Physiology of Ileal Pouch-Anal Anastomosis

Current Concepts

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PURPOSE: Increasing experience with ileal pouch-anal anastomosis (IPAA) associated with increasing knowledge about anorectal physiology has lead to a large number of publications. The purpose of this review is to evaluate the current understanding of fecal continence as revealed by the evolution of the ileoanal procedure. METHODS: Review of the literature covering the most important physiologic parameters involved in fecal continence was undertaken. RESULTS: Rectoanal inhibitory reflex is probably absent after IPAA but is preserved when distal anorectal mucosa is spared. Anal resting pressure decreases but is less affected when the internal anal sphincter is less traumatized. Squeeze pressure is not importantly affected, and the importance of reservoir function as a determinant of stool frequency is emphasized. IPAA does not affect the coordination between pouch and anal canal motility in the majority of cases. Normal continence is preserved, even during the night, by preserving a gradient of pressure between the pouch and anal canal. CONCLUSIONS: Physiologic concepts are well established, but controversies about the continence mechanism related to IPAA remain. The IPAA procedure has allowed discrimination of details about the function of multiple structures involved in fecal continence [Key words: Ileal pouch-anal anastomosis; Anal manometry; Restorative proctocolectomy; Anorectal physiology; Fecal continence]

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Since the last century there has been an interest in understanding the mechanisms of anal continence. In the last 25 years, however, there has been increased interest in this field, motivated by the introduction of operative techniques to preserve anal sphincter function. Development of ileoanal and coloanal techniques has created models that allow investigators to dissect variables previously inseparable. This has facilitated investigation and understanding of anorectal physiology.

Straight ileoanal anastomosis was the first attempt to preserve intestinal continuity after proctocolectomy.[1–8] Because of high stool frequency and poor continence, this procedure was replaced by proctocolectomy and end ileostomy, which remained the standard operation until the 1970s. Knowledge about the propulsive characteristic of ileal motility[9–12] and the reservoir as an important component of normal continence[13–15] was used by Valiente and Bacon[16] in 1955 and Karlan *et al.*,[17] in 1959 as the physiologic basis to build an ileal reservoir anastomosed to the anal canal in a canine model.

Interest in straight ileoanal anastomosis, renewed after successful results reported by Martin *et al.*,[18] in 1977, was followed by the introduction by Parks and Nicholls[19] in 1978 of the S-shaped ileal reservoir anastomosed to the anal canal. Better functional results were subsequently confirmed.[20–30]

Rapid development of experience with ileal pouch-anal anastomosis (IPAA), refinement in the technique, and an increasing knowledge about anorectal physiology have lead to a large number of articles. It is the purpose of this review to evaluate current understanding of the mechanisms of fecal continence as revealed by evolution of the ileoanal procedure.

PHYSIOLOGIC PARAMETERS

Rectoanal Inhibitory Reflex

The rectoanal inhibitory reflex (RAIR) was first described by Gowers[31] in 1877 and later confirmed by Denny-Brown and Robertson[32] in 1935. Since the report of Duthie and Bennett[33] in 1963, the function

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of this reflex is thought to allow sensory discrimination of rectal contents by proximal anal mucosa. Location of receptors and pathways for this reflex are still under investigation, and studies have identified relaxation during sleep and after spinal cord transection.[34–41] Various observations have been made after ileoanal procedures. In some studies RAIR is always absent,[42–44] and in others it is detected in a variable number of patients or may return later.[45–48] In some studies, it appears that the presence of RAIR after IPAA is caused by technical misinterpretation rather than real relaxation following rectal distention. Its presence in patients submitted to a low rectal resection with coloanal anastomosis[36, 49] or low colorectal anastomosis[50–53] presented the same variety of findings.

Some reasons have been postulated for loss of RAIR after IPAA: complete resection of the rectal wall, with balloon insufflation inside the ileum[54]; rectal transection and disconnection between the internal sphincter and more proximal myenteric plexus[55]; destruction of the Meissner's plexus, with mucosal and submucosal excision[36, 43, 45, 51, 56]; fibrosis between rectal cuff and the pouch[43, 57]; and direct damage to the internal sphincter because of use of anal retractors.[58–60] Mucosectomy, which includes the transitional zone of the anal canal combined with the use of anal retractors, could be the cause for its abolition,[61, 62] because RAIR is more often preserved with an end-to-end stapled anastomosis without mucosectomy.[61]

Because the majority of patients experience good continence and ability to discriminate pouch contents after IPAA, even in the absence of RAIR, its role for normal continence has been questioned.[60, 61, 63–70] However, for patients with suboptimal sphincter function or with decreased reservoir capacity, RAIR may help to improve continence.[55, 71]

