9 Investigations of Anorectal Function

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9.1 Introduction

When investigation of the anorectum is appropriate (i.e. those patients in whom empirical conservative measures have failed, concurrent disease has been excluded, and there is a significant impact of symptoms on quality of life), assessment should be carried out in the context of global pelvic floor evaluation, aimed at both morphology/anatomy and function. The former can be evaluated by physical examination, but in more detail by imaging (static or dynamic), and the latter by clinical history and examination, but in more detail by tests of physiology. It is important that assessment is combined with an understanding of the sufferer's expectations of treatment.

With the advance of diagnostic technology, it is now accepted that in the field of functional bowel disorders, symptom-based assessment, although important, is unsatisfactory as the sole means of directing therapy. The symptom repertoire of the gut is limited and relatively non-specific, such that similar symptom profiles may reside in differing pathoaetiologies and pathophysiologies.[1] In a field of practice in which normal physiological function is so complex (that of defaecation and continence), and in which pathoaetiology on a structural basis is only partly understood (e.g. mechanical sphincter trauma may be demonstrable by endoanal ultrasound, but suboptimal function only, reported after "successful" surgical repair[2]), reliance on clinical symptoms alone as a basis for taxonomy is now obsolete. A robust taxonomy based on underlying pathophysiology must therefore be paramount.[1]

The multifactorial pathoaetiology of female incontinence, incurred either simultaneously (e.g. neuropathy and sphincter disruption[3–5]) or sequentially, means that directed therapy requires comprehensive assessment of all understood and measurable components that contribute towards continence, including tests of suprasphincteric as well as sphincteric function.

9.2 Investigations

Incorporating the findings from clinical history, physical examination and investigations allows the cause of incontinence to be elucidated, coexisting pathology to be excluded, and a decision regarding choice of suitable, rather than empirical therapy to be made on an individual basis. It must be stressed, however, that the results of any individual tests have to be integrated within the clinical scenario, and not be interpreted in isolation. Several studies have looked at the clinical impact of anorectal physiological investigation in patients with faecal incontinence and demonstrated that the information provided markedly improved diagnostic yield[6,7] and directly influenced a change in management in a significant proportion of cases.[6–9]

There are many complementary investigations for the assessment of anorectal structure and function (Table 9.1). Ideally, an evaluation of all components of the continence mechanism, as outlined previously (see Table 8.1), should be performed. However, although many tests are now established in clinical practice (e.g. anorectal

Table 9.1. Tests available for the assessment of anorectal and colonic function in patients with faecal incontinence

Investigation	Modality Assessed	Clinical Use
Anorectal manometry	(i) anal sphincter function	Established
Traditional	(ii) rectoanal reflexes	Established
	(iii) rectal sensation	Established
	(iv) rectal compliance	Established
	(v) rectal evacuation (balloon expulsion test)	Established
	(vi) continence to liquid (saline continence test)	Established
Prolonged ambulatory	anorectal / rectosigmoid motility	Research
Vector volume	anal sphincter function / pressure profile	Research
Barostat studies	(i) rectal sensation	Established
	(ii) rectal compliance	Established
	(iii) rectal tone	Research
	(iv) rectal wall tension	Research
	(v) rectal capacity	Research
	(vi) rectal motility	Research
Impedance planimetry	Rectal biomechanical properties	Research
Endo-anal ultrasound		
2-Dimensional	imaging of the anal sphincters/associated structures	Established
3-Dimensional	imaging of the anal sphincters/associated structures	Research
Endo-anal MRI	imaging of the anal sphincters/associated structures	Research
Neurophysiological		
Nerve conduction	pudendal nerve terminal motor latency	Established – limited value
Electromyography	(i) motor unit potentials	Established – limited value
	(ii) fibre density	Established – limited value
Evoked potentials	(i) motor	Research
	(ii) somatosensory	Research
Other	anocutaneous reflex	Established – limited value
Other	clitoral-anal reflex	Established limited – value
	strength-duration test (muscle innervation)	Research
Anorectal sensation		
Anal	(i) mucosal electrosensitivity	Established – limited value
	(ii) mucosal thermosensitivity	Research
Rectal	(i) mucosal electrosensitivity	Established – limited value
	(ii) mucosal thermosensitivity	Research
Evacuation proctography		
Fluoroscopy	rectal evacuatory function	Established – limited value
Scintigraphy	rectal evacuatory function	Research
Dynamic MRI	rectal evacuatory function/pelvic organ movement	Research
Colonic transit studies		
Radio-opaque markers	global colonic transit	Established
Scintigraphy	segmental colonic transit	Established – limited value

manometry, endoanal ultrasound, etc.), the clinical value of some is controversial (e.g. neurophysiological techniques), and others (e.g. vector-volume manometry, prolonged rectosigmoid manometry, magnetic resonance imaging, etc.) currently remain as research techniques, limited to a few specialist centres. Consequently only a proportion of the factors contributing to the preservation of continence are routinely assessed. Nevertheless, the diagnostic yield undoubtedly improves, the broader the series of tests performed,[8] and thus it is our firm belief that all patients should undergo as thorough an assessment as is available, performed in a structured and systematic manner.

The patient should be fully informed about the details of the procedures; this will also enhance patient cooperation. Written consent should be obtained prior to commencement of the studies. Although some centres advocate rectal preparation using enemas and/or cathartics, this is not a necessity and can usually be avoided unless scybalous stool is expected or detected upon digital examination. The patient should be asked to void residual urine and faeces before the study starts. Sedatives are not required and should be avoided. Manometric procedures should not be carried out within 5 minutes of anorectal palpation (digital examination) or longer if an enema has been administered, in order to allow sphincter activity to return to basal levels.[10]

Imaging techniques are described in Chapter 10.

9.3 Established Methodologies

9.3.1 Anorectal Manometry

The human finger is a poor pressure-measuring device, and digital examination alone is not accurate enough for the diagnostic assessment of anal sphincter function.[11] In addition, it is not possible to assess other important components of the continence mechanism by this method, notably colorectal sensorimotor function or rectoanal reflex activity.

Anorectal manometry is the best established and the most widely available investigative tool. In patients with faecal incontinence, manometric evaluation commonly encompasses a series of measurements designed to test for:

1. Deficits in anal sphincter function
2. The presence or absence of rectoanal reflexes
3. Rectal sensory function and compliance.

In addition, a manometric assessment may also include components designed to assess defaecatory function, namely:

1. Expulsion of a rectal balloon
2. Saline continence test
3. Rectoanal pressure relationships during bearing down/straining manoeuvres (this test has not found routine use for patients with faecal incontinence).

