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MINIREVIEWS

High-resolution colonic manometry and its clinical application in patients with colonic dysmotility: A review

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Abstract

The detailed process and mechanism of colonic motility are still unclear, and colonic motility disorders are associated with numerous clinical diseases. Colonic manometry is considered to the most direct means of evaluating colonic peristalsis. Colonic manometry has been studied for more than 30 years; however, the long duration of the examination, high risk of catheterization, huge amount of real-time data, strict catheter sterilization, and high cost of disposable equipment restrict its wide application in clinical practice. Recently, high-resolution colonic manometry (HRCM) has rapidly developed into a major technique for obtaining more effective information involved in the physiology and/or pathophysiology of colonic contractile activity in colonic dysmotility patients. This review focuses on colonic motility, manometry, operation, and motor patterns, and the clinical application of HRCM. Furthermore, the limitations, future directions, and potential usefulness of HRCM in the evaluation of clinical treatment effects are also discussed.

Key words: High-resolution colonic manometry; Constipation; High-amplitude propulsive contractions; Low-amplitude propagated contractions; Colonic dysmotility

Core tip: Colonic motility disorders are associated with numerous clinical diseases, while the detailed process and mechanism of colonic motility remain unclear. High-resolution colonic manometry (HRCM) has rapidly developed into a major technique for obtaining greater insight into the physiology and/or pathophysiology of colonic contractile activity

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in patients with colonic motility disorders. This review focuses on colonic motility, manometry, operation, and motor patterns, as well as the clinical application of HRCM, and aims to assess whether the results of HRCM have led to the establishment of diagnostic criteria and/or have helped guide the treatment of patients.

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INTRODUCTION

The main function of the colon is to absorb water and electrolytes, form and store feces, and expel feces at the appropriate time. Also, the microbiome living in the colon is hugely important in the organisms' homeostasis. The detailed process and mechanism of colonic peristalsis are still unclear, partly because of the lack of appropriate animal models. Nevertheless, colonic manometry is considered be the most direct means of evaluating colonic peristalsis.

Colonic motility disorders are associated with numerous clinical conditions, such as constipation, irritable bowel syndrome, inflammatory bowel disease, Hirschsprung disease, and various intestinal cancers[1-3]. High-resolution colonic manometry (HRCM) has gradually become an important means to help diagnose colonic dysmotility and guide clinical treatment[4]. Although the human colon is about 120 cm long, only 5 to 16 recording sites have been set in colonic manometry catheters traditionally[5]. Owing to the spatial resolution and catheter length, most of the colonic manometry data are usually lost. Recently, HRCM with water perfusion that records the peristaltic contractions of the entire colon with a 36-channel catheter has been introduced[6,7]. The tightly spaced sensors can provide detailed images of the colonic transmission patterns, which can allow a functional evaluation of various colorectal diseases based on peristaltic contractions in the entire colon[8-10].

HRCM can record the dynamic colonic contractions of different colorectal segments in real time through the implantation of a manometry catheter into the ileocecal junction through the anus[11]. Although other inspection techniques are difficult to replace, the results of HRCM provide functional and objective data on the transmission and movement of the whole colon[10,12]. This review focuses on colonic motility, manometry, operation, and motor patterns, as well as the clinical application of HRCM, and aims to assess whether the results of HRCM have led to the establishment of diagnostic criteria and/or have helped guide the treatment of patients. The current status and future directions of HRCM are also discussed.

DEFECATION AND PHYSIOLOGICAL PROCESS OF COLONIC PERISTALSIS

Defecation has two stages: The first stage is the involuntary stage and the second stage is the autonomous stage[13]. In the autonomous stage, the pressure in the abdomen increases and the pressure in the pelvis decreases, which can straighten the angle between the anus and rectum and increase the pressure in the rectum. High pressure in the rectum leads to the relaxation of the internal anal sphincter. When the external anal sphincter is also sufficiently relaxed, defecation can be completed[14-16]. Normal colonic motility is a coordinated activity by the smooth muscle, intestinal nervous system, Cajal cells, and autonomic nervous system comprising sympathetic and parasympathetic nerve cells[17,18].

