants, to peripheral neuropathy such as in diabetes and to spinal disease, as in lumbar spondylosis. Underactivity may also follow gynaecological surgery. Shepherd (1979) analysed the effect of uterine surgery on lower urinary tract function. A preliminary review of the patients' symptoms showed a higher incidence of frequency and urgency in cases treated by abdominal hysterectomy compared with vaginal hysterectomy. Prospective urodynamic studies showed no increase in bladder instability in the abdominal hysterectomy group postoperatively. In the vaginal hysterectomy group there was a significant decrease in urine flow rate, decrease in voiding bladder pressure, increase in bladder capacity and increase in residual urine. Three out of 15 patients developed a residual urine of greater than 250 ml. Vaginal hysterectomy is more likely to produce bladder underactivity and voiding problems than abdominal hysterectomy. However, the majority of cases of bladder underactivity in women have no demonstrable cause.

Outflow obstruction has a variety of causes. Mechanical obstruction may occur de novo as urethral strictures, commonest at the external meatus. Bladder neck obstruction is very rare and if suspected endoscopically is more likely to be due to bladder muscle hypertrophy than to a true obstruction. Obstruction may also be caused by distortion, as in a severe cystocoele, which may kink the urethra. Mechanical obstruction may be iatrogenic and follow pelvic radiotherapy or surgery. One of the commonest postoperative causes of obstruction is an overtight repair operation for stress incontinence. Repeated urethral dilatations may also lead to obstruction due to a rigid, fibrotic urethra.

Obstruction may occur in the absence of a true mechanical cause. Functional obstruction is seen in a group of patients who may be described as having psychogenic voiding disorders. In these patients emotional factors, including anxiety and apprehension, lead to inhibition of urethral relaxation.

Symptomatic Diagnosis

The symptoms of voiding difficulties in women are similar to those found in men. These are hesitancy, a slow stream, interrupted flow, the need to strain to void and a feeling of incomplete emptying. Occasionally either acute or chronic retention is found. The cause of acute retention in the female is often obscure and a psychological cause has been suggested by some authors (Doran and Roberts 1975). A neurological problem must always be suspected and constipation excluded.

A lot of females have occasional hesitancy. Only 7% of females complaining of persistent hesitancy are found to be obstructed. Of obstructed females, 33% have a history of previous acute retention (10% spontaneous, 8% at childbirth and 15% postoperatively). Of females with voiding difficulties, 40% have a history of previous gynaecological surgery. Many have recurrent urinary infections.

There is no clinical way to distinguish between bladder underactivity and obstruction. The accuracy of diagnosis of obstruction in females in our series was only 17%.

Urodynamic Diagnosis

A flow rate alone cannot distinguish between obstruction and detrusor underactivity; a pressure flow study is required.

If a female patient in retention is investigated little abnormal is usually found, except the absence of a voiding contraction. It is then worth measuring the sphincter EMG in case the absence of detrusor activity is related to the failure of the urethra to relax. This situation may occur, even in the absence of a neurological lesion. In patients with psychogenic voiding disorders, spasm of the distal urethral sphincteric mechanism and the pelvic floor has been found. If the detrusor is found to be underactive then it is important to discover whether nerve or muscle is abnormal (see 'Why Is the Detrusor Failing to Contract?', p. 169).

Management

In this group of patients treatment, as outlined in the flow chart (Fig. 5.20), tends to be empirical. A flow rate should be performed to confirm that a problem exists, followed by endoscopy and a urethral dilatation. Failure to respond to urethral dilatation is an indication for full urodynamic studies, although in many cases the results may not facilitate the practical treatment of the patient's condition. The use of drugs such as Bethanechol to stimulate detrusor contraction, or Phenoxybenzamine to relax the proximal urethra, have given disappointing results. More encouraging reports have been published with the use of Diazepam, 2–6 mg daily (Kaplan et al. 1980) or up to 10 mg intravenously (Krane and Siroky 1979). Intermittent self-catheterisation has proved to be an effective method of treating some of these patients. The patient ceases to adopt a purely passive role in the management of her condition under these circumstances, which is a great advantage. The problem usually presents as an acute crisis, but does not progress to become a chronic problem. If the patient can be taught to catheterise herself the acute episode can be overcome in this way. Operative treatment by transurethral resection of the bladder neck has been undertaken in some patients, but can lead to severe incontinence. We feel that transurethral resection should be avoided.

Although chronic urinary retention in women is rare, the management can prove to be extremely difficult. The bladder of large capacity, which fails to contract on attempted voiding, may also be treated by intermittent self-catheterisation. Since continence in the female depends mainly on the competence of the bladder neck mechanism, operative treatment is only indicated for these patients when there is urodynamic evidence of bladder neck obstruction. Bladder neck incision is preferable to transurethral resection of the bladder neck. Those patients who have been referred to our Unit with urinary incontinence following empirical operative procedures form a particularly difficult group to manage.

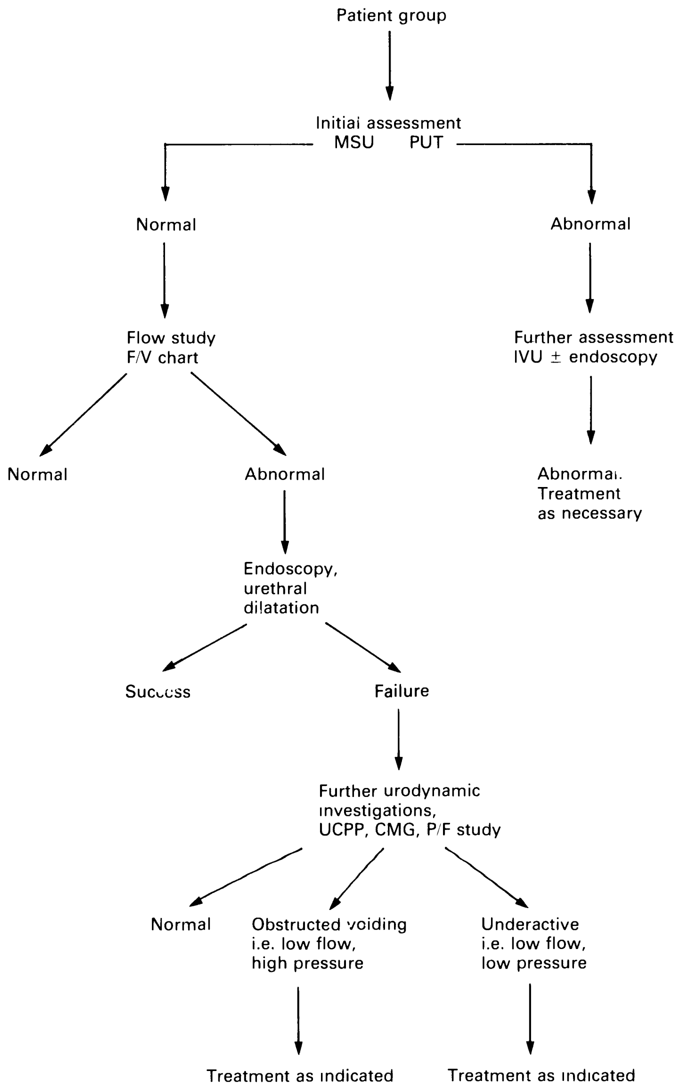

Fig. 5.20.. Suggested management of female patients with voiding disorders.

Geriatric Problems

An alteration in the pattern of micturition is a common feature amongst people over the age of 65 years, so that some individuals accept a few urinary symptoms as a natural consequence of ageing. An increase in frequency of micturition is usually well tolerated by day, but the constant disturbance of sleep at night becomes a source of irritation. Urgency of micturition disturbs the pleasure of normal social activities and for some the embarrassment that it causes leads to a severe restriction of their life style. The onset of incontinence for an individual with normal mental faculties produces immediate distress and the loss of morale can be irretrievable. Both elderly men and women experience symptoms of frequency, urgency and urge incontinence. Urodynamic evaluation has underlined the natural physiological changes that occur with age. They have also introduced objective criteria by which the results of operative treatment can be measured and they have stressed their contribution in the preoperative selection of elderly patients before lower urinary tract surgery.

All clinicians who have responsibility for the care of the elderly recognise the problem of urinary incontinence and yet each specialist tends to view differing aspects of the condition. The development of a urodynamic unit has provided a centre where patients from all sources have been referred for investigation and in this way the framework of a specialist incontinence service has been established.

Isaacs (1979) published the results of a postal questionnaire for 105 Departments of Geriatric Medicine in the United Kingdom which was designed to investigate various facilities such as urology, gynaecology, physiotherapy and urodynamic investigations in the management of urinary incontinence. Urologists and gynaecologists were only of help when a clearly defined anatomical lesion was identified, but this only applied to a minority of the patients. The most enthusiastic replies to the survey came from the departments in general hospitals which had their own urodynamic equipment and Isaacs commented that there appeared to be room for a large increase in the contribution made by urologists and modern urodynamic studies to the management of incontinent elderly patients.

Our Unit recognised the high incidence of incontinence amongst the referrals at an early stage of its development and this drew attention to the need for a comprehensive service which included both the investigation and management. The study of the prevalence of the condition was a necessary exercise to plan a service and the Unit participated in a survey in conjunction with the Epidemiology Unit at Northwick Park Hospital under Dr. T.W. Meade.

The Prevalence of Incontinence

The prevalence of urinary incontinence is appreciably higher in people over the age of 65 years, yet many patients in this age group prefer to avoid seeking medical advice. In the study of the prevalence of incontinence Thomas et al. (1980) investigated two main groups. The first group consisted of those recognised to have urinary incontinence by the Health and Social Service agencies and the second group consisted of those not recognised by these agencies, but identified by a postal survey. The definition of regular incontinence was the involuntary voiding or leakage of urine in inappropriate places or at inappropriate times, twice or more a month, regardless of the amount of urine lost. The results are outlined in Table 5.3 and compare the prevalence of incontinence in men and women aged 15–64 with those aged 65 years and older. It also shows the result of the postal survey which exposed a large number of people with the problem who did not seek help or advice from the Health and Social Services. A questionnaire was sent to, and received by, 20 398 patients over the age of 15 years on the practice lists of twelve general practitioners and 18 084 (89%) replied. On later interviewing 170 of those identified by the postal survey as experiencing incontinence, 20 (11%) were found not to be incontinent. Of the 158 who were incontinent, 34 had moderate or severe incontinence, which was defined as requiring extra laundry or pads, or appliances, and some restriction of activities, which in the severe cases required help from others. The majority of those in this category were receiving no help from the Health and Social Services.

Symptomatic Assessment

During the period 1975–1980, 3276 patients were investigated at the Urodynamic Unit. Of these, 814 (25%) were over the age of 65 years, with a distribution of 414 men and 400 women; 74% of the men and 67% of the women were aged between 65 and 75 years. Some degree of urinary incontinence was experienced by 62% of the men and 80% of the women. The investigations were undertaken mainly on ambulant patients as a pre-operative assessment, and the results are influenced by this selection. Comparison with other series of elderly patients should therefore be interpreted with caution.

The types of incontinence are shown in Table 5.15. There is a striking increase in the incidence of urge incontinence, affecting 52% of the men and 41% of the women. Combined stress and urge incontinence was also a common condition affecting 33% of the women, but this is no different from the incidence in women between the ages of 45 and 55 years, when it accounted for 36% of referrals. In the majority of patients the incontinence was intermittent and variable in the amount of loss, and only 10% of the men and 14% of the women experienced continuous incontinence.

Table 5.15. The types of incontinence, categorised by symptoms, seen in patients referred for urodynamic investigations

	Men		Women	
Incontinence (types)	% Under 65	% Over 65	% Under 65	% Over 65
Stress	1	3	26	11
Stress/urge	1	3	35	33
Urge	34	52	20	41
Enuresis	26	6	10	1
Post-micturition dribble	29	26	1	0
Continuous	9	10	8	14

The majority of men experienced only a minor degree of incontinence and no social incapacity. A much higher proportion of women needed to wear some protection for the urinary loss and suffered both social and physical restriction (Table 5.16).

Table 5.16. The degree of social incapacity suffered by incontinent patients

Social incapacity	Men %	Women %
None	82	9
Minimal	7	32
Restriction of activities	11	72

Urodynamic Investigations

Details of the routine urodynamic investigations which were performed on patients attending the Unit have already been outlined in the earlier chapters. They consisted of an initial measurement of the urine flow rate, followed by the urethral pressure profile and pressure/flow cystometry during filling and voiding.

Measurement of Urine Flow Rate

On arrival at the Unit 14% of the men and 20% of the women were unable to micturate and measurement of the initial flow rate was therefore not possible. Of those who managed to void the maximum flow rate was recorded as less than 10 ml/s in 70% of the men and 30% of the women, but the volume voided was less than 150 ml in the majority of these measurements.

Elderly patients are often apprehensive about hospital visits and the advantage of assessing men suspected of having bladder outflow obstruction with multiple flow measurements during the course of a day spent at the hospital has been fully appreciated. P.H. Powell and A. Ball (personal communication) studied a series of 27 male patients who were suspected of having bladder outflow obstruction. Pressure flow analyses showed that 20 out of 27 patients had bladder outflow obstruction. A single recording of the maximum urine flow rate correctly predicted the pressure/flow findings in only 8 cases (30%), whereas multiple urine flow measurements correctly predicted the results in 25 cases (93%). A wide variation in the maximum urine flow rate with the same individual patient was experienced. A urine flow rate of 12 ml/s, or more, was not associated with significant bladder outflow obstruction.

Urethral Pressure Profile

The urethral pressure profile is a static investigation undertaken in the supine position and has been of limited value in the investigation of urinary incontinence. The distal urethral sphincter may be classified as normal, weak or overactive and our studies have shown the rising incidence of sphincter weakness in women with age, particularly over the age of 50 (Fig. 5.11).

The results of 387 investigations on the female patients were available for analysis. Of the 313 incontinent women, 77% were considered to have weak sphincters on the urethral pressure profile. Of the 74 continent women, 60% were considered to have sphincter weakness.

Cystometric Results

The detrusor response to inflow cystometry has been classified as normal, hypercompliant, hypersensitive or unstable. The results are shown in Table 5.17 and they compare the detrusor response in incontinent and continent male and female patients over the age of 65 years. In both sexes the incidence of bladder instability rises with age, but this feature is most marked in the male patients. Table 5.18 shows the results of inflow cystometry in incontinent men and women under the age of 65 years. The differences in the detrusor response according to sex of the patient emphasised the higher incidence of bladder instability in men. Stress incontinence reached a peak incidence in our series between the ages of 45 and 55 years and this is associated with normal detrusor response on inflow cystometry.

Table 5.17. Cystometric diagnosis in 810 patients over 65 years old

	Men (410)		Women (400)	
Detrusor activity	Incontinent	Continent	Incontinent	Continent
Total	260	150	323	77
Successful CMG	240	138	231	50
Normal %	9	10	36	40
Hypercompliant %	23	14	4	5
Hypersensitive %	5	9	12	20
Unstable %	53	53	41	27

Table 5.18. Cystometric diagnosis in 1527 patients under 65 years old

Detrusor activity	Men (393)	Women (1134)
Normal %	24	45
Hypercompliant %	3	2
Hypersensitive %	17	18
Unstable %	40	27

The pressure/flow studies of the voiding cystometrogram have provided objective evidence with regard to bladder outflow obstruction. Outflow obstruction is rare in women and in our series of 400 women over the age of 65 years, 17 (4%) were considered to have obstructed micturition. The differentiation between bladder instability and bladder outflow obstruction is of particular value in the male patient. The routine clinical assessment, together with the measurement of the maximum urine flow rate, does select the majority of patients who have obstructed micturition, but there remains a group of patients with equivocal features. Urodynamic studies are indicated in those patients who persistently pass small volumes of urine of less than 200 ml, in whom the urine flow rate measurement cannot be considered reliable.

