3 Anorectal Physiology Testing

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Introduction

Throughout the past several decades, we have learned a great deal about the complex physiology of the distal rectum, pelvic floor, and anal canal. The majority of these discoveries have come through the advent of testing modalities including anal manometry, electromyography (EMG), cinedefecography, rectal compliance measurements, and measurements of specific anorectal reflexes. These testing modalities have led to a better understanding of the complex interplay between pelvic muscle and nerve functions as they relate to normal physiology as well as the ways that these mechanisms change in the setting of various disease states.

As knowledge of physiologic parameters has increased over time, the differing techniques have had ranges of "normal" values reported. Though these can be helpful guides in interpreting these studies, any given value needs to be evaluated in context because variations in measurement technique may provide differing results [1, 2]. It is most important for the surgeon to have knowledge of their own testing equipment and interpret testing values in the context of those typically seen with their own devices. Anal physiology testing has also allowed us to understand many different reflex arcs such as the bulbocavernosus reflex [3, 4], the cough reflex [5–7], cutaneous-anal reflex [8], the rectoanal excitatory reflex [9, 10], and rectoanal inhibitory reflex [11, 12]. Though most of these reflexes can be an important part of determining overall spinal nerve function, the rectoanal inhibitory reflex (RAIR) is the most relevant to the study of colorectal disease as it has been noted to affect such conditions as Hirschsprung's disease [13] and fecal incontinence [14]. Similarly, its abolition after low anterior resection may be associated with many of the post-operative functional disorders that affect patients. In recent years, many of the techniques have been modified and enhanced with the addition of modalities such as magnetic resonance defecography (MR defecography) [15, 16], high resolution anal manometry [17, 18], and anal canal vector volume manometry [19].

This chapter will provide a broad overview of the techniques commonly used to evaluate anorectal and pelvic floor anatomy and physiology. We will first describe the techniques in detail and describe the interpretation of the results both in the instance of normal findings as well as in states

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of disease. Finally, we will address present day clinical correlations, and how testing methodology can be used to guide clinical decision-making, or conversely, in which instances clinical judgment should supersede the need for testing.

Techniques

Anorectal Manometry

Instrumentation and Technique

There are a variety of methods for performing anorectal manometry testing. The essential components involve a pressure measuring probe, pressure transducers, a recording component, and in the setting of water perfusion methods, a hydraulic pump. Many modern devices are now self-contained systems, offering advanced functionality (Fig. 3.1). The most common difference in setup is in the transducing catheter, where small balloons filled with air or water, water-perfusion catheters, and solid state catheters have been used [20]. Currently, the most commonly utilized transduction system uses a soft multi-channel catheter, which is perfused with water or air. The unit then measures the pressure needed to overcome the sphincter pressure during various states such as resting or squeeze (Fig. 3.2).

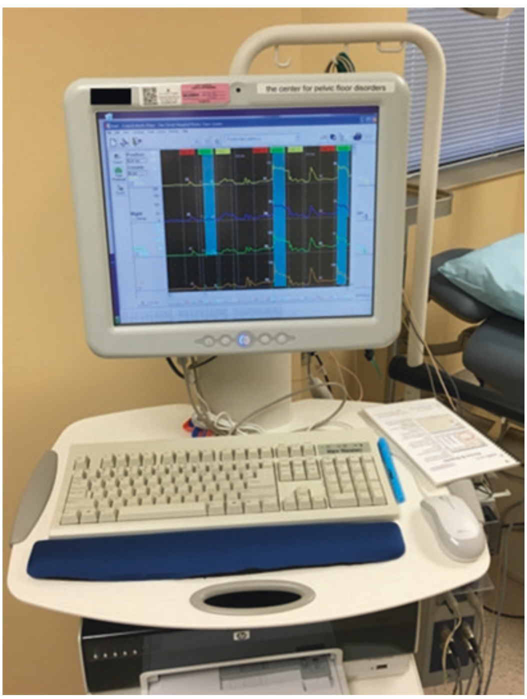

Fig. 3.1 Anal physiology testing system (Mediwatch Duet® Encompass™ System. Mediwatch, West Palm Beach, FL)

A variety of techniques to measure pressures throughout the anal canal are used. Some techniques include stationary measurements, where the catheter is left in one location. However, the more common techniques involve slowly withdrawing the catheter from the rectum by hand. Many systems are using an automated rather than manual pullback method, including those, which use vector volume techniques (Fig. 3.3) [19, 21–24].

The standard pull through technique involves placing the catheter into the rectum until it is above the sphincter complex. Subsequently, resting and squeeze pressures are measured at each station, usually in 1 cm intervals. Directional pressures (anterior, posterior, and left or right lateral) can be measured at each station. Squeeze duration may also be measured to determine the stamina exhibited by the sphincter muscles. During this process, rectal compliance and the RAIR can also be elucidated [20].

The newest techniques are the vector volume manometry technique and high-resolution anal

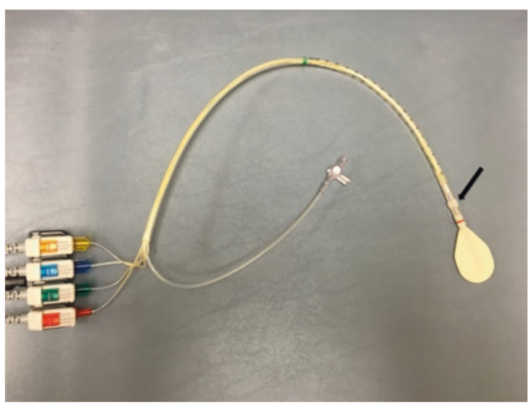

Fig. 3.2 Air charged manometry catheter. Arrow demonstrates the four small balloons used to measure pressures in the anal canal (T-DOC-ARM4 Catheter. T-DOC LLC, Wilmington, DE)

manometry. The vector volume technique involves a continuous pull through in which the system creates vector diagrams, which are used to generate a three dimensional reconstruction of anal canal pressures [19]. As algorithms have improved over the years, fairly accurate representations of anal canal squeeze pressure, resting pressure, length, and symmetry can be reasonably calculated (Fig. 3.4). The results of this technique suffer from a lack of generalizability, as there are a myriad of techniques and algorithms used for vector volume manometry.

Revaluation of standard manometry techniques utilizing a variety of measurement methods (water perfused side hole, water perfused end hole, microtransducer, or microballoon) have demonstrated relatively consistent results across platforms [20]. However, evidence suggests that vector volume manometry may yield higher estimations of anal canal pressures [25]. Yang et al. conducted a prospective analysis comparing vector volume manometry against standard pull through manometry in 50 consecutive patients with fecal incontinence. Their conclusion was that lower pressures may be measured during standard techniques because patients are given more time to rest between squeezes as opposed to the continuous pull through used in the vector volume methods [25]. These data suggest that surgeons need to become comfortable with the data generated by their own manometry system, and be cognizant of the fact that values generated on a given machine may not be directly correlated to external controls. Proponents of the vector volume imaging technique suggest that algorithms have improved over time and there is greater reproducibility in the results [19]. What is less clear is to what degree this technique adds clinical value over standard techniques, and whether it is cost-effective.

High-resolution manometry techniques were initially developed to investigate esophageal motility and have been adapted to study anorectal disease. This technique has the potential to generate 3-dimensional maps of pressure gradients throughout the anal canal (Fig. 3.5). Although

Fig. 3.3 Manometry catheter automated withdrawal system (Mediwatch, West Palm Beach, FL)

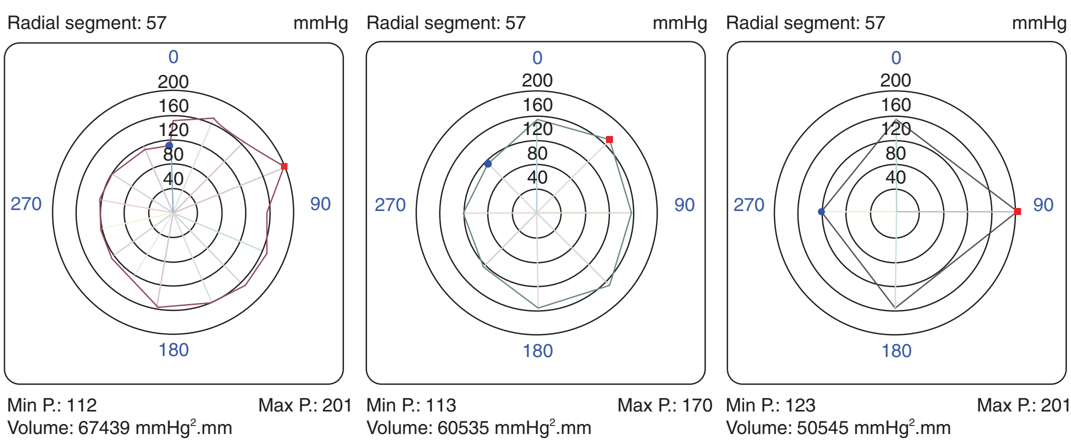

Fig. 3.4 Vector volume manometry. Pressures are measured in multiple planes and vector diagrams are generated. With permission [19] © 2011 Wolters Kluwer

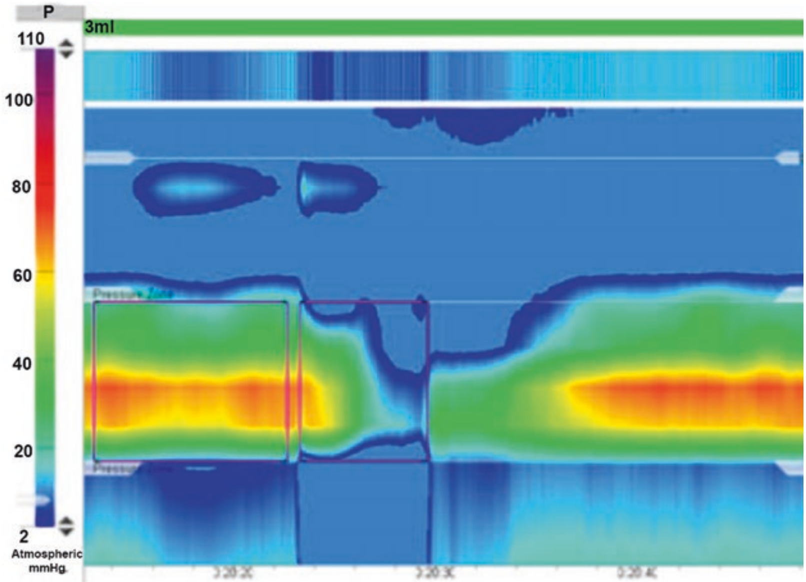

Fig. 3.5 High resolution manometry tracing demonstrating relaxation of the anal sphincter during a pushing maneuver. With permission from [18] © John Wiley and Sons

Table 3.1 Reference values of anal physiologic tests

Resting pressure	40–70 mmHg
Squeeze pressure	100–150 mmHg
Anal canal length	2–3 cm (female)
	2.5–3.5 cm (male)
RAIR	Present
Sensory threshold	10–30 cc
Rectal capacity	100–250 cc
Rectal compliance	5.1–15.7 mL/cm H_2O
Anorectal angle	75–90° at rest
	110–180° at evacuation
Perineal decent	<3 cm with straining

only small pilot studies have examined this technique in the setting of various disease states [17, 26, 27], data is beginning to emerge on the suggested "normal" values of this technique when measured in healthy volunteers [18]. The challenge for future research is to determine whether this technique can offer more useful information than traditional techniques, or whether other techniques such as dynamic distensibility measurements may correlate better with various disease states [28].