Anal Resting Pressure

Decrease in the anal resting pressure (ARP) after IPAA has been widely reported. Because the internal anal sphincter (IAS) represents 60 to 70 percent of the resting pressure of the anal canal, damage to the overstretched muscular fibers, and possibly its denervation, may be the main reasons for the decrease in ARP.[72, 73] O'Connell *et al.*[59] compared anal sphincter function after IPAA with normal controls and described a uniform reduction of anal canal pressure, therefore, concluding that the whole anal canal had some pattern of dennervation. Reduction in pressure of the proximal third, however, was the only significant reduction. Damage to the IAS is greater than to the external anal sphincter (EAS), which explains the decrease in basal tone.[74]

Correlation between preoperative or postoperative physiologic parameters in IPAA and anal sphincter function has been frequently investigated, and there is an association of lower ARP with poorer continence.[44, 45, 58–62, 73, 75–82] Other reports have not been able to establish the same relationship.[43, 57, 64, 68, 70, 83–89] Some studies have indicated decreased activity in the anal canal during sleep.[90–92] This physiologic condition, associated with lower ARP, can make the basal tone of the anal canal lower than intrapouch pressure, and, with the abolition of voluntary contraction, leakage can occur.[59, 66, 79, 93–97] Decrease in ARP can be detected immediately after surgery.[44–46, 53, 57, 60, 61, 74, 78, 83, 98–102] Horgan *et al.*[53] performed intraoperative measurements of anal pressure during rectal dissection and found no significant difference between the values of ARP before and after rectal mobilization, section of the inferior mesenteric artery, or rectal transection. However, after the stapled anastomosis there was a significant decrease in ARP, pointing out the importance of even minimal dilation of the IAS caused by stapler insertion. Some improvements in ARP can be achieved during the first to second year of follow-up, although these values remain lower than those assessed preoperatively.[43, 70, 86, 87] Use of anal retractors has been considered one of the more important factors damaging the IAS and consequently decreasing ARP. Even minimal dilation of the anal canal during insertion of the stapler may cause damage to the IAS.[53, 60, 68, 69, 87, 103]

There are different interpretations about the cause of injury to the IAS: forced dilation of the anal canal by using anal retractors to perform the mucosectomy[43–46, 57, 59, 62, 104–106] upward traction and dissection of the rectum with damage to autonomic nervous system[53, 57, 70, 84, 87, 107, 108]; transection of the intramural nervous plexus[104]; presence of a segment of ileum inside the anal canal impeding its occlusion[45]; and development of fibrosis between the anorectal muscular cuff and the pouch.[43, 57]

Lewis *et al.*[109] did not find differences in ARP, anal squeeze pressure (ASP), and anal canal sensation after end-to-end IPAA using the anorectal eversion technique with anal mucosal preservation. Despite full mobilization and complete eversion of the rectum and anal canal, when some compromising of the IAS innervation would be expected, they concluded that

eversion of the rectum and anal canal did not impair anal sphincter function.

The anal transition zone is a richly innervated area of the anal canal[110] and has been considered important to the discrimination of the enteric contents. It may play a role as an afferent pathway for RAIR.[33, 43, 111] Comparison between IPAA being performed with or without mucosectomy (handsewn *vs.* stapled anastomosis) has shown sparing of the anal mucosa as an important factor in ARP and anal sensation preservation.[60, 61, 70, 73, 80, 81, 112–115] Sagar *et al.*[114] hypothesized that better physiologic results with the stapled IPAA could be caused not only by mucosal preservation but also by avoiding the use of anal retractors. Preservation of the anal transition zone has not been widely confirmed as an independent factor improving postoperative continence.[68, 116, 117] Luukkonen and Järvinen[87] and McIntyre *et al.*[119] were not able to identify a difference between IPAA performed with mucosectomy and handsewn anastomosis and those with double-stapled anastomosis without mucosectomy. However, for patients with borderline function, the presence of this region may provide better anal sensation.[118]

The physiologic role of the rectal muscular wall is unclear. Clinical outcome improves with the use of a shorter rectal muscular cuff and efferent limb of the S-pouch.[46, 120] Grant *et al.*[56] did not observe a relationship between rectal muscular length and postoperative values of ARP; however, Shoji *et al.*[48] noted higher ARP and better continence when using a longer rectal muscular cuff.

Another important point is the potential risk for persistent disease and malignancy in the remaining mucosa after stapled anastomosis.[95, 121–126] Although these risks have not been considered clinically significant,[127] they may be smaller when compared with the possible advantage of better functional results.