Urodynamic studies should be undertaken in those patients in whom operative treatment has failed. Incontinence following lower urinary tract surgery requires detailed evaluation and in such cases of video-cystourethrography is of particular value in allowing a replay of the events occurring in the lower urinary tract on micturition and under the conditions of coughing or straining. Cystometry does require co-operation from the patient. It failed in 8% of the men and 30% of the women in our series, mainly owing to the practical difficulties encountered in patients of this age. Extrusion of the pressure line was the commonest problem in the female patients.

Management

Our fundamental philosophy in dealing with patients in the geriatric age group is that one should treat the patient according to their biological age and not their chronological age. An 80 year old who rides five miles a day on a bicycle will be insulted if regarded in the same way as a demented 70 year old.

Urinary incontinence in the elderly presents a far greater problem of management than of diagnosis. In our experience urodynamic investigations have a very limited role in clinical geriatric practice, but can be essential as a pre-operative assessment in the borderline case. Their use has shown a poor return of invested effort for the individual patient, yet for the age group as an entity the research studies have stimulated considerable interest in the pathophysiology of voiding disorders.

An outline of our regime of clinical management is shown in chart form (Fig. 5.21). The principal aim is to establish a methodical evaluation of each patient, balancing the need for accurate diagnosis with the patient's expectancy for practical advice and treatment. Initially the patient undergoes a careful medical examination consisting of the routine clinical assessment with a history, physical examination and basic investigations. The clinician is usually able to differentiate rapidly between those patients with an irremediable cause of incontinence and those with a remediable condition. Gross intellectual or neurological impairment, or severe physical disability, may preclude any hope of regaining continence. Under such circumstances appropriate long-term treatment with an appliance or catheter is indicated. The remediable problems are usually characterised by being variable, both in the pattern and the amount of urinary loss. Urge incontinence is the most common type in this age group and Frewen (1970) has indicated that the history in these cases often reveals inconsistencies and an element of predetermination about the episodes. For example, it is not uncommon for elderly patients to have long periods when they are completely dry, yet at other times urgency and urge incontinence may predominate. The association between the sound of running water and urge incontinence is well recognised and there are many other similar examples. A history of the recent onset of nocturnal incontinence usually raises the suspicion of chronic urinary retention with overflow incontinence. Drugs such as diuretics, sympathomimetic preparations or sedatives are common iatrogenic causes of urinary disturbance in the elderly. The history takes time and these patients cannot be assessed adequately in a busy outpatient clinic.

The physical examination is performed to exclude any obvious anatomical or pathological abnormality. Such features as obesity, chronic cough, a palpable

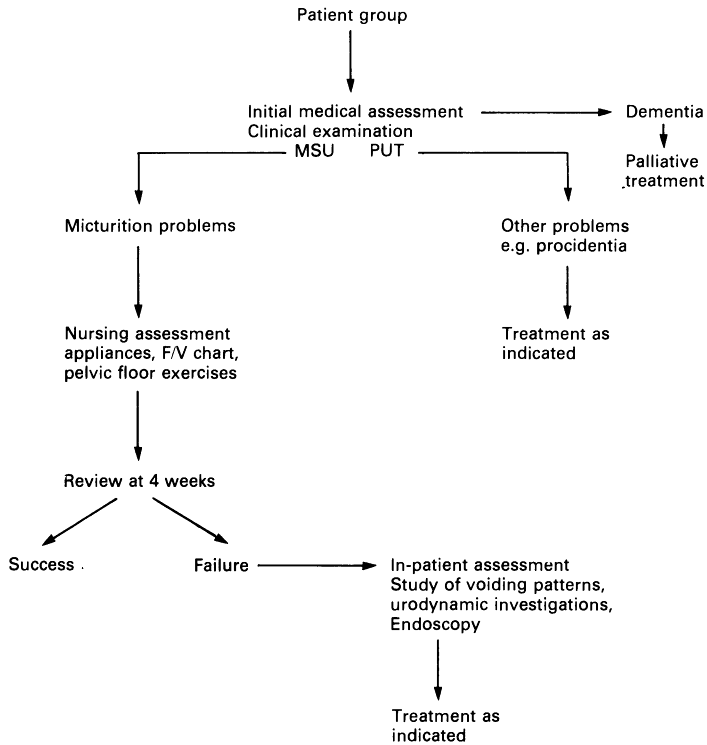

Fig. 5.21. Suggested management of geriatric problems.

bladder, procidentia, atrophic vaginitis or prostatic pathology are examples which may require appropriate treatment.

Urine analysis should exclude glycosuria or proteinuria and a midstream specimen of urine is sent to the laboratory for microscopy and culture. Contamination can readily occur at the time of the collection of the specimen and care must be exercised with the interpretation of the laboratory report. A tight phimosis in the male or a narrow, contracted introitus in the female can cause misleading results with evidence of pyuria and infection. In doubtful cases a repeat examination should always be performed. Further routine tests may include a full blood picture, blood urea estimation and a straight x-ray of the urinary tract. A small group of patients with bladder calculi have presented with urge incontinence and a history of catheterisation, or a prolonged period of immobilisation following an accident should suggest this possibility. A history of haematuria or loin pain indicates the need for an intravenous urogram.

Following the medical examination the patient is referred to the specialist nurse for advice on the practical management of the problem. The development of this clinic has been an interesting exercise. It started with the purpose of showing patients the available range of incontinence pads, pants or appliances that were available when they attended the Unit for urodynamic investigations. However, its therapeutic contribution soon became evident. The clinic gave the patients and their relatives an opportunity to discuss the problem in greater detail and depth with a nurse. The patient often mentioned problems to the nurse which were not considered to be relevant to the doctor. This exposed the psychological and social factors which were so often associated with the disorder. The supportive role of the specialist nurse has now become an essential part of the clinical management.

The nurse encourages the patient to adopt a positive attitude of 'self-help' with regard to the problem. The patient is taught how to keep a chart of their micturition pattern and how to undertake pelvic floor exercises using the perineometer. Charting of the frequency of micturition and the volumes voided has been of value. The actual frequency of micturition is often found to be less severe than the patient previously indicated. The measurement of the volume voided reveals both the average and the maximum functional bladder capacity and also indicates the total 24-h output. In some elderly patients more urine is passed at night than during the day and this alteration in circadian rhythm is a cause of nocturia which can be readily overlooked. The volumes voided at night should also be noted and if these are less than the maximum functional bladder capacity, nocturia may be a feature of the patient's inability to sleep rather than a bladder dysfunction. If the chart demonstrates that the maximum capacity of the bladder is less than 200 ml the possibility of bladder pathology arises and cystoscopy under general anaesthesia should be performed.

The specialist nurse usually arranges to see the patient again within 4 weeks of their first attendance. At this visit the nurse analyses the frequency/volume chart with the patient. Many patients do not appreciate that the bladder acts as a reservoir which possesses a measurable capacity. Once they have grasped this concept the patient is encouraged to hold larger volumes, up to 300–400 ml, before voiding. This approach to the management of incontinence has helped to restore the patient's confidence and self-respect. It does not rely on supportive measures such as drugs, but these are introduced when necessary.

Patients who are difficult to assess on an outpatient basis are admitted to hospital for a short-stay admission of 5 days. Medical and nursing assessments are undertaken during the first 2 days and episodes of incontinence noted. Use of the Urilos nappy is valuable in selected cases (James et al. 1971). This initial period of observation is most helpful in defining the severity of the incontinence. About 15% of the patients have no evidence of urinary incontinence during their stay in hospital and a further 25% have responded to simple routine measures. Patients are taught how to monitor their pattern of micturition and incontinence and, by simple adjustments such as voiding by the clock, they learn to regain control. By this method the psychosomatic aspects of incontinence are recognised and attention can be directed towards the social and environmental problems.

The scheme selects those patients who require further investigation by urodynamic tests and endoscopy. Male patients undergo multiple urine flow rate studies and if they suggest bladder outflow obstruction they proceed to endoscopy and prostatectomy. If the clinical assessment is equivocal full urodynamic studies are performed before surgery is undertaken. Similarly, female patients with stress and urge incontinence may require full urodynamic studies to differentiate between those with normal cystometry and weak sphincters, who may respond to operative treatment, and those with bladder instability. Patients with evidence of bladder instability have been treated by conservative methods based on the Frewen regime (Frewen 1980), whereas those with a normal bladder and sphincter weakness may be considered suitable for operative treatment. In practice elderly women with urinary incontinence benefit from an initial period of conservative treatment involving advice and supportive therapy. This period also allows further evaluation of the problem and urodynamic investigations are now only performed if this approach fails and operative treatment has to be considered. Urodynamic studies are therefore a pre-operative investigation.

Various therapeutic measures have been applied for those with bladder instability. Drug treatment using anticholinergic or sympathomimetic preparations are helpful in 25%–30% of patients. Cystoscopy under general anaesthesia with maximum perineal stimulation, producing faradic contraction of the pelvic floor muscles, has been of benefit in 25%–30% of cases. The use of hydrodilatation or balloon distension of the bladder has given disappointing results.

This regime of management has underlined the value of a conservative approach, particularly for women with stress, stress/urge or urge incontinence. It has also allowed careful pre-operative selection of male patients before prostatectomy is considered.

Irremediable Problems

The management of urinary incontinence by urethral catheterisation initiates a procedure that requires long-term supervision. The support of hospital and community nursing staff is essential and this close liaison has been established by a specialist incontinence nurse. Suprapubic catheterisation has been of benefit in patients who develop complications with urethral catheterisation. Urethral stricture or periurethral abscess in the male can be a complication of long-term catheterisation, and women with neurological conditions such as multiple sclerosis frequently experience urinary leakage around the catheter. Suprapubic catheterisation with urethral closure in the female patients has proved to be a valuable manoeuvre.

The close liaison between the specialist nurse and the clinician is an essential factor in the management of the elderly patient with urinary incontinence. These patients present individual problems and the nurse has expert knowledge of the various aids, appliances, catheters and the community services available both for the patients and the relatives.

The Neuropathic Bladder

The understanding of the neuropathic bladder has been complicated by confused terminology, imprecise assessment, empirical approaches to treatment and a preoccupation with cases of spinal trauma. Bladder function has often been classified by the location of the neurological lesion. Management decisions have usually been made on the basis of anatomical or radiological information. This approach is changing. The principal reason for this is that a more functional view of the lower urinary tract has developed because of the use of urodynamic assessment methods. Observation has shown, not only that it is difficult to predict the behaviour of the bladder from neurological signs, but also that bladder function changes considerably at different stages of disease and also in response to environmental factors, especially infection.

A brief note on terminology is appropriate here. 'Neurogenic' means produced by nerves. 'Neuropathic' means related to a disorder of nerves. It is therefore correct to speak in terms of 'the neuropathic bladder', and the title 'neurogenic bladder dysfunction' is also correct. Conversely, it is incorrect to refer to the 'neurogenic bladder' and mentioning 'neuropathic bladder dysfunction' is incorrect because dysfunction is already implied in the word 'neuropathic'. Perhaps this will help to clear up some of the confuson that has been developing around the use of these two words.

Classification of the Neuropathic Bladder

Since it has been shown that it is difficult to predict the function of the neuropathic bladder from the clinical symptoms and signs (Raezer et al. 1977; Thomas 1979) there is a strong case for relating the diagnosis, prognosis and management to objectively observed urodynamic parameters. The inter-relation between pathophysiology and urodynamic observations has already been discussed in Chap. 4. Using this approach it should be possible to express the function of the neuropathic bladder and urethra in terms of measured urodynamic variables, as outlined in Table 5.19.

Table 5.19. Urodynamic classification of the neuropathic lower urinary tract

		Increased	Normal	Decreased
Bladder	Sensation			
	Capacity			
	Contractility			
	Compliance			
Urethra	Sensation			
	Contractility			
	Relaxation			
	Urinary flow			

When there is, in relation to the sacral spinal cord and nerves (vertebral level L_1), either a complete lower or complete established upper motor neurone lesion, the function of the lower urinary tract should be relatively predictable.

Complete lower motor neurone lesion

Senseless
High capacity }
Acontractile } Low pressure
Hypercompliant }
Inactive sphincter
Voiding by strain

Complete upper motor neurone lesion

Senseless	
Low capacity	High pressure
Hypercontractile	High pressure
Hypocompliant	High pressure
Hyperactive sphincter	
Voiding reflexly	

One exception to this is a lower motor neurone lesion where the upper limit is below the thoracic sympathetic outflow (T_{10}–L_2 cord level), leaving the sympathetic innervation intact and allowing the possibility of persistent contraction of the smooth muscle of the urethra (see 'Urethral Overactivity and Obstruction', p. 105).

Whilst relatively complete upper and lower motor neuron lesions are found in spinal injuries, the majority of other neurological conditions affecting the bladder produce an incomplete lesion. Under these circumstances the use of urodynamic criteria for classification becomes even more important.

Finally, it is important to view the bladder disturbance in a complete medical and social context. Each patient will have a different problem depending not only on the function of the bladder, but also on the medical state of the patient, the disease involved, the mobility and dexterity of the individual and the relative desirability of promoting continence or protecting the function of the upper urinary tract.

Modification of Urodynamic Technique

From a practical point of view the investigation of the neuropathic lower urinary tract is one unequivocal indication for using synchronous urodynamic and video-cystourethrographic assessment. It is synchronisation between bladder and urethral function which is likely to be at fault. It is therefore appropriate not only to visualise the whole area, but also to measure the pressure in the bladder and the urethra at the same time. Such urethrocystometry (see 'Urethrocystometry', p. 60) is best carried out using two catheter-tip transducers mounted on one catheter, but can also be performed by the perfusion technique using a specially modified catheter such as that designed by Rossier (Yalla 1975). It is important to remember that catheters in the urethra may not only obstruct urinary flow, but also reflexly provoke bladder contraction.

The neuropathic bladder is often in a finely balanced state which can be upset easily by infection, rapid filling or a change in the volume of the residual urine normally present. Thomas (1979) emphasises that when investigating such patients the bladder should not be emptied first. Filling should be at physiological rates, 10–15 ml/min. To minimise reflex disturbance serious consideration should be given to using the suprapubic route for monitoring intravesical pressure and for filling the bladder. It will be found necessary to repeat the assessments of storage and voiding at least three times to ensure that the results are repeatable and representative.

If the urethra is being visualised and the pressure within it recorded, the only indication for electromyography is to distinguish between smooth and striated muscle contraction producing dyssynergic urethral obstruction. If urethral function is not being visualised or measured with a pressure recording device then EMG becomes essential. It is however less satisfactory than the two previously mentioned methods, partly because the activity of the various muscles in the pelvic floor may not be synchronous in neurological disease. Recording from the distal urethral sphincter itself is technically precarious. The presence of an anal plug within the anal canal could, by distending the anus, modify urinary function. It is likely that the use of EMG in the assessment of neurological disease in the future will be related more to quantitative examination of the state of denervation or reinnervation of the pelvic floor musculature.