Anal resting pressure receives as much as 55–85% of its contribution from the internal sphincter, while squeeze augmentation is mostly from the external sphincter [20, 29–33]. Studies of controls as well as patients with pelvic floor disorders have generated several "normal values" (Table 3.1). Differences have been noted between different gender and age, with generally higher pressures in males and decreased pressures in elderly patients [34]. Pressures are relatively low in the anterior aspect of the upper third of the anal canal, which corresponds to the area not surrounded by the puborectalis sling, and in the posterior aspect of the lower third of the anal canal.

Anal canal length is also assessed by manometric measurement [35]. In many instances, the length of the anal canal has been shown to correlate with sphincter function, and can be predictive of outcomes in disease states such as fecal incontinence [35–37]. Length of the sphincter can almost more be construed as a physiologic, rather than an anatomic length. Many modern systems are now able to reproduce dynamic pressure tracing curves of the anal canal pressures at rest and during maneuvers such as squeeze and push (Figs. 3.6 and 3.7).

Balloon Expulsion

An inexpensive simple test for obstructed defecation is balloon expulsion. Many of the current generation manometry catheters are equipped with a balloon, which can be utilized for this purpose. Though multiple different patient positions and balloon inflation methods have been examined, asking the patient to lay in a supine position and

RAIR (ml)

	1
Volume	N.A.

Resting Duration (s)

6.0 cm	7
5.0 cm	7
4.0 cm	7
3.0 cm	7
2.0 cm	7
1.0 cm	7

Resting Average (mmHg)

	Post	Right	Anter.	Left	Min	Max	Median	Mean
6.0 cm	9	6	5	12	5	12	8	8
5.0 cm	12	7	6	10	6	12	9	9
4.0 cm	26	11	12	20	11	26	16	17
3.0 cm	68	29	29	65	29	68	47	48
2.0 cm	71	29	30	64	29	71	47	48
1.0 cm	75	43	41	78	41	78	59	59

Squeeze Duration (s)

	Post	Right	Anter.	Left	Min	Max	Median	Mean
6.0 cm	6	6	5	6	5	6	6	6
5.0 cm	6	6	6	6	6	6	6	6
4.0 cm	5	5	5	5	5	5	5	5
3.0 cm	6	5	5	6	6	6	6	6
2.0 cm	6	6	6	6	6	6	6	6
1.0 cm	6	6	6	6	6	6	6	6

Squeeze Increase (mmHg)

	Post	Right	Anter.	Left	Min	Max	Median	Mean	HPZ
6.0 cm	14	9	7	34	7	34	11	16	
5.0 cm	45	15	26	50	15	50	35	34	
4.0 cm	87	42	59	76	42	87	68	66	X
3.0 cm	80	53	64	73	53	80	69	68	X
2.0 cm	69	39	53	63	39	69	58	56	
1.0 cm	131	112	132	113	112	132	122	122	X

Fig. 3.6 Sample readout from anal manometry testing

expel a balloon with a 60 mL volume appears to be the most reproducible method (Fig. 3.8) [38]. However, one of the editors (DEB) prefers to place an air or water filled 60 cc Helium type balloon into the anus and have the patient sit on a commode to pass the balloon. This is less embarrassing and more physiologic to the passage of stool [39].

Some investigators have cited this test as a reliable means of ruling out pelvic floor dyssynergia in the setting of constipation [40–43]. Minquez et al. studied two groups of constipated patients (106 with functional constipation, and 24 with pelvic floor dyssynergia based upon manometry and defecography assessments.) Balloon expulsion testing was pathologic in 21 of 24 with pelvic floor dyssynergia and only 12 of 106 with functional constipation [41]. However, a more recent study by Kassis et al., demonstrated a sensitivity of 33% and positive predictive value of 71% of balloon expulsion testing in patients who were diagnosed with pelvic floor dyssynergia suggesting that balloon expulsion is only a complementary test to other modalities in the diagnosis of pelvic floor dyssynergia [40].

Electromyography

Electromyography (EMG) has been used to study both normal anatomy as well as sphincter muscle

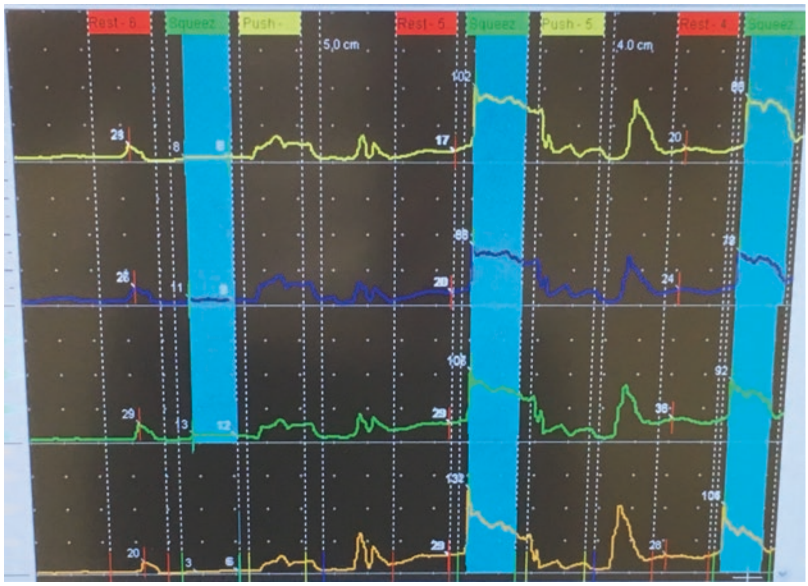

Fig. 3.7 Anal manometry measurements. An increase in pressure is demonstrated as expected during squeeze maneuver. A paradoxical increase in pressure is noted during pushing maneuver

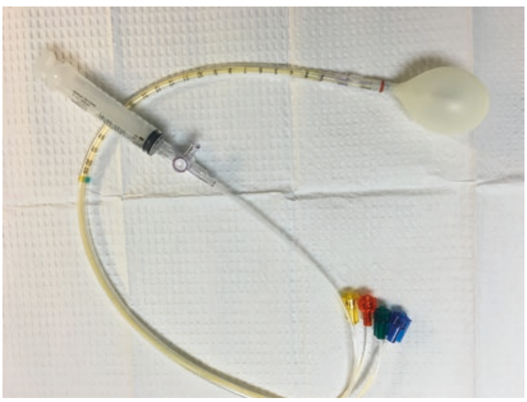

Fig. 3.8 60 cc balloon used for balloon expulsion testing

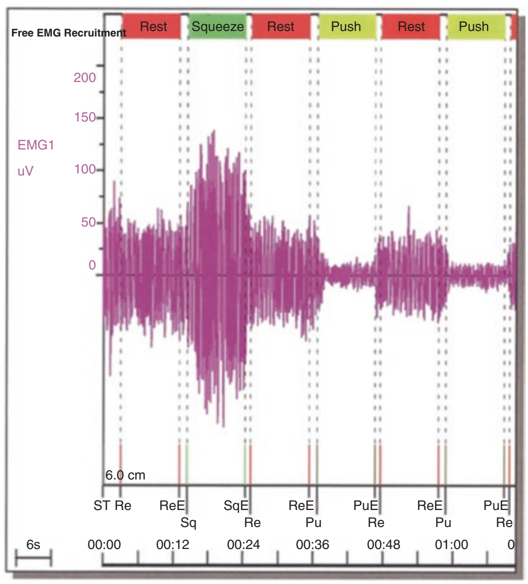

Fig. 3.9 Normal EMG. With permission from [50] © Springer

and pelvic floor muscle in various pathologic states such as fecal incontinence [44–49], paradoxical puborectalis contraction (Figs. 3.9 and 3.10) [51, 52], solitary ulcer syndrome [53], rectal prolapse [48], and perineal descent. One of the difficulties in interpretation of the literature regarding EMG is the multitude of techniques, which have been described. Based on the type of recording electrode used, there are four commonly described techniques available to evaluate pelvic floor muscles. These include concentric needle electrode, monopolar wire electrode, single fiber electrode and surface anal plug, which now include multi-channel devices.

Needle Electrode EMG

Older systems tended to utilize needle electrodes for EMG testing. These included the concentric needle, which is either a bare tipped 0.1 mm diameter steel wire which is introduced into the

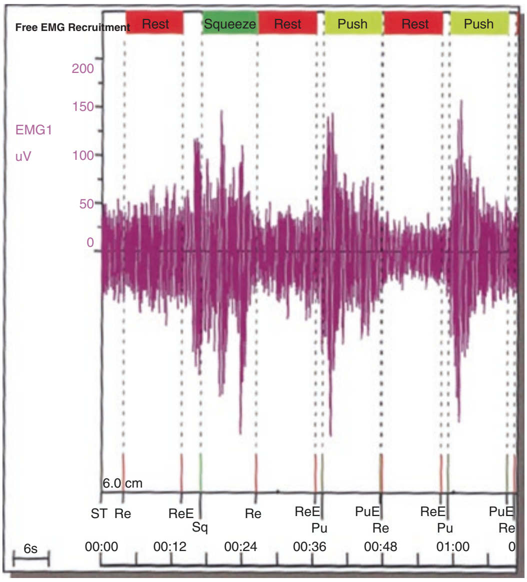

Fig. 3.10 EMG demonstrating a paradoxical increase in activity during push. With permission from [50] © Springer

external anal sphincter to record electrical activity, or the softer monopolar wire EMG electrode, which was thought to give the same information as concentric needle EMG with less patient discomfort. The electrical activity is recorded from each of the four quadrants of the external sphincter complex to ensure accurate sphincter mapping [49, 54–59]. Although accurate measurements may be obtained at the single point that the needle is placed, individual muscle fiber function cannot be reliably tested in this manner. Single fiber electrode techniques improved on this, by providing a representation of the activity of individual muscle fibers within a motor unit. However, the needle EMG techniques are currently less commonly utilized. The most common of these uses was historically, sphincter mapping; however, endoanal ultrasound has largely replaced EMG for this purpose [60–62].

Surface Electrode EMG

Currently, the most common clinical application for EMG is in examining external anal sphincter activity and whether contraction and relaxation is occurring appropriately. This is easily accomplished using a surface electrode EMG. The anal plug consists of two longitudinal or circular silver wires mounted on a plastic or sponge surface. Though surface electrodes have been modified in recent years and can afford more accurate depictions of the morphology of the sphincter complex [44, 63–65], the most common use currently is in the diagnosis of paradoxical puborectalis contraction (anismus), or as a means of demonstrating muscular activity during biofeedback retraining [51]. The incidence of EMG-documented paradoxical puborectalis contraction in chronically constipated patients ranges from between 42 to 100 [66–69]. Patient embarrassment plays a significant role in accurate diagnosis of anismus, and functional testing via cinedefecography may be more accurate.