SEGMENTAL MOVEMENT OF THE COLON

Colonic motility is mostly segmental and usually represented by low-amplitude propagated contractions (LAPCs), and the pressure of LAPCs is 5–40 mmHg[19]. These LAPCs are represented by waves of burst contraction of short spikes in an electromyogram[20,21]. They include single contractions and paroxysmal contractions. The frequency of paroxysmal contractions is usually irregular; however, occasionally, rhythmic patterns occur. The rhythmic patterns represent only about 6% of the entire colonic contraction activity. The frequency of rhythmic paroxysmal contractions is 2–8 times per minute, although the frequency of 3 times per minute is predominant especially in the descending colon and sigmoid colon. The frequency of 3 times per minute accounts for more than 80% of the total rhythmic frequency. This rhythm pattern commonly occurs in the junction area between the sigmoid and rectum, where there is no functional sphincter according to some studies[22]. The absence of a functional sphincter can lead to dysfunction in the defecation process, which can explain the pathological mechanism of some functional constipation disorders[23,24].

There is a periodic contraction activity in the rectum, namely, the so-called rectal motility complex wave. The rectal motility complex wave cannot propagate and is irrelevant to the motility of the anus or stomach[25,26]. However, recent evidence has suggested that the appearance of rectal motility complex waves occurs with the increase of anal pressure[27,28]. The higher pressure in the anus than that in the rectum may be a mechanism of anterior rectal fecal incontinence.

PROPAGATED MOVEMENT OF THE COLON

There are two main types of contraction activities: LAPCs and high-amplitude propagation contractions (HAPCs), which are represented by the spikes of burst contraction in an electromyogram[6,29]. The major difference between LAPCs and HAPCs lies in their amplitude.

In colonic manometry, HAPCs represent large-scale colonic movement[30,31]. Colonic motility has been described and quantified in healthy volunteers with long-term recording. The following details about HAPCs were obtained: (1) In the colon of healthy individuals, HAPCs have an average frequency of 6 every 24 h, which last for more than 10 s long, spread for at least 30 cm distance, and ends at the junction of the sigmoid colon and the rectum; (2) Because their average amplitude reaches 120 mmHg, it is easy to distinguish HAPCs from other background conditions on the manometric recording image; (3) HAPCs are often initiated from the ascending colon. Previous studies have shown that the appendix is also involved in this activity; (4) In some circumstances, HAPCs can initiate from the end of the ileum; (5) Most HAPCs (95%) propagate in the oro-aboral direction, but rarely in the distal colon, and HAPCs are often associated with defecation; and (6) HAPCs are associated with specific physiological or behavioral events, and there are more HAPCs in the daytime (80%) than at night. During the daytime, HAPCs often appear after meals (50%) and in the morning during awakening (35%). As shown by radiologic analysis, the major function of HAPCs is to push an amount of colon contents to the distal of the colon, which can lead to a right-left pressure gradient. In addition, HAPCs may be induced by oral or intracavitary injection of laxatives. However, it should be noted that: (1) Not all HAPCs lead to excretion; and (2) Excretion is not always accompanied by HAPCs (especially liquid excretion, which does not require a strong pushing force)[6,29].

Compared with HAPCs, the amplitude of propagation contractions in LAPCs is no more than 50 mmHg, which occur 45 to 120 times within 24 h, usually in the range of 5 to 40 mmHg. Similar to HAPCs, the LAPCs occur more noticeably during the day than at night, whose appearance increases after meals and after waking up. Preliminary studies about pressure measurements have shown that LAPCs may be related to the transport and discharge of gases (inflation) and liquid feces. It is interesting that the frequency of LAPCs considerably increases in ulcerative colitis and other intestinal diseases with diarrhea symptoms.

POSTPRANDIAL RESPONSE AND GASTROCOLIC REFLEX

Postprandial colon response is another important event that merits attention. In 1913, Hertz *et al*[32,33] described the ileal and colonic reactions after meals, and demonstrated that active peristalsis at the end of the ileum could cause the contents of the intestine to pass through the ileum into the colon, causing a considerable amount of movement to appear in the colon. Ritchie *et al*[34] also reported in 1968 that there is a decrease in haustral shunting and an increase in segmental propulsion after meals. Moreno-Osset *et al*[35,36] reported that considerable amounts of movements occur in the transverse colon, descending colon, and sigmoid colon after meals, which was proved by tracer observation. In that study, there was a significant increase in colonic pressure events including an increase of HAPCs and common colonic motility after meals. A colon transport study involving a high-calorie diet reported a relevant increasement of the intestinal contents' propulsion, and some colonic manometry studies also showed an increased frequency of HAPCs after meals[37,38]. The ultimate result of colonic movement is defecation. The pressure events recorded in colonic manometry coincide with the radiographic observation of the actual movement of the colon wall before defecation.