The apparatus required consists of four major components: (1) an intraluminal pressure-sensing catheter (water-perfused, or with mounted solid-state microtransducers, air- or water-filled microballoon(s), or a sleeve sensor); (2) pressure transducers; (3) a balloon for inflation within the rectum (either integral to the catheter assembly or fixed to an independent catheter); (4) the amplification/recording/display system. Unfortunately, the biggest pitfall with anorectal manometry is the lack of uniformity regarding such equipment and technique. As a consequence, comparison of results between centres is problematic. Each individual institution is therefore encouraged to develop its own control values (preferably sex and age stratified) or, if using normative data from the literature, adopt similar methodology, such that a particular result may be compared with the appropriate normal range.[11–13] Currently, a six-sensor probe (either water-perfused or solid-state) is recommended[13] with a balloon (preferably non-latex) of not less than 4 cm tied to the end. One pressure sensor, and a lumen opening to allow for inflation, should be located inside the balloon. The remaining five sensors should be arranged radially and spaced 1 cm apart.[13]

9.3.1.1 Anal Sphincter Function

The objectives of assessment are to identify the functional anal canal length and to record the maximum resting anal canal pressure and voluntary anal squeeze pressure (Figures 9.1 and 9.2). As noted above, however, there is marked variability in reported pressures, affected by:

1. The intraluminal pressure sensor itself
2. The assessment technique: station pull-through,[14,15] (the recommended method[12,16]) continuous pull-through[17,18] or stationary[19]
3. Catheter diameter
4. Orientation of the recording ports/sensors
5. Patient posture
6. Perfusion rate (for perfused-tube catheters)
7. The distending medium (air or water: for microballoons)
8. Size of the microballoon
9. The rate of withdrawal (for rapid pull-through technique).

The two most important considerations are probably catheter diameter and radial and longitudinal variations in pressure within the anal canal.[20,21] Large bore probes can distort the anal canal and falsely record high pressures; a positive correlation exists between catheter diameter and maximum anal resting and squeeze pressures.[17] Anterior quadrant pressures are lower in the

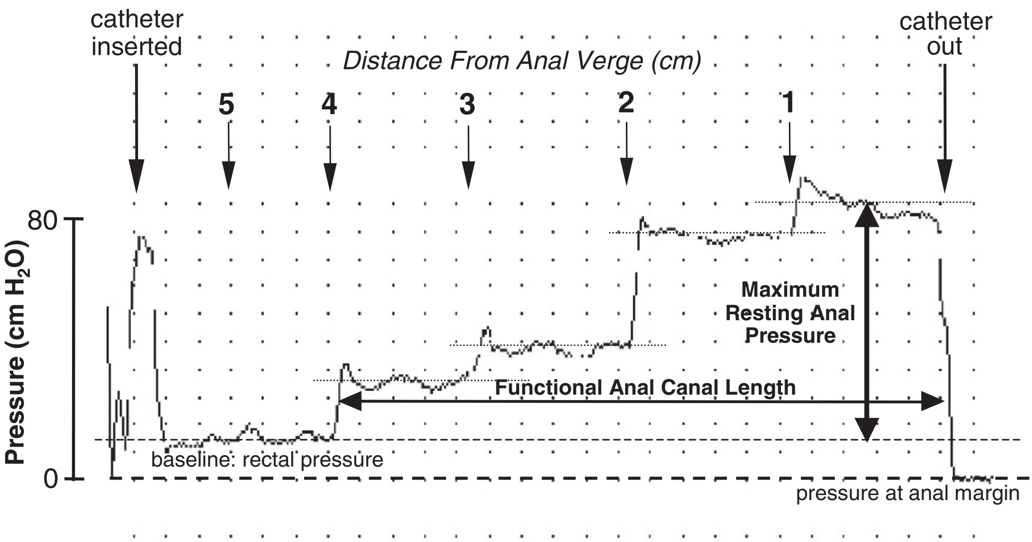

FIGURE 9.1. Functional anal canal length and maximum resting pressure. With the patient at rest, the pressure-sensitive recording device (in this case a water-filled microballoon) is pulled through the anal canal from the rectum. Pressures are allowed to stabilise at each station (denoted by the fine dotted lines). In this patient, a maximum resting pressure of 85 cmH_2O is recorded, 1 cm from the anal verge. The functional anal canal length is 4 cm.

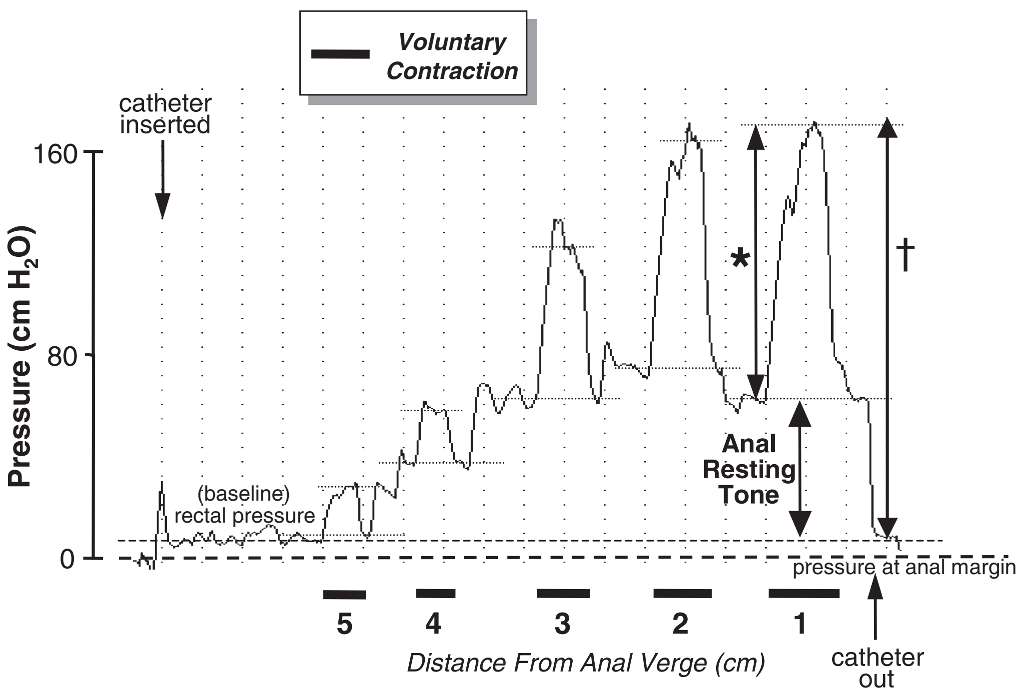

FIGURE 9.2. Maximum anal squeeze pressure/increment. By asking the patient to contract their anal canal musculature during a station pull-through procedure, the maximum voluntary squeeze pressure (†) or increment (*) at a given distance from the anal verge can be determined. In this patient, a maximum squeeze increment of 105 cmH_2O is recorded 1 cm from the anal verge.

proximal anal canal than those in the other three quadrants, whereas posterior quadrant pressures are lower in the distal anal canal. In the mid anal canal, radial pressures are equivalent in all quadrants.[21] Variation in radial and longitudinal pressures is also related to sex differences.[18] Given such functional asymmetry of the anal sphincters, pressures should be calculated by averaging values recorded in all four quadrants.[22]

The functional anal canal length is defined as the length of the anal canal over which resting pressure exceeds that of rectum by >5 mmHg,[18,19,23] or alternatively, as the length of the anal canal over which pressures are greater than half of the maximal pressure at rest.[14] The length of the functional anal canal is usually shorter in incontinent patients than in normal control subjects[23] (Figure 9.3). The clinical significance of this measure, however, has recently been questioned.[12]