The physical disability of the patient may make the overall conduct of urodynamic examination difficult. Adductor spasms may prevent easy catheterisation, especially in females. The patient may be unable to stand or sit for the investigation and under such circumstances it is appropriate for these studies to be undertaken on a couch which has been specially modified to allow the flowmeter to be positioned appropriately. If the posture of the patient can be changed it may well be found that lower urinary tract function varies substantially with position.

The Clinical Value of Urodynamics

Perhaps the most appropriate way to discuss the role of urodynamic investigation and management is to consider some of the commoner clinical problems that may occur in particular patients. The overall management is summarised in Fig. 5.22.

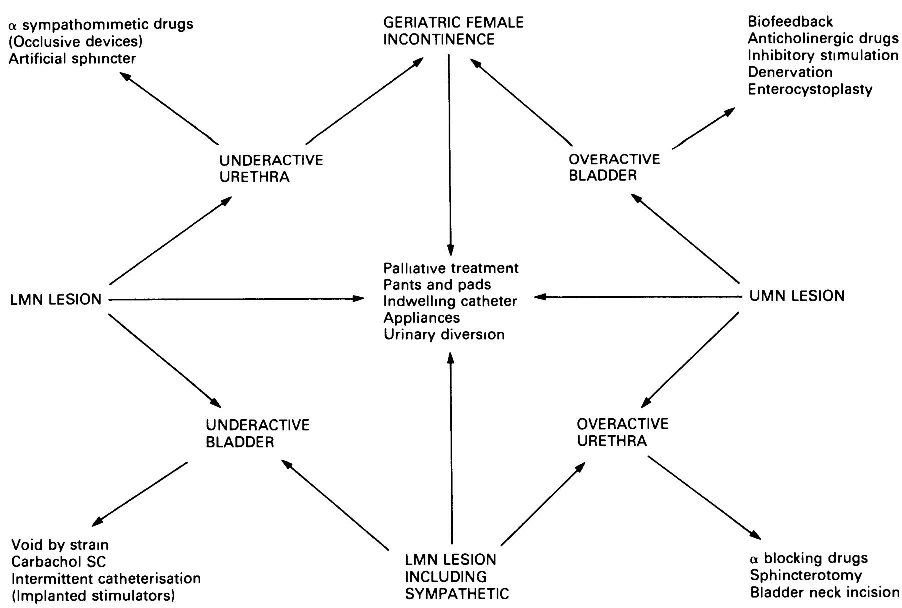

Fig. 5.22. Summary of management of the neuropathic bladder.

Is Sphincterotomy Indicated?

The sequence of events in certain cases of bladder and sphincter overactivity is that detrusor/sphincter dyssynergia produces a high intravesical pressure. These functional abnormalities are in turn related to autonomic dysreflexia, a high residual urine volume, vesico-ureteric reflux and upper tract dilatation. The last three factors can be identified radiologically, but it will be appreciated at once that they can only be identified after they have occurred. This may mean, especially in the presence of infection, that damage has already been done. The present approach to the problem relies on the identification of detrusor/sphincter dyssynergia and high intravesical pressure before complications occur and allows treatment at an early stage. The main problem arises in cases of incomplete lesions where the patient retains enough sensation to remain continent. Part of this continence may depend upon the dyssynergic contraction of the sphincter. In these cases sphincterotomy may result in increased incontinence and these are the cases that need to be watched most closely so that intervention at the first sign of a complication can be undertaken.

That there is still much disagreement about the timing of sphincterotomy is indicated by the fact that the sphincterotomy rate in spinal cord injured patients varies from 18% to 90%, depending on the type of lesion and the policy of the clinician. We should look forward therefore to prospective studies of patients followed by urodynamic testing to indicate the optimum time for operative intervention.

The use of intra-operative urethral pressure recording can help to define when an adequate sphincterotomy has been performed. Naturally, appropriate adjustments to anaesthetic technique must be made to avoid drug induced sphincter paralysis.

When Should Drugs Be Used to Relax the Urethra?

If drugs are employed, some of which have unpleasant side effects, then their efficiency should be monitored at least by frequency/volume charts, urine flow rates and residual urine estimation.

Drugs which relax striated muscle such as Dantrolene and Baclofen have been employed without conspicuous success. It is likely that an improvement occurs in only about 10% of patients. If significant detrusor/sphincter dyssynergia has been proven by urodynamic testing then it is likely that surgical intervention is required.

Sympathetic hyperactivity tends to be confined to the proximal part of the urethra and is due to alpha adrenergic influences. This is identified when functional urethral obstruction occurs at the level of the bladder neck or urethral sphincter, which is not associated with increased EMG activity. Modest therapeutic success has been claimed recently by workers using alpha-blocking drugs (Awad and Downie 1977). Olsson et al. (1977) described the use of a phentolamine test to determine which patients with neurogenic bladder dysfunction will benefit from alpha-blocking drugs. Urine flow rates, corrected for the volume voided, were recorded before and after the administration of 5 mg phentolamine IV. An improvement by 80% of the standard deviation for normal persons made it likely that Phenoxybenzamine therapy would improve the clinical status of the patient. In practical terms alpha blockers do not seem to be very useful in the treatment of urethral obstruction in spinal injuries, though they may suppress the symptoms of autonomic dysreflexia. They have been found to be more useful in children, especially those with myelodysplasia.

Why Is the Detrusor Failing to Contract?

Inadequate bladder contraction in the apparent absence of outflow tract obstruction may be a difficult problem to analyse. The various causes include neuropathy and myopathy or a mixture of the two, and also 'functional' or 'psychogenic' conditions.

The first distinction to be made is whether the bladder is acontractile and highly compliant with decreased sensation, or whether the problem is occurring in the presence of apparently normal sensation and bladder capacity. In the latter case an occult obstruction needs to be excluded by a pressure/flow study. If the pressure/flow study is normal or micturition cannot be initiated then it is worthwhile using EMG to find out whether or not there is persistent urethral sphincter contraction which inhibits the onset of detrusor contraction. This problem occurs both in functional disorders and in certain upper motor neurone lesions such as multiple sclerosis where difficulty in the initiation of detrusor contraction is one of the first symptoms.

If the problem falls into the acontractile/increased compliance group then the problem is usually to decide whether this is a neuropathic problem, a myopathic problem or a mixture of the two. If there are no neurological signs this may be difficult and further conventional urodynamics are of no help. Obviously syphilis should be ruled out and a glucose tolerance test performed to detect diabetes. Further assessment of the detrusor should be by a denervation hypersensitivity test (see 'Drug Administration During Cystometrograms', p. 71) and by a sacral evoked potential study (see 'Sacral Evoked Responses (SER)', p. 92) to detect occult neuropathy. If all these tests are normal then it is likely that the cause lies in the detrusor muscle itself.

Is Urinary Diversion Indicated?

The decision whether or not to perform urinary diversion is not one in which urodynamics has much of a part to play. The decision is made mainly on social grounds and diversion is being performed less often as experience with intermittent catheterisation increases. Urodynamic testing is only relevant in cases where there is upper tract dilatation and sphincterotomy has failed to protect the kidneys from back pressure effects. It is then appropriate to examine the lower tract functionally in order to discover why sphincterotomy has failed.

Urodynamic investigations are of course essential when 'undiversion' is being considered, in order to discover whether or not the bladder is capable of accepting the ureters again.

The Suspicion of Neuropathy

The incidence of bladder neuropathy in patients attending the Bristol Urodynamic Unit is approximately 10%. This means that the problems are relatively common in clinical practice. Despite this the occurrence of this form of bladder dysfunction is frequently unrecognised, especially in cases of acute retention. The subsequent delay in treatment may mean that the recovery of bladder function is compromised. We therefore list a series of circumstances where the clinical suspicion of bladder neuropathy should be recognised and the appropriate investigations and management instituted with rapidity.

1. Sudden onset of disturbed bladder function in a younger person.
2. Any acute bladder disturbance associated with back or neck pain, even if the deterioration in bladder function is associated with an improvement in the pain.
3. Any bladder disturbance where there is a long history of cervical or lumbar spondylosis. These conditions may not be as benign as they are commonly believed to be.
4. Any functional bladder disturbance where conventional investigation provides no explanation. For example, it may soon be feasible to investigate the onset of bladder overactivity by sensory evoked cortical potentials to test for early multiple sclerosis and spinal tumours.
5. Bladder disturbance in persons with known malignancy. A change of this nature is very often the first sign of impending spinal cord compression. If the lesion is treated at any early stage by radiotherapy or surgery there is a chance that paraplegia will be avoided. Once paraplegia has occurred it is seldom possible to improve neurological function.

Above all, it is important to emphasise that the nervous system must be examined carefully in any case of sudden onset of bladder dysfunction. Should neurological signs be found, the urgency of the situation must be recognised. It is failure in these two areas which leads to a continuing morbidity which is avoidable.

Conclusions

Before summarising the indications for urodynamic testing in lower urinary tract dysfunction it is perhaps appropriate to examine the influence of the urodynamic report on the policy of the referring clinicians.

We reviewed the hospital notes of, and sent postal questionnaires to 220 female patients who had been investigated 3 years previously. The urodynamic report was found to be filed in 90% of the records. In 86% of these cases the referring consultant had taken note of the urodynamic report and had acted on its recommendation. Of these, both the follow-up in the notes and the patients' replies suggested that 72% were cured or significantly improved. In the 14% of cases that received treatment contrary to that advised there was an improvement rate of only 38%.

From the questions posed to the patients in the postal questionnaire we found that 56% of the women said that there had been no problem with the test, and a further 26% found it to be a mildly distressing experience. Only 5% had reported that the tests had been distasteful and 13% had noted some pain.

From this we conclude that bladder function studies by our techniques are well tolerated by the vast majority of patients. Clinicians in charge of patients appear to find a urodynamic service helpful in patient management and the use of such information increases the success rate of treatment.

Indications for Urodynamic Studies

Children

Urine flow studies: suspected outflow obstruction

Pressure/flow studies: dysfunctional voiding problems

Synchronous urodynamics and video-cystourethrography: neurogenic bladder dysfunction

Adult Males

Urine flow studies: suspected outflow obstruction, urinary tract infections, suspected bladder overactivity to exclude obstruction

Pressure/flow studies: low flow rate in young males, postprostatectomy problems, equivocal urine flow rate

Synchronous urodynamics and video-cystourethrography: obstructed voiding in young males, neurogenic bladder dysfunction

Adult Females

Urine flow studies: suspected outflow obstruction

Pressure/flow studies: mixed stress/urge incontinence, low flow rates unresponsive to urethral dilatation, equivocal urine flow rates

Synchronous urodynamics and video-cystourethrography: postoperative incontinence problems, symptomatic stress incontinence not demonstrated during physical examination, neurogenic bladder dysfunction

Geriatric Patients

Should be investigated as indicated in the male and female sections, due regard being given to their mental and physical status.

The Neuropathic Bladder

Investigation is usually necessary to classify the problem.

In addition to the indications listed above urodynamic studies should be used to monitor the effects of both medical and surgical treatment. As such, urodynamic investigations represent a most useful assessment method in both research and routine clinical practice.

Suggestions for Future Research

There are three particular areas in which progress is needed: the definition of normality, the understanding of pathophysiology and the search for new investigational techniques.

Normality

It is always difficult to get adequate series of normal persons to undergo investigation, especially when a sensitive area is involved. Information on the limits of normality is conspicuously lacking in urodynamics, and those series that have been reported are rather small. A review of available data would be welcome and co-operative studies may be needed.

There is still dispute about the extent to which the commonly used investigations can reflect normality. The effect of infusion rate during cystometry is still unclear. Further work is appropriate on the correlation between maximum cystometric capacity and maximum or average functional bladder capacity. As the majority of urodynamic studies consist of a single cycle of micturition, it would be useful to know the reliability of one such test in representing the patient's normal voiding pattern.

Pathophysiology

Before dysfunction can be understood, normal physiology must be evident; as stated above, this is not yet the case. Parallel animal studies are needed to explain what urodynamic observations mean. Many of these are in progress, but are complicated by species variation in lower urinary tract function. Meanwhile the most fruitful areas of study are likely to be neuromuscular physiology and pharmacology. Interrelation of vesical and urethral activity is important to record. The combined study of ano-rectal with vesico-urethral function may also lead to useful conclusions.

Once the pathophysiology of, for example, genuine stress incontinence is understood adequately then prophylactic measures can be initiated which will be of more significance than research into therapy.

New Urodynamic Techniques

New methods should aim to be non-invasive. This includes a means of pressure registration. In particular assessment of the urinary stream can be more exhaustive (see 'Technique and Equipment', p. 33).

Micro-electronic technology will mean that urodynamic tracings can be analysed automatically and the probability of their conformity to a particular diagnosis computed. The need to provide a data base for this may make essential the studies of normality described above.

Digital recording techniques will allow the cancellation of artifacts, and great care must be taken to avoid inappropriate manipulation of data. Despite the mushrooming of microcomputers, it is likely that dedicated microprocessors will be more relevant to clinical practice. It is accordingly essential that clinicians should tell the commercial companies what is really necessary and properly justified.

The last comment must be that the existing urodynamic techniques still need to be employed in an optimal way. It is hoped that this book will assist in the achievement of this objective.

Urodynamics is a provocative subject in more ways than one and it is an exciting field in which to be involved. Many problems remain to be solved and if this book kindles interest in only a few it will have been worthwhile.

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Chapter 6

The Organisation of Urodynamic Units

The Evolution of the Bristol Urodynamic Unit

The initial concept of the Urodynamic Unit has been outlined in the first chapter. The aim was threefold: to develop urodynamic techniques, evaluating their contribution in the management of lower urinary tract disorders, to provide facilities for research by medical graduates during their surgical training and to reconsider the pathophysiology of various clinical problems, particularly where previous treatment had proved unsatisfactory. The original project was a modest one, but the demand for the investigations rapidly increased during the ensuing years (Fig. 6.1). When the Unit started there was no division between the research work and the service commitment, but this became necessary later as the pattern of referrals became apparent and specific projects were studied. Thus, the establishment both in terms of staff and equipment gradually evolved to balance the clinical demands. A urodynamic unit requires the same consideration as any other diagnostic department. The equipment appears expensive, but when compared with the cost of other modern diagnostic technology it is certainly not excessive. Furthermore, the results of the investigations are cost-effective if their contribution to clinical management is fully appreciated. The units needs to be housed in a suitable environment and staffed by experienced medical practitioners who are adequately supported by technical and clerical personnel. The organisation of our Unit is outlined in detail to illustrate some of the administrative factors that require consideration.