COLONIC MANOMETRY

It is traditionally believed that the colonic contraction function can be measured by placing a pressure-sensitive catheter into the length of the colon cavity. Most studies were conducted using water-filled catheters, whereas solid-state manometric catheters have also been used in a few cases[39,40]. In water perfusion manometry, the interval between the recording positions on the catheter is variable. A manometric catheter is customized according to the patient's age and the objectively measured length of the colon. The interval can be determined according to the length of the catheter and that of the colon. The interval is usually less than 5 cm, and the interval of high-resolution manometry is usually 1–2 cm. The micro water perfusion system is a low-compliance, low-perfusion pressure measurement system, with each pressure-measuring hole connected to a single pressure sensor through a separate chamber (channel). Distilled water is performed in perfusion at a constant pressure at a constant low rate[41].

The colon contraction hinders the current and its velocity, forming a pressure measurement channel. The resistance of each port is measured according to the change of pressure. The system has the advantage of simple and relatively inexpensive components, in which the catheter can be easily sterilized under high pressure. The main disadvantage of the system is that it needs to be connected to the filling pump and recording equipment, and cannot make recordings during bodily movements. Furthermore, the amount of water during long-term colonic manometry needs to be monitored, and a mix of dextrose water and normal saline is used to avoid electrolyte imbalances. Especially in infants, the potential risk of water intoxication should be taken into account[5,42].

Solid-state catheters consist of numbers of micro-sensors covered with pressure-sensitive membranes, which can measure a wide range of amplitude. Compared with the traditional water perfusion module, the solid-state pressure gauge can record the transmitted signal through a portable digital recorder, which can be used for dynamic research and acquisition of more representative data[7,43,44]. The disadvantages of colonic manometry with solid-state catheters are the high cost of sensors, the fragility of the catheters, and the limited number of channels.

CATHETER PLACEMENT

Catheters are always placed retrogradely, although they can be placed anterogradely from the stoma to the distant colon. Bowel preparation is necessary for colonoscopy, and some studies have shown that bowel preparation may affect basic movement. Endoscopy is used to place the catheter. The biopsy forceps can clamp the manometric catheter through the suture ring at the tip of the catheter. When the position of the catheter is determined, the forceps are opened and then slowly retracted. In recent studies, the catheter was clamped to the colonic mucosa to avoid displacement and abscission during manometry. Once the manometry is completed, the catheter can be easily pulled out. Another method of catheter placement is through the biopsy channel. In this method, the catheter is not fixed to the intestinal wall, and will be pulled out after the colonoscopy[6,9,29].

The colonic manometric catheter is guided by endoscopy, and colonic dilatation and poor bowel preparation, especially in patients with constipation, can make the catheter placement difficult. It should be emphasized that endoscopy is always performed with the patient under sedation or general anesthesia. Proximal colon catheter placement can also be performed by an experienced radiologist, for which general anesthesia is not necessary; however, this method expose patients to more radiation.

NEW COLONIC MANOMETRY TECHNIQUES

Dynamic colonic manometry for 24 h

The limitation of traditional colonic manometry is the time of the procedure. Some features of colonic manometry such as diurnal variations are easily omitted in short-term manometry. The 24-h colonic manometry method is considered to a good choice, and can assess colonic peristalsis influenced by environmental factors, diet, and sleep patterns. Dynamic water perfusion colonic manometry has been used in the clinical setting; however, solid-state manometric catheters, which do not restrict the patient's activity, are preferred. Solid-state catheters are placed at multiple sites of the colon wall through a colonoscopy. The end of the catheter is fixed to the hip and connected to the portable recorder. Patients are allowed to move, eat, and defecate in the hospital[42,45,46]. However, compared to short-term colonic manometry, whether the additional information gathered in the 24 h study can change the clinical management remains unclear.

