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Evaluation of Functional Studies on Anorectal Diseases

INTRODUCTION

Despite the high prevalence of their symptoms in general population, particularly constipation and anal incontinence, functional disorders in coloproctology are still challenging due to a multitude of reasons. Firstly, definitions vary among patients and professionals, which partly explains the tremendous differences among epidemiological studies and clinical trials.[1] Secondly, their etiology is multifactorial and complex, including not only anatomical and functional, but also dietary, psychological and cultural factors, which are more pronounced in constipation. Thirdly, this symptom is still surrounded by misbelief and taboos, which hamper an objective evaluation and determine self-medication, not always innocuous to the patient. Finally, the patient may either be labeled as having a psychiatric disorder or undergo more aggressive medicamentous therapy by the physician without previous physiologic investigation. Although less prevalent in general population compared to constipation, anal incontinence is an under-reported and unvoiced condition.[2] Furthermore, etiology may include failure of one or more mechanisms, including stool consistency and delivery of colonic contents to the rectum, rectal capacity and compliance, anorectal sensation, the function of the anal sphincter mechanism and the pelvic floor muscles and nerves.[3]

The interest in colorectal physiology is ancient and some studies have their primordials ranging from several decades to a century ago.[4-6] However, only recently they were improved, standardized and incorporated to practice.[7] Physiologic studies opposed to anatomic studies, such as endoscopic methods, probably require more accurate technology and more intense research in order to reproduce normal physiologic conditions, necessary for the evaluations. Through the widespread propagation and routine use of these studies, potentially disabling and highly prevalent disorders such as fecal incontinence and chronic idiopathic constipation can be stratified into diverse causative diagnoses with distinctive therapeutic approaches. On the other hand, physiology testing is time consuming, costly, and demands judicious interpretation, since secondary findings can be misleading. Therefore patients must undergo clinical evaluation before being referred to the physiologic investigation.

Exclusion of both intestinal and systemic organic etiologies is an imperative step prior to referring the patient with functional symptoms to the physiology laboratory. Barium enema and/or colonoscopy are usually indicated, and the primary pathology treated. Additional tests are dictated by history and physical examination. Additionally, a therapeutic schema is introduced, which includes dietary assessment, a diary of defecation and symptoms and, when indicated, psychological evaluation. In constipated patients, supplemental fiber, increased fluid intake and physical activity are helpful measures. This initial therapy will permit better evaluation of the severity of the symptom. Furthermore, symptoms may even improve, if they are dietary or psychologically related. Therefore, patients referred for colorectal physiologic testing present with refractory and severe idiopathic symptoms. In order to adequately evaluate the different factors involved, an association of physiologic studies may be required, including colonic transit time study, anorectal manometry, electromyography and pudendal nerve latency, and defecography.[8]

COLONIC TRANSIT TIMES

Patient complaints of stool frequency are subjective, thus an objective method for measuring colonic transit time is desirable to evaluate patients with chronic and "idiopathic" symptoms of constipation and diarrhea. Since the colon accounts for approximately 90% of the total digestive transit time, colonic transit time has been primarily evaluated as the total digestive transit through the elimination of markers in the feces. Since 1907, several types of markers have been proposed; these methods can be classified as: radiological (barium sulphate), colorimetric (carmine, charcoal),[9] particulate (seeds, colored glass beads),[10] chemical (copper thiocyanate)[11] and isotopic.[12] These methods, however, have been abandoned due to lack of practicity, difficulty in interpretation, or inaccuracy. In 1969, Hinton[13] proposed a marker that was atoxic, able to follow the intraluminal contents without affecting the intestinal transit, and easy to quantificate, making it ideal for colonic transit time. These markers were prepared by cutting radiopaque Levine tubes in circular or cylindrical shapes. More recently, markers have become commercially available, enclosed in gelatine capsules, which ensure simultaneous arrival of all markers into the gastric lumen. The simplest and most practical method of evaluating colonic transit requires ingestion of 24 radiopaque markers and quantification of these markers on abdominal radiographs. Normal total intestinal transit time involves elimination of at least 80% of markers on the fifth day of study.[13]

Subsequently, segmental colonic transit time study was proposed as the ideal assessment of colonic transit.[14] Rather than measuring the elimination or clearence of markers, the index of transit time of this method was the actual number of retained markers on each colonic segment. The spinal processes and imaginary lines from the fifth lumbar vertebra to the pelvic outlet have been used to recognize the three segments of the large bowel (right colon, left colon and rectosigmoid) on the radiographs. The classical technique of measuring segmental transit time consisted of a single ingestion of 24 markers followed by serial radiographs taken at 24-hour intervals until total elimination of markers occurred. When using 24 markers, the sum of the retained markers in each colonic segment on the successive radiographs represents the value, in hours, for each segmental transit time. In order to reduce irradiation exposure and achieve more practicality, subsequent technical modifications included multiple ingestion of markers, rather than multiple radiographs and the use of markers of different shapes.

The rationale behind segmental colonic transit time study is that embryological, anatomical and functional differences exist among the right colon, left colon and rectosigmoid. Therefore, all three segments may be affected independently in motility disorders. In fact, with the advent of this method of study, the motility patterns of colonic inertia, outlet obstruction and left colon delay could be demonstrated.[15] However, although proven useful, the value of this assessment remains a controversial issue. Accurate assessment of segmental transit times still involves either multiple ingestion of markers or multiple abdominal radiographs.