Equipment

The first major decision during the formulation of the earliest research project centred on the type of equipment required. Criteria included versatility, reliability

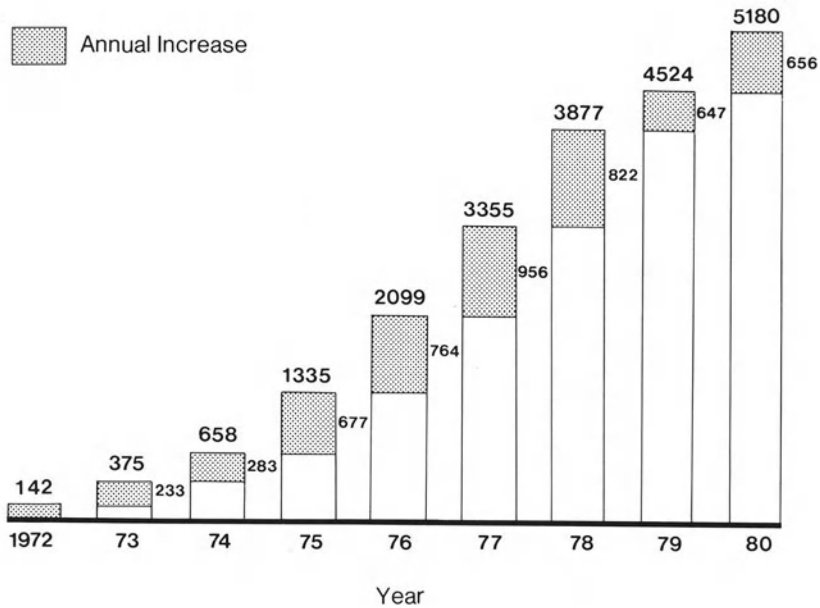

Fig. 6.1. The increase in the referral rate of patients for urodynamic investigations since the inception of the Bristol Unit.

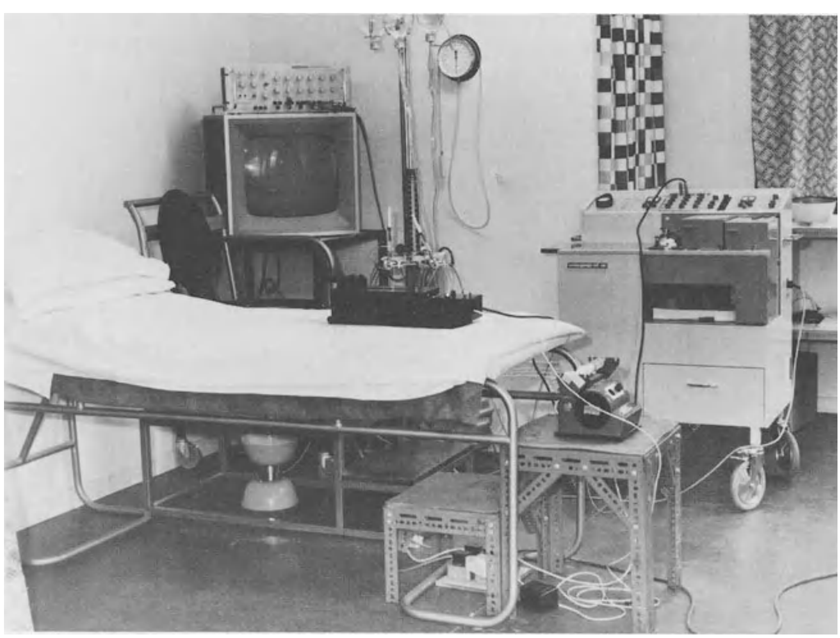

Fig. 6.2. The original urodynamic system in 1971 still in use at present for routine investigation.

and the capacity for expanding the system when necessary. An Elema Schonander Mingograf M 81 multichannel recorder was chosen (Fig. 6.2). This was of modular construction and had facilities for eight channels, although only five were fitted initially. The write-out was by ink jets. By using the internal switching system any five of eight or even more signals could be chosen. The system was used to record abdominal pressure, intravesical pressure, detrusor pressure, urine volume and flow rate, urethral pressure, urethral length and the output from various stimulators. Subsequently, the system has been expanded to eight channels and has worked efficiently for 10 years.

By 1976 the volume of service work had expanded to such an extent that research time was becoming compromised. A new urodynamic system was designed at low cost with even greater versatility. This was based on the Medelec modular unit, often used for neurophysiological investigation, coupled with a Bryans 12-channel UV recorder. Extra conditioning units and patch panel systems were built by the local medical physicists (Fig. 6.3). This arrangement was designed especially for multichannel EMG research and could be expanded in the future to measure evoked responses. For routine use we have been disappointed by the poor quality and expense of the UV recordings.

Over the years various independent flowmeters of all types have been purchased. Some of these are now installed on the hospital wards (Fig. 6.4). They are of particular value in screening male patients suspected of having bladder outflow

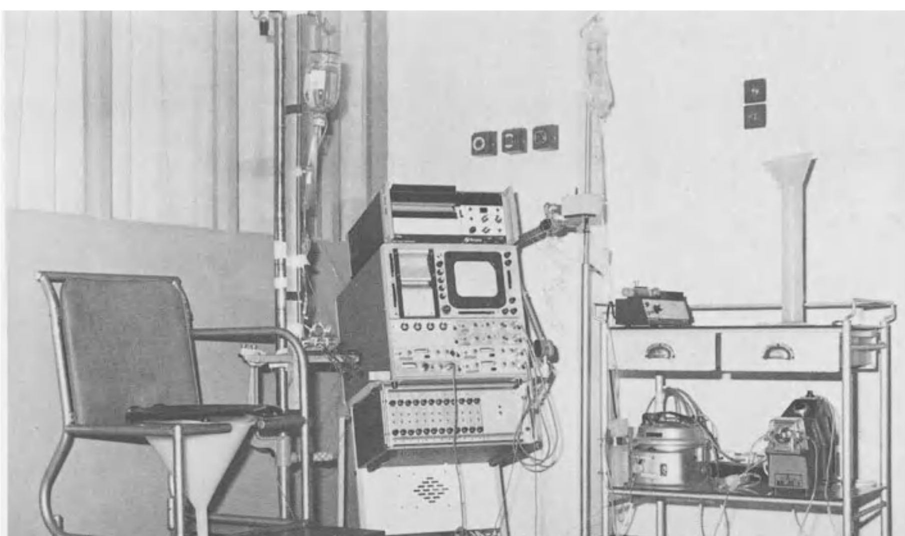

Fig. 6.3. A 12-channel urodynamic system for research studies.

Fig. 6.4. An independent flowmeter installed in the ward toilet. This can be swung into use as necessary, the recording system being remote from the flowmeter. It can also be adjusted to go under a mobile commode. The recording system is activated when urine flows through the meter.

obstruction. By studying a series of urine flow rates together with the volumes voided a graph of these measurements can be obtained on an individual patient and the diagnosis of obstruction can often be made, avoiding the invasive catheter studies of pressure/flow analysis (see 'Normal Values', p. 76).

Although we still believe that most urodynamic investigations can be undertaken without synchronous video-cystourethrography, the demands of a regional referral service and the need to replace old equipment led, in 1980, to the purchase of a DISA uro-video system incorporating a 'U matic' video cassette recorder. This equipment has been organised in a slightly unconventional way. Often a complex system such as this is rack mounted and difficult to move any distance. It is therefore standing unused in the x-ray department for much of the time. To avoid this we arranged that the urodynamic part should be separate and portable. This

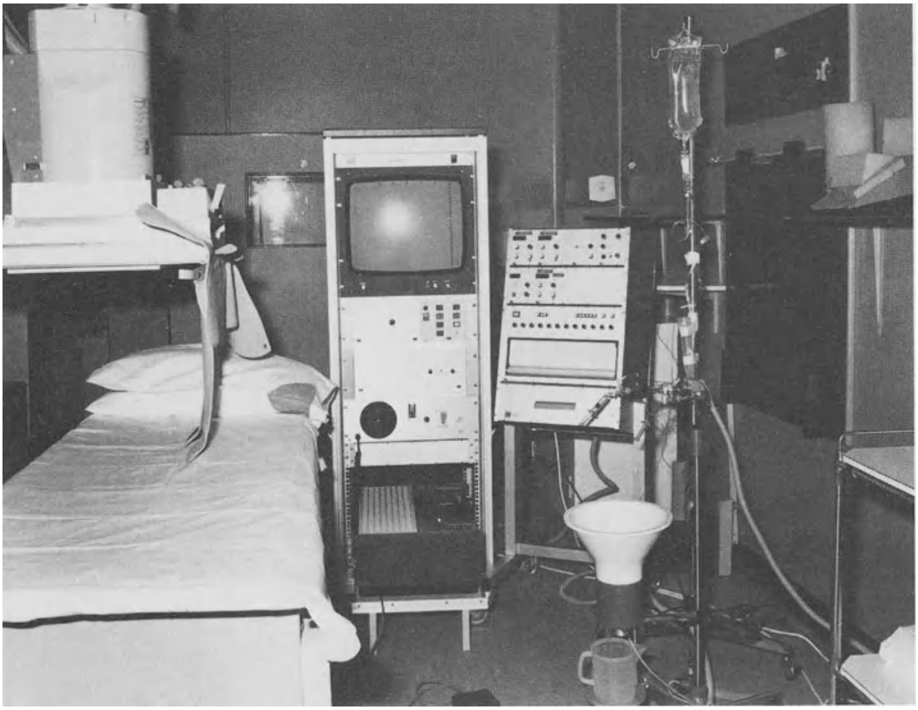

Fig. 6.5. The uro-video system used for synchronized radiology and urodynamics. The rack contains the monitor, analogue-to-video converter and videotape recorder. The urodynamic recording system is separate so that it can easily be transported for use elsewhere.

uses the DISA 2100 chassis and can be taken from the urodynamic unit where it is in use every day, to the x-ray department for video recording sessions (Fig. 6.5)

The close co-operation of the Medical Physics Department has been essential for the efficient continuity of the urodynamic service. The assistance provided by individual medical physicists experienced in urodynamic monitoring has resulted in the development of specific equipment. For example, the catheter used for testing the electrosensitivity of the urethra (see 'The Evaluation of Sensation', p. 114) was developed by Dr. Douglas James at the Sphincter Research Unit at Exeter.

Staffing

Research

Throughout the development of the Unit the research staff have played a fundamental role. With the purchase of the original equipment a full-time research fellow was seconded from the University Department of Surgery for a period of one year. He developed the routine techniques for performing filling and voiding cystometry, simultaneous urine flow measurement and urethral profile studies. The catheter-withdrawal apparatus for the profile studies was constructed by members of the University Electrical Engineering Department. These techniques have formed the foundation for the investigations performed subsequently in the Unit, and his work identified the contribution of urodynamic studies in the clinical evaluation of many disorders such as enuresis, bladder neck obstruction and female urinary incontinence. In retrospect, the commitment of the research fellow also initiated the clinical service and this would have been a difficult and tedious task for a busy clinician on a part-time basis.

Subsequent support for the research fellows has been generously provided by grants from the Medical Research Council and the South-West Regional Health Authority. Furthermore, their major contributions to the work have vindicated the aim of the Unit as a research department. The active participation of medical graduates has stimulated new and original ideas regarding the pathophysiology of lower urinary tract disorders. The various topics that have been investigated include the effects of electrical stimulation, denervation, gynaecological surgery, prostaglandins, local anaesthetics and other drugs on the lower urinary tract. The value of urodynamic testing has been assessed, especially in adult enuresis, male outflow tract obstruction and bladder underactivity. New investigations have been elaborated such as bladder work calculation and electrosensitivity.

An active research programme keeps any department in touch with progress in related fields.

Fundamental support for the expansion of the Unit was provided in 1976 by a Medical Research Council programme grant. This provided medical, nursing and clerical staff for 5 years and allowed research into the epidemiology and management of incontinence.

The Urodynamic Service

Although the attachment of research assistants for a period of one or two years is to be commended, the provision for a continuity of experience is vital in a department with a heavy service commitment. This continuity has been achieved by the appointment of two medical practitioners who undertake three or four sessions of urodynamic studies in a week. A session consists of a morning or afternoon or an afternoon period of 3½ h. These members of staff have become highly experienced with the clinical problems, the urodynamic studies and their interpretation. Meaningful reports can result only if the limitations and the pitfalls of the techniques are fully appreciated. With regard to the clinical problems, one medical practitioner has a particular interest in female urinary incontinence and the other has studied a large group of children and young adults.

The Technician

The need to appoint a technician was recognised during the early stage of development of the Unit. This member of the staff now undertakes a variety of essential tasks which contribute significantly to the efficiency of the service. The technician performs routine maintenance and calibration of the equipment and liaises with the Medical Physics Department of the hospital or the manufacturer's local representative whenever serious faults arise. Adequate supplies of disposable equipment, catheters, sterilising solutions, dressing packs and sterile gloves need to be ordered and stocked. The duties have also included assistance with the analysis of the tracings, preparation of the urodynamic data before reporting and the maintenance of the computer records. In our Unit her services have also been helpful as a chaperone for female patients.

In a new field such as urodynamics it is understandable that problems have arisen regarding the correct grading, salary and career structure for the post of the technician. Depending on the previous training and the qualifications of the individual, this appointment in the United Kingdom would seem correctly structured for a Medical Physics Technician or a Physiological Measurement Technician.

The Secretary

As the workload of the Department increased the stage was reached when a full-time secretary became essential to co-ordinate the various activities within the Department. The secretary is responsible for arranging the patients' appointments, obtaining relevant hospital notes, typing the reports and distributing them to the appropriate source. The maintenance of the patients' records both within the Department and on the computer, together with the records of the clinical trials in progress has been an important assignment for the secretary because ready access to these has been essential for the research programmes. Finally, the secretary plays an important role in the organisation of the regular meetings within the Unit.

The Nurse

The appointment of a trained nurse rapidly expanded the clinical contribution of the Unit. A high proportion of the patients (52% of the men and 78% of the women) who are referred to the Department experience some degree of urinary incontinence. Whilst the need for accurate diagnosis involves detailed investigations and inevitable delay in treatment, the patient eagerly awaits practical advice on the management of their problem. The nurse has been able to provide this, instructing the patient on pelvic floor exercises and the various types of pants, pads, etc. that are available. She has participated in the study on the prevalence of urinary incontinence in the community (Thomas et al. 1980) and undertaken market research on the various aids, appliances and catheters that are available. A nursing clinic is held once a week for incontinent patients referred by consultants and medical practitioners. Her teaching role on the subject of incontinence to hospital and community nursing staff and medical students is vital. The education of nurses on the subject of incontinence has been enhanced by publications in the nursing literature (Blannin 1980a,b).

Patient Management

The Referral Pattern

The pattern for patient referrals for urodynamic investigations is related to many factors, not least of which is the commitment of the clinicians to the value of these studies in assessing lower urinary tract disorders. Conclusions related to the population figures can be misleading, but the development of our Unit has shown a pattern which indicates the demand that the service has generated within the first decade. The Unit in Bristol is situated in a Health Authority Area which serves a population of nearly 800 000. During an average month 70 patients are investigated in the Unit and 82% of these live within the area. Ninety-five percent of the requests arise from the Urological and Gynaecological clinics with an almost equal distribution between men and women. The remainder are referred mainly from Neurological, Geriatric and Orthopaedic clinics.

Seventy-five percent of the patients visit the Unit as out-patients and are referred back to their original clinic. The remainder undergo the urodynamic tests during their hospital admission and 80% of these are men with symptoms suggesting possible urinary tract obstruction. They usually have the investigations as a pre-operative study, proceeding to endoscopy and lower tract surgery if obstruction is confirmed.