Rectal Pressure Testing (Manometry)

The role of the rectum in normal, healthy people is to act as social organ. It is a storage reservoir, one that accommodates stool without initiating the urge to defecate and subsequently allows defecation at a socially appropriate time. This is dependent upon the complex interplay between rectal distensibility and complex defecatory reflexes. Basal pressures within the rectum range from between 5 to 25 cm H_2O (or 2–18 mmHg). The initial inflation of an intrarectal balloon is associated with an initial rise in pressure, often followed by a secondary increase in pressure due to rectal contraction. A degree of accommodation then occurs after which the rectal pressure gradually falls to a baseline value. Eventually, as intrarectal pressure increases above a certain threshold, a person will feel an urge to defecate. This threshold is different across individuals and can be affected by conditions, which reduce the capacity of the rectal vault such as low anterior resection [70], or conditions which reduce rectal compliance such as radiation proctitis [71], or ulcerative colitis [72]. The contractile response of the rectum to distention is decreased or absent in patients with spinal cord lesions, suggesting a spinal contribution to this reflex.

Rectal Capacity and Compliance

Rectal capacity determines the frequency of defecation. This is apparent in individuals who have had a low anterior resection for rectal cancer, where increased stool frequency is an expected functional consequence of surgery [73, 74]. Rectal compliance is responsible for the degree of urgency for evacuation. Some of the factors commonly utilized to determine rectal compliance are the rectal volume at first sensation, volume at first urge to defecate, and the maximum tolerable volume (MTV). These measurements are obtained utilizing a balloon attached to the end of the catheter and positioned inside the rectum. Most commonly, the balloon is distended with water and pressure measurements are recorded as cm of H_2O. The water in the balloon is usually maintained at 37 °C, and should not be lower than room temperature, or higher than body core temperature. Prior to injecting water, the patient needs to be instructed on the purpose of the test, and informed of what is being asked of them. Baja et al. demonstrated that a single injection of water can be used with accurate results, and that the technique of multiple injections to permit "conditioning" appear to be unnecessary [75]. Commonly, the volume in the balloon at the first urge to defecate is recorded. Maximum tolerable volume is not often recorded due to patient discomfort. One of the only studies demonstrating utility in maximum tolerable volume demonstrated that patients with a maximum tolerable volume <60 cc had a high incidence of fecal incontinence [76], however, this predictive value was shown to be no better than the predictive value of anal manometry [77], thus, the added patient discomfort of this test is not justified. Rectal compliance, by definition, is 1/slope $\Delta P/\Delta V$. Put simply, compliance measures the response of the rectum (by change of pressure) in response to a change in volume [78–80]. Rectal compliance, measured as mL/cm H_2O have been shown to vary, and normal values ranging from 5.1–15.7 mL/cm H_2O have been reported [80]. Conditions associated with low rectal compliance include radiation proctitis and inflammatory bowel disease, while idiopathic constipation with megarectum may be associated with abnormally high compliance [80]. Recent evidence suggests that patients with impaired continence after anal fistulotomy may have impaired rectal compliance due to scarring in addition to diminished muscle pressures, and this may be an additional mechanism leading to incontinence [81]. Due to the wide range of values reported as normal in the literature, some have suggested that the accuracy of this measurement needs to be interpreted with caution due to limitations with the technique [80]. Other factors have been shown to impact rectal compliance measurements including the contribution of extrarectal tissues to the measurement, as well as differences in rectal size. Newer techniques have been developed to attempt to control for variations in rectal size such as the barostat technique, which uses a large volume bag (with infinite compliance to the limit of its capacity) to test rectal compliance. The proposed advantage of this technique is to attempt to control for variation in capacity. This can hopefully address the issue where a patient with a larger volume rectum will appear more compliant due to the volume of water it can accommodate, as opposed to basing this measurement simply on wall distensibility [78].

The Rectoanal Inhibitory Reflex (RAIR)

One notable aspect of the complex neuromuscular network of the anal canal is the rectoanal inhibitory reflex (RAIR). Distention of the rectum leads to a consequent relaxation of the internal sphincter allowing the rectal contents access to the specialized sensory epithelium lining the upper anal canal. This mechanism allows for sampling and conscious or subconscious discrimination between solid, liquid, or gas contents [82]. Increasing degrees of rectal distention lead to complete internal sphincter inhibition. While the internal sphincter relaxes, the external sphincter contracts to maintain continence. During this episode, there is a small decrease in anal pressure noted: this normal reflex is what defines the RAIR [11, 83]. RAIR is thought to play an important role in maintenance of continence, as it facilitates "sampling" of rectal contents to the specialized sensory apparatus of the anal canal; this is what allows a person to distinguish between solid, liquid, and gas contents. The RAIR is mediated by nitric oxide and relies on the presence of the interstitial cells of Cajal to mediate its effect [84, 85]. RAIR is noted to be absent in conditions with an impaired myenteric nerve plexus such as Hirschsprung's disease or Chagas' disease, or after surgical resection of the rectum [11, 83, 86, 87].

The test is performed utilizing a balloon catheter. The balloon is placed 2 cm proximal to the anal verge. The expected result is a 50% drop in resting pressure in at least one channel in response to balloon insufflation. The test is interpreted as normal if this condition is met. If the RAIR is absent, this suggests impaired neuromuscular function, and disease states such as Hirschsprung's disease, rectal prolapse, scleroderma, or dermatomyositis should be considered in the proper clinical context [86]. RAIR is also often absent in the setting of chronic rectal prolapse due to a neuropathy induced by chronic stretching of the prolapsed tissue, resulting in continuous stretching of the receptors.

Cinedefecography

Defecography is a technique utilized to assess the process of defecation in a dynamic manner (Fig. 3.11). The primary clinical indication is for the workup of obstructed defecation, or pelvic organ prolapse [88]. Through the past decades the imaging protocols have been modified, but the goal remains to assess the functional interaction of the pelvic floor during the defecatory process.

The patient is placed on the left lateral position, with instillation of 50 mL of liquid barium into the rectum, followed by insufflation of a small quantity of air. In addition, 100–200 mL of barium paste is injected into the rectum [89–91]. Though various other techniques for contrast administration (intravesical [92], oral [93], intravaginal barium soaked tampon [93], or intraperitoneal [94, 95]) have all been described, the most common configuration is rectal barium combined with a vaginal barium paste. This allows for accurate identification of additional pathology such as

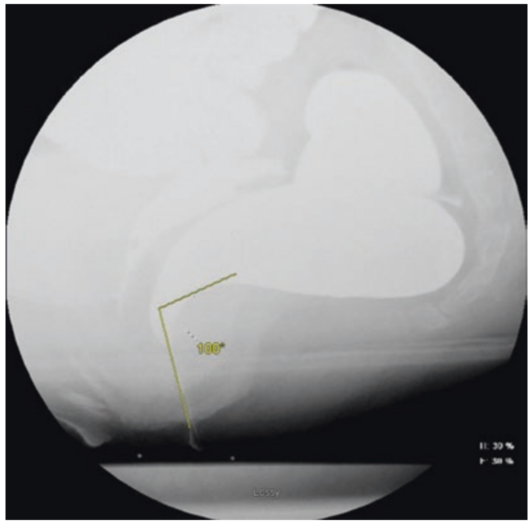

Fig. 3.11 Defecography demonstrating a resting anorectal angle of 100°

enterocele or vaginal vault prolapse, while minimizing patient discomfort and inconvenience [96–98]. Often, a radio-opaque marker is placed on the perineum, which allows measurement of perineal descent.

The patient is then seated on a commode, and lateral radiographs, both static and dynamic are obtained during the process of defecation. The patient is coached to attempt to recreate a normal bowel movement and evacuate the contents of the rectum as completely as possible.

X-ray images are recorded at rest, as well as during squeezing and pushing maneuvers.

Parameters commonly measured are the anorectal angle, degree of perineal descent, and whether paradoxical contraction of the puborectalis is observed [99, 100]. However, many other diagnoses such as internal or complete rectal prolapse, sigmoidocele, enterocele, rectocele, or vaginal vault prolapse may be demonstrated (Figs. 3.12 and 3.13).

The anorectal angle is the angle created between straight lines traversing the anal canal and the rectum. This angle is thought to be largely created by the function of the puborectalis muscle at rest. Normal values have been reported to be 90–110° at rest, and 110–180° at evacuation (Fig. 3.11) [99, 101, 102]. Though the examination of the dynamic change in anorectal angle in

Fig. 3.12 Defecography demonstrating no relaxation of the puborectalis muscle during an attempted defecation

Fig. 3.13 Defecography demonstrating an anterior rectocele with retained contrast during an attempted evacuation

a given patient can be clinically useful, the absolute numbers generated are not very useful because there is disagreement among experts as to the suggested normal values. Though techniques vary, a common reference point for measurement is between the axis of the anal canal and the tangential line of the posterior rectal wall [103].

Perineal decent is measured in relation to a line drawn from the most anterior portion of the symphysis pubis to the coccyx (the pubococcygeal line) [104]. In general, the pelvic floor is observed to rise during squeeze maneuvers and descend with defecation. Perineal descent of more than 3 cm in the resting phase or an increase of more than 3 cm during the pushing phase are the definitions of fixed and dynamic perineal descent, respectively [105, 106]. Additionally, the degree of emptying of the rectum is assessed. Normal rectal emptying should take less than 30 s, and less than 10% of the contrast should remain in the rectum in order for emptying to be read as normal. The degree of emptying should be carefully assessed, as anatomic "abnormalities" can appear on defecography, and correlation of these findings to the patient's symptoms as well as a dynamic analysis of the defecatory process is paramount. Shorvon et al. illustrated that in a mixed gender group of "normal" volunteers, half showed radiological evidence of mucosal prolapse and intussusception. Additionally, 17 of the 21 women studied also had evidence of a rectocele [107]. Other studies have corroborated these findings as well, suggesting that the mere presence of a rectocele on physical examination or defecography is not enough to warrant a repair [108–113]. We would suggest that symptoms of difficult evacuation, need for vaginal splinting to precipitate evacuation, and evidence of non-emptying of the rectocele on defecography should be requisite conditions which should be met prior to consideration of a rectocele repair. We will go into further detail correlating defecography findings to clinical outcomes later in this chapter.

Magnetic Resonance Defecography

More commonly, MRI technology is being utilized in the study of pelvic floor disorders [114–122]. Magnetic resonance (MR) defecography has been proposed as an alternative to fluoroscopic defecography. Proponents of this technique cite the absence of ionizing radiation and excellent depiction of anatomy. Detractors to this approach cite that the supine patient positioning may alter the normal physiologic process of defecation, which can only be recreated in the upright position. Ideally, an open MRI configuration would be utilized, allowing a patient to sit upright during the examination, however this equipment is not readily available in most institutions. The procedure is typically carried out using a 1.5 T MRI detector, and a body coil is used rather than an endorectal coil. Though fluoroscopic defecography still appears to be the gold standard radiographic test for pelvic floor disorders, a recent study by Vitton et al. demonstrated that MRI techniques are improving. Though the concordance rate of MRI to conventional defecography in diagnosing rectocele (82%), or enterocele (93%) were reasonably good, the concordance of MRI to standard defecography in diagnosing perineal decent was only 57% [123]. This is likely because the supine positioning of MRI is not able to reproduce perineal descent in an accurate manner. There is however, some evidence that MR may be better than cinedefecography at demonstrating internal prolapse [120]. Though MR techniques continue to emerge, the current gold standard modality for assessing pelvic floor function radiographically remains conventional cinedefecography.