Anal Squeeze Pressure

Stryker *et al.*[128] and Emblem *et al.*[113] performed electromyography in IPAA patients and found a denervation pattern of the EAS in those patients with poor continence. O'Connell *et al.*[59] reported a smaller increase in anal pressure after squeezing for incontinent patients, compared with those who were continent. Nasmyth *et al.*[58] demonstrated that patients who were able to postpone the desire to evacuate for more than 30 minutes had higher ASP than those with urgency to defecate. The majority of reports have presented similar values of ASP after IPAA compared with controls or preoperative values,[43, 46, 54, 57, 87, 98–100, 129, 130] although some reports have mentioned an association between decreased activity of the IAS (decreasing in ARP) with a compensatory increase of activity of the EAS.[68, 70, 71, 83, 85, 101]

Pouch Compliance

Compliance of the pouch has been considered an important factor in fecal continence. The pouch retains compliance values similar to normal rectum.[64, 76, 131, 132] This correlates with decreased stool frequency.[28, 43, 54, 86, 129] The greater the compliance of the pouch, as observed by Taylor *et al.*,[28] the less the magnitude of propulsive waves and the less the urgency to defecate.

Variation in pouch design and different length of ileum used in construction may lead to differences in compliance. The W-pouch has been shown to be more compliant than the S-pouch[82, 133] and the S-pouch to be more compliant than the J-pouch.[58, 134] There is a lower stool frequency and incidence of nocturnal leakage in more compliant pouches.[58, 134] Examinations up to one year indicated a progressive increase in the compliance of all pouches associated with a decrease in stool frequency.[79, 133]

Pouch Volume

Since the studies of Gaston,[13–15] fecal continence has been related to anal sphincter function and the need for a reservoir. Early physiologic reports in patients submitted to IPAA confirmed the role that a reservoir improved continence and decreased stool frequency.[25, 28, 43, 45, 54, 64, 83, 98, 99, 129, 135–142] Some investigators have also found the intraoperative pouch volume predictive of later function.[86, 133, 139]

Pouch volume increases during the first year after ileostomy closure.[83] Öresland *et al.*[86] reported an average two times expansion of the volume during this period. After one year, stabilization of the volume has been noted.[86] These morphologic changes are associated with a decrease in the stool frequency and improved continence.[96, 134, 143–146] However, a larger pouch does not always mean better function, particularly after two postoperative years. Stelzner *et al.*[147] compared large and small reservoirs and found enlargement associated with pouchitis and diarrhea in 6 of 14 patients with a large reservoir and only 1 of 14 patients with a small reservoir.

Correlation between pouch design and better func-

tional outcome has been controversial because of the wide variation in functional results. Some investigators have not observed significant differences in the clinical outcome between the different pouches one year after ileostomy closure.[115, 148, 149] With the S-pouch initially proposed by Parks and Nicholls,[19] using a long efferent limb, 54 percent of patients needed to catheterize the pouch to have evacuation, and better function was achieved with a shorter efferent limb.[150] Some studies that correlate pouch design and function have considered the S-pouch more capacious than the J-pouch and, therefore, presented more favorable functional results.[58, 69, 96, 134, 140] Studies including the quadruple-loop W-pouch have shown greater capacity and better functional results than the S-pouch and J-pouch.[82, 133, 139, 143, 151] However, better function has been associated more with compliance and evacuation volume than with pouch design[58, 74, 86, 115, 137] and may be related to the length of ileum used to build the pouch instead of the motility pattern of the different pouches.[86]

Threshold Pouch Sensation

Threshold pouch sensation (TPS) defines the threshold volume that produces a generation of large pressure waves inside the pouch. There is no significant difference between pouch and normal rectal threshold sensation.[44, 64] Maximum pouch capacity is the maximum volume that can be tolerated. Higher threshold volume and larger amount of stool during evacuation are related to fewer bowel movements.[59, 64, 131, 132] The presence or absence of the anal transition zone[60] and decrease in the length of the muscular rectal cuff[56] do not significantly affect TPS.

Anal Canal Sensation

Patients with an IPAA can discriminate between gas and fecal contents after mucosectomy.[62, 129, 152] Preservation of the anal canal mucosa may lead to better anal canal sensation and the capacity to discriminate.[66, 73, 152]

Pouch and Anal Canal Motility

Studies have been performed to investigate the motor response of the terminal ileum and continent ileostomy. When not distended there is no difference in the electric and motor activity between a terminal ileostomy and an ileal pouch.[153–156] During distention, there is a delay in the elevation of intrapouch pressure because of its greater capacity to accommodate intestinal contents.[54, 157] There is a corresponding delay in the onset of large-amplitude waves and less frequent evacuation.[98, 132, 154, 155]