Maximal resting anal pressure is defined as the difference between intrarectal pressure and the highest recorded anal sphincter pressure at rest.[13,18] Pressure at the level of the anal margin can alternatively be used as the zero baseline.[19] The maximal pressure is generally recorded 1–2 cm cephalad to the anal verge (Figure 9.1), which corresponds to the condensation of smooth muscle fibres of the internal anal sphincter. Anal resting tone is subject to pressure oscillations caused by slow waves, of amplitude 5–25 cmH_2O, occurring at a frequency of 6–20/min,[15,17] or high-amplitude "ultra-slow" waves, 30–100 cmH_2O in magnitude, occurring at 0.5–2/min[20] (although the latter are rarely observed in patients with low resting pressures). Symptoms of passive faecal incontinence correlate with low resting anal tone[24] (Figure 9.4) and often a reversal of the anal pressure gradient.[25] This is typically due to internal anal sphincter rupture (e.g. secondary to obstetric trauma[25,26] or iatrogenic injury[25,27]), but may also be secondary to smooth muscle degeneration.[28] However, patients with very low basal pressures may be fully continent, and thus measurement of resting tone, though of pathophysiological significance in patients with incontinence, must be considered in combination with other functional findings.[12]

The measure of a patient's ability to squeeze their striated anal musculature can be calculated as the maximal voluntary anal squeeze pressure (the difference between intrarectal pressure, or the pressure at the level of the anal margin, and the highest recorded pressure during anal squeeze),[13] or the maximal voluntary anal squeeze increment

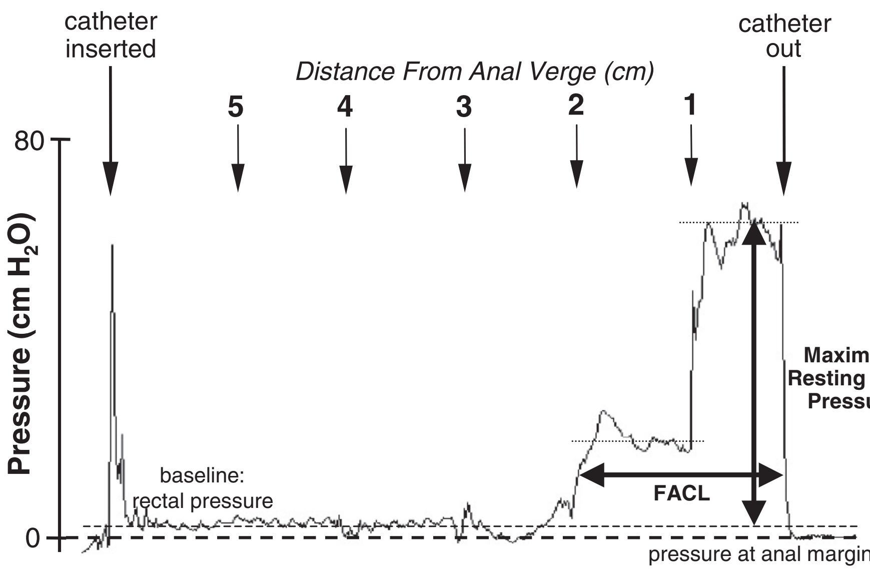

FIGURE 9.3. Short functional anal canal length (*FACL*). In this patient with faecal incontinence, an increase in pressure above that of rectal (baseline) pressure is only observed at 1–2 cm from the anal verge, with maximal anal resting pressure (67 cmH_2O) being recorded in the last 1 cm. Steady-state is denoted by the fine dotted lines.

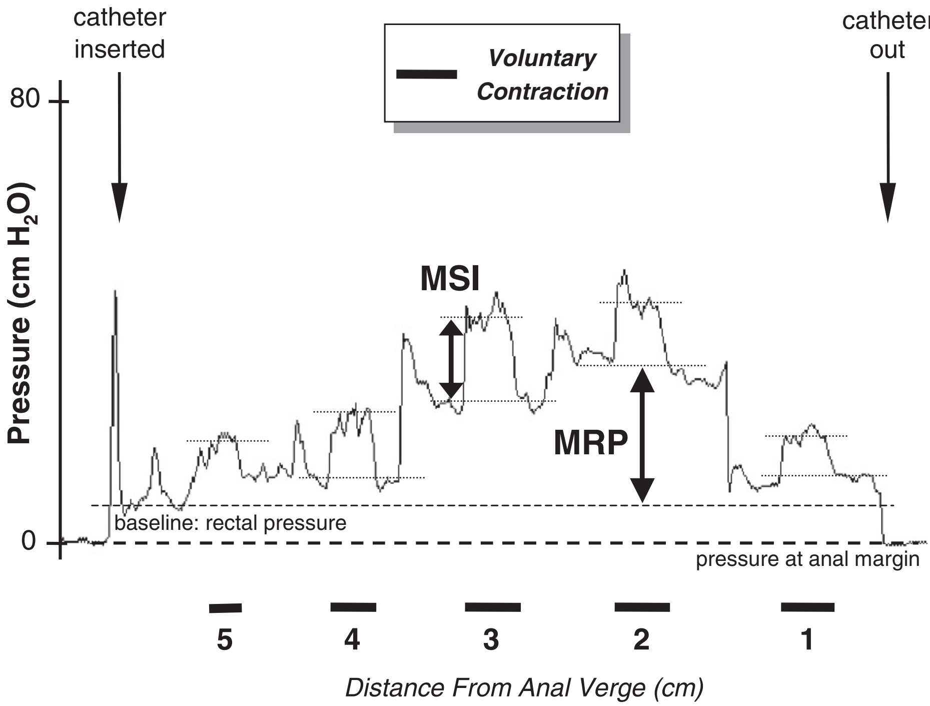

FIGURE 9.4. Attenuated anal resting and squeeze pressures. In this patient presenting with symptoms of both passive and urge faecal incontinence, both maximum anal resting pressure (*MRP*) and maximum anal squeeze increment (*MSI*) are abnormally low (33 and 15 cmH_2O, respectively). The fine dotted lines denote steady-state.

(the difference between resting pressure at any given level of the anal canal, and the highest recorded pressure during anal squeeze);[12,19] the latter is probably a better determinant of anal squeeze function (Figure 9.2). The squeeze response normally consists of an initial peak, followed by a decrease to "steady-state level", followed by a decline toward resting (baseline) pressure.[15] The measurement of highest recorded pressure may be taken as the true maximum pressure at any point during the squeeze manoeuvre (usually the initial peak), or as the maximum steady-state pressure. The duration of the sustained squeeze can be defined as the time interval at which the subject can maintain squeeze pressure at ≥50% of the maximum squeeze pressure.[13]

Symptoms of urge or stress faecal incontinence often correlate with low anal squeeze pressures[24] (Figure 9.4), with the major causative factor being obstetric injury.[3,26] In addition, squeeze duration is reduced[29] and "fatigue rate" is significantly shortened[30] in incontinent patients compared to controls (Figure 9.5). However, though low or