Wireless pH pressure capsules

The United States Food and Drug Administration has approved the use of wireless pH pressure capsules to measure gastric emptying and intestinal transit times[47,48]. The pH, pressure, and temperature throughout the gastrointestinal tract can be measured after the large capsule has been swallowed. The data are transmitted to the data receiver and then analyzed. The time of gastric evacuation is from the time of swallowing the capsule to the time when the pH value is higher than 6, which indicates that the capsule has been discharged from the stomach into the duodenum and entered the neutral pH from the acidic environment. Wireless pH pressure capsules can only measure the colonic pressure; it is not able to evaluate the peristalsis or propagation of colonic contractions. In addition, the gastric evacuation time of the wireless pH pressure capsule is likely to be long, as the gastric evacuation of non-digestible solids is different from that of digestible food[49,50]. Wireless pH pressure capsules are useful in assessing colonic motility as an alternative radiation-free marker; however, their cost is unjustifiably large when they are used only for the purpose of assessing colonic motility.

HRCM

High-resolution manometry has been widely used in the evaluation of the esophagus and the anorectum. Similar colon assessment techniques are being developed. The sensor spacing in HRCM is 1 cm, whereas the traditional catheter spacing is more than 5 cm. All the data are transferred to professional computers for recording and analysis[38,51].

Prospective studies are needed to identify the applications of HRCM and to provide criteria for its use in clinical practice. HRCM has a value in evaluating colonic motility in children with complex biopsychosocial disorders[52,53]. In most other colonic manometric studies, the presence or absence of HAPCs is used to distinguish between persons with colonic motility disorders and healthy people. For example, in healthy people, the frequency of HAPCs is reported to be 6 to 20 times within 24 hours, while in severe constipation patients, this frequency is shown to decrease or disappear completely. However, the results of HRCM have confirmed that HAPCs also appear in some patients with constipation[29].

Because the maximum diameter of colonic dilatation is 50 mm but the diameter of the colonic manometer catheter is only 3–5 mm, most minor intestinal wall movements and pressure events may be overlooked by colonic manometry. A study using a pneumatic device confirmed that pressure measurements might miss up to 70% of contraction events when the diameter of the colon exceeds 5.6 cm. It should be noted that the 5.6 cm diameter quoted here was obtained through isobaric balloon expansion of the colon, which cannot represent the natural colonic state. In fact, there are still doubts about the colonic motor evaluation ability of colonic manometry. In a short-term (3 h) study of descending colon movement, there was no significant difference in the frequency of HAPCs between healthy controls and constipated patients. In patients with constipation, the colon can produce stress events related to normal colonic motility, which is an important issue when attempting to diagnose constipation and guide its treatment by colonic manometry[6,29].

These data suggest that retrograde transmission events occurring in the human colon are actually progressive, whose occurrence may be to block anterograde transmission and help mix the colon contents. Retrograde transmission can immediately occur during and after anterograde transmission, and helps the intestinal wall to have enough time to absorb water and electrolytes. This also explains why the speed of intestinal content passage is much slower through the colon than through other areas of the gastrointestinal tract. It can be concluded that although intestinal manometry cannot detect every pressure wave in the colon, it can detect most of the important movement patterns. Although HAPCs have attracted the attention of many researchers, a well-developed system for assessing normal colonic motility needs to incorporate all detectable colon events.

CLINICAL APPLICATION

Identification of the etiology and the diagnosis of functional intestinal diseases are essential for the choice of clinical therapeutic strategies and for improving the quality of life of patients. However, the current treatment is not appropriate for a considerable number of patients with functional intestinal diseases. To improve the treatment strategies and therapeutic effects, it is necessary to identify the etiology of the disease. The use of colonic manometry can help clinicians reveal the truth about these diseases.

Unfortunately, especially in adults, there are no guidelines for the use of colonic manometry in the diagnosis and treatment of functional intestinal diseases including constipation.