Patient Referral in Practice

When a request for urodynamic investigations is received at the Unit the secretary sends the patient an appointment and includes a frequency/volume chart, with the request that the patient maintains a record of his or her micturition pattern for 7 days and nights prior to the appointment. The patients are also forewarned that they will be required to pass urine when they attend the Department.

On arrival for the investigation the patient is seen by one of the medical staff and a detailed history is taken and recorded on a proforma. This interview takes about 20 min and a full physical examination, including a neurological evaluation, is performed. The care with which this part of the procedure is undertaken is important as it develops the necessary rapport and confidence of the patient. Anxiety inhibits micturition and may produce a misleading urine flow measurement. The patient's co-operation is essential for accurate evaluation of the pressure/flow studies.

Whilst these preliminaries are taking place the technician prepares the examination room for the investigation and calibarates the equipment. The initial urine flow rate is performed before commencing the cystometric studies and every effort is made to place the patient at ease and in privacy. The patient should feel that the bladder is comfortably full before micturition and a feeling of overdistension of the bladder should be avoided.

Following this initial urine flow rate estimation the urodynamic investigations are undertaken. Details of these have already been given in the earlier chapters. If a patient is suffering from distressing urinary incontinence advice is given on the practical management of this before the patient leaves the Department. The patient may be encouraged to perform pelvic floor exercises, stopping and starting during micturition and exercising the pelvic floor regularly. If frequency of micturition is a major problem the patient can be helped by explaining the storage function of the bladder and discussing the frequency/volume chart which they have maintained. If the chart shows wide variation of the functional bladder capacity, the simple instruction to increase the volume by 'holding on' can be most beneficial. Many patients still believe that urinary symptoms are associated with kidney disease rather than bladder dysfunction.

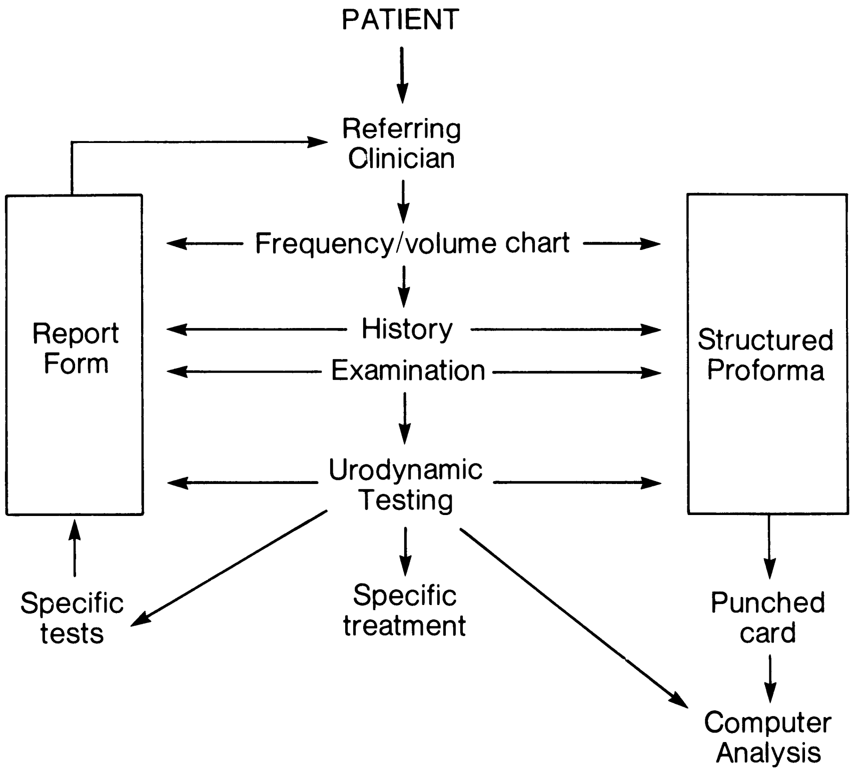

Fig. 6.6. The system by which the patients' records are produced.

Records and Reports

The clinical and urodynamic data on all the patients are recorded on the proforma sheets (Fig. 6.6 and App. 2). The clinical details are completed during the patient's interview in the Unit and the urodynamic results are added following the investigations. These proformas are filed within the Department together with the pressure/flow tracings. The data on the proformas is transferred to punch cards routinely every month and thence to a computer file. Between 1975 and 1980 a total of 3276 records have been stored and this provision of ready access to information on specific clinical and urodynamic subjects has stressed the unique advantage of the computer for this type of work.

Individual reports are prepared for each patient (Fig. 6.7) and these are sent both to the specialist referring the patient and to the general practitioner. This report includes not only the urodynamic findings but also comments on the interpretation of the results. The preparation of reports in this way has familiarised clinicians with urodynamic investigations and they have helped to overcome the suspicion with which new methods of investigation are viewed.

REPORT OF URODYNAMIC INVESTIGATIONS

NAME: Age

ADDRESS:

Hosp. No.

Referred by:

G.P.

Clinical Investigation Unit
HAM GREEN HOSPITAL
Pill
Bristol BS20 OHW

tel: Pill (STD 027581) 261 ex.35

Date:

CLINICAL FEATURES

PRE-TEST C.S.U.:

FILLING CYSTOMETROGRAM (C.M.G.)

cm H_2O

150–
140–
130–
120–
110–
100–
90–
80–
70–
60–
50–
40–
30–
20–
10–
0–

100 200 300 400 500 600 700 800
volume ml.

Initial max. flow	ml/sec.
Initial volume	ml.
Init.resid.urine	ml.

C.M.G.

Capacity	ml.
First desire	ml.
Urgency	ml.
Leakage	ml.
at	cm.H_2O

MICTURATING CYSTOMETROGRAM

Micturition pressure	(P)	cmH_2O
Maximum flow	(F)	ml/sec.
Volume voided		ml.
Residual urine		ml.
Urethral resistance factor (P/F^2)		

URETHRAL PROFILE

	Pressure(cmH_2O)	Length (cm)
Resting		
Squeeze		

COMMENT:

Fig. 6.7. The report form circulated after urodynamic investigation to the referring practitioners.

Accommodation

This Unit has always been situated in a separate building, remote from other hospital services. This has been a significant advantage in providing a congenial atmosphere away from the hubbub of other activities, and the patient appreciates the privacy and the individual attention.

At the start the Unit shared accommodation with respiratory physiology and thence derived its name — The Clinical Investigation Unit. Subsequently, the Unit was able to expand into adjacent buildings. This has provided space for two urodynamic laboratories, several offices and an out-patient/nursing area (Fig. 6.8).

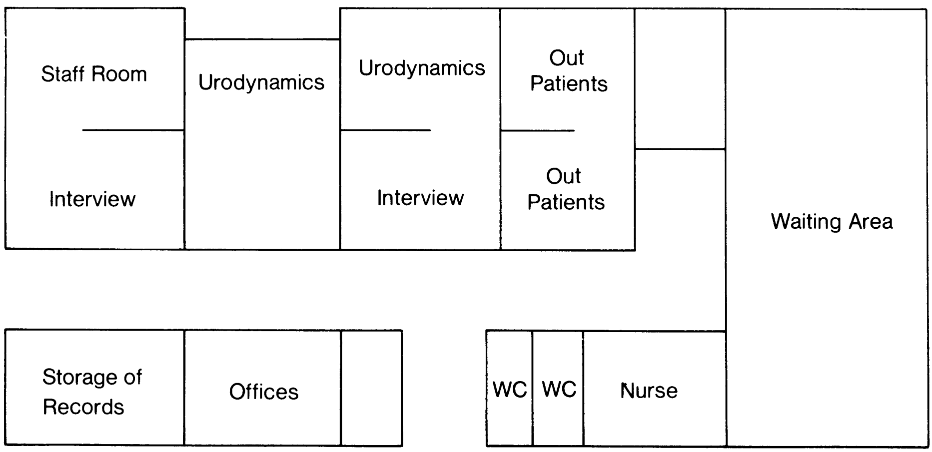

Fig. 6.8. A plan of the Urodynamic/Incontinence Unit at Bristol.

Planning a New Urodynamic Service

Many of the larger teaching centres already have access to urodynamic facilities. It is likely that the majority of new services will be planned in response to the needs of District General Hospitals and of individual clinicians. The contemporary urologist and gynaecologist require facilities for urodynamic evaluation of selected patients and they should decide what type of service is suitable for their clinical needs. Such a service may be considered on three levels; simple screening tests, basic but comprehensive urodynamic facilities and equipment for research and referral centres.

The most basic consideration is the assessment of demand and this may be related to local enthusiasm. The figures quoted above (see 'The Referral Pattern', p. 181) suggest that in Bristol 1 : 10000 of the population are tested each month. We estimate that this is less than the number that might benefit from testing. However, it is a realistic figure to work on. It would seem that the distribution of urodynamic units should be one for every 250000 population. This would produce six patients each week for investigation, and to assess these carefully would require two sessions. A demand less than this would hardly justify the capital expenditure and would not provide sufficient experience for the clinicians concerned.

Simple Screening Investigations

A urine flowmeter is essential for the urologist. Some form of cystometry is useful for urologists and gynaecologists. One form of cystometry which, in practice, falls into this category is that performed with carbon dioxide. This method is relatively popular with those clinicians who conduct their own 'office' urodynamics. Whilst we have important reservations about the use of CO_2 cystometry (see 'Medium Used for Bladder Filling', p. 65) it is better than no objective assessment at all.

The clinician who wishes to provide a simple screening system might consider a unit containing a CO_2 insufflation unit with inbuilt transducer, a flowmeter and a two-channel recorder. This would allow urethral pressure profiles (see 'Gas Perfusion Profilometry', p. 52), infusion cystometry, urine flow rates and possibly pressure/flow studies (see 'Medium Used for Bladder Filling', p. 65). Various systems of this type are available.

Basic Urodynamic Services

To cater for the needs of 250 000–500 000 population, where there would be 5–10 referring clinicians, a small but defined department is appropriate. The most important consideration is finding a medical practitioner to perform the tests. Since the clinical history and examination are so important it is not appropriate to delegate the test to a technician. It is likely that a part-time general practitioner who wishes to take up a hospital attachment would be the most suitable appointment in the British system.

The equipment necessary would incorporate:

Uroflowmeter, commode and stands
2 pressure transducers (P_{ves}, P_{abd})
Subtraction unit (P_{det})
Four-channel chart recorder
Infusion pump for bladder filling
Motorised syringe pump for urethral pressure profiles
Profile catheter withdrawal system

The cost of such a system may vary widely and it is advisable to contact various manufacturers, asking for specific quotations (App. 3). Several firms now produce equipment designed specifically for urodynamics. While this may be more expensive than assembling the elements of a general system, it is usually easier to operate.

It is desirable to have the exclusive use of a room for the unit. This means that the equipment can be left ready for use and tests can be done at times convenient for doctor and patient. The room should be quiet, secluded and allow some privacy for the patient. The space required is about 25 m^2 and the reason for such a large room is given in Fig. 6.9.

In addition to the medical practitioner it will be necessary to employ a nurse or patient measurement technician to act as assistant to prepare and clean up trolleys,

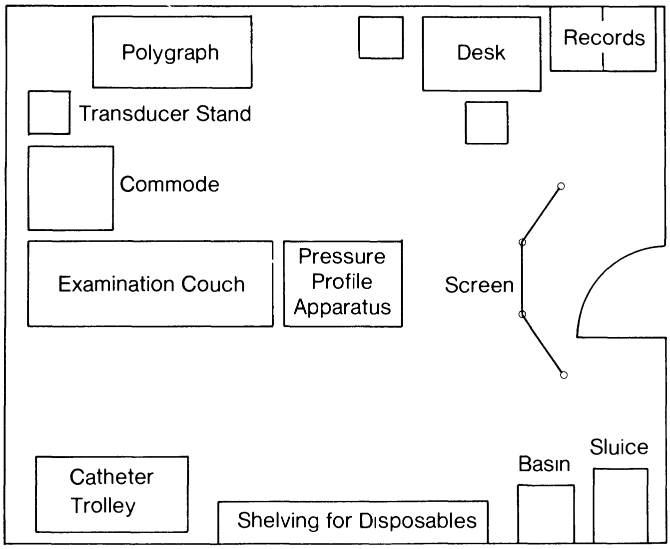

Fig. 6.9. The possible arrangement of equipment and facilities within a urodynamic recording room. Some workers prefer to have the recording apparatus out of sight of the patient. We have found this neither convenient nor necessary.

to operate the recording apparatus to order supplies and perhaps to chaperone the patient. This individual may become very experienced and assist in the processing of data or perform some investigations. If a nurse is employed it would be most appropriate if she were to become Incontinence Nurse Adviser to the District, responsible for training other nursing staff and for offering practical advice to the patients on palliative treatment.

Research and Referral Centres

Such centres already exist in teaching districts on a regional basis. With appropriate variations their activities are similar to those described above for Bristol. In these centres there should be access to synchronous uro-video studies and it may be useful for there to be links with the regional spinal injuries and neurological units.

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Appendix 1

International Continence Society Reports

First Report on the Standardisation of Terminology of Lower Urinary Tract Function

Urinary Incontinence

Procedures Related to the Evaluation of Urine Storage

  Cystometry

  Urethral Closure Pressure Profile

Units of Measurement

Produced by the International Continence Society Committee on Standardisation of Terminology, February, 1975.
Members: Patrick Bates, William E. Bradley, Eric Glen, Hansjörg Melchior, David Rowan, Arthur Sterling and Tage Hald (Chairman).

This report contains the first set of recommendations dealing with the terminology of lower urinary tract function. Specifically, it covers the storage of urine in the bladder, urinary incontinence and units of measurement. The recommendations were subject to discussion during the Fourth Annual Meeting of the International Continence Society in Mainz, Germany in September, 1974.

These standards are proposed to facilitate comparison of results by investigators who use urodynamics methods. It is recommended that the acknowledgement of these standards in written publications be indicated by a footnote to the section 'Methods and Material' or its equivalent: 'Methods, definitions, and units conform to the standards proposed by the International Continence Society except where specifically noted.'

Urinary Incontinence

Incontinence is a condition where involuntary loss of urine is a social or hygienic problem and is objectively demonstrable. Loss of urine through channels other than the urethra is extraurethral incontinence.

Stress incontinence denotes:
1. a symptom,
2. a sign, and
3. a condition = genuine stress incontinence.

The *symptom* 'stress incontinence' indicates the patient's statement of involuntary loss of urine when exercising physically (in the broadest possible sense of the words).

The *sign* 'stress incontinence' denotes the observation of involuntary loss of urine from the urethra immediately upon an increase in abdominal pressure.

The *condition* 'genuine stress incontinence' is involuntary loss of urine when the intravesical pressure exceeds the maximum urethral pressure but in the absence of detrusor activity.

Urge incontinence is involuntary loss of urine associated with a strong desire to void. Urge incontinence may be subdivided into *motor urge incontinence*, which is associated with uninhibited[1] detrusor contractions, and *sensory urge incontinence*, which is not due to uninhibited detrusor contractions.

Reflex incontinence is voluntary loss of urine due to abnormal reflex activity in the spinal cord in the absence of the sensation usually associated with the desire to micturate.

Overflow incontinence is involuntary loss of urine when the intravesical pressure exceeds the maximum urethral pressure due to an elevation of intravesical pressure associated with bladder distension but in the absence of detrusor activity.