For practicality, however, the technique involving two radiographs, taken on days 3 and 5 after a single day ingestion of 24 radiopaque markers, may suffice. Prior to testing, a digital examination and, if necessary, a simple abdominal radiograph are indicated to ensure that the colon is cleared of any contrast material from previous studies and that there is no fecal impaction in the rectum. The use of enemas, laxatives, or any other medication known to affect gastrintestinal motility should be discontinued for 3 days prior to ingestion of the markers until completion of the study. Markers should be taken at a specified time, usually at 8 am. Patients are oriented to maintain their normal diet, however supplemental fiber such as bran or psyllium can be helpful to exclude dietary causes. The use of a diary of bowel frequency and related symptoms during the period of the study is also helpful, as symptoms can be better evaluated; the study may be repeated if the patient reports that the frequency during the study is not representative of his usual bowel habits. The abdominal radiograph should include the diaphragm and the pubis to yield identification of all markers in the colon.

In normal individuals, markers reach the cecum within 8 hours after their ingestion. The mean and maximal values for normal individuals for the total colonic transit time are 36 and 55 hours, respectively.[16] The mean segmental transit times are 12, 14 and 11 hours for right colon, left colon and rectosigmoid, respectively; the maximal values for the segmental transit times are 22, 34 and 27 hours for right colon, left colon and rectosigmoid, respectively. The mean value of normal total colonic transit time is about 32 hours for men and 41 hours for women. This difference is even greater when the right colon transit time is analyzed separately. Age, however, does not seem to affect total colonic transit times. In children, although the rectosigmoid transit time is more prolonged, the total colonic transit time is similar to the adult, probably due to the proportional reduction of segmental transit times for the right and left colons.[14]

Several factors including diet, physical activity and psychologic and hormonal factors may affect digestive transit time results, therefore significant variation is expected. However, segmental colonic transit time study using radiopaque markers has proven reproducible when analyzed in the same individual within a mean interval of 3 months.[17] When colonic transit times are evaluated using two different methods, specifically single ingestion and multiple ingestion of markers, the mean difference between the two measurements are 2.1 hours, 0.34 hours, and 1.54 hours for the right colon, left colon and rectosigmoid, respectively.[18]

Colonic transit time assessment is especially indicated in the evaluation of patients with chronic idiopathic constipation. Colonic transit time assessment provides a definition for constipation by converting an otherwise hopelessly subjective symptom to an objective part of the medical record. Therefore, its most important role lies in excluding factitious constipation. Additionally, segmental transit times can help to uncover causative diagnoses, by stratifying motility disorders into two main patterns: colonic inertia and outlet obstruction.

Colonic inertia is characterized by diffuse stasis of markers throughout the colon, usually more markedly in the right colon. This condition typically affects young women as a severe and incapacitating symptom.[19] The etiopathogeny of colonic inertia remains unclear. Lesions of the myenteric plexus have been demonstrated in patients with colonic inertia;[20] these lesions can be either primary or related to chronic use of laxatives.[21] Colonic inertia can be also associated with other symptoms of visceral stasis, and a hypothesis of a systemic disorder has been proposed.[22] Its treatment, however has been less controversial; total colectomy with ileorectal anastomosis may alleviate symptoms in 80-96% of cases, yet careful patient selection is mandatory.[23] Selection criteria include reassessment of severity of symptoms (history, transit times and response to trials of therapy with laxatives and prokinetics), exclusion of small bowel dysmotility (lactulose, H2 breath test) and exclusion of pelvic floor dysfunction· If dyspeptic symptoms such as nausea, vomiting, heartburn and bloating are present, gastric emptying studies are indicated in order to exclude a generalized gastrintestinal stasis.[24]

Outlet obstruction is characterized when the stasis of markers is limited to the rectosigmoid. In this condition, the association of other tests, particularly cinedefecography, anorectal manometry and anal electromyography are of paramount importance to diagnose the causative disorder. A third abnormal pattern found during segmental colonic transit time assessment is the isolated delay of markers in the left colon. However, this pattern is of uncertain physiopathology and usually representative of patients with less severe and dietary related symptoms.

ANORECTAL MANOMETRY

Anorectal manometry is an objective method of study of the physiologic apparatus of defecation provided by the anorectal sphincter mechanism. The cumbersome aspect related to anorectal manometry is the lack of uniformity, since there is no accepted standardized method of performing or interpreting this test. Basically the apparatus includes two major components: an intra-anal or intrarectal pressure sensing device such as a microballoon, a microtransducer or a water perfused catheter, and a recording system such as a polygraph or a computer. The most important advantage that perfused catheters offer when compared to balloon manometry, is that multiple channels, usually 4 - 8 channels with radially distributed orifices, can be set on a single catheter. Microtransducers can be incorporated directly into the probe to eliminate the need for perfusion systems and allow ambulatory measurement. Although still expensive and fragile, microtransducers may have a promising future.

The most commonly used sensing devices are soft plastic multichannel water-perfused catheters. The principle of this technique is based on the measurement of the resistance in terms of pressure that the sphincters offer to a constant flow of water, usually 0.3 cc/channel/minute, through the port. These orifices can be displayed in either a radial or in a stepwise fashion. The technique of manometric measurement also varies. The catheter can be left at one position (stationary pull-through technique) or can be continuously and automatically withdrawn (continuous or automated pull-through technique). The continuous pull-through techniques provide a longitudinal profile, which is important because of the considerable variation in pressures along the axis of the anal sphincter. Theoretically, the stationary pull through provides a more accurate pressure at a single point, since a stabilization period is obtained before each interval recording.