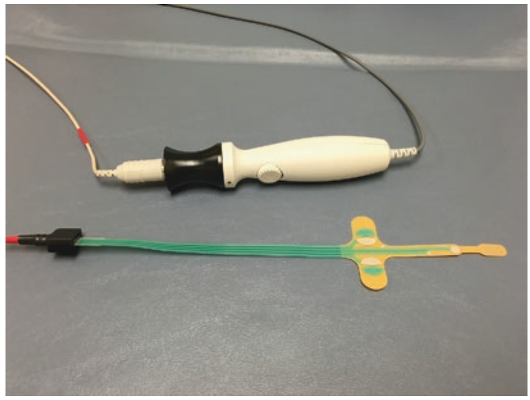

Fig. 3.14 St. Mark's Pudendal Electrode (Alpine Biomed Skovlunde, Denmark)

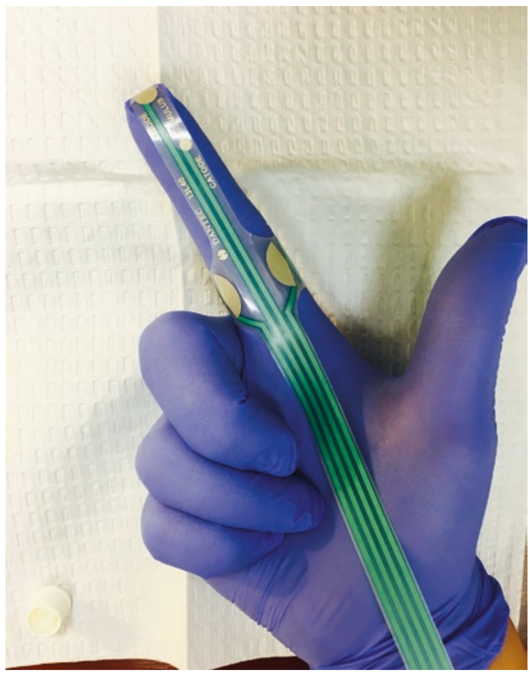

Fig. 3.15 The pudendal electrode is secured to the examiner's finger to allow for pudendal nerve terminal motor latency testing

Pudendal Nerve Terminal Motor Latency Testing (PNTML)

Pudendal nerve terminal motor latency testing has been performed for the past several decades in an attempt to determine whether the neuromuscular function of the pelvic floor is intact. The technique is accomplished by using a finger-mounted transanally inserted electrode (St. Marks electrode). The fingertip portion of the electrode contains the stimulating portion, while a sensor at the base of the finger measures the response (Figs. 3.14 and 3.15). The clinician places the fingertip on the pudendal nerve as it traverses over the ischial spine. The latency period between pudendal nerve stimulation and electromechanical response of the muscle is then measured. Generally, stimulation is checked bilaterally a total of two to three times to be sure that the measurement is reproducible.

Pudendal nerve function has been demonstrated to correlate with age, particularly in women [124–127]. Though it was previously thought that pudendal neuropathy (PN) correlated with abnormal perineal descent, emerging data suggests that this relationship may be confounded, as both perineal descent and PN are common in older age. PN has been demonstrated to occur in such varied conditions as fecal incontinence [45, 128–130], constipation [131–135], rectal prolapse [133–135], combined fecal and urinary incontinence [133], and low anterior resection syndrome [136, 137]. A study by Lim et al. in 2006 suggested that patients treated with neoadjuvant chemotherapy and radiation for rectal cancer may develop PN after treatment [138, 139]. The authors suggested that this may contribute to the development of low anterior resection syndrome (LARS). More recently, Tomita et al. correlated postoperative PN to soiling and incontinent episodes following low anterior resection. Though PN was thought to be important, the factor most highly predictive of soiling was the height of the anastomosis, with lowest anastomoses producing the most severe symptoms. LARS will be discussed in greater detail below [136]. PN is also associated with traumatic vaginal delivery. Surprisingly, up to, 20% of women who undergo vaginal delivery *without* apparent injury to the external sphincter may also have prolonged pudendal nerve terminal motor latencies. Subsequent recovery occurs approximately in 15% of these patients [139]. Recently, Loganathan et al. also demonstrated that either unilateral, or bilateral PN predicts diminished resting and squeeze tone, even in patients who are found to have an intact internal and external sphincter complex [128].

The technique is interpreted by assessing the amount of time that is taken to elicit a motor response after stimulation of the pudendal nerves. Though different values are reported at different institutions, a normal PNTML is generally considered to be 2 ± 0.2 ms [67, 140]. Though some studies have reported higher "normal" values [1, 124, 141] a surgeon must interpret the results of this test in the context of values typically seen with their own equipment. Pudendal nerve studies are interpreted independently on the left vs. the right side. Additionally, the conduction curve should be examined to be sure that it is reproducible between one test and the next to ensure a reliable measurement of pudendal nerve function.

Clinical Considerations

While a detailed understanding of the various testing modalities is critical to the practice of pelvic floor evaluation, the utility of these tests is best understood in a clinical context. In the following section, we detail several common disease states that may benefit from pelvic floor evaluation. We will review commonly used tests and expected results to help frame the practical utility of pelvic floor testing. A detailed discussion of therapeutic intervention is beyond the scope of this chapter, but will be addressed elsewhere in the text.

Hirschsprung's Disease

Hirschsprung's disease, or congenital aganglionosis of the colon, was first detailed by Dr. Hirschsprung in 1887, when describing a detailed report of constipation in newborns due to dilation and hypertrophy of the colon [142]. In 1948, Zuelzer and Whitehouse identified the pathophysiology as aganglionosis in the rectum and distal bowel, which provided the first scientific basis for intervention [143, 144]. The diagnosis of Hirschsprung's is usually made early after birth, due to the lack of passage of meconium, prompting appropriate surgical intervention. In a small segment of the population, however, with extremely short segment involvement, patients may progress into adulthood, with bowel habits characterized by chronic constipation, and varying degrees of megacolon. Given that the pathophysiology involves a lack of caudal migration of neural crest cells to the distal gut, the end result is aganglionosis, and muscular hypertrophy of the distal rectum and anal canal. Histopathologically, this is characterized by the absence of ganglion cells, and hypertrophied nerve bundles. Functionally, this results in chronic nonrelaxation of the muscular wall of the bowel. Pelvic floor testing is the primary initial step to aid in diagnosis. The most common finding during physiologic testing is absence of the rectoanal inhibitory reflex. Other than as a result of surgical disruption, there are few other pathophysiologic processes that result in the absence of a RAIR, and in the proper clinical setting, it is considered a proxy for diagnosis [145]. In a patient who presents with a lifelong history of chronic constipation, especially in the face of endoscopic evidence of megacolon, RAIR testing provides the first key piece of evidence towards the diagnosis. Once the absence of a RAIR is confirmed, diagnosis is further made by histologic confirmation. Full-thickness biopsy of the rectal wall is required in order to perform microscopic assessment. Figure 3.16 shows the absence of a RAIR as compared to normal.

Low Anterior Resection Syndrome (LARS)

Low anterior resection syndrome (LARS) refers to the constellation of issues that to 80% of patients who undergo a low anterior resection will experience postoperatively. Symptoms include fecal urgency, frequency, bowel fragmentation, evacuation difficulty and incontinence to name a few. Most patients do regain relatively normal function by 6–12 months after surgery, however symptoms persisting after 1 year, are usually representative of permanent changes. The etiology of LARS is multifactorial, possibly due to sphincter injury, pudendal neuropathy, lumbar plexopathy, and in many cases radiation damage [146]. Diagnosis is primarily clinical, though scoring systems have been developed [74, 147–149]. Pelvic floor testing offers little in the way of predictive value in diagnosis and management since diagnosis is essentially based on symptoms, however after low anastomosis, there are significant decreases in compliance, as well as threshold volume and maximal tolerated volume [87]. To assess the effect of proctectomy on the RAIR, O'Riordain followed a cohort of 46 patients with pelvic floor testing after surgery. Pre-operatively, the RAIR was present in 93%. On the tenth postoperative day, it was only seen in 18%, and after 6–12 months only an additional 3% of patients had regained the reflex [150]. Thus, it is critical that patients are counseled preoperatively about the likelihood of functional changes after proctectomy. Treatment options include dietary management with bulking agents, antidiarrheal

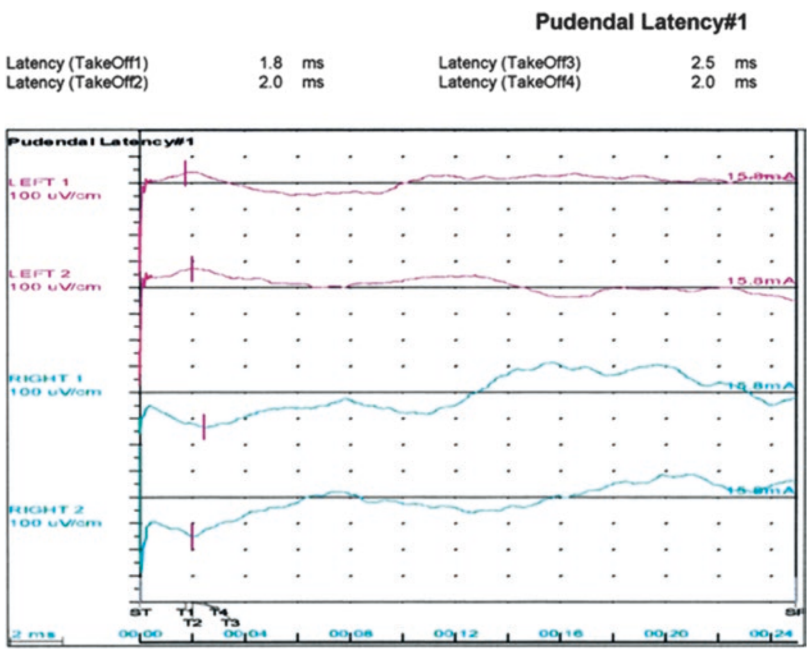

Fig. 3.16 Pudendal nerve tracings. The readings should be repeated two to three times on each side to be sure that similar appearing curves are generated, and that the PNTML values measured are repeatable

agents, daily enema therapy, biofeedback and sacral nerve stimulation [151].

Anismus

Anismus, otherwise known as nonrelaxation, or paradoxical contraction of the puborectalis during defecation is one of the more common etiologies for obstructive defecation syndrome [152]. In the normal state, the puborectalis muscle relaxes during defecation, straightening the anorectal angle, and allowing for unimpeded passage of stool. When this normal reflex is disordered, it is termed anismus. The cause of this dysfunction is unclear. It is felt to be multifactorial, involving both electro myogenic and psychological mechanisms [153–157]. Nonrelaxation of the puborectalis can be diagnosed in the office, both on physical examination as well as with anorectal manometry. Pressure over the puborectalis posteriorly during digital rectal exam while asking the patient to bear down and simulate defecation can reveal abnormal nonrelaxation. This finding can be more objectively confirmed during the "pushing" phase of manometric testing (Fig. 3.6) or EMG testing (Fig. 3.10). However, patient embarrassment during manometric testing may contribute to false positive results. Thus, diagnosis is made not only based on testing but also careful clinical history. The diagnosis is best confirmed by defecography, as the anorectal angle fails to open during defecation (Fig. 3.12). Once diagnosed, anismus may be treated with a variety of approaches including botulinum toxin injection, transanal electrostimulation and pelvic floor physiotherapy.