Colonic manometry has been used in only a few studies in patients with constipation[6,10,29]. First, some studies using colonic manometry failed to identify colon contraction events in constipated patients with delayed transit. Second, colonic manometry could not be used to distinguish patients with colonic slow-transit disorder from patients with rectal evacuation disorders in a study about colonic motor dysfunction. Third, colonic manometry has been used in a subgroup analysis of 40 adults with slow-transit constipation. These 40 patients were divided into four groups according to the frequency of HAPCs, colon response to high-calorie meals, and increased sigmoid pressure events. However, the clinical significance of the outcomes remains uncertain. Another study showed that colonic manometry cannot be used to distinguish patients with slow-transit constipation or with evacuation disorders from those with normal-transit constipation according to the colonic motility patterns and pressure measurement. The study also showed that decreased colonic tension and/or compliance appeared in 40% to 53% of patients with constipation at fasting and/or after meals, whereas 47% to 60% of patients did not show these characteristics.

Intractable constipation

Increased colon transit time, reduced propulsive movements, and the poor response to dietary fiber and laxatives are the typical clinical symptoms of constipation[2,3]. The most commonly used diagnostic criteria for constipation are the Rome IV, and different clinical therapeutic strategies are applicable to different types and stages of constipation. In patients with intractable constipation, colonic manometry can be used to evaluate the severity of constipation, confirm the effectiveness of drug treatment, guide surgical procedures including shunt placement and partial colectomy, and assess the function of the disconnected colon before closing the stoma. Li *et al*[29] have reported that constipation could be categorized into different types and subtypes including implement qualitative constipation (IQC), functional constipation (FC), mixed IQC and FC, and functional outlet obstruction constipation (FOOC) based on the results of HRCM. In mild IQC patients, the number of HAPCs with complete transmission was ≥ 1 and ≤ 3, or the number of LAPCs with complete transmission was > 10, and the LAPC amplitude had no change after neostigmine injection, which needed a conservative treatment. Moderate IQC showed no HAPCs, while LAPCs with complete transmission could be observed (the number was ≤ 10), and no colonic response occurred after using neostigmine, which is a relative indication for surgery. Severe IQC showed no HAPCs or LAPCs with complete transmission, while HAPCs and LAPCs could be induced after neostigmine injection, serving as an indication for a total or subtotal colectomy. FC includes transmission disorder and transmission inhibition. The former showed LAPCs with complete transmission, low-amplitude retrograde pressure waves, and retrograde HAPCs during the daytime, while LAPCs and HAPCs with complete and/or incomplete transmission could be observed at night. The latter showed no HAPCs and only a few LAPCs with complete transmission, and > 3 HAPCs could be induced after using neostigmine. The first-choice for FC patients was conservative treatment. Mixed IQC and FC included mild, moderate, and severe subtypes. In mild patients, the number of HAPCs with complete transmission was ≥ 1 and ≤ 3, or LAPCs with complete transmission was > 10, and the amplitude of LAPCs increased and the increased amplitude number was > 10 in an hour after neostigmine injection, which just required conservative treatment. Moderate patients showed only a few weak peristaltic waves, with no HAPCs or LAPCs, and LAPCs with complete transmission could be induced and the number was > 5 and < 10 within an hour after neostigmine injection. Severe patients showed no HAPCs or LAPCs, or only a few weak peristaltic waves, and LAPCs with complete transmission could be induced after neostigmine injection with the number was < 5.

Moderate and severe mixed IQC and FC were relative indications for surgery. In FOOC patients, HAPCs with complete transmission could be observed and the colonic motility was almost normal, in which local excisions, including procedure for prolapse and hemorrhoids and tissue-selecting therapy stapler, were common treatments. Based on the results of HRCM, the clinical characteristics and treatment modalities for 326 patients with intractable constipation (aged 11-83 years) at our hospital from July 2016 to April 2019 are showed in Table 1.

Most patients with constipation are functional, whereas a small proportion of patients with constipation have severe symptoms that do not respond to active clinical treatment. A lack of response to clinical treatment can cause patients to develop depression, distrust of the clinician, and loss of self-esteem[54,55]. Colonic manometry is used to assess colonic motility in these patients and to distinguish between normal colonic motility and abnormal colonic motility, which may be related to nerves and/or muscles associated with diseases of the colon[56,57]. This information can also be used to guide the management of chronic diseases. Excision of the colon segment with abnormal peristalsis function can improve the symptoms of constipation. Interestingly, there is almost no correlation between abnormal pressure measurements and histopathologic abnormalities.