The mean anal canal **resting pressure** in healthy subjects is generally in the range of 50-70 mmHg and is lower in women and in the elderly.[25] There is a graduated increase in pressure from proximal to distal in the anal canal. The highest resting pressures are generally recorded from 1-2 cm cephalad to the anal verge, which corresponds anatomically to the condensation of the smooth muscle fibers of the IAS. Accordingly, Lestar et al.[26] analyzed the components of the maximal resting tone and found that 55-60% is determined by the IAS, 45% being nerve induced activity and 15% purely myogenic IAS activity. The IAS is a smooth muscle in a state of continuous maximum contraction or "tone" which represents a natural barrier to the involuntary loss of stool from the rectum. The striated sphincter tonic activity (EAS) plays relatively little part in the resting tone (25-30%).[27] EAS tone, mediated by a low sacral reflex, is maintained during the day and is significantly reduced, but still present during sleep.[28] The remaining 15% of maximal resting tone is attributed to the expansion of the anal cushions (hemorrhoidal plexus), which although more difficult to be comprehensively studied seem to be essential for perfect anal continence.[29]

Squeeze pressure is generated primarily by contraction of the EAS and the puborectalis muscle. During maximal squeeze efforts, intra-anal pressures usually reach two or three times their baseline resting value (100-180 mmHg). However, maximal voluntary contraction can be maintained only for a short time, approximately 50 seconds, because the EAS rapidly fatigues. Unlike the IAS, which accounts for the continuous state of continence, the EAS, although also tonically active, more likely acts only sporadically to prevent leaking. Furthermore, these voluntary muscles undergo reflex contraction in response to rectal distension, increased abdominal pressure and alteration in posture. This automatic mechanism enables prevention of leakage during activities such as coughing.[30] The rate of fatigue, defined as the change in stationary squeeze over a 40 second period of voluntary contraction, and, more recently, the **fatigue rate index**, defined as a calculated measure of time necessary for the external sphincter to become completely fatigued, have been proposed as additional measurements of the external anal sphincter function.[31,32] Compared to volunteers (3.3 minutes) and patients with seepage (2,3 minutes), incontinent patients have shown a significantly shorter fatigue rate index (1,5 minutes).[32]

The **high pressure zone** or **functional anal canal length** can be defined as that length of the IAS through which pressures are greater than half of the maximum pressure at rest. Alternatively, the high pressure zone can be defined by its cephalad aspect. This aspect is recognized by a decrease in pressures to below 20 mmHg in at least 50% of the circumference of the anal canal.[33] The length of the high pressure zone is generally about 2.0-3.0 cm in females and 2.5-3.5 cm in males.[33]

The automated pull-through of a multi-channel catheter, may provide more detailed recording of the radial and longitudinal pressure profiles. The vector diagrams of these profiles can be plotted together. A computer can then generate a three dimensional representation of the entire pressure profile of the anal canal profiles, which may provide more accurate identification of surgically reparable defects in cases of sphincter injuries.[34] The anal ultrasound is probably more accurate to visually demonstrate the defect, however the **sphincter asymmetry index** analysis has been demonstrated to correlate accurately with sphincteric trauma.[34,35] The anal sphincter has a normal degree of asymmetry, usually up to 10%, related to the inherent anatomic asymmetric configuration of its components.[35] Control values of 7.2% ± 2.3 are not significantly different from patients with incontinence without history of trauma (10,3% ± 4,9). These values, however, were significantly different from those obtained in patients with possible traumatic etiology (19,0% ± 10,6) and patients in whom a previous traumatic etiology was directly related to the onset of symptoms (23,6%±14,0). Additionally, the accuracy of the sphincter asymmetry index is not affected by dramatic reduction of pressure in patients with sever incontinence, and can be of value to discriminate traumatic etiology.[35]

In normal subjects, a small amount of rectal distension will cause transient EAS contraction followed by pronounced IAS relaxation. The **RAIR** is normally evoked with as little as 10-30 ml distension of the rectum, and the response is usually maximal at 40-60 ml. This reflex, first described by Gowers in 1887,[4] is thought to enable rectal contents to “be sampled” by the sensory area of the anal canal. By providing accurate distinction between flatus and feces, this sampling mechanism accounts for the fine adjustment in anal incontinence.[36,37] Patients with Hirschsprung’s disease, Chagas’s disease, dermatomyositis and scleroderma all have abnormal RAIR’s. Failure of the reflex to occur at any volume is strong evidence of Hirschsprung’s disease.[38] In Chagas’s disease, an endemic infection caused by destruction of the autonomic enteric nervous plexuses by the *Trypanosoma cruzi*, the IAS relaxation is also absent, and instead, a rectal contraction is occasionally observed.[39] Patients with dermatomyositis have normal IAS relaxation but no EAS contraction, whereas the scleroderma group has no IAS relaxation but normal EAS contraction.