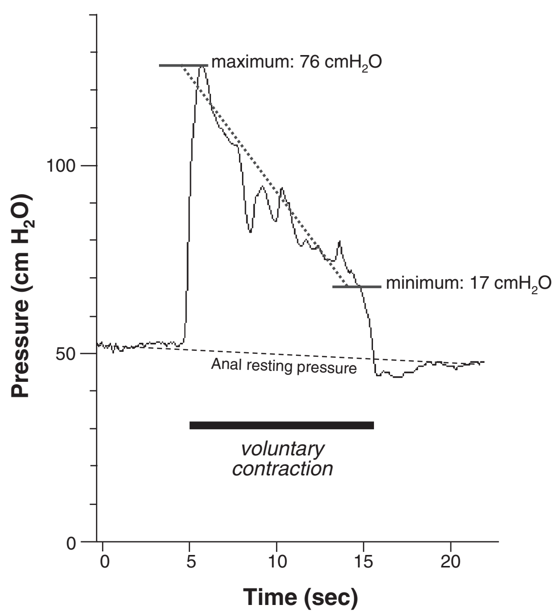

FIGURE 9.5. External anal sphincter fatigability. In this patient with urge faecal incontinence, the voluntary squeeze increment rapidly "decays" with time during an anal squeeze manoeuvre. The fatigue index is the coefficient of maximum squeeze pressure and gradient of decay.

poorly sustained voluntary anal squeeze pressures imply external anal sphincter (EAS) weakness, standard manometry alone cannot differentiate between compromised muscle integrity, impaired innervation, or both (or indeed a poorly compliant patient[12]) as a cause of that weakness. Anal squeeze pressure has been shown to be reasonably sensitive and specific for discrimination of patients with faecal incontinence;[31] nevertheless, the correlation between anal canal pressures and incontinence is not perfect[32] given the wide range of normal values and the contribution of those various other factors crucial to anorectal continence. This is compounded by the fact that simply recording maximum pressures may not reflect global sphincter function along its length, a problem that might be overcome by recording pressures at several points along the anal canal, but which then makes comparison with normal more difficult due to the complex radial and longitudinal pressure profiles that exist within the anal canal.

Overall, anal resting tone is probably less susceptible to artefact than the measurement of squeeze pressures, which is dependent upon the patient's understanding and ability to comply with instructions.[12,16] However, recording of both measures has been shown to be highly reproducible in the same subject on separate days.[33] At present, there is no accepted method for the evaluation of puborectalis contractile activity.[12]

9.3.1.2 Rectoanal Reflex Activity

Relaxation of the caudad anus in response to rectal distension, the rectoanal inhibitory reflex,[34] is thought to allow rectal contents to be sampled by the sensory area of the anal canal, thus allowing discrimination between flatus and faecal matter, i.e. "fine-tuning" of the continence mechanism. It is an intramural reflex mediated by the myenteric plexus, and modulated via the spinal cord.[17] The rectoanal inhibitory reflex can be simply measured by concomitantly recording resting anal pressures during rapid inflation of the rectal balloon (i.e. mimicking a sudden arrival of faecal bolus).[12] The amplitude and duration of the drop in pressure (relaxation) are correlated with the distending volume, in that the greater the distension volume, the greater the fall in anal pressure, and the more sustained the response.[35] However, although differences in reflex parameters have been shown between incontinent patients and healthy subjects,[36,37] the clinical significance of these findings is unclear.

As stressed previously, one aspect of the continence mechanism is that anal pressure needs to exceed rectal pressure. During transient increases in intra-abdominal or intrarectal pressure, preservation of this positive anal to rectal pressure gradient is maintained by a compensatory multisynaptic sacral reflex, the rectoanal contractile reflex, which results in a contraction of the EAS. This protective mechanism prevents faecal leakage during activities such as coughing.[14] Investigation of the rectoanal contractile reflex requires simultaneous monitoring of intrarectal and anal pressures during a sudden increase in intra-abdominal/intrapelvic pressure caused by blowing up a balloon placed in the rectum, or by having the patient cough to test the "cough reflex".[12,19,31] This test is also useful for further evaluation of EAS function, especially in those patients with apparently attenuated voluntary anal squeeze pressures in whom poor compliance is suspected.[12] Under normal circumstances, intra-anal pressure should exceed intrarectal pressure. An abnormal reflex response, but normal squeeze pressures indicate neural damage of the sacral arc, either of the spinal sacral segments or the pudendal nerves;[12] such patients usually suffer from urge incontinence. Both the reflex response and voluntary squeeze pressures are absent in patients with lesions of the cauda equina or sacral plexus.[4,31]

9.3.1.3 Rectal Sensation

Rectal sensory function is most commonly quantified using balloon distension, during which the patient is instructed to volunteer a range of sensations: first sensation, constant (flatus) sensation (optional), desire to defaecate, and maximum toleration.[38] The distending volume (and/or pressure) at each of these sensory thresholds should be recorded. Two techniques are used for inflation: (1) ramp (continual); or (2) intermittent, which can be either phasic (volumes injected and then withdrawn)[39] or stepwise (volumes are maintained between inflations)[40] in nature. It has been suggested that a ramp inflation technique is superior to that of intermittent distension in assessing rectal sensation.[39,41] Unfortunately, the results of this investigation are probably influenced more by differences in methodology than that of any other anorectal physiological technique. Sensory responses are altered by:

1. The type of inflation
2. The distending medium (air or water)
3. The speed of inflation[39]
4. The material, e.g. the size and shape of the balloon
5. The distance of the balloon from the anal verge
6. The position of the patient.

However, despite large intersubject variation, several studies have reported a high degree of reproducibility with regard to recorded sensory thresholds,[39,42,43] notably for maximum tolerable volume.[17] It is probable that sensory threshold pressures, as opposed to volumes, are an even more robust measure,[33] but their use is less practical in the clinical setting.

The purpose of any clinically useful test, including tests of rectal sensation, is to allow an individual patient to be clearly placed within, or be discriminated from, the normal population. Accordingly, once normal ranges have been determined in healthy control subjects, abnormalities of rectal sensitivity may be defined on the basis of aberrant values in comparison to those normal ranges. Sensory thresholds reduced below the normal range imply heightened sensory awareness and can be termed rectal hypersensitivity, while elevated sensory thresholds related to impaired or blunted rectal sensory function can be termed rectal hyposensitivity.[44] Both abnormalities have been reported in patients with faecal incontinence. Those with rectal hypersensitivity typically complain of urgency/urge incontinence and increased frequency of defaecation.[26,35,45,46] Those with significant blunting of the ability to sense distension may have passive (overflow) incontinence.[47–50]

Other methods of assessing rectal sensitivity are described below.

9.3.1.4 Rectal Compliance

Compliance, which reflects rectal capacity and distensibilty, may be measured in conjunction with the evaluation of sensory thresholds (Figure 9.6). Though feasible using conventional manometry, rectal compliance can be most accurately assessed using a programmable barostat (see below), which minimises both observer bias and error.[15] Employing an intermittent balloon distension technique, intraballoon (intrarectal) volumes and pressures must be recorded concomitantly.[13] Measurement by means of latex (or equivalent) balloons requires correction to account for their intrinsic elasticity.[12,13] Oversized polyethylene bags are favoured; provided that the range of volumes used for the study remains below 90% of the maximum volume of the bag, polyethylene can be regarded as infinitely compliant, in that its own properties have no influence on the internal pressure (i.e. large volumes can be accommodated without an increase in intrabag pressure, until the volume injected is >90% of the maximum bag volume).[51] Rectal compliance describes the pressure/volume relationship, and is (perhaps simplistically) calculated as change in volume divided by change in pressure ($\Delta V/\Delta P$).[11,12,19] However, for technical and physiological reasons, the pressure/

