



Distal Colon Motor Coordination: The Role of the Coloanal Reflex and the Rectoanal Inhibitory Reflex in Sampling, Flatulence, and Defecation

Jan D. Huizinga, Lijun Liu, Ashley Barbier and Ji-Hong Chen*

Department of Medicine, Division of Gastroenterology, Farncombe Family Digestive Health Research Institute, McMaster University, Hamilton, ON, Canada

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INTRODUCTION

Chronic constipation can be associated with a colonic motility disorder and/or obstructive defecation. An obstructive defecation disorder is suspected if the patient uses digital evacuation, performs excessive straining, and/or has a sensation of incomplete evacuation. A study using radiopaque shapes can reveal abnormal transit; colonic manometry can inform on abnormal colonic motor patterns or aberrant autonomic reflexes; anorectal manometry can reveal dyssynergia. Here, we discuss the physiological and clinical aspects of anal sphincter relaxation associated with continence, flatulence, and defecation, focussing on the rectoanal inhibitory reflex (RAIR) and the coloanal reflex.

The impetus for this opinion paper was to discuss the conclusion by Pucciani and Trafeli (1) that parameters of a normal RAIR, can reveal the *pathophysiology* of obstructive defecation. Their methodology involved a detailed evaluation of the parameters of the RAIR, in a cohort of 58 patients. The patients reported a normal bowel movement frequency and stool form was normal, but most performed digital evacuation with excessive straining. The patients as a group had normal minimum and maximum anal sphincter pressures, the maximum tolerated volume was normal and so was the threshold for initiation of the RAIR. The authors concluded that the RAIR was impaired in these patients because the average internal anal sphincter (IAS) relaxation was 74% upon rectal distention by a 60 ml balloon compared to 92% in their control group of 20 subjects. Although the difference was statistically significant, it is not clinically relevant since 74% relaxation associated with the RAIR is normal, if not excellent, according to international standards (2, 3). In addition, the relaxation evoked by the RAIR was deemed too short because of excessive external anal sphincter (EAS) contraction *prior* to the relaxation (what was named a rectoanal excitatory reflex RAER) (1). The relevance of this short transient excitatory reflex that gave on average a 13 mmHg pressure increase is unclear because it does not prevent relaxation, and it is therefore fundamentally different from the type of dyssynergia where anal sphincter contraction *prevents* proper relaxation (4); this RAER is indeed considered normal (5, 6).

The relaxation that allows defecation and gas expulsion involves a proper sensation to initiate reflex relaxation, a sufficient relaxation of the IAS and the EAS, and the absence of counteracting contraction of the pelvic floor muscles and anal sphincters. It is the coloanal reflex that can produce full relaxation of both the IAS and the EAS, whereas the RAIR relaxes the IAS to allow sampling of content in the proximal anal canal.

Abbreviations: RAIR, rectoanal inhibitory reflex; HAPW, high amplitude propagating pressure wave; SPW, simultaneous pressure wave; EAS, external anal sphincter; IAS, internal anal sphincter.

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*Correspondence:

Ji-Hong Chen
chen338@mcmaster.ca

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THE VALUE OF ASSESSING THE RAIR

The RAIR test is executed to assess the response of the IAS to rapid and transient graded distentions of the rectum induced by a balloon. It is the classic test to discover Hirschsprung's disease: the inability of IAS relaxation in a newborn who does not pass stool suggests abnormal intrinsic inhibitory innervation of the anal canal, likely as the result of distal colon aganglionosis. In addition, nitrergic innervation of the IAS can be absent in children with Hirschsprung's disease (7). The RAIR can also be absent in asymptomatic patients with dys-ganglionosis, post-circular myotomy, and lower anterior resections (8).

The RAIR, in response to balloon distention is usually interpreted as absent or present, and a relaxation of 20% or more of baseline pressure is considered normal. In a characterization of the RAIR in healthy subjects by Rao and co-workers, a transient distention by a 70 ml balloon at a peak anal sphincter pressure of 70–80 mmHg for 30 s, caused a maximal relaxation of 47 mmHg, leaving a minimum pressure of 32 mmHg, proposed to be maintained by the EAS and puborectalis (4).