Rectal sensation is generally achieved at between 10-30 cc of air, which can be introduced into an intrarectal balloon. The proprioceptor receptors are probably located in the levators, PR, and external and internal anal sphincter muscles. Abnormal or delayed conscious rectal sensation has been demonstrated to be the etiology of anal incontinence in approximately 28% of patients with this symptom.[40] In fact, different diseases, including neurological and endocrine disorders, may selectively reduce conscious sensation and awareness of rectal fullness even with intact autonomic pathways. This can result in either fecal impaction, fecal incontinence, or both.

Rectal capacity is usually measured by instillation of fluid into an intra-rectal balloon. Normal capacity usually ranges from 100-300 cc. Younger and constipated patients tend to have larger capacity rectums than do older and incontinent patients. Rectal contents must be accommodated if defecation is to be delayed. This deferral of the call to stool is possible through the mechanism of **rectal compliance**. The rectum has both viscous and elastic properties, which allow it to maintain a low intraluminal pressure while being filled, in order to not threaten continence. An overly compliant rectum, therefore, is one in which a tremendous difference in the two volumes results in a very small change in pressures. Conversely, a poorly compliant rectum, when confronted with a minimal change in volume, will generate a tremendous increase in pressure. Compliance appears to depend on an intact intrinsic nervous system and viable muscle, and like capacity, varies with age and underlying factors. The non-diseased rectum is highly compliant (2-6 cc $H_2 0$/mmHg) - it can accept a tremendous increase in volume with a very small change in pressure. On the other hand, rectal compliance is impaired in diseases such as ulcerative colitis, chronic rectal ischemia, radiation and Hirschsprung's disease.[41,42]

The actual advantage of manometric evaluation over a standard office examination has been the subject of several studies, however, it has been demonstrated that the sensitivity, specificity and predictive values of digital examination in estimating normal resting and squeeze pressures are less than optimal.[43] Physical examination is unquestionably a mandatory step in anorectal function investigation, however, manometry seems to be essential if more accurate and detailed assessment of anal pressures is desired.

Anorectal manometry is widely recognized as an important test for assessment of common conditions such as chronic constipation and fecal incontinence. Assessment of anal pressures permits the therapeutic decision to be reached from an objective basis. Moreover manometric evaluation can be used as a baseline for comparison with functional results after treatment. In patients who undergo sphincter repair, anorectal manometry provides objective physiologic evidence of improvement of continence.[44] Improvement of the HPZ in 57%, squeeze pressures in 71% and resting tone and resting tone in 79% has been correlated with good functional results.[45] In patients who undergo double stapled IAR objective evaluation of the functional outcome has been obtained by documenting the recovery of the anal pressures.[46,47]

There is no routine acceptance of anorectal manometry prior to colorectal or anorectal procedures. However, if available, this evaluation should be considered prior to any procedure in which fecal continence may be jeopardized. For instance, patients in whom a low colorectal, a coloanal, or an ileoanal anastomosis is being contemplated may benefit from manometry. Significantly higher resting and squeeze pressures have been demonstrated in patients with hemorrhoids or fissure, than in controls.[48] Hemorrhoidectomy, unlike band ligation, has been associated with decreased intra-anal pressures.[49-51] Other procedures such as sphincterotomy, manual dilatation (Lord's procedure) or unintentional damage with oversized retractors may result in temporary or permanent incontinence.[52-54]

ELECTROMYOGRAPHY

Anal electromyography is the recording of myoelectrical activity from the striated sphincter at rest, during voluntary and reflex contraction and simulated defecation. Electrical activity of contracting human muscle was first recorded by a string galvanometer in 1908 by Piper.[55] Electromyography, however, gained widespread use only after the advent of the concentric needle in 1929 by Adrian and Bronck.[56] In 1930, Beck[6] applied this test to record the striated anal sphincter activity. This study is especially valuable in assessing fecal incontinence and constipation due to paradoxical puborectalis contraction.

Electromyography can be performed using needle, wire or cutaneous patch electrodes. The concentric needle electromyography has achieved more widespread acceptance in North America than other techniques.[57] Patients are given a single disposable phosphate enema prior to the examination. They are then placed in the left lateral decubitus position with maximum flexion of the knees. A bipolar disposable concentric needle electrode Teca type DC75 (Teca, Pleasantville, NY) is used for testing. This electrode has a diameter of 0,64 mm, a length of 75 mm and a recording area of 0.07 mm^2. The needle electrode is connected to a Nicolet Viking II Electromyography System (Nicolet, Madison, WI). The sphincter muscle halves are independently examined both at rest and during activity. Activity consists of squeezing (prevention of bowel evacuation), coughing (to evaluate reflex sphincteric activity) and pushing (attempted evacuation).

A normal study is defined as the recruitment of an ample number of motor units with normal amplitude and duration while squeezing and coughing, and either electrical silence or a marked decrease in motor unit potentials during pushing.

Although anorectal manometry can assess the strength of the anal sphincters, it can not evaluate neuromuscular integrity. Conventional concentric needle electromyography is especially valuable in the assessment of fecal incontinence by providing quantification of motor unit potentials, mapping external anal sphincter defects, and assessing reinnervation patterns. Anal endosonography also provides useful internal and external anal sphincter mappings and a high correlation with electromyographic mapping has been demonstrated in patients with traumatic fecal incontinence. Although unable to assess denervation, anal endosonography by locating the external anal sphincter defect, may reduce the number of needle insertions required for electromyographic mapping.