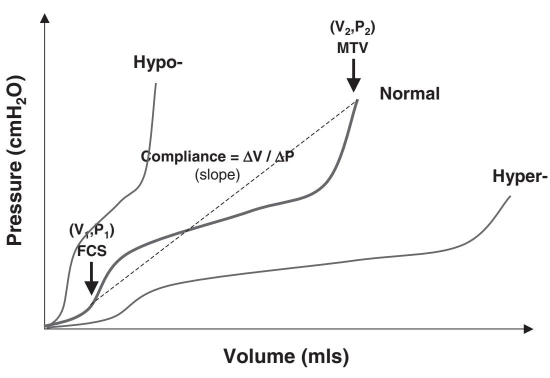

FIGURE 9.6. Pressure-volume relationships during rectal distension. Rectal compliance is calculated from the slope (denoted by the dashed line) over that part of the curve between first constant sensation (*FCS*: V_1, P_1) and maximum tolerable volume (*MTV*: V_2, P_2), and is defined as $\Delta DV/\Delta P$. In a patient with rectal hypocompliance (stiff rectal wall), the curve is shifted to the left, and the slope steepens; conversely, in a patients with rectal hypercompliance, the curve shifts to the right, and the slope is shallower.

volume curve is non-linear, and thus calculating a single value to describe the slope of that curve (i.e. ascribing a linear measurement for compliance) is imprecise.[11,13] It is more accurate to express compliance values as a graphical plot of all volumes tested,[11,13] although this is rather cumbersome in practice. Alternatively, compliance can be approximated to an exponential function.[16] Irrespective of the methodology employed, however, measurement of compliance has been shown to be highly reproducible.[33,42]

9.3.1.5 Balloon Expulsion Test

Evaluation of a patient's ability to expel a filled balloon from the rectum is a simple method of assessing (simulated) defaecation dynamics. Inflation volume (either water at 37°C or air) of the catheter-mounted balloon is typically 50 ml[19,52] and need not exceed 150 ml.[53] The patient can then be transferred to a commode and instructed to expel the balloon. The time taken for expulsion should be recorded and intraballoon pressure can be monitored concomitantly to evaluate changes in intrarectal pressure. Asymptomatic subjects can expel the balloon in a median of 50 s (range 10–300)[19] with an increase in intra-abdominal pressure of >80 cmH_2O.[19,52] Despite generating similar increases in intra-abdominal/pelvic pressure on straining as normal subjects, patients with constipation are often unable to expel a filled balloon,[54] which may be secondary to functional (variably termed paradoxical pelvic floor contraction, pelvic floor dyssynergia or anismus) or mechanical outlet obstruction. Understandably, however, some patients find this test extremely embarrassing, which may inhibit normal evacuation, leading to a gross overdiagnosis of functional outlet obstruction.[55,56] Evacuation proctography remains the gold-standard method for investigating the process of rectal evacuation[5] (see below). In patients with faecal incontinence, most have no problems expelling the balloon.[4] However, in those presenting with faecal seepage, many demonstrate impaired evacuation,[48] suggesting that a disorder of defaecation may underlie their symptoms. The balloon expulsion test may be incorporated into therapeutic biofeedback programmes.[4]

9.3.1.6 Saline Continence Test

This investigation is designed to evaluate the continence mechanism by reproducing a situation simulating diarrhoea.[19,57] The test may be useful in providing objective proof/evidence of faecal incontinence, and also in assessing improvement in continence following conservative medical or surgical therapy.[4] The aims are to determine: (i) the efficiency (resistance) of the anal sphincters, and (ii) the capacity of the rectum/defaecation mechanism. With the patient lying in the left-lateral position, a fine bore (~2 mm) plastic tube is introduced 8–10 cm into the rectum. The patient should then be seated on a commode, and the tube attached to an infusion pump. Saline at 37°C can then be infused into the rectum at a steady flow rate of 60 ml/min up to a maximum of either 800 ml[19] or 1.5 litres[57,58] (the former is quicker and enhances the sensitivity and specificity of the test[19]). The subject should be instructed to retain the fluid for as long as possible. Leaked saline may be collected in a graduated vessel located in the bowl of the commode. Measurements taken are: (i) volume infused at onset of first leak, (ii) volume of first leak, and (iii) total volume leaked at the end of the study period. If simultaneous monitoring of rectal and anal pressure changes is performed, anorectal reflex activity (inhibitory and contractile reflexes) can be identified.[20]

Normal subjects are able to retain a volume in excess of 1.5 litres without any significant leakage of saline.[8,57] Significant leakage is defined as a leak of >10[57] or 15 ml.[4] The volume of saline retained at the end of the study is calculated as the difference between the volume infused and the volume leaked. Patients with a weak sphincter mechanism or with reduced rectal capacity/compliance can retain a lesser volume of fluid than normal asymptomatic subjects.[58,59] In patients with faecal incontinence, leakage starts after infusion of only 250–600 ml, with volume retention of 500–1,000 ml.[58]

9.3.2 Barostat Studies

A major recent innovation in the field of anorectal physiological investigation is the establishment of the computerised barostat as the method of choice, in favour of traditional manometric techniques for the evaluation of various components of rectal sensorimotor function.[12,15,16] The fact that that this device was developed 20 years ago[60] gives an indication of the time it may take for a research technique to be accepted in clinical practice. Primarily, the barostat is used for accurate assessment of pressure/volume relationships (and hence compliance) during the measurement of rectal sensitivity;[13,51] however, it can also be employed for the study of other parameters of visceral sensation, reflex activity, wall tension and capacity, and changes in rectal tone or phasic activity over a prolonged period (although these modalities remain within the realms of research at present).[51,61] In simple terms, the barostat is a pneumatic device that maintains a constant pressure within an air-filled bag situated in the rectum, by a feedback mechanism that rapidly aspirates air from the bag when the rectum contracts, and injects air when the rectum relaxes. The volume of air aspirated/injected is proportional to the magnitude of contraction/relaxation. The use of the barostat has the following advantages:

1. The infinitely compliant, oversized bag (see above) is attached at both ends to the catheter, which ensures distension in the circumferential axis by eliminating axial migration into the sigmoid colon.
2. Simultaneous acquisition of volume and pressure data is possible, and thus it is not subject to the same limitations as volume-based (simple balloon) distension techniques.[51]
3. The distension is computerised, which allows distension parameters known to affect visceral sensitivity (see above), such as rate and pattern of inflation,[39] to be tightly controlled and standardised using the associated computer software. In addition, the influence of response bias may be minimised by employing the use of (pseudo-) random distension sequences.[51] This improves reproducibility and removes some observer bias.[11]

In regard to the measurement of sensation/compliance, either phasic (ascending methods of limits)[15] or stepwise (staircase)[16] isobaric distension paradigms may be employed. Good reproducibility for both measures has been reported.[33,62] In patients with faecal incontinence, studies have been limited thus far,[32,63] but have confirmed alterations in compliance (and sensation) in some subjects. The major limitation with the barostat is its expense, which may preclude its widespread use, in view of the relative low cost of traditional manometry.