Rectocele, Sigmoidocele and Enterocele

Rectocele, sigmoidocele, and enterocele are clinical entities, which are often associated with constipation. Though clinical history can be suggestive of these disorders, defecography is the diagnostic modality of choice. Rectocele is an outpouching of the rectal wall during defecation. This is far more commonly found in females due to the relatively thin rectovaginal septum [158–160]. Rectoceles are classified anatomically depending on the location as low mid or high. Etiology is most commonly due to sphincter injury during childbirth, but may also be a result of chronic distention and straining with constipation [161]. The most common symptom of rectocele is a sense of incomplete evacuation, commonly associated with post-defecatory stool loss as the rectocele empties [162]. Rectocele is often a concomitant diagnosis with other pelvic organ prolapse including cystocele, enterocele and sigmoidocele, as well as uterine prolapse. Physical examination yields a prompt diagnosis. Rectoceles are graded relative to the degree of bulging into the vagina. Grade 1 rectocele is mild with little bulging, grade 2 rectocele is defined as bulging to the vaginal introitus, and grade 3 rectocele is bulging outside of the vaginal introitus. Dynamic studies such as defecography provide the most accurate and objective measure of rectocele (Fig. 3.13). A careful distinction must be made regarding the existence of a rectocele and its clinical importance. Studies have found that up to 80% of women have some degree of asymptomatic rectocele [163, 164]. Indication for surgical repair is based not only on symptomatology, but also predictive factors for successful repair. Karlbom found that the most predictive factor related to successful surgical treatment was resolution of obstructive symptoms with digital vaginal or perineal splinting (23/27 in the improved group vs. 3/7 in the non-improved group; $p = 0.04$) whereas a previous hysterectomy, large rectal area on cinedefecography and preoperative use of enemas, motor stimulants or several types of laxatives related to a poor result [165]. Other predictive factors that indicate prior success rates after surgical intervention include barium retention on defecography. Thus, patient selection is critical to successful surgical resolution. Good selection results in success rates of over 80% at 1-year follow-up [159, 164].

Sigmoidocele and enterocele refer to descent of the bowel into a deep rectovaginal sulcus. These are additional etiologies that can contribute to functional pelvic outlet obstruction. Previous hysterectomy is one of the risk factors, with incidences ranging from 6–25% [166]. Obliteration of the rectovaginal cul-de-sac is the typical approach for enterocele. Like with rectocele, the mere presence of enterocele or sigmoidocele may be an incidental finding on defecography. Only patients with clinically significant obstructive defecation merit consideration for surgical intervention. The pathophysiologic mechanism of obstruction may be multifactorial including collapse of the rectal wall due to extrinsic pressure by the sigmoidocele, as well as obstruction or stasis of the relatively entrapped bowel loop. This process is frequently accompanied by other manifestations of pelvic floor dysfunction including internal rectal prolapse, rectocele and anismus. Jorge and Wexner proposed classification based on the degree of descent of the lowest portion of the sigmoid. First-degree was defined as descent above the pubococcygeal line. Second-degree was descent below the pubococcygeal line and above the ischiococcygeal line, and third-degree was defined as descent below the ischiococcygeal line. In this study, the majority of third-degree sigmoidoceles were treated with sigmoid resection with or without rectopexy. The majority of first and second-degree sigmoidoceles were managed conservatively. In all patients who were treated surgically but in only one third of patients were treated surgically did post treatment symptoms improve [167]. Despite this success rate, surgery is rarely advised as although the anatomic deformity of the sigmoidocele is likely to be corrected, functional symptoms may persist or even be exacerbated.

Perineal Descent

Perineal descent is defined by excessive pelvic floor relaxation, resulting in descent of the perineum relative to the ischial tuberosities. It was first observed by Parks in 1966 in association with chronic constipation [106]. Subsequently it was found to be associated with other anorectal disorders such as incontinence and solitary rectal ulcer syndrome. Excessive perineal descent can force the anterior rectal wall to protrude into the anal canal, which may result in a sensation of incomplete evacuation, and pelvic floor weakening. This may feed forward, causing more straining, further stretching of pelvic floor musculature and further perineal descent. Parks postulated that such chronic straining of the pelvic floor anatomy could result in pudendal neuropathy [48]. Despite this logical association, no reliable correlation has been found between perineal descent and pudendal nerve terminal motor latency prolongation [168]. Perineal descent can be best measured by perineometry or defecography. Typically, during defecography a radio opaque marker is placed on the perineum and the pubococcygeal line is marked on static spot films. During the straining portion of defecography, the degree of descent can be measured directly.

Fecal Incontinence

The evolution of the utility of pelvic floor testing in the management of fecal incontinence has changed dramatically over the last 5 years. Prior to FDA approval in the United States, of sacral nerve stimulation in 2011, management of the majority of fecal incontinence was related to anatomic repair of sphincter injury. As a result, significant attention was paid to pelvic floor imaging and testing techniques. Although the gold standard, sphincter repair has poor long-term functional results. Thus, much attention was paid to identifying predictive factors for success or failure. Endoanal ultrasound is the most effective test for identifying the degree of sphincter injury. More recently, the use of three-dimensional ultrasound has enhanced our ability to image the sphincter and pelvic floor. Pudendal nerve testing showed conflicting results when relating to success after sphincteroplasty. Many investigators, including Barisic, Londono-Schimmer and Gilliland found significant differences in incontinence scores after sphincteroplasty in patients with and without pudendal neuropathy [169–171], however other, contemporaneous studies found no differences [172–174]. Since the advent of sacral nerve stimulation, the role of pelvic floor testing has been further weakened. Ratto and others have demonstrated equivalent efficacy of sacral nerve stimulation in the setting of sphincter injury, thus essentially obviating the need for preoperative endoanal ultrasound [175, 176]. Similarly, pelvic floor manometry has no predictive utility, likely since the overall success rate of sacral nerve stimulation is so high. In Hull's publication on 5-year outcomes of sacral neuromodulation, multiple variables were examined to assess predictive value for success, including presence of sphincter defects and pudendal neuropathy as well as prior pelvic floor pathology, and no predictive values emerged [177]. Further studies have confirmed that manometry pressures, pudendal neuropathy, presence of a sphincter defect, or history of a prior sphincter repair do not predict the success of sacral nerve stimulation [178, 179]. Thus, in the setting of fecal incontinence, clinical judgment is more important than physiologic testing.

Summary

Pelvic floor testing can provide important objective information regarding the function of the pelvic floor. A careful understanding of the clinical significance of the information that can be gleaned aids the clinician in characterization, and in many cases, guides diagnosis and management. It is always important to interpret such data in the relevant clinical context, since only in selected cases, does such data provide clinically useful information.

References

1. Amarenco G, Kerdraon J. Pudendal nerve terminal sensitive latency: technique and normal values. J Urol. 1999;161(1):103–6.
2. Felt-Bersma RJ, Gort G, Meuwissen SG. Normal values in anal manometry and rectal sensation: a problem of range. Hepato-Gastroenterology. 1991;38(5):444–9.
3. Laudano MA, Chughtai B, Lee RK, Seklehner S, Elterman D, Kaplan SA, et al. Use of the bulbocavernosus reflex system in assessing voiding dysfunction. World J Urol. 2013;31(6):1459–62.
4. Granata G, Padua L, Rossi F, De Franco P, Coraci D, Rossi V. Electrophysiological study of the bulbocavernosus reflex: normative data. Funct Neurol. 2013;28(4):293–5.
5. Deffieux X, Raibaut P, Rene-Corail P, Katz R, Perrigot M, Ismael SS, et al. External anal sphincter contraction during cough: not a simple spinal reflex. Neurourol Urodyn. 2006;25(7):782–7.
6. Shafik A. Re: Cough anal reflex: strict relationship between intravesical pressure and pelvic floor muscle electromyographic activity during cough. Urodynamic and electrophysiological study. J Urol. 2005;174(4 Pt 1):1502–3. author reply 3.
7. Amarenco G, Ismael SS, Lagauche D, Raibaut P, Rene-Corail P, Wolff N, et al. Cough anal reflex: strict relationship between intravesical pressure and pelvic floor muscle electromyographic activity during cough. Urodynamic and electrophysiological study. J Urol. 2005;173(1):149–52.
8. Henry MM, Parks AG, Swash M. The anal reflex in idiopathic faecal incontinence: an electrophysiological study. Br J Surg. 1980;67(11):781–3.
9. Sangwan YP, Coller JA, Barrett RC, Murray JJ, Roberts PL, Schoetz DJ Jr. Prospective comparative study of abnormal distal rectoanal excitatory reflex, pudendal nerve terminal motor latency, and single fiber density as markers of pudendal neuropathy. Dis Colon Rectum. 1996;39(7):794–8.
10. Sangwan YP, Coller JA, Barrett RC, Murray JJ, Roberts PL, Schoetz DJ Jr. Distal rectoanal excitatory reflex: a reliable index of pudendal neuropathy? Dis Colon Rectum. 1995;38(9):916–20.
11. Guinet A, Verollet D, Deffontaines Rufin S, Sheikh Ismael S, Raibaut P, Amarenco G. Qualitative and quantitative analysis of rectoanal inhibitory reflex (RAIR) modulation in functional bowel disorders. Int J Color Dis. 2011;26(4):501–5.
12. Xu X, Pasricha PJ, Sallam HS, Ma L, Chen JD. Clinical significance of quantitative assessment of rectoanal inhibitory reflex (RAIR) in patients with constipation. J Clin Gastroenterol. 2008;42(6):692–8.
13. Morais MB, Sdepanian VL, Tahan S, Goshima S, Soares AC, Motta ME, et al. Effectiveness of anorectal manometry using the balloon method to identify the inhibitory recto-anal reflex for diagnosis of Hirschsprung's disease. Rev Assoc Med Bras. 2005;51(6):313–7. discussion 2.
14. Herman RM, Berho M, Murawski M, Nowakowski M, Rys J, Schwarz T, et al. Defining the histopathological changes induced by nonablative radiofrequency treatment of faecal incontinence—a blinded assessment in an animal model. Color Dis. 2015;17(5):433–40.
15. Nikjooy A, Maroufi N, Ebrahimi Takamjani I, Hadizdeh Kharazi H, Mahjoubi B, Azizi R, et al. MR defecography: a diagnostic test for the evaluation of pelvic floor motion in patients with dyssynergic defecation after biofeedback therapy. Med J Islam Repub Iran. 2015;29:188.
16. Brandao AC, Ianez P. MR imaging of the pelvic floor: defecography. Magn Reson Imaging Clin N Am. 2013;21(2):427–45.