Decreased recruitment of motor unit potentials are found in approximately 60% of patients with fecal incontinence and polyphasic motor unit potentials can be demonstrated in 40% of these patients. Increased amplitude and duration of motor unit potentials may also be demonstrated in injured areas. These findings are characteristic of injury, denervation, and subsequent partial reinnervation of the external anal sphincter and puborectalis from adjacent intact neuromuscular units. Reinnervation, however, seems to be best assessed with single fiber electromyography as extensive muscle atrophy results in insufficient motor unit potentials to be evaluated with the concentric needle electrode.[58] Single fiber electromyography allows calculation of fiber density, which is the mean number of single muscle fiber action potentials recorded within the electrode uptake area. Normally, at least four needle insertions are required with small adjustments of the position of the electrode during the recording process in order to calculate the mean number of single fiber action potentials for 20 different positions within the muscle. Therefore, this is a useful quantitative method of assessing denervation in fecal incontinence. The normal single fiber value for the external anal sphincter is 1.5 ± 0.16 and it increases with age and in incontinent patients.[61] Although single fiber electromyography permits quantification of the injury, it does not alter clinical management any more than does concentric needle electromyography. Moreover, single fiber studies are more uncomfortable for the patient than are concentric needle exams. Non-invasive surface or anal plug electrodes have also been proposed, however detailed findings of denervation and reinnervation are less likely to be demonstrated with these devices.[60]

In patients with idiopathic constipation, electromyography may corroborate with the diagnosis of nonrelaxing puborectalis syndrome if doubt persists after cinedefecography. Failure to achieve a significant decrease in the electrical activity of the external anal sphincter and puborectalis during attempted evacuation is considered as a criteria for the electromyographic diagnosis of nonrelaxing puborectalis syndrome. For this particular purpose, the surface electrodes may be of use. Both electromyography and cinedefecography have comparable sensitivity and specificity, but are individually suboptimal.[61] Cinedefecography should be performed initially as it is pain free and provides useful data on rectal emptying.[62]

PUDENDAL NERVE TERMINAL MOTOR LATENCY

Pudendal nerve terminal motor latency measurement is a simple method of assessing pudendal nerve function. This test indicates the integrity of the distal motor innervation of the pelvic floor musculature. This assessment is of paramount importance in the evaluation of neurogenic fecal incontinence. Pudendal nerve terminal motor latency is performed by transrectal stimulation of the pudendal nerve by a special electrode designed by Kiff and Swash[63] while the evoked response of the striated sphincter is observed.

Pudendal nerve terminal motor latency measurement is performed according to the technique described by Snooks and Swash.[64] The test is assessed transrectally with the patient placed in the left lateral decubitus position. The sensor consists of two stimulating electrodes located at the tip of the index finger of a glove and two surface recording electrodes incorporated into its base (St Marks electrode, Dantec, Skovlunde, Denmark). The electrode is then connected to a recording system. The ischial tuberosities are used as landmarks in the assessment of the pudendal nerves. Stimuli of 22 mV of amplitude and 0.1 msec duration are applied to the nerves. These stimuli are given at one second intervals and the tip of the finger is gradually moved until the sphincter is felt to contract around the base of the finger and the motor unit action potential achieves a maximum amplitude. The latency from each stimulus to the evoked muscle action potential in the external anal sphincter is recorded on each side. The mean pudendal nerve terminal motor latency is calculated from the best amplitude measured. The normal value of the mean pudendal nerve terminal motor latency is 2.0 ± 0.2 ms.[64-65] Latencies greater than 2.2 msec are considered excessive and representative of pudendal neuropathy.

The cutaneo-anal reflex latency and pudendal nerve terminal motor latency have both been used in the assessment of pudendal nerve damage. Bartolo and co-workers[66] observed that the latency of both the early and late components of the cutaneo-anal reflex in incontinent patients did not differ from control subjects. Despite this finding, conventional electromyography of the external anal sphincter revealed neuropathy in the incontinent group. Therefore, the cutaneo-anal reflex latency seems a less adequate method of demonstrating pudendal nerve damage.

Pudendal nerve terminal motor latency is particularly important in suspected neurogenic incontinence and in parous women prior to sphincter repair. This test is the most important predictor of functional outcome after sphincter repair as neuropathy, even when unilateral, is associated with poor postoperative functional results.[67] Alternatively, pudendal nerve terminal motor latency does not seem to predict functional results after biofeedback.[68] However, pudendal nerve terminal motor latency is not a quantitative method; it is a measurement of the fastest motor conduction in the pudendal nerve.[69] Although normal pudendal nerve terminal motor latency does not exclude partial damage, when prolonged, pudendal latencies seem to be reliably related to neuropathy. Despite the substantial anatomic overlapping of the pudendal innervation on both sides of the external anal sphincter, asymmetrical pudendal neuropathy is not an uncommon finding.