9.3.3 Transit Studies

In patients with symptoms of constipation and incontinence, gastrointestinal (predominantly colonic) transit studies provide an objective confirmation of a subjective complaint of infrequent defaecation and enable a distinction between normal and slow colonic transit.[11] Stool frequency, as reported by the patient, is an unreliable measure for defining constipation.[64] Radio-opaque marker studies, with plain abdominal films taken 3–5 days later, are an adequate screening test for detecting transit abnormalities;[65–67] the simplest method is a modification of that originally described by Hinton et al.,[65] and involves the patient swallowing 50 markers (radio-opaque feeding tube, cut up into 2-mm slices) contained in a gelatin capsule. A single abdominal x-ray is taken 96 h later.[68,69] The patient is instructed to discontinue laxative medication for the duration of the study. The study is considered abnormal if >20% of markers remain.[66,68,69] For accurate assessment of segmental colonic transit, however, more complex marker studies,[66,67] or radionuclide scintigraphy is required.[68,70,71] A comprehensive description of such methods is given in detail elsewhere.[72,73] Irrespective of methodology, if a delay in colonic transit is identified, the management strategy can be altered accordingly.

Conversely, rapid gastrointestinal transit may result in diarrhoea and underlie symptoms of urgency and frequency of defaecation in patients with incontinence.[74] Evaluation of accelerated transit is feasible using radio-opaque markers,[75] but is best appreciated with scintigraphy.[76] However, methodologies need to be refined and more robust normative data need to be acquired.

9.4 Established Methodologies: Contentious Clinical Value

9.4.1 Electrophysiology

9.4.1.1 Pudendal Nerve Terminal Motor Latency

The pudendal nerve is a mixed nerve providing efferent and afferent pathways to the EAS, urethral sphincter, perineal musculature, mucosa of the anal canal and perineal skin. The branches of the pudendal nerve that course over the pelvic floor are vulnerable to stretch injury, which may result in muscle weakness and consequently incontinence. Prior to the advent of endoanal ultrasound, the majority of cases of idiopathic or neurogenic faecal incontinence were believed to be a result of pudendal nerve injury.[77] However, it is now recognised that structural damage to the anal sphincters rather than pudendal neuropathy is the underlying pathogenic mechanism in most patients[78,79] and true isolated neuropathy may be rare.[80]

Pudendal nerve terminal motor latency (PNTML) is a measurement of the conduction time from stimulation of the pudendal nerve at the level of the ischial spine to the EAS contraction. This is achieved using disposable glove-mounted stimulating and recording electrodes (St Mark's pudendal electrode) connected to a suitable recorder. To ensure that all motor fibres within the nerve are stimulated, a supramaximal stimulus should be applied. Prolonged latencies are used as a surrogate marker of pudendal neuropathy, and have been demonstrated in incontinent patients who have suffered obstetric trauma[81–83] (Figure 9.7), have abnormal perineal descent[84] (perhaps due to excessive straining at stool[85]), have rectal prolapse,[86] or have a recognised neurological disorder.[87] However, the value, and indeed the validity, of pudendal nerve latency testing has come under increasing scrutiny,[4,11,12,22] given that most patients are now recognised as having identifiable muscle damage or degeneration.[28,78] Although grouped data show that incontinent patients with bilaterally prolonged PNTMLs have reduced anal squeeze pressures compared to controls[88] (thus supporting the concept that a neuropathic process impairs EAS function[88]), the sensitivity and specificity of this test is poor; many patients with delayed latencies have squeeze pressures within the normal range and vice versa.[88,89] This lack of agreement is likely to be due to methodological limitations:

1. Pudendal nerve terminal motor latency increases with age, independent of continence status.[90,91]
2. Pudendal nerve terminal motor latency reflects the function of the fastest conducting motor fibres and thus normal latencies may be recorded in a damaged nerve, as long as some fast-conducting fibres remain.[90]
3. The test is operator dependent[5,22] and may be technically difficult to perform in some patients, notably those with a high body mass index or a long anal canal.
4. Reproducibility of the test is unknown.[22]

In conclusion, recording PNTML may contribute little to the management of individual patients with faecal incontinence; for example, it does not appear to be predictive of surgical success in restoring continence.[11,22] The routine use of PNTML measurement is thus now questioned;[88] indeed, recent consensus reports have stated that, on the evidence to date, this technique is no longer to be advocated.[11,12,22] Unilateral prolongation of PNTMLs has been regarded historically as of little clinical significance,[91] but with evidence of laterality of pudendal nerve innervation of the EAS,[92] this perhaps merits further investigation.

9.4.1.2 Electromyography

In patients with incontinence, pelvic floor electromyography (EMG) can be used in a variety of ways.[11,93] The primary purposes are to:

1. Map the sphincter to identify areas of injury or congenital abnormality
2. Determine striated muscle function (i.e. whether the muscle contracts or relaxes appropriately, based on recruitment of firing motor units)
3. Assess denervation-reinnervation potentials, indicative of neural injury.

In addition, EMG can be combined with other tests of motor function (e.g. manometry, proctography[94]) to provide an integrated assessment.

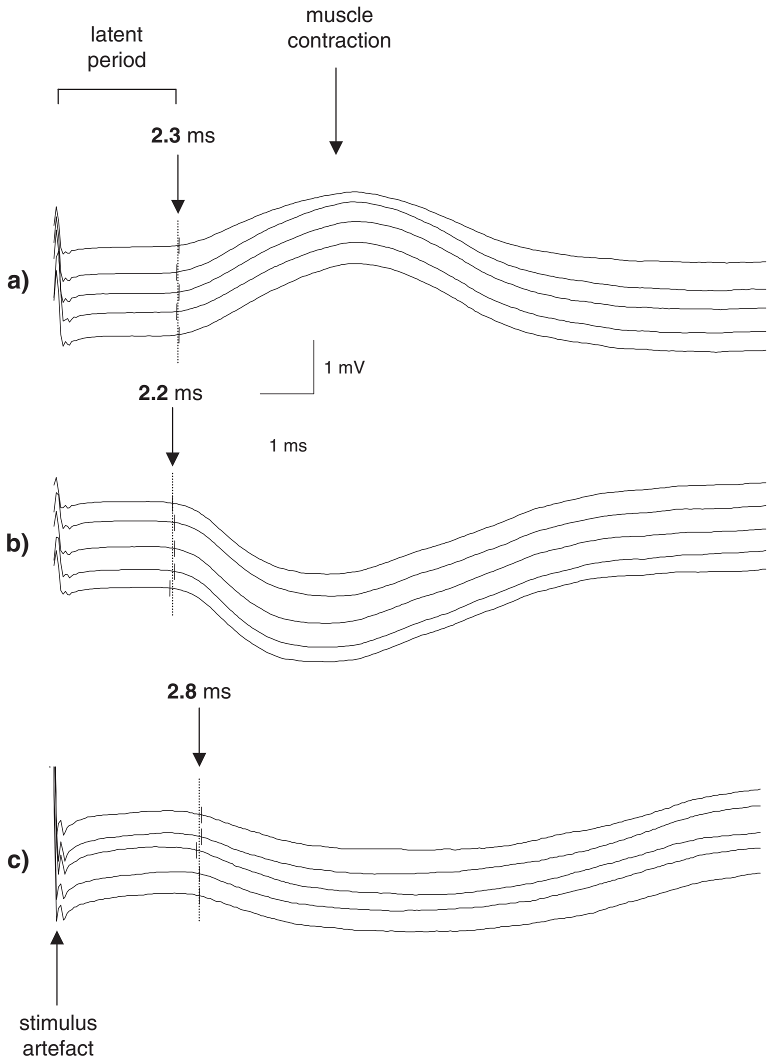

FIGURE 9.7. Pudendal nerve terminal motor latency. The latency is measured as the time from stimulation of the pudendal nerve at the level of the ischial spine to the onset of external anal sphincter contraction. Recordings (five separate stimuli) from (**a**) the right and (**b**) the left pudendal nerves of an asymptomatic volunteer show latencies within the normal range, whereas in (**c**), left pudendal nerve terminal motor latencies are prolonged, indicative of neuropathy, in a patient with urge faecal incontinence.