Chronic intestinal obstruction

Colonic manometry can be used to assess whether chronic intestinal obstruction is caused by the dysfunction of the colon or by extra-intestinal factors (chronic intestinal pseudo-obstruction, CIPO). CIPO is a group of diseases with a different etiology, severity, and treatment response[57,58]. Di Sigurdsson *et al*[59] showed that some symptoms of chronic constipation including an unresponsive gastrocolic reflex or lack of colonic motility were obvious in some patients with CIPO. Furthermore, in assessing the possibility of small-bowel or combined transplantation of multiple organs in children with CIPO, a comprehensive manometric assessment including colonic manometry is needed to assess which organs need transplantation and whether a permanent ileal shunt should be planned.

Hirschsprung disease and anorectal malformation

After the excision of the abnormal intestinal segment in the treatment of Hirschsprung disease, a large proportion of patients still experience abnormal defecation patterns. Colonic manometry can stratify patients with Hirschsprung disease requiring surgical treatment into four groups with different physiological characteristics[60-62]. The first group includes patients with HAPCs, in whom the HAPCs can pass through the rectum to the anal margin, but the amplitude of HAPCs is greater than the voluntary contraction of the external anal sphincter. Despite attempts to retain stool, these patients experience fecal incontinence or rectal pain. The second group includes patients with normal colonic motility but have fears of defecation and are unable to defecate. Possible complications associated with fecal retention may occur after anterior constipation resection. The third group includes patients with abnormal colonic manometry, lack of HAPCs, poor transmission, or increased distal colon pressure, which may be due to neurological disorders, dysplasia of colon neurons, or the common “hollow” phenomenon. The last group includes a small number of patients with defecation disorders after surgery for Hirschsprung disease but with normal colonic motility. However, a high anal sphincter pressure can lead to dysfunction of defecation. For these patients, the clinical treatments include anal sphincterectomy and injection of kreotoxin into the anal sphincter pressure zone. Excessive HAPC entry into the rectum and anal sphincter dysfunction could lead to fecal incontinence.

CLINICAL TREATMENT AND COLONIC MANOMETRY

It should be pointed out that the clinical application of colonic manometry might be more valuable in pediatric patients than in adult patients with functional intestinal diseases. Colonic manometry may be the only way to distinguish constipation due to intrinsic neuromuscular disorders from that caused by behavioral factors in children. Only two studies to date have tried to perform colonic manometry to guide adults’ clinical treatment.

Bassotti *et al*[63] reported three cases of severe constipation in 1992. They demonstrated that the frequency of HAPCs and the peristalsis of the whole colon decreased, and the postprandial response of the colon was poor. The patients showed no response to the stimulation of edrophonium chloride. These patients did not undergo standardized medical treatment. The results of colonic manometry suggested that the colon would still lack of sensitivity to drug therapy and spontaneous

Table 1 Characteristics of 326 patients with intractable constipation in our hospital based on high-resolution colon manometry

Sex	*n*	Age (yr)	Subtype of constipation	*n*	Treatment based on HRCM	*n*
Male	83	60.70 ± 12.68	Neurogenic constipation	13	Conservative treatment	172
			Myogenic constipation	177	Subtotal colectomy	41
			Mixed constipation	74	Total colectomy	45
Female	243	53.19 ± 12.99	FOOC	62	TST	53
					Ileostomy	14
					Intestinal mucosal lysis	1

HRCM: High-resolution colon manometry; FOOC: Functional outlet obstruction constipation; TST: Tissue-selecting therapy stapler.

remission would not occur, resulting in a recommendation of surgical resection of the colon. Total colectomy was performed in two patients and subtotal colectomy in one. However, these diagnostic and treatment procedures for constipation are not well described, and there are no long-term follow-up data.