17. Heinrich H, Sauter M, Fox M, Weishaupt D, Halama M, Misselwitz B, et al. Assessment of obstructive defecation by high-resolution anorectal manometry compared with magnetic resonance defecography. Clin Gastroenterol Hepatol. 2015;13(7):1310–7.e1.
18. Carrington EV, Brokjaer A, Craven H, Zarate N, Horrocks EJ, Palit S, et al. Traditional measures of normal anal sphincter function using high-resolution anorectal manometry (HRAM) in 115 healthy volunteers. Neurogastroenterol Motil. 2014;26(5):625–35.
19. Schizas AM, Emmanuel AV, Williams AB. Anal canal vector volume manometry. Dis Colon Rectum. 2011;54(6):759–68.
20. Simpson RR, Kennedy ML, Nguyen MH, Dinning PG, Lubowski DZ. Anal manometry: a comparison of techniques. Dis Colon Rectum. 2006;49(7):1033–8.
21. Noelting J, Bharucha AE, Lake DS, Manduca A, Fletcher JG, Riederer SJ, et al. Semi-automated vectorial analysis of anorectal motion by magnetic resonance defecography in healthy subjects and fecal incontinence. Neurogastroenterol Motil. 2012;24(10):e467–75.
22. Nazir M, Carlsen E, Nesheim BI. Do occult anal sphincter injuries, vector volume manometry and delivery variables have any predictive value for bowel symptoms after first time vaginal delivery without third and fourth degree rupture? A prospective study. Acta Obstet Gynecol Scand. 2002;81(8):720–6.
23. Kroesen AJ. Extended anal sphincter assessment by vector manometry. Int J Color Dis. 2000;15(5–6):311–2.
24. Zbar AP, Kmiot WA, Aslam M, Williams A, Hider A, Audisio RA, et al. Use of vector volume manometry and endoanal magnetic resonance imaging in the adult female for assessment of anal sphincter dysfunction. Dis Colon Rectum. 1999;42(11):1411–8.
25. Yang YK, Wexner SD. Anal pressure vectography is of no apparent benefit for sphincter evaluation. Int J Color Dis. 1994;9(2):92–5.
26. Vitton V, Ben Hadj Amor W, Baumstarck K, Behr M, Bouvier M, Grimaud JC. Comparison of three-dimensional high-resolution manometry and endoanal ultrasound in the diagnosis of anal sphincter defects. Color Dis. 2013;15(10):e607–11.
27. Lee TH, Lee JS. High-resolution anorectal manometry and anal endosonographic findings in the evaluation of fecal incontinence. J Neurogastroenterol Motil. 2012;18(4):450–1.
28. Gourcerol G, Granier S, Bridoux V, Menard JF, Ducrotte P, Leroi AM. Do endoflip assessments of anal sphincter distensibility provide more information on patients with fecal incontinence than high-resolution anal manometry? Neurogastroenterol Motil. 2016;28(3):399–409.
29. Felt-Bersma RJ, Meuwissen SG. Anal manometry. Int J Color Dis. 1990;5(3):170–3.
30. Dreznik Z, Bat L. Value of anal manometry in anorectal diseases. Harefuah. 1989;117(7–8):196–8.
31. Kuypers JH. Anal manometry, its applications and indications. Neth J Surg. 1982;34(4):153–8.
32. Frenckner B, Euler CV. Influence of pudendal block on the function of the anal sphincters. Gut. 1975;16(6):482–9.
33. Lestar B, Penninckx F, Kerremans R. The composition of anal basal pressure. An in vivo and in vitro study in man. Int J Color Dis. 1989;4(2):118–22.
34. Wexner SD. Re: Manometric tests of anorectal function in the management of defecation disorders. Am J Gastroenterol. 1997;92(8):1400.
35. Nivatvongs S, Stern HS, Fryd DS. The length of the anal canal. Dis Colon Rectum. 1981;24(8):600–1.
36. Rajasekaran MR, Jiang Y, Bhargava V, Lieber RL, Mittal RK. Novel applications of external anal sphincter muscle sarcomere length to enhance the anal canal function. Neurogastroenterol Motil. 2011;23(1):70–5.e7.
37. Rajasekaran MR, Jiang Y, Bhargava V, Littlefield R, Lee A, Lieber RL, et al. Length-tension relationship of the external anal sphincter muscle: implications for the anal canal function. Am J Physiol Gastrointest Liver Physiol. 2008;295(2):G367–73.
38. Seong MK. Clinical utility of balloon expulsion test for functional defecation disorders. Ann Surg Treat Res. 2016;90(2):89–94.
39. Beck DE. A simplified balloon expulsion test. Dis Colon Rectum. 1992;35:597–8.
40. Kassis NC, Wo JM, James-Stevenson TN, Maglinte DD, Heit MH, Hale DS. Balloon expulsion testing for the diagnosis of dyssynergic defecation in women with chronic constipation. Int Urogynecol J. 2015;26(9):1385–90.
41. Minguez M, Herreros B, Sanchiz V, Hernandez V, Almela P, Anon R, et al. Predictive value of the balloon expulsion test for excluding the diagnosis of pelvic floor dyssynergia in constipation. Gastroenterology. 2004;126(1):57–62.
42. Fleshman JW, Dreznik Z, Cohen E, Fry RD, Kodner IJ. Balloon expulsion test facilitates diagnosis of pelvic floor outlet obstruction due to non-relaxing puborectalis muscle. Dis Colon Rectum. 1992;35(11):1019–25.
43. Barnes PR, Lennard-Jones JE. Balloon expulsion from the rectum in constipation of different types. Gut. 1985;26(10):1049–52.
44. Cescon C, Riva D, Zacesta V, Drusany-Staric K, Martsidis K, Protsepko O, et al. Effect of vaginal delivery on the external anal sphincter muscle innervation pattern evaluated by multichannel surface EMG: results of the multicentre study TASI-2. Int Urogynecol J. 2014;25(11):1491–9.
45. Thomas C, Lefaucheur JP, Galula G, de Parades V, Bourguignon J, Atienza P. Respective value of pudendal nerve terminal motor latency and anal sphincter electromyography in neurogenic fecal incontinence. Neurophysiol Clin. 2002;32(1):85–90.
46. Neill ME, Swash M. Increased motor unit fibre density in the external anal sphincter muscle in ano-rectal incontinence: a single fibre EMG study. J Neurol Neurosurg Psychiatry. 1980;43(4):343–7.

47. Penninckx F, Kerremans R. Objective evaluation of anorectal function in fecal incontinence. Acta Chir Belg. 1985;85(5):335–40.
48. Parks AG, Swash M, Urich H. Sphincter denervation in anorectal incontinence and rectal prolapse. Gut. 1977;18(8):656–65.
49. Cheong DM, Vaccaro CA, Salanga VD, Wexner SD, Phillips RC, Hanson MR, et al. Electrodiagnostic evaluation of fecal incontinence. Muscle Nerve. 1995;18(6):612–9.
50. Mellgren A, editor. Physiologic testing. New York: Springer; 2011.
51. Glia A, Gylin M, Gullberg K, Lindberg G. Biofeedback retraining in patients with functional constipation and paradoxical puborectalis contraction: comparison of anal manometry and sphincter electromyography for feedback. Dis Colon Rectum. 1997;40(8):889–95.
52. Rutter KR. Electromyographic changes in certain pelvic floor abnormalities. Proc R Soc Med. 1974;67(1):53–6.
53. Rutter KR, Riddell RH. The solitary ulcer syndrome of the rectum. Clin Gastroenterol. 1975;4(3):505–30.
54. Wiesner A, Jost WH. EMG of the external anal sphincter: needle is superior to surface electrode. Dis Colon Rectum. 2000;43(1):116–8.
55. Podnar S, Vodusek DB. Standardisation of anal sphincter EMG: high and low threshold motor units. Clin Neurophysiol. 1999;110(8):1488–91.
56. Podnar S, Rodi Z, Lukanovic A, Trsinar B, Vodusek DB. Standardization of anal sphincter EMG: technique of needle examination. Muscle Nerve. 1999;22(3):400–3.
57. Binnie NR, Kawimbe BM, Papachrysostomou M, Clare N, Smith AN. The importance of the orientation of the electrode plates in recording the external anal sphincter EMG by non-invasive anal plug electrodes. Int J Color Dis. 1991;6(1):5–8.
58. Claes G. EMG study of the external anal sphincter: current diagnostic aids. Acta Belg Med Phys. 1990;13(2):79–83.
59. Strijers RL, Felt-Bersma RJ, Visser SL, Meuwissen SG. Anal sphincter EMG in anorectal disorders. Electromyogr Clin Neurophysiol. 1989;29(7–8):405–8.
60. Enck P, von Giesen HJ, Schafer A, Heyer T, Gantke B, Flesch S, et al. Comparison of anal sonography with conventional needle electromyography in the evaluation of anal sphincter defects. Am J Gastroenterol. 1996;91(12):2539–43.
61. Law PJ, Kamm MA, Bartram CI. A comparison between electromyography and anal endosonography in mapping external anal sphincter defects. Dis Colon Rectum. 1990;33(5):370–3.
62. Tjandra JJ, Milsom JW, Schroeder T, Fazio VW. Endoluminal ultrasound is preferable to electromyography in mapping anal sphincteric defects. Dis Colon Rectum. 1993;36(7):689–92.
63. Cescon C, Mesin L, Nowakowski M, Merletti R. Geometry assessment of anal sphincter muscle based on monopolar multichannel surface EMG signals. J Electromyogr Kinesiol. 2011;21(2):394–401.
64. Gregory WT, Clark AL, Simmons K, Lou JS. Determining the shape of the turns-amplitude cloud during anal sphincter quantitative EMG. Int Urogynecol J Pelvic Floor Dysfunct. 2008;19(7):971–6.
65. Merletti R, Bottin A, Cescon C, Farina D, Gazzoni M, Martina S, et al. Multichannel surface EMG for the non-invasive assessment of the anal sphincter muscle. Digestion. 2004;69(2):112–22.
66. Preston DM, Lennard-Jones JE. Anismus in chronic constipation. Dig Dis Sci. 1985;30(5):413–8.
67. Jorge JM, Wexner SD, Ger GC, Salanga VD, Nogueras JJ, Jagelman DG. Cinedefecography and electromyography in the diagnosis of nonrelaxing puborectalis syndrome. Dis Colon Rectum. 1993;36(7):668–76.
68. Jones PN, Lubowski DZ, Swash M, Henry MM. Is paradoxical contraction of puborectalis muscle of functional importance? Dis Colon Rectum. 1987;30(9):667–70.
69. Womack NR, Williams NS, Holmfield JH, Morrison JF, Simpkins KC. New method for the dynamic assessment of anorectal function in constipation. Br J Surg. 1985;72(12):994–8.
70. Suzuki H, Matsumoto K, Amano S, Fujioka M, Honzumi M. Anorectal pressure and rectal compliance after low anterior resection. Br J Surg. 1980;67(9):655–7.
71. Varma JS, Smith AN, Busuttil A. Correlation of clinical and manometric abnormalities of rectal function following chronic radiation injury. Br J Surg. 1985;72(11):875–8.
72. Suzuki H, Fujioka M. Rectal pressure and rectal compliance in ulcerative colitis. Jpn J Surg. 1982;12(1):79–81.
73. Bregendahl S, Emmertsen KJ, Lous J, Laurberg S. Bowel dysfunction after low anterior resection with and without neoadjuvant therapy for rectal cancer: a population-based cross-sectional study. Color Dis. 2013;15(9):1130–9.
74. Emmertsen KJ, Laurberg S. Low anterior resection syndrome score: development and validation of a symptom-based scoring system for bowel dysfunction after low anterior resection for rectal cancer. Ann Surg. 2012;255(5):922–8.
75. Bajwa A, Thiruppathy K, Emmanuel A. The utility of conditioning sequences in barostat protocols for the measurement of rectal compliance. Color Dis. 2013;15(6):715–8.
76. Felt-Bersma RJ, Sloots CE, Poen AC, Cuesta MA, Meuwissen SG. Rectal compliance as a routine measurement: extreme volumes have direct clinical impact and normal volumes exclude rectum as a problem. Dis Colon Rectum. 2000;43(12):1732–8.
77. Rasmussen OO, Ronholt C, Alstrup N, Christiansen J. Anorectal pressure gradient and rectal compliance in fecal incontinence. Int J Color Dis. 1998;13(4):157–9.