Studies of EMG activity can be performed using a needle electrode (either a concentric needle, which samples approximately 30 motor units simultaneously, or a single-fibre electrode, which samples only one motor unit at a time), a skin electrode, placed on the perianal skin, or an anal plug electrode. The choice of recording electrode is dependent upon the modality under study. Needle electrodes are usually favoured and are inserted transcutaneously without anaesthesia into the EAS (usually at multiple sites) and the puborectalis. Concentric needle electrodes enable various parameters of motor unit potentials (duration, amplitude, percentage polyphasia and recruitment) to be measured at rest, and during moderate voluntary muscle contraction.[16,93] These parameters may be altered (e.g. motor unit potential duration is prolonged, number of polyphasic motor unit potentials is increased, etc.) in partially denervated muscle where there has been attempted reinnervation.[93] Alternatively, using single-fibre electrodes, fibre density can be calculated, which is an index of motor unit grouping, a consequence of denervation and subsequent reinnervation.[93,95] For either method, 20 motor unit potentials are traditionally recorded at each site.[95] Single-fibre EMG has been shown to be highly repeatable.[96] In the striated anal musculature of patients with faecal incontinence, both motor unit potential activity (duration, amplitude, polyphasic nature) and fibre density have been shown to be increased, in comparison to controls.[89,93,95,97–99]

It has recently been suggested that the results of anal sphincter EMG are more sensitive, and more closely related to the anal functional status, as assessed on manometry, than measurement of PNTMLs.[97–99] However, the routine use of EMG studies for the assessment of patients with faecal incontinence is diminishing in clinical practice, given patient discomfort, the widespread availability of endoanal ultrasonography, and the fact that interpretation may require specialised training and experience.

The clinical relevance of other electrophysiological techniques, including the strength-duration test[100] (a minimally invasive technique for the measurement of muscle innervation) and motor[101] and somatosensory[102] evoked potentials remains controversial.

9.4.2 Anorectal Sensation

9.4.2.1 Anal Sensation

The epithelium of the anal canal has a rich sensory nerve supply made up of both free and organised nerve endings. The modalities of anal sensation can be defined precisely, with stimuli such as touch, pain and temperature being readily appreciated.[11,103] Such exquisite sensitivity allows for the sampling of rectal contents and enables discrimination between flatus and faeces. Anal mucosal sensation can be quantified using a catheter-mounted bipolar ring electrode inserted into the anal canal (anal mucosal electrosensitivity).[104] A current is passed through the electrode and steadily increased until sensation threshold (usually reported as a "prickling" feeling) is noted by the patient.[104] Mucosal sensitivity may be impaired in patients with faecal incontinence.[104–106] This impairment has been shown to persist long-term following a traumatic vaginal delivery.[107] Although such findings have contributed to our understanding of the pathophysiology of faecal incontinence, the diagnostic value of this test and its influence on management are limited.[11,106] An alternative measure for anal sensation is using thermal stimulation via specialised thermoprobes.[43,108] Again, this technique has not found routine use in clinical practice.

9.4.2.2 Rectal Sensation

Similar methods have been used for the assessment of rectal sensation.[43,109] Such techniques carry theoretical advantages over distension-based protocols in that they are thought to test purely the afferent (sensory) pathway by excitation of mucosal receptors, rather than a composite of rectal sensory function and wall biomechanics.[11] However, both electro- and thermostimulation techniques have been criticised as "non-physiological",[16,110] and their use is primarily restricted to research laboratories.

9.4.3 Evacuation Proctography

Passive (overflow) incontinence, or post-defaecation leakage may occur secondary to disorders of rectal evacuation.[47,48,111] Evacuation proctography may thus be useful to exclude outlet obstruction due to anatomy (e.g. large rectocoele, intussusception, megarectum, etc.)[111–113] or function (e.g. pelvic floor dyssynergia, etc.).[47,114] In addition, given the incidence of new-onset rectal evacuatory dysfunction following continence-restoring procedures,[115–117] proctography may be considered in the clinical work-up of patients with incontinence being considered for surgery. Any abnormalities revealed and deemed significant may be amenable to concurrent surgical correction, or adjunctive postoperative conservative therapy (e.g. a bowel retraining programme).

Proctography is a simple, dynamic radiological technique,[118] which provides morphological information regarding the rectum and anal canal. It involves fluoroscopic imaging of the process, rate and completeness of rectal emptying following insertion of enough barium paste (mimicking stool) to give the patient a sustained desire to defaecate.[119] The patient is seated upright on a radiolucent commode during lateral screening.

There are several limitations to this technique, however, which render the clinical usefulness uncertain:

1. It is not a normal study of defaecation.
2. It is not performed in response to the spontaneous desire to defaecate.
3. Patients' embarrassment of the nature and setting of the test may inhibit normal evacuation (leading to overdiagnosis of functional outlet obstruction;[55,56] see above).
4. Inter-observer agreement may be poor.[120]
5. There is a large degree of overlap in results between patients and controls.[121,122]
6. Normal rates of emptying vary widely.[122]

To reduce radiation exposure, scintigraphic proctography utilising a gamma-camera[123,124] can be carried out, substituting a radionuclide compound (usually ^{99M}Tc) for barium. Although quantitative measures of rectal evacuation are improved, anatomical resolution is greatly inferior.

Proctography, as well as assessing rectal evacuatory function, may be used to determine objectively the ability to retain stool. However, a much simpler and more practical way is the "porridge continence test" (equivalent to the saline continence test, but using a closer approximation of stool consistency[11]). After instillation of porridge (pseudostool), several manoeuvres can be requested of the patient (e.g. coughing, walking, climbing stairs, etc.). This test may be especially useful in patients who have been defunctioned with a proximal stoma, and who therefore cannot volunteer continence symptoms at that time.

9.4.4 Perineometry

The pelvic floor normally descends <1.5 cm during straining in association with anal relaxation. Excessive perineal descent (>3 cm) is closely related to faecal incontinence and is likely associated with traction of the pudendal nerve.[74] Descent of the perineum, relative to the ischial tuberosity, can be measured using the perineometer.[125] This test, however, has fallen out of favour, as reproducibility is poor,[12] and it grossly underestimates movement of the pelvic floor as compared to radiological measurement (which it was designed to replace).[126]

Recently, the perineal dynamometer was developed specifically to assess levator ani contraction.[127] This technique has yet to find common use.

9.4.5 Reflex Testing

9.4.5.1 Anocutaneous Reflex Test

Lightly scratching the perianal skin will elicit contraction of the EAS, termed the "anocutaneous reflex", or the "anal wink".[74] This reflex has its afferent and efferent pathways in the pudendal nerve and arcs via the sacral cord. When positive, the anal wink indicates an intact pathway and functioning sacral cord. However, it can be inhibited voluntarily, or may appear absent if the patient is tense, and thus to date there are no data to support its routine clinical use.[13] However, in the setting of acute onset of faecal incontinence, an absent anal wink may direct the clinician to further evaluate the patient's spinal cord for lesions or disc protrusions causing cauda equina syndrome.