Rao *et al*[64] used 24 h colonic manometry in slow-transit constipation patients, observed their colon reactions during eating and waking up in the morning, and recorded the frequency of HAPCs. According to the presence, absence, and decrease of colon reactions and HAPCs, the patients were usually classified as normal colonic movement, myogenic, or neurogenic dysmotility. Myogenic is defined as the decrease of above two or more factors, whereas neurogenic is considered the absence of above two or more factors. Patients with suspected neuropathy underwent the colon resection, whereas those with myopathy were treated with biofeedback therapy. Similarly, the description of the clinical outcomes in terms of intestinal symptoms improvement after colon resection was not exhaustive, although a slight improvement after 1 year in patients with myopathy was described. Colonic reactions after eating or waking up in the morning are likely to be mediated by the central nervous system. The absence of colon reactions may provide evidence of neurogenic disorders. However, this does not mean that a decrease of colonic reactions reflects a myogenic disease. In fact, based on our current understanding of colonic contractile activity, decreased colonic response only provides evidence of a potential neuropathy[29]. Furthermore, there are several lines of evidence refuting the above concept. First, colonic manometry studies in adults have provided substantial evidence of spontaneous activity. Second, colonic manometry studies on constipation have indicated that chemical stimulants can induce colonic motility. Third, a recent *in vitro* study showed that there was no difference in the motion patterns of the proximal and distal colon between patients with constipation after subtotal colectomy and those with a "healthy" colon. These observations indicate that the intrinsic pacing mechanism can induce transmission events in patients with constipation, but the parenteral nerve input is partly decreased. Therefore, the failure or weakening of the colonic reaction to physiological stimulation may be on behalf of different neurogenic dysmotilities. Accordingly, unless a confirmed and definite criterion for colonic manometry based on histopathology is produced, the diagnosis of myogenic or neurological disorders will always be speculative. At present, evidence on the usefulness of colonic manometry in classifying intestinal dysfunction and myogenic disorder is unconvincing.

Because it seems that colonic manometry can detect most of the important propulsive events in colonic transit, this raises the question of why colonic manometry is difficult to be considered a useful clinical tool in adults. There has been no important change in the knowledge of colonic manometry since 1988. Pharyngeal/esophageal manometry is used by clinicians worldwide only to predict the subtypes of dysphagia and the treatment outcomes[65,66], for the following reasons: First, the esophagus is short and the manometric catheter can easily reach the stomach. Second, as patients can relatively control their esophageal movement, they can be told when to swallow. Third, significant esophageal motility is immediate and transient, which means that its detection can be completed in 30 min, and rapid analysis based on effective and relatively easy-to-identify pressure "signals" can be performed.

Esophageal manometry has made some considerable progress in the past decade. The most important advancement is the development of high-resolution pressure measurement. The catheter contains up to 36 sensors spaced at a distance of 1 cm, which provides a detailed outline of the pressure throughout the target area. Another technological advancement is the creation of visualization and analysis software. In esophageal manometry, the differences between pressure points allow the establishment of a space-time color map of the pressure profile, which enables laypersons to quickly understand normal or heterogeneous pressure patterns. Recently, the data from combined pharyngeal manometry with impedance tests has been performed in automatic software analysis to accurately evaluate inhalation risk of dysphagia patients.

It is believed that the length of the high-resolution catheter for recording the whole colonic pressure will remain unsatisfactory for a long time. Recently, the appearance of fiber-optic manometric catheters has resulted in a significant increase in the number of sensors (as many as 144 channels/cm) without compromising its flexibility. Analyzing these high-resolution recording data can provide a correct understanding of missing or mismarked retrograde and anterograde pressure events. Data obtained from conventional catheters can produce aliasing-like effects in signal processing. In practice, the data from colonic manometry may be twice the number of actual colon transmission events. However, even with the improved spatial resolution of manometric catheters, the summarization of HAPCs or areas under the reporting curves is still obviously insufficient to separate all the sick from the healthy. There is no specific pattern of colonic motility that can distinguish patients from the healthy, except in some special cases. A comprehensive evaluation of the data recorded during colonic manometry, including the temporal-spatial relationship between all pressure events throughout the colon, is necessary. In 1933, a researcher suggested that muscle dysfunction (not paralysis) is the basis of all constipation events except absolute mechanical obstructive constipation. Furthermore, the absence of HAPCs is not always the most obvious characteristic of a potential neuropathy. The inhibitory nerve input can also affect colonic motility. In many patients with constipation, the frequency of LAPCs and/or retrograde transmission increase, especially in the resting state at night. The lack of inhibition of these motor patterns is considered a sign of underlying neurogenic disorders.