Procedures Related to the Evaluation of Urine Storage

Cystometry

Cystometry is the method by which the pressure–volume relationship of the bladder is measured. Zero reference for pressure is the level of the superior edge of the symphysis pubis.

Specify:

1. Access: a) Transurethrally
   b) Percutaneously
2. Medium: a) Liquid
   b) Gas
3. Temperature: state temperature in degrees Celsius.
4. Position of patient:
   a) Supine
   b) Sitting
   c) Standing

[1] A term subsequently discouraged — see fourth report.

5. Filling:
a) Continuous
b) Incremental

The precise filling rate should be stated. When using incremental method, also state volume of increment. For general discussion, the following terms for the range of filling rate may be used:

1. Up to 10 ml per minute is a *slow fill cystometry*.
2. 10–100 ml per minute is a *medium fill cystometry*.
3. Over 100 ml per minute is a *rapid fill cystometry*.

Technique:

1. Single or double lumen catheter or multiple catheters
2. Type of catheter (manufacturer)
3. Size of catheter
4. Measuring equipment

Findings:

Before starting to fill, residual urine should be measured. The presence of contractions exceeding 15 cmH_2O clearly indicates an uninhibited[1] detrusor contraction when the patient has been asked to inhibit. Pressure elevations smaller than 15 cmH_2O indicate that clinical judgement should be exercised. An indication of the volume at first desire to void should be made.

Maximum cystometric capacity is the volume at which the patient has a strong desire to void.

Effective cystometric capacity is the maximum cystometric capacity minus the residual urine.

Compliance indicates the change in volume for a change in pressure. It is defined as $C = \Delta V/\Delta P$ where ΔV is the volume increment and ΔP is the change in pressure associated with this volume increment. During cystometry, it is taken for granted that the patient is awake and not sedated. If otherwise, this should be specified.

Urethral Pressure Profile

Urethral pressure profile denotes the intraluminal pressure along the length of the urethra with the bladder at rest.

Zero reference for pressure is the level of the superior edge of the symphysis pubis.

To be meaningful, bladder pressure should be measured simultaneously.

The subtraction of intravesical pressure from urethral pressure produces the *urethral closure pressure profile.*

Specify:

1. Catheter type and size
2. Measurement technique
3. Rate of infusion
4. Continuous or intermittent withdrawal

[1] A term subsequently discouraged—see fourth report.

5. Rate of withdrawal
6. Bladder volume
7. Position of patient: a) Supine
   b) Sitting
   c) Standing

Findings (see Fig. A.1.1):

Maximum urethral pressure is the maximum pressure of the measure profile.

Maximum urethral closure pressure is the difference between the maximum urethral pressure and the bladder pressure.

Functional profile length is the length of the urethra along which the urethral pressure exceeds bladder pressure.

(*Total profile length* is not generally regarded as a clinically useful parameter).

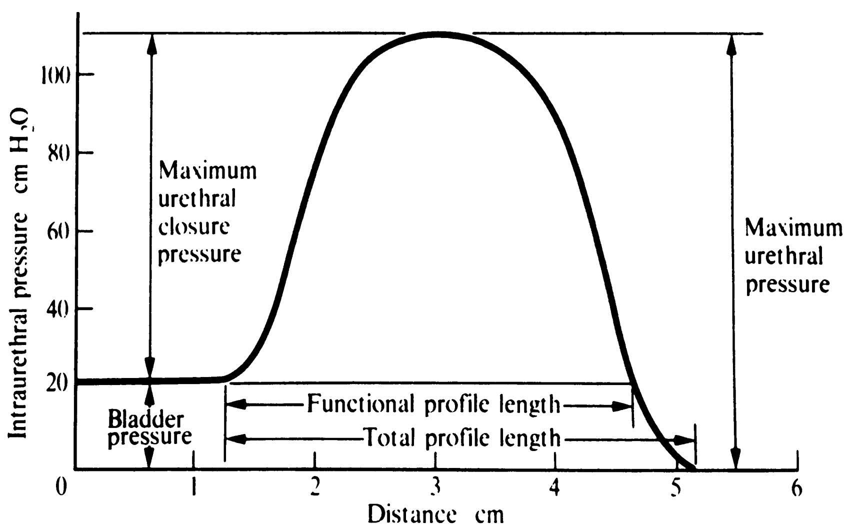

Fig. A.1.1. A schematic representation of the urethral closure pressure profile. (*British Journal of Urology* 48: 39-42, 1976)

Units of Measurement

In current urodynamic literature there is no standardisation in the units of measurement. For example, intravesical pressure is sometimes measured in mmHg and sometimes in cmH_2O. When Laplace's law is used to calculate tension in the bladder wall, it is often found that pressure is then measured in dyne cm^{-2}. This lack of uniformity in the systems used leads to confusion when other parameters, which are a function of pressure, are computed, for instance, 'compliance', 'urethral resistance', etc. From these few examples it is evident that standardisation is essential for meaningful communication. Many journals now require that the results be given in SI Units.

This system will be used in all future I.C.S. papers. The following report is designed to give guidance in the application of the SI system to urodynamics and defines the units involved. The principal units to be used are listed below. A fuller explanation of the SI system is given below.

Quantity	*Acceptable unit*	*Symbol*
Volume	Millilitre	ml
Time	Second	s
Flow rate	Millilitres/second	ml s^{-1}
Pressure	Centimetres of water[1]	cmH_2O
Length	Metres or submultiples	m, cm, mm
Velocity	Metres/second or submultiples	m s^{-1}, cm s^{-1}
Temperature	Degrees Celsius[2]	°C

Le Système Internationale d'Unités (SI Units)

At the Conférence Générale des Poids et Mesures (CGPM) in Paris in 1960 it was agreed internationally that this system of units (abbreviated to SI in all languages) should be adopted for all scientific and technical work. It is an extension and refinement of the traditional metric system and is rational, coherent and comprehensive. It is therefore logical that this system should be used in all urodynamic studies.

There are 7 fundamental units; all other units are derived from these. The 3 basic mechanical quantities are mass, length and time.

The complete list is given below:

Quantity	*Unit*	*Symbol*
Mass	Kilogramme	kg
Length	Metre	m
Time	Second	s
Temperature	Kelvin	K
Electric current	Ampere	A
Luminous intensity	Candela	cd
Amount of substance	Mole	mol

[1]The SI Unit is the pascal, but it is only practical at present to calibrate our instruments in cmH_2O. One centimetre of water pressure is approximately equal to 100 pascals (1 cm H_2O = 98.07 Pa). When calculating parameters that are a function of pressure, for example, 'compliance', the pascal must be used to avoid confusion. Measurements reported in millimetres of mercury will not be acceptable.

[2]The SI Unit is the degree Kelvin. The Kelvin temperature interval is identical with the degree Celsius (centigrade) temperature interval. The Kelvin scale starts at absolute zero (−273.16°C), and this is inconvenient in medical practice. The Celsius scale will therefore be used.

Second Report on the Standardisation of Terminology of Lower Urinary Tract Function

Procedures Related to the Evaluation of Micturition
Flow Rate
Pressure Measurement
Symbols

Produced by the International Continence Society Committee on Standardisation of Terminology, Copenhagen, August, 1976.
Members: Patrick Bates, Eric Glen, Derek Griffiths, Hansjörg Melchior, David Rowan, Arthur Sterling, Norman R. Zinner, Tage Hald (Chairman).

This report contains the second set of recommendations dealing with the terminology of lower urinary tract function. It covers micturition and recommendations for the use of symbols. The recommendations were subject to discussion during the Fifth Annual Meeting of the International Continence Society in Glasgow, Scotland, September, 1975.

Urodynamics encompasses the morphological, physiological, biochemical and hydrodynamic aspects of urine transport. This report deals with the urodynamics of the lower urinary tract.

Procedures Related to the Evaluation of Micturition

Flow Rate

Flow rate is defined as the volume of fluid expelled via the urethra per unit time. It is expressed in ml/s.

Specify:

1. Patient environment and position:
   a) Supine
   b) Sitting
   c) Standing
2. Filling: a) By diuresis: i) Spontaneous
   ii) Forced (specify regimen)
   b) By catheter: i) Transurethral
   ii) Suprapubic } State rate
3. Fluid: Indicate temperature.

Technique:

1. Measuring equipment
2. Solitary procedure or combined with other measurements

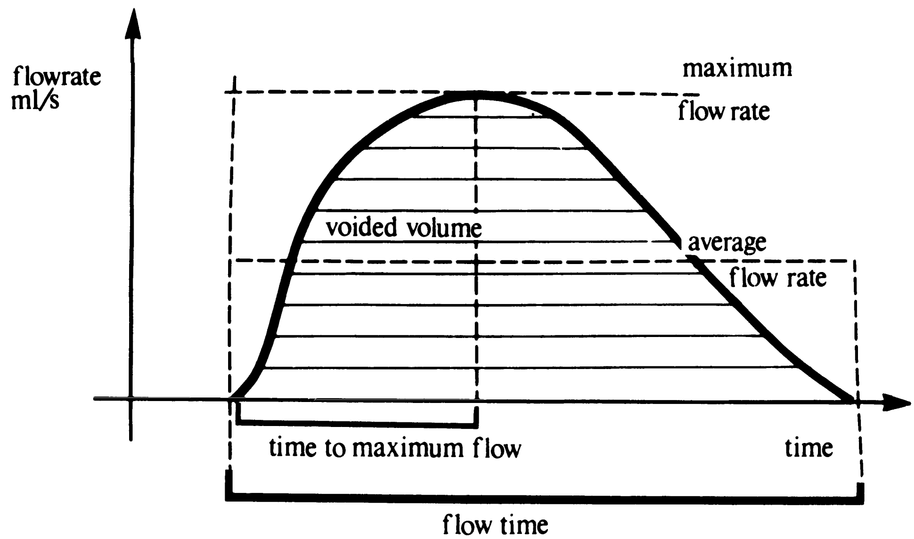

Fig. A.1.2. Continuous flow curve. (*British Journal of Urology* 49:207–210, 1977)

Definitions:

1. *Continuous flow* (see Fig. A.1.2).
   Flow time is the time over which measurable flow actually occurs.
   Time to maximum flow is the elapsed time from onset of flow to maximum flow.
   Maximum flow rate is the maximum measured value of the flow rate.
   Voided volume is the total volume expelled via the urethra.
   Average flow rate is voided volume divided by flow time.
2. *Intermittent flow* or *continuous flow with substantial terminal dribbling* (see Fig. A.1.3).
   The same parameters are applicable if care is exercised in measuring flow time as defined above, i.e. time intervals between flow episodes are disregarded, or if the duration of very low terminal flow is disregarded.
   Voiding time is total duration of micturition, including interruptions. In continuous flow situation voiding time is equal to flow time.

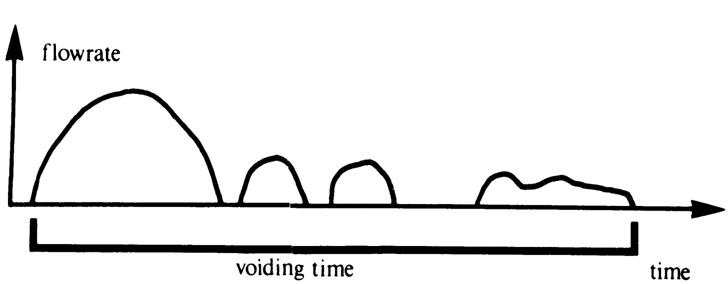

Fig. A.1.3. Intermittent flow curve. (*British Journal of Urology* 49:207–210, 1977)

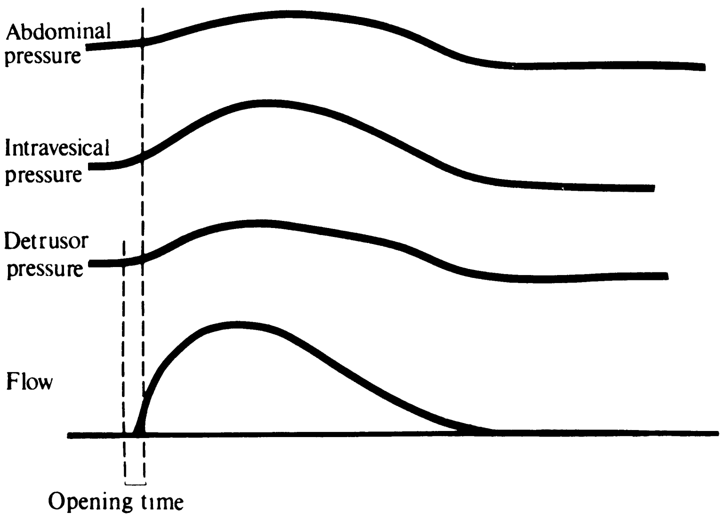

Fig. A.1.4. Corresponding pressures and curve of flow. The order of presentation of curves as shown is recommended. (*British Journal of Urology* 49:207–210, 1977)

Flow Pattern

Specify pattern description. This cannot be defined at present and is best illustrated.

Comment

Measurement of the flow rate has value:
1. As screening procedure
2. In assessing results of treatment
3. In assessing progression of disease

However, as an isolated measurement it has limitations. In particular it may have to be related to bladder pressure, initial and residual volume in the bladder and of course age and sex.

Pressure Measurements During Micturition

Zero reference for all pressure measurements is the level of the superior edge of the symphysis pubis. Pressures are expressed in cmH_2O.

Specify:

1. Access to: a) Intravesical pressure:
   - i) Transurethral
   - ii) Suprapubic
   - iii) Telemetry

b) Abdominal pressure:
i) Rectal
ii) Gastric
iii) Intraperitoneal

2. Position of patient:
   a) Supine
   b) Sitting
   c) Standing

Technique:

1. Catheter type and size
2. Measuring equipment

Definitions (see Fig. A.1.4):

Intravesical pressure is the pressure within the bladder.

Abdominal pressure is taken to be the pressure surrounding the bladder. In current practice it is estimated from rectal, gastric or intraperitoneal pressure.

Detrusor pressure is that component of intravesical pressure which is created by forces in the bladder wall (passive and active). It is estimated by subtracting abdominal pressure from intravesical pressure.

Opening time is the elapsed time from initial rise in detrusor pressure to onset of flow. This is the initial isovolumetric contraction period of micturition. Time lags should be taken into account.

Table A.1.1. Parameters of pressure in the micturition cycle

	Pressure curves		
Premicturition pressure	Intravesical premicturition pressure	Abdominal premicturition pressure	Detrusor premicturition pressure
Opening pressure	Intravesical opening pressure	Abdominal opening pressure	Detrusor opening pressure
Maximum pressure	Maximum intravesical pressure	Maximum abdominal pressure	Maximum detrusor pressure
Pressure at maximum flow	Intravesical pressure at maximum flow	Abdominal pressure at maximum flow	Detrusor pressure at maximum flow
Contraction pressure at maximum flow	Intravesical contraction pressure at maximum flow	Abdominal contraction pressure at maximum flow	Detrusor contraction pressure at maximum flow

The following parameters are applicable to measurements of each of the pressure curves: intravesical, abdominal and detrusor pressure (see Table A.1.1):

Premicturition pressure is the pressure recorded immediately before the initial isovolumetric contraction.

Opening pressure is the pressure recorded at the onset of measured flow.

Maximum pressure is the maximum value of the measured pressure.

Pressure at maximum flow is the pressure recorded at maximum measured flow rate.