78. Fox M, Thumshirn M, Fried M, Schwizer W. Barostat measurement of rectal compliance and capacity. Dis Colon Rectum. 2006;49(3):360–70.
79. Krogh K, Ryhammer AM, Lundby L, Gregersen H, Laurberg TS. Comparison of methods used for measurement of rectal compliance. Dis Colon Rectum. 2001;44(2):199–206.
80. Madoff RD, Orrom WJ, Rothenberger DA, Goldberg SM. Rectal compliance: a critical reappraisal. Int J Color Dis. 1990;5(1):37–40.
81. Awad RA, Camacho S, Flores F, Altamirano E, Garcia MA. Rectal tone and compliance affected in patients with fecal incontinence after fistulotomy. World J Gastroenterol. 2015;21(13):4000–5.
82. Gang Y. What is the desirable stimulus to induce the rectoanal inhibitory reflex? Dis Colon Rectum. 1995;38(1):60–3.
83. Yin S, Zhao K. Research progress of rectoanal inhibitory reflex. Zhonghua Wei Chang Wai Ke Za Zhi. 2015;18(12):1284–7.
84. de Lorijn F, de Jonge WJ, Wedel T, Vanderwinden JM, Benninga MA, Boeckxstaens GE. Interstitial cells of Cajal are involved in the afferent limb of the rectoanal inhibitory reflex. Gut. 2005;54(8):1107–13.
85. Rattan S, Sarkar A, Chakder S. Nitric oxide pathway in rectoanal inhibitory reflex of opossum internal anal sphincter. Gastroenterology. 1992;103(1):43–50.
86. Zbar AP, Jonnalagadda R. Parameters of the rectoanal inhibitory reflex in different anorectal disorders. Dis Colon Rectum. 2003;46(4):557. author reply -8.
87. Carmona JA, Ortiz H, Perez-Cabanas I. Alterations in anorectal function after anterior resection for cancer of the rectum. Int J Color Dis. 1991;6(2):108–10.
88. Bozkurt MA, Kocatas A, Surek A, Kankaya B, Kalayci MU, Alis H. The importance of defecography in the assessment of the etiology of chronic constipation: an analysis of 630 patients. Ulus Cerrahi Derg. 2014;30(4):183–5.
89. Peznanski AK. The use of a semisolid contrast medium in a defecography. Radiology. 1970;97(1):82.
90. Ikenberry S, Lappas JC, Hana MP, Rex DK. Defecography in healthy subjects: comparison of three contrast media. Radiology. 1996;201(1):233–8.
91. Goei R. Defecography: principles of technique and interpretation. Radiologe. 1993;33(6):356–60.
92. Altringer WE, Saclarides TJ, Dominguez JM, Brubaker LT, Smith CS. Four-contrast defecography: pelvic "floor-oscopy". Dis Colon Rectum. 1995;38(7):695–9.
93. Saclarides TJ, Brubaker LT, Altringer WE, Smith CS, Dominguez JM. Clarifying the technique of four-contrast defecography. Dis Colon Rectum. 1996;39(7):826.
94. Bremmer S, Mellgren A, Holmstrom B, Lopez A, Uden R. Peritoneocele: visualization with defecography and peritoneography performed simultaneously. Radiology. 1997;202(2):373–7.
95. Bremmer S, Ahlback SO, Uden R, Mellgren A. Simultaneous defecography and peritoneography in defecation disorders. Dis Colon Rectum. 1995;38(9):969–73.
96. Faccioli N, Comai A, Mainardi P, Perandini S, Moore F, Pozzi-Mucelli R. Defecography: a practical approach. Diagn Interv Radiol. 2010;16(3):209–16.
97. Low VH, Ho LM, Freed KS. Vaginal opacification during defecography: direction of vaginal migration aids in diagnosis of pelvic floor pathology. Abdom Imaging. 1999;24(6):565–8.
98. Ho LM, Low VH, Freed KS. Vaginal opacification during defecography: utility of placing a folded gauze square at the introitus. Abdom Imaging. 1999;24(6):562–4.
99. Kim AY. How to interpret a functional or motility test—defecography. J Neurogastroenterol Motil. 2011;17(4):416–20.
100. Brennan D, Williams G, Kruskal J. Practical performance of defecography for the evaluation of constipation and incontinence. Semin Ultrasound CT MR. 2008;29(6):420–6.
101. Mellgren A, Bremmer S, Johansson C, Dolk A, Uden R, Ahlback SO, et al. Defecography. Results of investigations in 2,816 patients. Dis Colon Rectum. 1994;37(11):1133–41.
102. Poon FW, Lauder JC, Finlay IG. Technical report: evacuating proctography—a simplified technique. Clin Radiol. 1991;44(2):113–6.
103. Mellgren A, Bremmer S. Defecography and its clinical significance. Increased use of an "old" technique. Lakartidningen. 1995;92(47):4416–21.
104. Jorge JM, Ger GC, Gonzalez L, Wexner SD. Patient position during cinedefecography. Influence on perineal descent and other measurements. Dis Colon Rectum. 1994;37(9):927–31.
105. Henry MM, Parks AG, Swash M. The pelvic floor musculature in the descending perineum syndrome. Br J Surg. 1982;69(8):470–2.
106. Parks AG, Porter NH, Hardcastle J. The syndrome of the descending perineum. Proc R Soc Med. 1966;59(6):477–82.
107. Shorvon PJ, McHugh S, Diamant NE, Somers S, Stevenson GW. Defecography in normal volunteers: results and implications. Gut. 1989;30(12):1737–49.
108. Chen HH, Iroatulam A, Alabaz O, Weiss EG, Nogueras JJ, Wexner SD. Associations of defecography and physiologic findings in male patients with rectocele. Tech Coloproctol. 2001;5(3):157–61.
109. Delemarre JB, Kruyt RH, Doornbos J, Buyze-Westerweel M, Trimbos JB, Hermans J, et al. Anterior rectocele: assessment with radiographic defecography, dynamic magnetic resonance imaging, and physical examination. Dis Colon Rectum. 1994;37(3):249–59.
110. Kaiser A, Buchmann P, Bruhlmann W. The value of defecography for diagnosis of rectocele and rectal prolapse. Helv Chir Acta. 1994;60(5):697–700.
111. Piloni V, Pomerri F, Platania E, Pieri L, Pinto F, Gasparini G, et al. The National Workshop on

Defecography: anorectal deformities with a functional origin (prolapse, intussusception, rectocele). Radiol Med. 1994;87(6):789–95.
112. Soares FA, Regadas FS, Murad-Regadas SM, Rodrigues LV, Silva FR, Escalante RD, et al. Role of age, bowel function and parity on anorectocele pathogenesis according to cinedefecography and anal manometry evaluation. Color Dis. 2009;11(9):947–50.
113. van Dam JH, Ginai AZ, Gosselink MJ, Huisman WM, Bonjer HJ, Hop WC, et al. Role of defecography in predicting clinical outcome of rectocele repair. Dis Colon Rectum. 1997;40(2):201–7.
114. Thapar RB, Patankar RV, Kamat RD, Thapar RR, Chemburkar V. MR defecography for obstructed defecation syndrome. Indian J Radiol Imaging. 2015;25(1):25–30.
115. Reginelli A, Di Grezia G, Gatta G, Iacobellis F, Rossi C, Giganti M, et al. Role of conventional radiology and MRi defecography of pelvic floor hernias. BMC Surg. 2013;13(Suppl 2):S53.
116. Piloni V, Tosi P, Vernelli M. MR-defecography in obstructed defecation syndrome (ODS): technique, diagnostic criteria and grading. Tech Coloproctol. 2013;17(5):501–10.
117. Cappabianca S, Reginelli A, Iacobellis F, Granata V, Urciuoli L, Alabiso ME, et al. Dynamic MRI defecography vs. entero-colpo-cysto-defecography in the evaluation of midline pelvic floor hernias in female pelvic floor disorders. Int J Color Dis. 2011;26(9):1191–6.
118. Mortele KJ, Fairhurst J. Dynamic MR defecography of the posterior compartment: indications, techniques and MRI features. Eur J Radiol. 2007;61(3):462–72.
119. Hetzer FH, Andreisek G, Tsagari C, Sahrbacher U, Weishaupt D. MR defecography in patients with fecal incontinence: imaging findings and their effect on surgical management. Radiology. 2006;240(2):449–57.
120. Roos JE, Weishaupt D, Wildermuth S, Willmann JK, Marincek B, Hilfiker PR. Experience of 4 years with open MR defecography: pictorial review of anorectal anatomy and disease. Radiographics. 2002;22(4):817–32.
121. Paetzel C, Strotzer M, Furst A, Rentsch M, Lenhart M, Feuerbach S. Dynamic MR defecography for diagnosis of combined functional disorders of the pelvic floor in proctology. Rofo. 2001;173(5):410–5.
122. Hilfiker PR, Debatin JF, Schwizer W, Schoenenberger AW, Fried M, Marincek B. MR defecography: depiction of anorectal anatomy and pathology. J Comput Assist Tomogr. 1998;22(5):749–55.
123. Vitton V, Vignally P, Barthet M, Cohen V, Durieux O, Bouvier M, et al. Dynamic anal endosonography and MRI defecography in diagnosis of pelvic floor disorders: comparison with conventional defecography. Dis Colon Rectum. 2011;54(11):1398–404.
124. Pradal-Prat D, Mares P, Peray P, Lopez S, Gagnard-Landra C. Pudendal nerve motor latency correlation by age and sex. Electromyogr Clin Neurophysiol. 1998;38(8):491–6.
125. Laurberg S, Swash M. Effects of aging on the anorectal sphincters and their innervation. Dis Colon Rectum. 1989;32(9):737–42.
126. Vernava AM 3rd, Longo WE, Daniel GL. Pudendal neuropathy and the importance of EMG evaluation of fecal incontinence. Dis Colon Rectum. 1993;36(1):23–7.
127. Vaccaro CA, Cheong DM, Wexner SD, Nogueras JJ, Salanga VD, Hanson MR, et al. Pudendal neuropathy in evacuatory disorders. Dis Colon Rectum. 1995;38(2):166–71.
128. Loganathan A, Schloithe AC, Hakendorf P, Liyanage CM, Costa M, Wattchow D. Prolonged pudendal nerve terminal motor latency is associated with decreased resting and squeeze pressures in the intact anal sphincter. Color Dis. 2013;15(11):1410–5.
129. Suilleabhain CB, Horgan AF, McEnroe L, Poon FW, Anderson JH, Finlay IG, et al. The relationship of pudendal nerve terminal motor latency to squeeze pressure in patients with idiopathic fecal incontinence. Dis Colon Rectum. 2001;44(5):666–71.
130. Chen AS, Luchtefeld MA, Senagore AJ, Mackeigan JM, Hoyt C. Pudendal nerve latency. Does it predict outcome of anal sphincter repair? Dis Colon Rectum. 1998;41(8):1005–9.
131. Vaccaro CA, Cheong DM, Wexner SD, Salanga VD, Phillips RC, Hanson MR. Role of pudendal nerve terminal motor latency assessment in constipated patients. Dis Colon Rectum. 1994;37(12):1250–4.
132. Lubowski DZ, Swash M, Nicholls RJ, Henry MM. Increase in pudendal nerve terminal motor latency with defaecation straining. Br J Surg. 1988;75(11):1095–7.
133. Rakas P, Liapis A, Karandreas A, Creatsas G. Pudendal nerve terminal motor latency in women with genuine stress incontinence and prolapse. Gynecol Obstet Investig. 2001;51(3):187–90.
134. Pfeifer J, Salanga VD, Agachan F, Weiss EG, Wexner SD. Variation in pudendal nerve terminal motor latency according to disease. Dis Colon Rectum. 1997;40(1):79–83.
135. Birnbaum EH, Stamm L, Rafferty JF, Fry RD, Kodner IJ, Fleshman JW. Pudendal nerve terminal motor latency influences surgical outcome in treatment of rectal prolapse. Dis Colon Rectum. 1996;39(11):1215–21.
136. Tomita R, Igarashi S, Ikeda T, Koshinaga T, Fujisaki S, Tanjoh K. Pudendal nerve terminal motor latency in patients with or without soiling 5 years or more after low anterior resection for lower rectal cancer. World J Surg. 2007;31(2):403–8.
137. Matsuoka H, Masaki T, Sugiyama M, Atomi Y. Pudendal nerve terminal motor latency in evaluation of evacuatory disorder following low anterior resection for rectal carcinoma. Hepato-Gastroenterology. 2007;54(77):1426–9.
138. Lim JF, Tjandra JJ, Hiscock R, Chao MW, Gibbs P. Preoperative chemoradiation for rectal cancer