In addition to pudendal nerve terminal motor latency, spinal latency may be indicated in selected cases of idiopathic fecal incontinence to exclude cauda equine injury as a cause of incontinence. Conduction delay in cauda equine between L1 and L4 levels have been noted in 23% of patients with idiopathic fecal incontinence and prolonged pudendal nerve terminal motor latency.[70]

Abnormally prolonged pudendal latency is usually found in patients with other pelvic floor disorders such as constipation with chronic straining, rectal prolapse, solitary rectal ulcer and descending perineal syndrome.[71,72] Neuropathy due to stretching of the pudendal nerve has been implicated, in theory, to explain the prolonged latencies in those patients with chronic straining at stool.[73] This entrapment/stretch theory is also thought to be the mechanism of pudendal lesion during vaginal delivery.[74] However, a lack of correlation between perineal descent measurements and pudendal latencies has been recently demonstrated, and therefore, other mechanisms may be involved.[75]

CINEDEFECOGRAPHY

Defecography, the radiographic imaging of the pelvic dynamic changes during defecation was proposed in 1952, by Lennart Walldén to[76] investigate the relationship between deep rectovaginal pouches, enterocele and obstructed defecation. More recently, interest in this technique has expanded due to the increased availability of colorectal physiology testing and evidence has shown that cinedefecography is of value in routine evaluation of functional disorders of the pelvic floor.[77-80] Specifically, this study provides pelvic measurements at rest and during both squeeze and push, which are used to assess evacuation dynamics. As a result, disorders such as paradoxical puborectalis contraction, rectocele, intussusception and perineal descent can be diagnosed. Moreover, cinedefecography is the only method of assessing both anatomical detail and rectal emptying.

Patient preparation for cinedefecography includes a disposable phosphate enema 30 minutes prior to the procedure. The patient is placed in the left lateral decubitus position and a small amount of barium suspension, usually 50 ml, is injected into the rectum in order to coat the rectal mucosa and enhance the contrast imagery. After initial barium instillation, air is insufflated to outline the rectal mucosa. Subsequently, the thick barium paste (Anatrast™, E-Z-EM, Westbury, NY) is introduced using a caulking gun injector. Usually 250 cc (500 g) is introduced, or less if the patient experiences rectal fullness prior to that point. Injection is continued even as the injector is withdrawn in order to outline the entire anal canal.[81] The x-ray table is tilted upright to a 90° angle and the patient is comfortably seated on a water filled radiolucent commode (Sunburst, Ladson, SC). Lateral films of the pelvis are then taken at rest and during both squeeze and push. The patient is then asked to evacuate the rectal contents and, with the aid of fluoroscopy, the process of defecation is recorded on videotape using a high resolution recorder.

The use of video recording is of greatest importance in cinedefecography to effectively study all phases of defecation; the entire process of defecation can be reviewed and the effects of abnormalities such as rectocele, intussusception, and non-relaxing puborectalis in rectal emptying can be better evaluated, by both the investigator and the referring physician. Additionally, "spot" films may not demonstrate enterocele and sigmoidocele because deep rectogenital pouches may contain bowel only intermittently, usually after prolonged straining.[76]

Although cinedefecography has become more widely available, to date no optimal patient position has been established. Most authors consider the standard seated position more physiological, however this position yields poor quality static films. The left lateral decubitus position offers better imagery, is better accepted by radiologists and may provide a similar overall diagnostic rate compared to the conventional seated position.[82] Additionally, some authors consider the standard seated technique too sensitive and therefore potentially susceptible to overdiagnosis.[83] In a recent prospective study, reproducibility of cinedefecographic measurements and abnormal findings between the seated and left lateral decubitus positions was assessed in 105 patients.[84] Although static values of anorectal angle, perineal descent and puborectalis length were significantly higher in the seated position, dynamic changes of all these measurements during evacuation were essentially the same for both positions. Consequently, the diagnosis of either dynamic increased perineal descent or nonrelaxing puborectalis syndrome was not affected by the patient's position. However, since static values of perineal descent were significantly higher in the seated position, the diagnosis of fixed increased perineal descent was significantly more accurate in the seated position. Thirty-one of 50 (62%) patients with fixed increased perineal descent were diagnosed only in the seated position ($p<0.001$). The weight of rectal and other abdominal contents probably contributes to the downward pull of a flaccid pelvic floor and may account for higher static values of perineal descent in the seated position. The seated position may be more sensitive for the diagnosis of increased fixed perineal descent based on the fact that it is a more physiological position and as such, is preferred in patients with constipation. However, premature evacuation severe enough to hamper cinedefecographic measurements occurred only in the seated position, as noted in 6 of 22 (27%) patients with fecal incontinence. Therefore, in these patients, the left lateral decubitus position should be adopted to ensure better results. More importantly, given the statistically significant differences between the two positions, centers should elect the same position for a given diagnostic group.

Balloon proctography was introduced to document change in the anorectal angle during evacuation along with the inability to expel the balloon.[85,86] This technique was intended to reduce radiation exposure, however it does not assess either anatomic detail of rectal configuration or completeness of evacuation. Furthermore, frequent displacement of the balloon results in inaccurate or dubious measurements.[81] Therefore the conventional method using barium paste is preferred. Other technical variants have been proposed in an attempt to enhance the diagnostic capability of cinedefecography, specifically to assist delineation of deep cul-de-sac pouches, enterocele and sigmoidocele. Oral ingestion of 150 ml of barium contrast one to three hours prior to the examination may assist in the delineation of pelvic small bowel loops.[80,87] More recently intra-peritoneal instillation of 50 ml of nonionic contrast has been proposed. Despite the potential risk of complications, peritoneography combined with dynamic proctography can provide better assessment of pelvic floor pathology in selected cases.[88] The use of a tampon soaked in iodine contrast medium placed in the posterior fornix of the vagina either as an isolated method or combined with a voiding cystography (colpocystodefecography) also helps to assess the depth of the rectogenital fossa and the eventual interposition of intra-abdominal content between the rectum and vagina.[87,89]

Essentially, static proctography has been used to measure the following parameters: anorectal angle, perineal descent and puborectalis length. The anal canal length can also be measured; however, anal manometry, which provides the functional anal canal length or high pressure zone, is the preferred method for this purpose. The cinedefecographic measurements are taken at rest and during both squeeze and pushing. In order to assess the pelvic floor dynamics during evacuation, the difference between rest and maximal push is calculated for each measurement.