Contraction pressure at maximum flow is the difference between pressure at maximum flow and premicturition pressure.

Postmicturition events are at present not well understood and so cannot be defined.

It is common practice to relate pressure and flow by calculation of a resistance factor. However, caution should be exercised in interpreting this number. The subject of resistance factors will be dealt with in a later report.

Table A.1.2. List of symbols

Basic symbols		Urological qualifiers		Value	
Pressure	P	Bladder	ves	Maximum	max
Volume	V	Urethra	ura	Minimum	min
Flow rate	Q	Ureter	ure	Average	ave
Velocity	v	Detrusor	det		
Tme	t	Abdomen	abd		
Temperature	T	Length	l		
Area	A				
Diameter	d				
Force	F				
Energy	E				
Power	P				
Compliance	C				
Work	W				

Example: P_{ves} max = maximum intravesical pressure

Symbols

It is often helpful to use symbols in a communication. The system below has been devised to standardise a code of symbols for use in urodynamics.

The rationale of the system is to have a basic symbol representing the physical quantity with qualifying subscripts. The list of basic symbols largely conforms to international usage. The qualifying subscripts relate the basic symbols to commonly used urodynamic parameters (Table A.1.2).

If all parameters were to be given standard symbols the system would be clumsy. If further qualifiers therefore are required they should follow this system and be defined.

Third Report on the Standardisation of Terminology of Lower Urinary Tract Function

Procedures Related to the Evaluation of Micturition
Pressure-Flow Relationship
Residual Urine

Produced by the International Continence Society Committee on Standardisation of Terminology, Nottingham, February, 1977.
Members: Patrick Bates, William E. Bradley, Eric Glen, Derek Griffiths, Hansjörg Melchior, David Rowan, Arthur Sterling, Tage Hald (Chairman).

This report continues with recommendations on procedures related to the evaluation of micturition. It covers pressure–flow relationships and residual urine. These recommendations were discussed at the Seventh Annual Meeting of the International Continence Society in Portoroz, Yugoslavia, September, 1977.

Procedures Related to the Evaluation of Micturition

Pressure–Flow Relationships

To accomplish micturition a driving pressure is necessary. The driving pressure for micturition is the pressure within the bladder. This pressure can be generated by detrusor contraction (P_{det}), by abdominal pressure (P_{abd}) or by both ($P_{ves} = P_{det} + P_{abd}$). The urethra is an irregular and distensible conduit whose walls and surroundings, which have active and passive elements, influence the flow of urine through it. The bladder and urethra each have their own characteristics and in combination these characteristics determine the pressure–flow relationships of micturition. The relationships vary throughout a micturition and, in one individual, from one micturition to the next. Many attempts have been made to reduce the pressure–flow relationships to 'urethral resistance factors' in an attempt to distinguish between normal and pathological conditions. The following formulae have all been used at one time or another:

1. P_{ves}/Q
2. P_{ves}/Q^2
3. $\sqrt{P_{ves}}/Q$
4. P_{det}/Q
5. P_{det}/Q^2
6. $(P_{ves} - E_{str})/Q$
7. $(P_{ves} - E_{str})/Q^2$
8. $(P_{ves} - E_{str})/P_{ves}$
9. $d_{ura,eff} = \dfrac{32\, \rho\, f l Q^2}{\Delta p g \pi^2}$

E_{str} is the kinetic energy per unit volume in the external stream, sometimes (unfortunately) called the 'exit pressure', and $d_{ura,eff}$ is a calculated 'effective urethral diameter'.

where ρ = density of fluid
f = Fanning's friction factor
l = urethral length
Δp = friction loss
g = acceleration due to gravity.

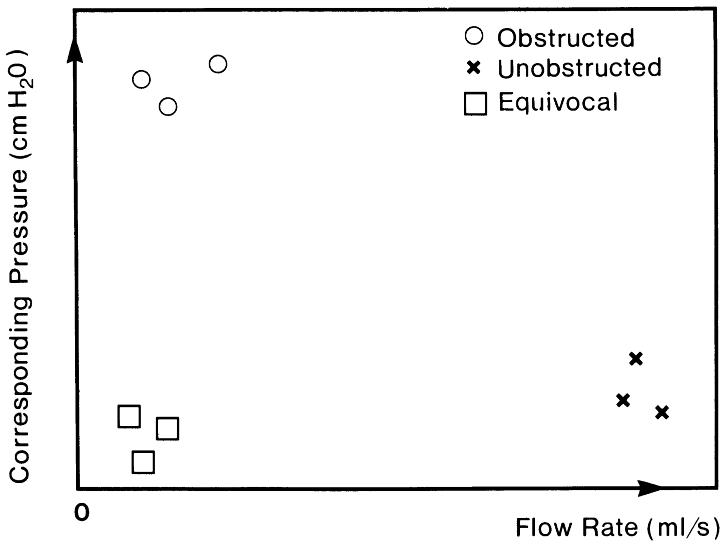

Fig. A.1.5. Recommended presentation of pressure flow relationships. The points shown are purely illustrative to indicate now the data might fall into groups.

Ideally we should like to choose the most useful of the above formulae and recommend it for general use. However, all of them originate from rigid tube hydrodynamics. The urethra is not a rigid tube. Therefore these factors vary not only during micturition but also from one micturition to another and so cannot provide a valid comparison between patients. They may even be misleading.

However, pressure–flow studies are still valuable since some characteristic, pressure–flow patterns may be identified. For example: (a) low flow rate accompanied by high pressure indicates obstruction; (b) high flow rate accompanied by low pressure indicates freedom from obstruction; (c) intermittent flow rate associated with abdominal contractions and absence of detrusor activity indicates motor impairment of the detrusor; (d) intermittent interruptions of the flow in the absence of abdominal straining, with concomitant increases in the intravesical pressure, indicate intermittent contractions of the urethral and/or periurethral striated musculature.
In all cases the urodynamic findings should be assessed in conjunction with the results of routine urological investigations.

Presentation of Pressure–Flow Relationships

It is suggested that it is more useful to present both the flow rate and the corresponding intravesical or detrusor pressure (P_{ves} or P_{det}), rather than to rely on a 'urethral resistance factor'. It is common to relate the maximum flow rate to the pressure at maximum flow, but any instant during micturition can be examined in this way.

When presenting data from a group of patients, pressure–flow relationships may be shown on a graph as illustrated in Fig. A.1.5. This form of presentation allows lines of demarcation to be drawn on the graph to separate the results according to the problem being studied. The points shown in the figure are purely illustrative to indicate how the data might fall into groups. The group of equivocal results might include either an unrepresentative micturition in an obstructed or an unobstructed patient, or detrusor insufficiency with or without obstruction. This is the group which invalidates the use of 'urethral resistance factors'.

Residual Urine

Residual urine is defined as the volume of fluid remaining in the bladder immediately following the completion of micturition. The measurement of residual urine forms an integral part of the study of micturition. It is commonly estimated by the following methods:

1. Palpation
2. Catheter or cystoscope: a) Transurethral
   b) Suprapubic
3. Radiography: a) Intravenous urography
   b) Micturition cystography
4. Ultrasonics: a) A-scan
   b) B-scan
5. Radioisotopes: a) Clearance
   b) Gamma camera

Findings:

Residual urine may result from various causes, such as detrusor insufficiency, infravesical obstruction or psychological inhibition. In the condition of vesico-ureteral reflux, urine may re-enter the bladder after micturition and may falsely be interpreted as residual urine. The presence of urine in bladder diverticula following micturition presents special problems of interpretation, since a diverticulum may be regarded either as part of the bladder cavity or as outside the functioning bladder.

The methods mentioned above each have limitations as to their applicability and accuracy in the various conditions associated with residual urine. Therefore it is necessary to choose a method appropriate to the clinical problem.

The absence of residual urine is usually an observation of clinical value, whereas the finding of residual urine may need confirmation.

In infravesical obstruction there is a variable and poorly understood connection between the occurrence of residual urine and abnormalities in the pressure–flow relationships. In the study of this condition both need to be taken into account and their interrelation could be a fruitful area for future research.

Fourth Report on the Standardisation of Terminology of Lower Urinary Tract Function

Terminology Related to Neuromuscular Dysfunction of the Lower Urinary Tract

Produced by the International Continence Society Committee on Standardisation of Terminology, following discussion at the International Continence Society Meetings in Manchester, September, 1978 and in Rome, October, 1979.
Members: Patrick Bates, William E. Bradley, Eric Glen, Hansjörg Melchior, David Rowan, Arthur M. Sterling, Torsten Sundin, David Thomas, Michael Torrens, Richard Turner-Warwick, Norman R. Zinner, Tage Hald (Chairman).

This report deals with recommendations on terminology related to neuromuscular dysfunction of the lower urinary tract with particular reference to classification of the neuropathic bladder.

Lower urinary tract dysfunction may be caused by:

1. Disturbance of the pertinent nervous or psychological control systems
2. Disorders of muscle function
3. Structural abnormalities

The term *neuromuscular dysfunction* includes the first two categories. Classifications based on concepts of the cause of a dysfunction, especially on the site of a neurological lesion, may be confusing. A lesion is often difficult to locate with certainty and different lesions may produce identical functional changes in the lower urinary tract. Therefore such a classification gives little help when considering the management of the end organ abnormality. Without objective information about the function it is impossible to compare results of treatment from different centres. An underlying neurological pathology is, of course, equally important from a prognostic, therapeutic and counselling point of view and must be considered at the same time.

The increasing use of urodynamic methods has made it possible to classify disorders of the detrusor and urethral closure mechanism with some accuracy. However, the range of bladder and urethral abnormalities cannot fully be defined at the present time.

This report presents a basic classification of function. Only neuromuscular function is considered, leaving structural organ changes and complicating factors aside. The lower urinary tract is composed of the *bladder* and *urethra*. They form a functional unit and their interaction cannot be ignored. Each has two functions, the bladder to store and void, the urethra to control and convey. When a reference is made to the hydrodynamic function or to the whole anatomical unit as a storage organ — the vesica urinaria — the correct term is the *bladder*. When the specific smooth muscle structure known as the m. detrusor urinae is being discussed, the correct term is the *detrusor.*

For simplicity the bladder/detrusor and the urethra will be considered separately so that a classification based on a combination of functional anomalies can be reached. No attempt has been made to define these in a quantitative way or to consider efficiency. *Sensation* cannot be accurately evaluated, but must be assessed. This classification depends on the results of various objective urodynamic investigations. The number of specific tests may vary from one person to another.

Studies of the filling and voiding phases are essential for each patient. Terms used should be objective, definable and ideally should be applicable to the whole range of abnormality. When authors disagree with the classification presented below, or use terms that have not been defined here, their meaning should be made clear.

Detrusor Function

The detrusor function may be:
1. Normal
2. Overactive
3. Underactive

Activity in this context is related to detrusor contractions interpreted from intravesical (P_{ves}) or detrusor pressure (P_{det}) changes, preferably the latter. Assessment of activity must be made during both filling and voiding, and the classification may change between these two phases.

Normal Detrusor Function

During the filling phase the bladder contents increase in volume without a significant rise in pressure (accommodation). No involuntary contractions occur despite provocation. Normal voiding is achieved by a voluntarily initiated detrusor contraction that is sustained and can be suppressed voluntarily. A normal detrusor so defined may be described as 'stable'.

Overactive Detrusor Function

Overactive detrusor function is indicated when during the filling phase there are involuntary detrusor contractions, which may be spontaneous or provoked, that the person cannot suppress. Provocation includes rapid filling, alterations of posture, coughing, walking, jumping and other triggering procedures. Voiding may be due to involuntary contractions or to voluntary contractions that cannot be suppressed. Various terms have been used to describe these features and they are defined as follows:

The *unstable detrusor* is one that is shown objectively to contract, spontaneously or on provocation, during the filling phase while the patient is attempting to inhibit micturition. The unstable detrusor may be asymptomatic, and its presence does not necessarily imply a neurological disorder.

Detrusor hyperreflexia is defined as overactivity due to disturbance of the nervous control mechanisms.

Whether the unstable detrusor is synonymous with detrusor hyperreflexia is unknown at present. Until this controversy is resolved, detrusor hyperreflexia should be confirmed by objective evidence of a neurological disorder.

The use of conceptual and undefined terms such as hypertonic, systolic, uninhibited, spastic and automatic should be avoided. When referring to the volume/pressure relationship in a bladder with a high pressure rise the correct term is a *low-compliance bladder* (e.g. a shrunken bladder following radiotherapy).

Underactive Detrusor Function

In the underactive detrusor there are no contractions during filling. During voiding the contraction may be absent or inadequately sustained. *A non-contractile detrusor* is one which does not contract under any circumstances. *Detrusor areflexia* exists where underactivity is due to an abnormality of nervous control and denotes the complete absence of centrally co-ordinated contraction. In detrusor areflexia due to a lesion of the conus medullaris or sacral nerve outflow, the detrusor should be described as *decentralised* — not denervated, since the peripheral neurones remain. The bladder function may be described as *autonomous*. In such bladders pressure fluctuations of low amplitude may occur. The use of terms such as atonic, hypotonic, autonomic and flaccid should be avoided. If the volume/pressure relationship of a bladder is referred to as being capacious with little change in pressure, then the correct term is a *high-compliance bladder*.

Urethral Function

The urethral closure mechanism may be:
1. Normal
2. Overactive
3. Incompetent

Normal Urethral Closure Mechanism

The *normal* urethral closure mechanism maintains a positive urethral closure pressure during filling even in the presence of increased abdominal pressure. It may be overcome by detrusor overactivity. During micturition the normal closure pressure decreases to allow flow. The normal closure mechanism is capable of interrupting urination voluntarily.

Overactive Urethral Closure Mechanism

An *overactive* urethral closure mechanism contracts involuntarily against a detrusor contraction or fails to relax at attempted micturition. Synchronous detrusor and urethral contraction is *detrusor/urethral dyssynergia*. This diagnosis should be qualified by stating the location and type of the urethral muscles (striated or smooth) which are involved (Fig. A.1.6).

Despite the confusion surrounding 'sphincter' terminology the use of certain terms is so widespread that they are retained and defined here. The term *detrusor/sphincter dyssynergia* describes a detrusor contraction concurrent with an

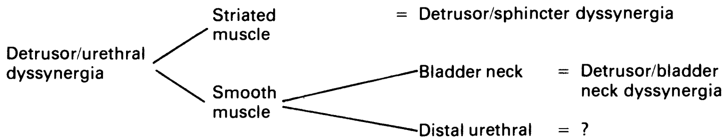

Fig. A.1.6. Classification of overactive urethral closure mechanisms.

inappropriate contraction of the urethral and/or periurethral striated muscle. In the absence of other neurological features the validity of this diagnosis should be questioned. The term *detrusor/bladder neck dyssynergia* is used to denote a detrusor contraction concurrent with an objectively demonstrated defect of bladder neck opening. No parallel term has been elaborated for possible detrusor/distal urethral (smooth muscle) dyssynergia.

Incompetent Urethral Closure Mechanism

An *incompetent* urethral closure mechanism allows leakage of urine. The negative urethral closure pressure may be persistent (continuous leakage) or due to a rise in abdominal pressure (genuine stress incontinence) or an involuntary fall in intraurethral pressure in the absence of detrusor activity (unstable urethra). Detrusor overactivity is more likely to be accompanied by leakage if there is an involuntary decrease in urethral pressure.