Anal sphincter relaxation in response to the RAIR is primarily due to activation of enteric nitrergic nerves (9, 10) and hence restricted to the IAS. In a study by Beuret-Blanquart et al. (11), all patients with complete transection of the spinal cord exhibited the RAIR. In patients with absence of sympathetic control (transection between T9 and L2), the RAIR was completely normal. In patients with parasympathetic lesions (transection between S2 and S4), the RAIR was present, but amplitude and duration were not correlated with distention volume suggesting a regulatory role by the parasympathetic nucleus (11). Similarly, in patients with sacral agenesis, the RAIR is present but not modulated by different levels of rectal distention (12). Hence, the rapid transient distention of the rectum when a RAIR is assessed, will stimulate both enteric and spinal sensory nerves and the subsequent relaxation is mediated by enteric inhibitory nerves with or without involvement of parasympathetic nerves acting on the enteric inhibitory nerves (13).

The RAIR is sometimes called a defecation reflex, but it is more aptly called a sampling reflex; relaxation of the proximal IAS allows filling of the proximal anal canal which gives the central nervous system a chance to stop, or go ahead, with flatulence or defecation, hence it is involved in maintaining continence. The RAIR does not relax the EAS for expulsion. It is illustrative that patients with Hirschsprung's disease, after successful surgery, still do not have a RAIR but have normal defecation, indicating that the RAIR is not needed for defecation (14, 15).

RELAXATION AND DYSSYNERGIA

Dyssynergia involves the inability to relax the anal sphincters because of an autonomic dysfunction to prevent relaxation and/or the presence of counteracting contractions of the anal sphincters and/or pelvic floor muscles; hence reflex relaxation is prevented that may indicate abnormal sensory or motor innervation, or may indicate an acquired behavioral problem that can be rectified with biofeedback (16, 17). Dyssynergia

is identified when *several* tests provide evidence, since the reflexes evoked in the laboratory are often abnormal, even in healthy subjects, because of the unnatural testing conditions. With anorectal manometry, relaxation can be observed in response to rapid transient balloon distention. Relaxation can also be evaluated by asking the patient to bear down, simulating defecation during anorectal manometry or digital examination. With dyssynergia, tightening of the sphincters may occur, increasing pressure. A water filled balloon inserted in the rectum is normally expelled within a minute but with dyssynergia it may be delayed or absent. It should be noted that the patient will strain in response to bearing down or to expel the balloon, hence, these are tests of straining-assisted defecation, not necessarily a test of a normal defecation reflex. Of note, chronic excessive straining maybe a *cause* of dyssynergia (2). Dyssynergia can also be observed with defecography although it is mostly qualitative, with fluoroscopic defecography preferred over MRI defecography, since the fluoroscopic assessment is done in a more physiological condition where patients can maneuver according to their habits (18).

THE COLOANAL REFLEX

The coloanal reflex refers to the relaxation of the anal sphincters in response to a propulsive motor pattern of the colon (6, 14, 19–23). The relaxation can be evoked by a high-amplitude propagating pressure wave (HAPW) generated in the proximal colon, that does not visibly come anywhere near the rectum (24). It can be evoked when a simultaneous pressure wave (SPW) enters the rectum associated with gas expulsion, evoking pressures during the SPW in the colon that rarely exceed 20 mmHg (21, 25), or it can be evoked when an HAPW travels through the transverse or descending colon and changes into an SPW that instantly relaxes the sphincters. The coloanal reflex is an essential part of defecation and flatulence. The coloanal reflex can relax both sphincters completely (24, 25) (**Figure 1**) in contrast to the RAIR that involves relaxation of the proximal IAS. The HAPW takes part in the preparatory phase of defecation (26) and can be part of the act of defecation itself (27). High-amplitude propagating pressure waves and SPWs are generated as part of reflexes such as the gastrocolic reflex and autonomic reflexes mediated by vagal and sacral parasympathetic nerves in response to colonic or rectal distention (24, 25, 28–30).