Between the pouch and healthy rectum, there is a difference in the motor response to distention, despite similar capacity.[132] Whereas the rectum responds with accommodation,[54, 157–159] the pouch develops large-amplitude pressure waves, with distal propagation of intestinal contents.[157] The onset of these waves is an important determinant of the urge to evacuate, and the higher the frequency, the more frequent the pouch evacuation.[98, 132] The nature of waves is different between normal rectum and the pouch. After maximum distention, the rectum presents only infrequent low amplitude waves. In contrast, the pouch shows two different types of motor waves: low amplitude and short duration (<10 mmHg and 3–6 seconds) or large amplitude and high duration (>25 mmHg and 40–60 seconds).[11, 12, 54, 98, 132, 153, 154, 160, 161] These waves can occur simultaneously, with large amplitude waves superimposed on low amplitude.[132]

Frequency and amplitude of large pressure waves have a direct relation to the rate of pouch filling.[29, 98, 99, 132] Stryker *et al.*[64] performed pressure studies during a 24-hour period and reported higher frequency of these waves (once every two minutes) just preceding evacuation, followed by a cessation of the motor activity soon after evacuation. It was also found that the greater the interval between the last evacuation and appearance of the first phasic wave, the lower the stool frequency. They stated that factors leading to rapid filling of the pouch could generate propulsive waves and greater frequency of evacuation. Recent studies using prolonged recordings[162–164] have demonstrated intrapouch high-pressure waves exceeding the pressure in the anal canal of patients with poor function. High-pressure waves in patients with incontinence are frequent during sleep[162–164] and have been observed even after pouch evacuation.[164]

Two types of waves characterize anal canal motility: slow wave (10–20 cycles/min and 5–25 cm of water), related to basal variations in the ARP, and ultraslow wave (0.6–1.9 cycles/min and 25–100 cm of water) that originate from variations in the electric activity of the IAS.[59, 165, 166] O'Connell *et al.*[59] reported a decrease in frequency and an increase in amplitude of the slow wave in patients after IPAA compared with controls, but not related to clinical results. These

changes in slow-wave pattern may be related either to the changed activity of the IAS after IPAA or to the motility of the segment of ileum inside the anal canal instead of IAS motility. Ultraslow waves may be related to spontaneous occurrence of RAIR.[167] O'Connell *et al.*[59] hypothesized that the occurrence of ultraslow wave after IPAA with absent RAIR should not be misinterpreted as a recurring RAIR but could explain its presence not observed with standard examinations.

Association between rectal or pouch motility and anal canal pressures has been evaluated.[60, 63, 92, 93, 130, 168] Ferrara *et al.*[92] performed studies in healthy volunteers and in patients with IPAA during 24 hours. During sleep it was possible to verify a decrease in the resting pressure; however, during rectal or pouch motor activity, there was a recovery in mean ARP. This motor response keeps the gradient of pressure between anal canal and the rectum or pouch, therefore, preserving continence during a sleeping state. These coordinations between contractions of the pouch and anal canal are not completely understood.

The "sampling" mechanism after IPAA is different than normal relaxation of the anal canal following rectal distention. It consists of an equalization of intrapouch pressure and anal canal pressure, which allows enteric contents to be in contact with the anal canal. If evacuation is not desirable a voluntary contraction of the anal canal occurs, therefore, preserving continence.[66, 93] Continence after IPAA is multifactorial;[66, 128, 149, 157, 168, 169] however, it is related to pouch motor activity (frequency of large waves generation) and ability of the anal canal to generate an effective contraction in response to increased intrapouch pressure.[66, 92, 130, 168]

CONCLUSIONS

RAIR is probably obliterated by most IPAA, but if the distal anorectal mucosa is not sacrificed then RAIR can be preserved. Continence is a function of interrelated factors. Anal resting pressure is mostly function of the IAS function and is decreased after IPAA, particularly at night. Almost all techniques compromise ARP, but it appears to be less impaired by procedures that traumatize the IAS less. ASP is generally preserved following IPAA. The concept of reservoir is very important to continence; however, the pouch should be neither too small, that is associated with high stool frequency, nor too large, frequently related to poor evacuatory efficiency and associated with increased stool frequency as well. Compliance and volume are important to functional results. Generally, TPS is preserved by creating a 400-ml to 500-ml pouch, and pouch motility presents a delay in the onset of large-amplitude waves, therefore, decreasing stool frequency. In the majority of cases, IPAA does not adversely affect coordination between the pouch and anal canal motility. This coordination keeps the gradient of pressure between the pouch and anal canal, leading to normal continence, even during sleep.

The study of anorectal physiology has been a remarkable development. Preoperative assessment of sphincteric function does not reliably predict indication of success or failure of IPAA. However, its use as an important tool in research has allowed evaluation of multiple structures involved in continence and, therefore, allowed more clear discrimination between these functions when evaluating patients with fecal incontinence.

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