The range of normal values for each of these parameters is immense.[79,80] However the exact value of any of these isolated parameters is of relatively little consequence and comparison of an absolute measurement in a patient against a group of controls is frequently frustrating. Instead, the role of static proctography is to provide a basis for relative comparison among rest, squeeze and push values in a single patient. Evaluation of both absolute and dynamic (evacuation - rest) values of anorectal angle, perineal descent and puborectalis length allows diagnosis of excessive perineal descent and paradoxical puborectalis.

The anorectal angle is the most often quoted measurement on cinedefecography.[4,24] This parameter is better defined as the angle between the axis of the anal canal and the distal half of the posterior rectal wall.[79,80] The resting anorectal angle ranges from 70-140º with a mean of 92-114º·. During evacuation, this angle becomes more obtuse, 110-180º, and more acute during squeeze, ranging from 75-90º. This wide variation is, at least in part, due to discrepancies in technique. Perineal descent is quantitatively defined by measuring the vertical distance between the position of the anorectal angle and a fixed plane, which is usually represented by the pubococcygeal line as it apparently reflects a more exact relationship of the levator ani muscle to the pelvis. The normal pelvic floor position is up to 1.8 cm below the pubococcygeal line at rest and up to 3.0 cm below the pubococcygeal line during maximal push effort; therefore, abnormally increased perineal descent has been classically defined as descent of more than 3.0 cm during evacuation when compared to the value measured at rest.[79,80,84] However the dynamic changes in the pelvic floor during straining may not account for the diagnosis of abnormal perineal descent in all cases. Patients may present with a flaccid and non-contractile pelvic floor. In this situation, although little change is seen during straining, an abnormally increased perineal descent is already observed at rest. This so called " fixed increased perineal descent", considered when perineal descent exceeds 4.0 cm at rest, has been particularly associated with advancing age.[84] The puborectalis length is measured as the distance between the anorectal angle and the pubic symphysis. The resting puborectalis length ranges from 14-16 cm. During squeeze, the puborectalis length is shorter (12-15cm), and during evacuation the muscle length increases (15-18cm). Comparison of these measurements, along with the anorectal angle, corroborates with the diagnosis of paradoxical puborectalis syndrome.

Cinedefecography also permits the diagnosis of causative or associated anatomical abnormalities such as nonrelaxing puborectalis (puborectalis indentation), rectocele, occult internal intussusception, sigmoidocele and enterocele. These findings, particularly a small rectocele and an intussusception may be found in 25-77% of asymptomatic individuals[80] Failure to recognize these variants of normal can easily lead to overdiagnosis and overtreatment. Therefore, a decision for treatment should be made based upon both clinical history and evaluation of rectal emptying during cinedefecography.

During cinedefecography, most individuals evacuate their rectum within 15-20 seconds.[90,91] A variety of detailed techniques to quantitate rectal emptying have been described. A weight transducer, located under the disposable bag for barium collection and connected to an amplifier and chart recorder has been used to plot the contrast expelled against time.[90,92] This rectodynamic study permits validation of the proctographic estimation of evacuation time and completeness. Other techniques include planimetrical evaluation of the retained contrast media area,[93] digital subtraction cinedefecography[94] and scintigraphic studies.[95]

Factors affecting rectal emptying rate include consistency of contents and patients' embarrassment. The estimated rectal evacuation time to solid contents is within 10-12 seconds; liquid contents are more rapidly evacuated (8-9 seconds).[96] Paradoxical contraction of the pelvic floor during attempted defecation may represent either an embarrassed reaction of the patient or a true functional disorder. Patients must be reassured and fully informed regarding the importance of the cinedefecographic findings in their therapeutic approach. In this situation, a valuable technique is to ask the patient to evacuate in the privacy of a bathroom and reassess the rectum fluoroscopically.

Cinedefecography is particularly indicated in patients with chronic idiopathic constipation to exclude causes of obstructed defecation. Standard propedeutic examinations such as colonoscopy and barium enema detect essentially anatomic abnormalities, whereas functional disorders will require a radiographic study that demonstrates the physiological process involved during rectal evacuation. Specifically, cinedefecography provides pelvic dynamic measurements during evacuation, and consequently basis for the diagnosis of functional disorders such as paradoxical puborectalis contraction and excessive perineal descent and assesses anatomic detail of abnormalities such as rectocele, rectoanal intussusception and enterocele. Moreover, rectal emptying can be evaluated, which may help to differentiate a mere cinedefecographic finding from a causative disorder. Anatomical defecographic findings, particularly a small rectocele or an intussusception, are frequently found in asymptomatic individuals and failure to recognize these variants of normal can easily lead to overdiagnosis and overtreatment. Therefore, decisions for treatment should be made based on clinical history and evaluation of rectal emptying during cinedefecography.