causes prolonged pudendal nerve terminal motor latency. Dis Colon Rectum. 2006;49(1):12–9.
139. Snooks SJ, Setchell M, Swash M, Henry MM. Injury to innervation of pelvic floor sphincter musculature in childbirth. Lancet. 1984;2(8402):546–50.
140. Wexner SD, Marchetti F, Salanga VD, Corredor C, Jagelman DG. Neurophysiologic assessment of the anal sphincters. Dis Colon Rectum. 1991;34(7):606–12.
141. Lefaucheur J, Yiou R, Thomas C. Pudendal nerve terminal motor latency: age effects and technical considerations. Clin Neurophysiol. 2001;112(3):472–6.
142. Tam PK. Hirschsprung's disease: a bridge for science and surgery. J Pediatr Surg. 2016;51(1):18–22.
143. Zuelzer WW, Wilson JL. Functional intestinal obstruction on a congenital neurogenic basis in infancy. Am J Dis Child. 1948;75(1):40–64.
144. Whitehouse FR, Kernohan JW. Myenteric plexus in congenital megacolon; study of 11 cases. Arch Intern Med (Chic). 1948;82(1):75–111.
145. Tang YF, Chen JG, An HJ, Jin P, Yang L, Dai ZF, et al. High-resolution anorectal manometry in newborns: normative values and diagnostic utility in Hirschsprung disease. Neurogastroenterol Motil. 2014;26(11):1565–72.
146. Martellucci J. Low anterior resection syndrome: a treatment algorithm. Dis Colon Rectum. 2016;59(1):79–82.
147. Carrillo A, Enriquez-Navascues JM, Rodriguez A, Placer C, Mugica JA, Saralegui Y, et al. Incidence and characterization of the anterior resection syndrome through the use of the LARS scale (low anterior resection score). Cir Esp. 2016;94(3):137–43.
148. Hou XT, Pang D, Lu Q, Yang P, Jin SL, Zhou YJ, et al. Validation of the Chinese version of the low anterior resection syndrome score for measuring bowel dysfunction after sphincter-preserving surgery among rectal cancer patients. Eur J Oncol Nurs. 2015;19(5):495–501.
149. Samalavicius NE, Dulskas A, Lasinskas M, Smailyte G. Validity and reliability of a Lithuanian version of low anterior resection syndrome score. Tech Coloproctol. 2016;20:215–20.
150. O'Riordain MG, Molloy RG, Gillen P, Horgan A, Kirwan WO. Rectoanal inhibitory reflex following low stapled anterior resection of the rectum. Dis Colon Rectum. 1992;35(9):874–8.
151. Bleier JI, Maykel JA. Outcomes following proctectomy. Surg Clin North Am. 2013;93(1):89–106.
152. Podzemny V, Pescatori LC, Pescatori M. Management of obstructed defecation. World J Gastroenterol. 2015;21(4):1053–60.
153. Mathers SE, Kempster PA, Swash M, Lees AJ. Constipation and paradoxical puborectalis contraction in anismus and Parkinson's disease: a dystonic phenomenon? J Neurol Neurosurg Psychiatry. 1988;51(12):1503–7.
154. Kuijpers HC, Bleijenberg G. The spastic pelvic floor syndrome. A cause of constipation. Dis Colon Rectum. 1985;28(9):669–72.
155. Kuijpers HC, Bleijenberg G, de Morree H. The spastic pelvic floor syndrome. Large bowel outlet obstruction caused by pelvic floor dysfunction: a radiological study. Int J Color Dis. 1986;1(1):44–8.
156. MacDonald A, Shearer M, Paterson PJ, Finlay IG. Relationship between outlet obstruction constipation and obstructed urinary flow. Br J Surg. 1991;78(6):693–5.
157. Heymen S, Wexner SD, Gulledge AD. MMPI assessment of patients with functional bowel disorders. Dis Colon Rectum. 1993;36(6):593–6.
158. Sullivan ES, Leaverton GH, Hardwick CE. Transrectal perineal repair: an adjunct to improved function after anorectal surgery. Dis Colon Rectum. 1968;11(2):106–14.
159. Khubchandani IT, Sheets JA, Stasik JJ, Hakki AR. Endorectal repair of rectocele. Dis Colon Rectum. 1983;26(12):792–6.
160. Sehapayak S. Transrectal repair of rectocele: an extended armamentarium of colorectal surgeons. A report of 355 cases. Dis Colon Rectum. 1985;28(6):422–33.
161. Picirillo MTT, Yoon K, Patino Paul R, Lucas J, Wexner S. Rectoceles: the incidence and clinical significance. Tech Coloproctol. 1996;2:75–9.
162. Block IR. Transrectal repair of rectocele using obliterative suture. Dis Colon Rectum. 1986;29(11):707–11.
163. Karasick S, Karasick D, Karasick SR. Functional disorders of the anus and rectum: findings on defecography. AJR Am J Roentgenol. 1993;160(4):777–82.
164. Siproudhis L, Ropert A, Lucas J, Raoul JL, Heresbach D, Bretagne JF, et al. Defecatory disorders, anorectal and pelvic floor dysfunction: a polygamy? Radiologic and manometric studies in 41 patients. Int J Color Dis. 1992;7(2):102–7.
165. Karlbom U, Graf W, Nilsson S, Pahlman L. Does surgical repair of a rectocele improve rectal emptying? Dis Colon Rectum. 1996;39(11):1296–302.
166. Hawksworth W, Roux JP. Vaginal hysterectomy. J Obstet Gynaecol Br Emp. 1958;65(2):214–28.
167. Jorge JM, Yang YK, Wexner SD. Incidence and clinical significance of sigmoidoceles as determined by a new classification system. Dis Colon Rectum. 1994;37(11):1112–7.
168. Jorge JM, Wexner SD, Ehrenpreis ED, Nogueras JJ, Jagelman DG. Does perineal descent correlate with pudendal neuropathy? Dis Colon Rectum. 1993;36(5):475–83.
169. Barisic GI, Krivokapic ZV, Markovic VA, Popovic MA. Outcome of overlapping anal sphincter repair after 3 months and after a mean of 80 months. Int J Color Dis. 2006;21(1):52–6.
170. Gilliland R, Altomare DF, Moreira H Jr, Oliveira L, Gilliland JE, Wexner SD. Pudendal neuropathy is predictive of failure following anterior overlapping sphincteroplasty. Dis Colon Rectum. 1998;41(12):1516–22.
171. Londono-Schimmer EE, Garcia-Duperly R, Nicholls RJ, Ritchie JK, Hawley PR, Thomson

JP. Overlapping anal sphincter repair for faecal incontinence due to sphincter trauma: five year follow-up functional results. Int J Color Dis. 1994;9(2):110–3.
172. Bravo Gutierrez A, Madoff RD, Lowry AC, Parker SC, Buie WD, Baxter NN. Long-term results of anterior sphincteroplasty. Dis Colon Rectum. 2004;47(5):727–31. discussion 31–2
173. Karoui S, Leroi AM, Koning E, Menard JF, Michot F, Denis P. Results of sphincteroplasty in 86 patients with anal incontinence. Dis Colon Rectum. 2000;43(6):813–20.
174. Malouf AJ, Norton CS, Engel AF, Nicholls RJ, Kamm MA. Long-term results of overlapping anterior anal-sphincter repair for obstetric trauma. Lancet. 2000;355(9200):260–5.
175. Ratto C, Litta F, Parello A, Donisi L, De Simone V, Zaccone G. Sacral nerve stimulation in faecal incontinence associated with an anal sphincter lesion: a systematic review. Color Dis. 2012;14(6):e297–304.
176. Johnson BL 3rd, Abodeely A, Ferguson MA, Davis BR, Rafferty JF, Paquette IM. Is sacral neuromodulation here to stay? Clinical outcomes of a new treatment for fecal incontinence. J Gastrointest Surg. 2015;19(1):15–9. discussion 9–20.
177. Hull T, Giese C, Wexner SD, Mellgren A, Devroede G, Madoff RD, et al. Long-term durability of sacral nerve stimulation therapy for chronic fecal incontinence. Dis Colon Rectum. 2013;56(2):234–45.
178. Quezada Y, Whiteside JL, Rice T, Karram M, Rafferty JF, Paquette IM. Does preoperative anal physiology testing or ultrasonography predict clinical outcome with sacral neuromodulation for fecal incontinence? Int Urogynecol J. 2015;26(11):1613–7.
179. Brouwer R, Duthie G. Sacral nerve neuromodulation is effective treatment for fecal incontinence in the presence of a sphincter defect, pudendal neuropathy, or previous sphincter repair. Dis Colon Rectum. 2010;53(3):273–8.