9.4.5.2 Clitoral-anal Reflex Test

As an alternative to evaluation of pudendal nerve terminal motor latencies (see previously), which only assesses the short distal segment of the nerve, the clitoral-anal reflex, a multisynaptic sacral reflex, allows assessment of both pudendal afferent sensory and motor functions. The afferent limb of the reflex arc is the clitoral branch of the pudendal nerve, and the efferent limb is via the inferior haemorrhoidal branch; the reflex is integrated at the S2–S2 level of the spinal cord.[99,128,129]

Electrical stimulation is applied periclitorally; the sensory threshold is volunteered by the patient, and the clitoral-anal reflex latency recorded either via a fine needle electrode placed in the EAS,[128] or surface electrodes positioned at the mucocutaneous junction of the anal mucosa.[98,129]

In one recent study, comprehensive neurophysiological assessment in women with postpartum faecal incontinence, which included assessment of the clitoral-anal reflex, showed four patterns of abnormal pudendal nerve function: demyelinating (involving increased sensory threshold of the clitoral-anal reflex); axonal (normal reflex parameters); mixed demyelinating and axonal neuropathy (increased sensory thresholds and prolonged latencies); and a more widespread polyneuropathy (also involving abnormal reflex parameters), inconsistent with obstetric damage, and attributable to lumbosacral disease/injury.[128] Indeed it has been suggested that the test would be most clinically useful in cauda equina or conus medullaris syndromes.[129]

9.5 Non-established (Research) Methodologies

9.5.1 Ambulatory Manometry

Prolonged assessment of anorectal, rectosigmoid or colonic motor activity may provide further invaluable information regarding the pathophysiology of faecal incontinence; such techniques are gaining more widespread use.[130] To date, the majority of studies have been limited to the pelvic colon by a retrograde (per rectal) approach.[45,130–133] However, recent technological advances have facilitated pan-colonic investigation.[134–136] For the study of rectosigmoid motility, a manometric catheter, incorporating several solid-state pressure microtransducers, is stationed intraluminally at flexible sigmoidoscopy (unprepared bowel), so that recording sites lie within the sigmoid, rectum and anal canal.[131] The catheter is connected to a portable, solid-state recording system, which allows monitoring of intraluminal pressure changes under normal physiological conditions, over prolonged periods, in ambulant subjects. This is particularly useful in patients in whom symptoms are intermittent, where an extended recording period may enable symptom episodes (e.g. urgency, incontinence) to be correlated with pressure events.[15,130]

In patients presenting with incontinence, prolonged manometric studies have shown that transient internal anal sphincter relaxation or sampling reflexes (equalisation of rectal and anal canal pressures) occur more frequently than in control subjects, and that duration of relaxation is longer.[137] Symptoms of urgency or urge incontinence may be associated with high-amplitude contractions of the rectosigmoid,[45,131,138] or increased periodic rectal motor activity,[131,133] suggesting that rectal hypercontractility may contribute to the pathogenesis of this condition. However, studies of rectosigmoid or colonic motility are time-intensive and technologically challenging, notably in terms of data interpretation and analysis. Consequently, there is a relative paucity of data on normal motor function, and until this is expanded, our understanding of motility disorders affecting the large bowel and anorectum will remain inadequate. The clinical value of prolonged ambulatory manometry therefore remains unproven and studies should at present be limited to specialty centres.[15,130]

9.5.2 Vector Volume Manometry (Vectography)

This technique is designed to assess the circumferential symmetry of anal canal pressures.[139,140] A multichannel manometric catheter with radially-orientated side holes (typically eight orifices, set 45° apart) is utilised. With the patient at rest or during sustained, voluntary contraction of the anal canal musculature, an automated, continuous pull-through technique is used, following which a computer-derived, three-dimensional pressure profile of the anal canal can be obtained[14,15] (Figure 9.8). Cross-sectional analysis permits accurate localisation of pressure defects and allows differentiation between global and sector pressure deficits in patients with incontinence.[141] Sphincter asymmetry, which indicates sphincter injury, may be a useful parameter for assessing the competence of anal sphincter function[142,143] (Figure 9.8). However, as with electrode mapping of the anal sphincter, use of vector volume manometry has largely been superseded by endoanal ultrasonography.

9.5.3 Impedance Planimetry

An alternative methodology for studying biomechanical properties of the rectal wall is impedance planimetry, which combines rectal balloon inflation with measurement of intrabag (i.e. intraluminal) impedance[144,145] and may give a better appreciation of capacity (cross-sectional area) and tension-strain relationships in comparison to studies utilising the barostat.

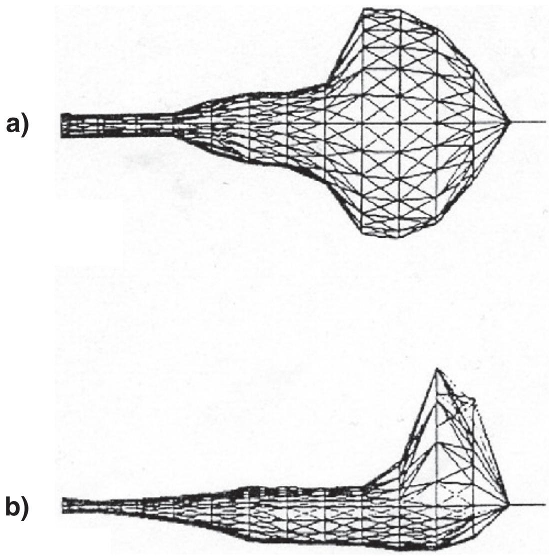

FIGURE 9.8. Anal pressure profile as recorded by vector volume manometry. In a normal asymptomatic volunteer (**a**), the pressure profile is relatively symmetrical, whereas in a patient with faecal incontinence (**b**), vectography demonstrates sphincter pressure asymmetry, indicative of sphincter damage, as well as reduction in functional length. (Reproduced with permission from Rao.[140])

9.6 Summary

Faecal incontinence is a common, yet underappreciated condition, whose physical and psychosocial consequences may be devastating. In the majority of patients, symptoms occur secondary to disordered function of the anorectum (both sphincteric and suprasphincteric components), and in females are most often acquired following obstetric trauma. Specialist referral for assessment of colorectal/anorectal function is not required for all patients with faecal incontinence, as the majority with mild to moderate symptoms will successfully respond to simple medical management. However, those patients with intractable and sufficiently severe symptoms, in whom such measures have failed, warrant rigorous clinical evaluation at a tertiary centre. The modern management of patients with faecal incontinence should involve a multidisciplinary team of professionals, reflecting the multifaceted approach to the different aspects of patient assessment, education, support and treatment.

In recent years, with the advent of anorectal physiological investigations, a more detailed understanding of the pathophysiological mechanisms underlying faecal incontinence is evolving. As several physiological abnormalities may be present, it is recommended that patients with intractable symptoms should undergo a structured, comprehensive series of tests in order to evaluate systematically all aspects of anorectal function. The results of these tests will help to suggest appropriate, rather than empirical management, both non-surgical and, in particular, surgical.

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