In addition, in patients with idiopathic fecal incontinence, specifically if a history of chronic straining at stool is reported, cinedefecography can be helpful to exclude an internal rectal prolapse. In patients with solitary rectal ulcer and chronic idiopathic rectal pain, this study may also uncover a causative disorder.[97]

Cinedefecography also has been indicated to assess the functional results of procedures such as rectopexy, postanal repair, gracilis neosphincter and ileoanal reservoir. The effect of the procedure on the mechanism of continence can be evaluated, including changes in pelvic dynamic measurements, rectal configuration and rectal emptying rate.

CLINICAL APPLICATION

Colonic transit study, anal manometry, cinedefecography, electromyography and pudendal nerve latency assessment are considered standard arsenal of physiology investigation. At the moment studies are accumulating to evaluate several aspects of physiologic testing, such as reproducibility, clinical impact and costs. In order to assess repeatability of tests of anorectal function, Ryhammer[98] evaluated 58 healthy female volunteers on two separate occasions. Mean difference for perineal position was 0.1 cm, perineal descent: 0.02 cm, anal mucosa electrosensitvity:-0.1 mA, maximal resting pressure: 2.2 cmH_2O, maximal squeeze pressure: -1.0 cmH_2O and pudendal nerve terminal motor latency: 0.04 msec. Coefficients of variation were 8% for pudendal nerve terminal motor latency, 22% for resting pressure, 31% for mucosal electrosensitivity, 33% for squeeze pressure and 49% for perineal descent. The authors concluded that although the nonsystematic variation was large, there was no systematic variation in repeated measurements for any of the parameters studied.

Physiologic testing is costly, time consuming, frequently uncomfortable to the patients and not easily available in all institutions. For these reasons, the first question to be made is whether the diagnosis and therapeutic approach can be significantly altered as compared to a structured history and physical examination alone. In a study of 308 consecutive patients with functional disorders of defecation, Wexner and Jorge[99] assessed the number of diagnosis made after physiological testing, including colonic transit study, anal manometry, cinedefecography, electromyography, and pudendal nerve terminal motor latency, compared with routine history and examination alone. Definite diagnoses were made after history and physical examination alone in 15/180 (8%) with constipation, 9/80 (11%) with incontinence, and 11/48 (23%) with idiopathic rectal pain. The figures after physiological tests were 135/180 (75%), 53/80 (66%) and 20 (42%), respectively. Among the diagnosis made by physiologic testing alone were: in patients with constipation, paradoxical puborectalis contraction (n = 59), colonic inertia (n = 31), rectocele (n = 19), and intussusception (n = 18); in patients with incontinence, loss of muscle fiber (n = 21), neuropathy (n = 10), and both (n = 15); and in those with rectal pain, neuropathy (n = 6) and paradoxical puborectalis contraction (n = 3). The number of patients that remained undiagnosed in the three groups were 45 (25%), 27 (34%) and 28 (58%), respectively. The authors considered the value of colorectal physiologic testing greatest in patients with constipation and incontinence, as treatable conditions of the colon, rectum and anus can be diagnosed in 67% and 55% of patients, respectively. In patients with rectal pain, however, these tests permit definite diagnosis in only 18%, and this condition remains poorly understood and refractory to therapy.[100]

Rantis[101] et al. studied 51 patients with chronic constipation, and after colonoscopy, barium enema, colonic transit times, defecography and manometry, eletromyography and rectal biopsy, found outlet obstruction in 16%, colonic inertia in 24% and constipation of unclear etiology in 61%. The mean cost of diagnosis was $2,752 (range$1,150 - $4,792). According to these authors, exhaustive diagnostic evaluation of constipation is costly, and its benefits are unclear, since only 23% patients seems to benefit from this evaluation. On the other hand, In a study of ninety-eighty constipated patients who underwent physiologic tests, manometry, colonic transit times, balloon compliance, defecography, pudendal nerve latency and electromyography, Halverson and Orkin[102] found that the pretesting impression was uncertain, and in 43 (94 percent) of these, testing aided significant information to lead a specific diagnosis. In the remaining 43 patients (44 percent), testing did not provide useful information. These authors also found that although prior hysterectomy, urinary incontinence and outlet obstruction symptoms were significantly associated with high incidence of rectocele, pretesting history and symptoms did not predict which patients were most likely to benefit from these studies. In addition, defecography and transit times were the most useful tests.

Keating et al.,[103] In a study of fifty patients, the addition of physiologic investigation, specifically endoanal ultrasound, anal manometry, electromyography and defecography, altered the diagnosis of the cause of incontinence based on history and physical examination alone in 19 percent of cases, altering the management plan in 16 percent of cases. Therefore, these authors concluded that although surgically correctable causes of incontinence are rarely missed on history and physical examination alone, when all causes are included, up to one fifth of patients will be misdiagnosed by clinical assessment alone. Specifically, physiologic tests were most useful in discriminating neuropathy, rectal wall disorders, and unexpected internal anal sphincter defects.

In conclusion, physiologic testing permits objective assessment and reliable post-therapeutic follow-up of subjective functional colorectal disorders. The most important test for constipation are colonic transit times, cinedefecography and manometry and for incontinence, manometry, endosonography, electromyography and pudendal nerve latency. A number of other test have been described, but not routinely used in clinical practice. However a multidisciplinary approach, including psychologists and nutritionists are at times recommended. Interpretation of these tests requires well trained personnel, because secondary findings are frequent and can be misleading. Increasing experience with these methods will ensure a new perspective of evaluation of these highly prevalent and, at times, incapacitating symptoms.

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