Sensation

Sensation is difficult to evaluate because of its subjective nature. It is usually assessed by questioning the patient in relation to the fullness of the bladder either during the taking of the clinical history or during cystometry. There are two groups of sensory modalities: Proprioception, which serves to inform on tension and contraction, and exteroception, which serves to inform on pain, touch and temperature. Sensation can be classified broadly as follows:

1. Normal
2. Hypersensitive
3. Hyposensitive

Appendix 2

Computer Proforma

UNIVERSITY OF BRISTOL
BLADDER FUNCTION STUDY

DEPARTMENT OF SURGERY
CLINICAL INVESTIGATION UNIT
HAM GREEN HOSPITAL

Name:
Date:
HGH/SM. Reg. no.:
Ref. Cons.:
G.P.:

Address.

Ref. Hosp. no.:

Presenting complaint:

Previous treatment for presenting complaint:

Examination (state abnormal findings):

1–3	Job. No.:
4–7	Survey No.:
8	Card No.:
9, 10	Age
11	Investigator

12 LENGTH HISTORY

- 0 less than 6 months
- 1 6 months –
- 2 1 year
- 3 2 years
- 4 4 years
- 5 10 years
- 6 lifelong
- 7 not stated

13, 14 FREQUENCY

[ ][ ]

XX not stated

15 NOCTURIA

[ ]

Y not stated

16 STREAM

- 0 Normal
- 1 Decreased
- 2 Interrupted
- 3 Decreased & interrupted
- 4 Not stated

17 HESITANCY

- 0 none
- 1 occasional/morning
- 2 usually
- 3 have to strain to mict.
- X not stated

PREMICTURITION SYMPTOMS 18

- normal 0
- decreased 1
- absent 2
- increased abdo (bladder pain) 3
- increased perineal (urgency) 4
- not stated 5

DYSURIA (painful micturition) 19

- none 0
- occasional 1
- assoc. with U.T.I. 2
- not stated 3

POST MICTURITION SYMPTOMS 20

- normal 0
- persistent abdo. sensation 1
- persistent perineal sensation 2
- feeling incomp. emptying 3
- not stated 4

INCONTINENCE (type) 21

- none 0
- stress 1
- stress/urge 2
- urge 3
- urge/enuresis 4
- enuresis only 5
- post-mict. dribbling 6
- continuous (conscious) 7
- continuous (unconscious) 8
- uncategorised 9
- not stated X

2

22		INCONTINENCE (grade)
	0	none
	I	drops
	2	clothes wet
	3	pads
	4	appliance
	5	catheter
	X	not stated

23		SOCIAL INCAPACITY
	0	none
	I	minimal
	2	social restriction
	3	physical restriction
	4	house bound
	5	hospitalised
	X	not stated

24		ENURESIS
	0	Past history enuresis
	I	No P.H. enuresis
	2	Not stated

25		HAEMATURIA
	0	never
	I	on one occasion
	2	more than once
	3	not stated

26		PAST INFECTION
	0	none
	I	history of infection
	2	occasional proven infection
	3	frequent proven infection
	4	not stated

27		RETENTION
	0	none
	I	spontaneous
	2	after childbirth
	3	after operation
	4	not stated

28		FAMILY HISTORY OF PRESENTING COMPLAINT
	0	none
	I	present
	2	not stated

PRESENT DRUG THERAPY		29
none	0	
antibiotics	I	
bladder stimulants	2	
bladder depressants	3	
antidepressants	4	
diuretics	5	
oral contraception	6	
other (state)	7	
not stated	8	

NEUROLOGICAL FEATURES		30
none	0	
diabetes	I	
cervical disc/spondylosis	2	
lumber disc/spondylosis	3	
other spinal cord disorder (state)	4	
cerebral disorder (state)	5	
D.S.	6	
Myelodysplasia/spina bifida	7	
Epilepsy	8	
Peripheral neuropathy	9	
not stated	X	
other neurological disease	Y	

SYMPTOMATIC DIAGNOSIS		31
normal	0	
unstable	I	
hypersensitive	2	
obstructed	3	
obstructed/unstable	4	
obstructed/hypersensitive	5	
stress incontinence	6	
stress incont/unstable	7	
unclassified (state)	8	
not stated	9	

-3-	MALE PAGE

32		OPERATIONS/TRAUMA
	0	none
	1	previous T.U.R.
	2	previous R.P.P.
	3	urethral dilitation
	4	other urethral surgery (state)
	5	major pelvic surgery (state)
	6	not stated
33		PROSTATE
	0	normal
	1	benign +
	2	benign ++
	3	benign +++
	4	malignant
	5	prostatitis
	6	not stated
34,35	☐☐▨	MAXIMUM URETHRAL CLOSURE PRESSURE (cmH_2O ÷ 10) XX not stated
36,37	☐☐	PROSTATIC PEAK (cmH_2O) YY not stated
38,39	☐☐	PROSTATIC LENGTH (cms) XX not stated
40,41	☐☐	PROSTATIC PLATEAU HEIGHT (cmH_2O) YY not stated

-3- FEMALE PAGE

32 MENSTRUAL HISTORY

0	premenopausal
1	menopausal
2	post-menopausal
3	not stated

33 PARITY

☐ X not stated

34 DELIVERY

0	normal, less than 4.0Kg. child
1	normal, more .. .. ..
2	forceps, less .. .. ..
3	forceps, more .. .. ..
4	breech, less .. .. ..
5	breech, more .. .. ..
6	lower segment caesar
7	other (state)
8	not stated

35 OPERATIONS

0	none
1	cystoscopy
2	urethral dilatation
3	other urethral surgery
4	D. & C./T.O.P.
5	Abdo. hyst.
6	Vag. hyst.
7	routine pelvic floor repair
8	other repair (state)
9	not stated

36 VAGINAL EXAMINATION

0	normal
1	strophic vaginitis
2	infective vaginitis
3	not stated

37 PROLAPSE

0	normal
1	uterine prolapse Gd.1
2	uterine prolapse Gd.2
3	uterine prolapse Gd.3
4	slight cystocele
5	marked cystocele
6	rectocele
7	uterine prolapse & cystocele
8	uterine prolapse & rectocele
9	cystocele & rectocele
X	other (state)
Y	not stated

MAXIMUM URETHRAL PRESSURE 38,39
($cmH_2O \div 10$)
YY not stated ☐☐☐

URETHRAL LENGTH 40,41
(cm)
XX not stated ☐☐

–4–

42 NEUROLOGICAL SIGNS

- 0 no signs
- 1 equivocal signs
- 2 UMN legs
- 3 LMN legs, normal anal function
- 4 LMN legs, lax anus + sacral/sensory loss
- 5 normal legs, lax anus + sacral/sensory loss
- 6 other signs (state)
- X not stated

43 OBESITY

- 0 slim
- 1 slight obesity
- 2 moderate obesity
- 3 gross obesity
- 4 not stated

44 BLADDER

- 0 not palpable
- 1 palpable
- 2 not stated

45 PELVIC FLOOR ACTIVITY

- 0 normal
- 1 decreased
- 2 absent
- 3 not stated

46 OBSERVED INCONTINENCE

- 0 none
- 1 stress
- 2 urge unstable
- 3 urge hypersensitive
- 4 unclassified
- 5 not stated

47 M.S.U.

- 0 clear
- 1 clear on antibiotics
- 2 infected
- 3 infected on antibiotics
- 4 not stated

48,49 INITIAL FLOW RATE (ml/sec) [ ][ ]

XX not stated

50,51 INITIAL VOLUME PASSED (ml ÷ 10) [ ][ ][/]

YY not stated

52–54 INITIAL RESIDUAL (ml ÷ 10) [ ][ ][ ][/]

XXX not stated

55,56 INSTABILITY [ ][ ]

YY not stated

VOLUME AT FIRST UNSTABLE CONTRACTION 57,58 (ml ÷ 10) [ ][ ][\]

XX not stated

CAPACITY 59–61 (ml ÷ 10) [ ][ ][ ][\]

YYY not stated

PEAK FLOW PRESSURE 62–64 (cmH_2O) [ ][ ][ ]

XXX not stated

PEAK FLOW RATE 65,66 (ml/sec) [ ][ ]

YY not stated

PEAK FLOW URETHRAL RESISTANCE 67–69 $\log (P/F^2 \times 100)$ [ ][ ][ ]

XXX not stated

VOLUME PASSED 70,71 (ml ÷ 10) [ ][ ][/]

YY not stated

TIME 72–74 (secs) [ ][ ][ ]

XXX not stated

BLADDER WORK 75–77 [ ][ ][ ]

XXX not stated

CYSTOMETROGRAM 78

- normal 0
- hypotonic 1
- hypersensitive 2
- contracted 3
- unstable 4
- uninhibited/normotonic 5
- uninhibited hypertonic 6
- sustained hypertonic 7
- unclassified 8
- not stated 9

SPHINCTER DIAGNOSIS 79

- weak resting 1
- weak squeeze 2
- normal 3
- spastic 4
- hypertrophic 5
- not stated 6

URODYNAMIC DIAGNOSIS 80

- normal 0
- unstable 1
- hypersensitive 2
- stress incontinence/weak sphincter 3
- obstructed 4
- obstructed/unstable 5
- obstructed/hypersensitive 6
- 'neurogenic' 7
- not stated 8

Appendix 3

Manufacturers of Equipment

We have endeavoured to make the list of firms supplying urodynamic equipment as complete as possible. We did not consider it our place to conduct a consumers' report on the available equipment although we hope the book contains adequate information to allow the clinician to purchase the equipment best suited to the particular needs. In each case we have listed the product range where applicable to urodynamics. All recorders write either by a heated stylus on sensitive paper or by ink unless otherwise stated. Where cystometry is mentioned the company provides pressure transducers. It is advisable for a potential purchaser to ask of the possible vendor:

"Can your equipment be connected to my existing system or are electronic adaptations essential?"

"Can we perform urodynamic studies with the equipment you have provided, or are other pieces of apparatus necessary?"

In our opinion the purchaser would be sensible to obtain advice in detail from an experienced user of urodynamic equipment. Indeed it might be sensible to have such a person available when the equipment is demonstrated by the company concerned. It is certainly essential that a practical demonstration of equipment is arranged and that the company should set this up so that it can be used to investigate a sample patient. It is appropriate that any local medical physicist should be present during such a demonstration.

Manufacturers	*UK Agent*	*Products*
American Medical Systems Inc. 3312 Gorham Avenue Minneapolis Minnesota 55426 USA		2- or 4-channel recorder Gas or water cystometry UPP withdrawal machine Diagnostic catheters Uroflowmeter EMG (catheter)
Browne Corporation 203 Chapala Street Santa Barbara California 93101 USA	Eschmann Bros Peter Road Lancing Sussex BN15 8TJ	1- or 2-channel recorder Gas or water cystometry UPP withdrawal machine Diagnostic catheters Uroflowmeter EMG
Bard International Pennywell Industrial Estate Sunderland SR4 9EW UK		Diagnostic catheters (including 10 Fr triple lumen urodynamic catheter)
Braun Electronic D3508 Melsungen West Germany	F.T. Scientific Instruments Ltd Station Industrial Estate Bredon Tewkesbury GL20 7HH	Constant perfusion syringe pump for UPP
Bryans Southern Ltd Willow Lane Mitcham, Surrey CR4 4UL UK		XY and XXY recorders 1–6 channel flatbed and 6–25 channel ultraviolet recorders
DISA Electronik A/S DK-2740 Skovlunde Denmark	DISA Techno House Redcliffe Way Bristol BS1 6NU	1-, 2-, 4- and 6-channel recorders Gas or water cystometry UPP withdrawal machine Uroflowmeter EMG (surface, needle and catheter) Uro-video system Evoked potential system

N.H. Eastwood & Son Ltd 70 Nursery Road London N14 5QH UK		Urilos urine measuring system (electronic nappy)
Elcomatic Ltd Kirktonfield Road Neilston, Glasgow G78 3PL UK		1-, 2- and 4-channel recorders Pressure transducers Water cystometry Uroflowmeter
Ely Science Systems 3 Longfields Ely, Cambridgeshire CB6 3DN UK		Uroflowmeter 1–4 channel recorder Water cystometry
Gaeltech Ltd Dunvegan Isle of Skye IV51 9CL UK		Catheter-tip pressure transducers
Gaeltech Research Ltd Treneuk, Callestick, Truro, Cornwall TR4 9LL UK		Microprocessor based Urodynamic system
Henlys Medical Supplies Ltd Alexandra Works Clarendon Road Hornsea, London N8 0DL UK		Diagnostic catheters
Hewlett Packard Inc 1501 Page Mill Road Palo Alto California 94304 USA	Hewlett Packard King Street Lane Wokingham Berk RG11 5AR	2- and 4-channel recorders Pressure transducers
Lectromed Ormed Engineering Ltd 32 Hydeway Welwyn Garden City Hertfordshire AL7 3AW UK		2-, 4- and 6-channel recorders Water cystometry UPP withdrawal machine Uroflowmeter EMG

Life-Tech Instruments Inc Box 36221 Houston Texas 77036 USA	Abbey Surgical Ltd 31 Wates Way Mitcham, Surrey CR4 4HR UK	1-, 2-, 3- and 4-channel recorders Gas or water cystometry UPP withdrawal machine Diagnostic catheters Uroflowmeter, EMG (needle and catheter) Evoked potential system
Medelec Ltd Manor Way Old Woking, Surrey GU22 9JU UK		EMG 4-channel UV recorder Pressure modules Evoked potential system
Millar Instruments Inc PO Box 18227 6001 Gulf Freeway Houston Texas 77023 USA	Albury Instruments Ltd 165 Dukes Road London W3 0SL	Catheter-tip pressure transducer
Polman &c. S.p.A Via Commenda 21 40068 S. Lazzaro di Savena (BO) Italy		6 Channel Urodynamic System Computer Link
Porges Société Porges Quai Anatole-France 75007 Paris France	Endoscopic Instrument Co Ltd 62 Shirland Road London W9 2EJ	UPP catheter Double-lumen catheter
Portex Ltd Hythe Kent UK		Diagnostic catheters including epidural and 2- or 3-channel UPP catheters
Siemens-Elema AB Medicinsk Teknik Solna Sweden	Siemens Ltd Siemens House Windmill Road Sunbury on Thames TW16 7HS	2- to 8-channel recorder Uroflowmeter EMG Pressure registration Uro-video system

Watson Marlow Ltd Falmouth, Cornwall TR11 4RU UK		Peristaltic pumps for cystometry
F.M. Wiest KG Elsterstrasse 1 D-8025 Unterhaching B Munchen West Germany	Rimmer Bros Aylesbury House 18–19 Aylesbury St London EC1R 0DD	Gas cystometer Uroflowmeter
Richard Wolf D-7184 Knittlingen West Germany	Richard Wolf Ltd PO Box 47 Mitcham, Surrey	1-, 2- and 3-channel recorders Gas or water cystometry EMG UPP withdrawal machine Uroflowmeter

Appendix 4

Bibliography

This list of references is not intended to be exhaustive, but to provide a means whereby the reader can obtain quickly some of the most relevant information. The appendix is arranged with the original articles listed under a number of general headings.

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Physiology
Pharmacology
Cystometry

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