The IAS relaxation as a consequence of the coloanal reflex (**Figure 1**), is mediated by intrinsic activation of enteric nitrergic nerves, parasympathetic activation of nitrergic nerves, and nitric oxide release from nNOS+ parasympathetic nerve fibers (29). Internal anal sphincter tone is primarily myogenic, a summation of phasic contractions of the musculature orchestrated by intramuscular interstitial cells of Cajal (31). Internal anal sphincter pressure is normal in patients with isolated sacral agenesis (12). Anal sphincter relaxation in response to a proximal HAPW is often not accompanied by pressure generation in the descending colon and rectum (22, 24), hence, it involves a spinal reflex. The varicose sympathetic innervation of the IAS musculature contributes to tone and high spinal nerve

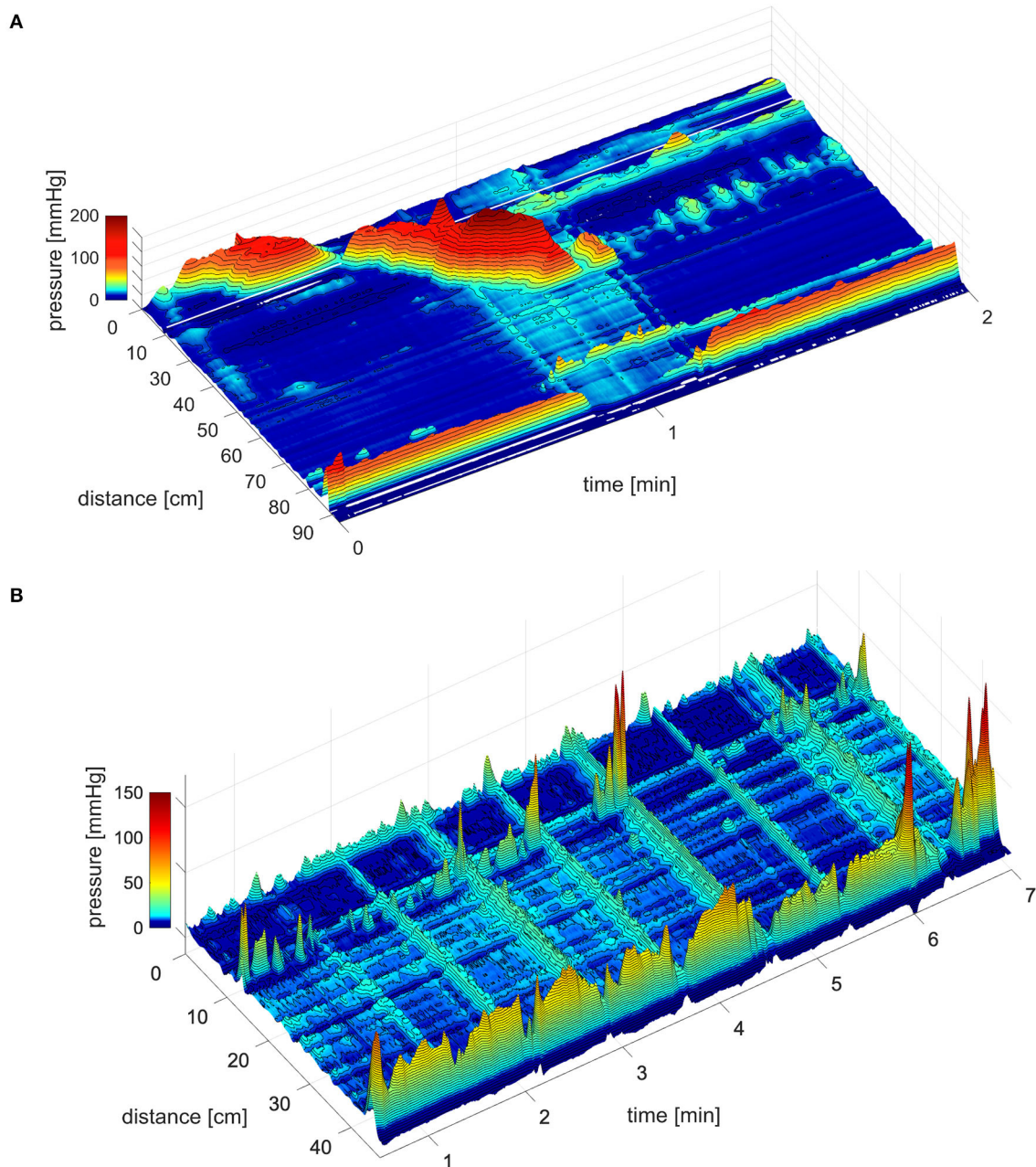


FIGURE 1 | The coloanal reflex. **(A)** The coloanal reflex associated with an HAPW followed by a simultaneous pressure wave that enters the rectum followed by complete relaxation of the anal sphincters. 0 cm is in the proximal colon, the anal sphincter is at 85 cm. The white line represents a 10 cm section where a balloon is situated. From Milkova et al. (24). **(B)** Simultaneous pressure waves followed by anal sphincter relaxation, in this particular session, the strength of the relaxation was related to the amplitude of the SPW. However, even low amplitude SPWs can generate complete AS relaxation. From Chen et al. (25).

block reduces IAS pressure (32, 33). Hence, it is conceivable that overexcitation of sympathetic nerves may inhibit normal relaxation and so contribute to dyssynergia.

The relaxation of the EAS as a consequence of the coloanal reflex (Figure 1), is likely facilitated by autonomous inhibition of motor neurons in Onuf's nucleus (25). It is an autonomous reflex associated with autonomic control of EAS tone (34). The EAS

tone is achieved by the (unusual) tonic activity of a somatic nerve, the pudendal nerve. External anal sphincter tone was not normal in patients with isolated sacral agenesis and these patients were incontinent (12). Relaxation of the EAS occurs autonomously when a propulsive motor pattern enters the rectum as part of the coloanal reflex (35) (Figure 1) just as autonomic contraction of the EAS is an important part of maintaining continence (34).

Assessment of the coloanal reflex with high-resolution colonic manometry, can identify distal colon discoordination and dyssynergia, when the anal sphincters fail to relax in association with propulsive motor patterns or when excessive contraction of the anal sphincters and/or the sphincter of O'Beirne is observed (36). The sphincter of O'Beirne is the specialized musculature at the rectosigmoid junction that can play a critical role in constipation (19, 36). The voluntary contraction of the EAS can be evoked as a reaction to an urge to defecate following the generation of an HAPW or the arrival of a SPW into the rectum, to maintain continence. However, excessive, aberrant autonomous contraction of anal sphincters, pelvic floor muscles, and/or the sphincter of O'Beirne that prevent reflex relaxation, constitutes autonomous dyssynergia (36). The RAIR, on the other hand, is a response to a *conscious* experience of rectal distention that can also reveal dyssynergia. Low or high-resolution anorectal manometry can assess various aspects of rectoanal function such as the degree of IAS pressure inhibition, the slope of inhibition and recovery, any excitatory responses, etc. (37). High-resolution manometry, in addition, can inform about detailed pressure differences throughout the anal canal. These details may inform about the physiological parameters of the reflex and may reveal differences between constipation and incontinence (37), but lack of standardization and the likelihood of a large variability in control values, makes clinical relevance uncertain.

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DISCUSSION

The RAIR in daily life is a sampling reflex that allows filling of the proximal anal canal to allow us to make a decision whether or not to accept expulsion of gas or stool; it is an integral part of our ability to maintain continence and can be the first step toward defecation or flatulence. The manometric parameters of a normal RAIR do not reveal the pathogenesis of obstructed defecation. The coloanal reflex is critical for complete defecation or gas expulsion as it involves relaxation of both the IAS and EAS, and absence will lead to distal colon dysmotility. An abnormal coloanal reflex is an autonomic nervous system dysfunction that can be the primary pathophysiology in outlet obstruction.

AUTHOR CONTRIBUTIONS

This review was conceived and written by JH and J-HC. LL and AB made substantial contributions. All authors approved the final version.

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