CONCLUSION

In the past decade, research about colonic movement has provided substantial information for clinicians. Colonic manometry has been considered a standard diagnostic examination in pediatric patients. There is now a clear use of colonic manometry and its clinical value has been recognized. Moreover, new treatment indications have been determined using the results of HRCM. Colonic manometry has been studied for more than 30 years[7,10,52,67-70], although the long time of the examination, high risk of catheterization, large amounts if real-time data, strict catheter sterilization, and high cost of disposable equipment restrict its wide application in clinical practice. With the development of high-resolution technologies and more economical and convenient silicone catheters, HRCM has gradually become an indispensable and effective means of evaluating colonic dysmotility[9,11]. HRCM with water perfusion technology helps assess the ability of colorectal peristaltic contractions and plays a central role in the clinical evaluation of colonic function, determination of constipation subtypes, and accurate identification of diseased colon segments[64,69]. Besides the role of HRCM in guiding clinical treatment, the colon propagating motor patterns including HAPCs and LAPCs, retrograde pressure wave, transmission integrity, and provocation test using neostigmine can also predict the clinical treatment effect. HRCM needs to be performed in specialized research centers. The technicians should have special expertise in the study of colonic movement and can well assess patients with complex biopsychosocial disorders. Other new technologies including high-resolution fiber-optic manometers and wireless power capsules will continue to increase the knowledge about colonic dyskinesia.

REFERENCES

1 **Dinning PG**, Carrington EV, Scott SM. Colonic and anorectal motility testing in the high-resolution era. *Curr Opin Gastroenterol* 2016; **32**: 44-48 [PMID: 26574870 DOI: 10.1097/mog.0000000000000229]

2 **Bharucha AE**, Phillips SF. Slow transit constipation. *Gastroenterol Clin North Am* 2001; **30**: 77-95 [PMID: 11394038 DOI: 10.1016/S0889-8553(05)70168-0]

3 **Hutson JM**, Chase JW, Clarke MC, King SK, Sutcliffe J, Gibb S, Catto-Smith AG, Robertson VJ, Southwell BR. Slow-transit constipation in children: our experience. *Pediatr Surg Int* 2009; **25**: 403-406 [PMID: 19396449 DOI: 10.1007/s00383-009-2363-5]

4 **Dinning PG**. A new understanding of the physiology and pathophysiology of colonic motility? *Neurogastroenterol Motil* 2018; **30**: e13395 [PMID: 29971850 DOI: 10.1111/nmo.13395]

5 **Bampton PA**, Dinning PG. High resolution colonic manometry--what have we learnt?--A review of the literature 2012. *Curr Gastroenterol Rep* 2013; **15**: 328 [PMID: 23709203 DOI:

10.1007/s11894-013-0328-2]
6 **Li Y**, Yu Y, Li S, Zhang M, Zhang Z, Zhang X, Shi Y, Zhang S. Isobaric tags for relative and absolute quantification-based proteomic analysis that reveals the roles of progesterone receptor, inflammation, and fibrosis for slow-transit constipation. *J Gastroenterol Hepatol* 2018; **33**: 385-392 [PMID: 28699285 DOI: 10.1111/jgh.13873]
7 **Vather R**, O'Grady G, Lin AY, Du P, Wells CI, Rowbotham D, Arkwright J, Cheng LK, Dinning PG, Bissett IP. Hyperactive cyclic motor activity in the distal colon after colonic surgery as defined by high-resolution colonic manometry. *Br J Surg* 2018; **105**: 907-917 [PMID: 29656582 DOI: 10.1002/bjs.10808]
8 **Dinning PG**, Carrington EV, Scott SM. The use of colonic and anorectal high-resolution manometry and its place in clinical work and in research. *Neurogastroenterol Motil* 2015; **27**: 1693-1708 [PMID: 26224550 DOI: 10.1111/nmo.12632]
9 **Lee YY**, Erdogan A, Rao SS. High resolution and high definition anorectal manometry and pressure topography: diagnostic advance or a new kid on the block? *Curr Gastroenterol Rep* 2013; **15**: 360 [PMID: 24271955 DOI: 10.1007/s11894-013-0360-2]
10 **Lin AY**, Du P, Dinning PG, Arkwright JW, Kamp JP, Cheng LK, Bissett IP, O'Grady G. High-resolution anatomic correlation of cyclic motor patterns in the human colon: Evidence of a rectosigmoid brake. *Am J Physiol Gastrointest Liver Physiol* 2017; **312**: G508-G515 [PMID: 28336544 DOI: 10.1152/ajpgi.00021.2017]
11 **Giorgio V**, Borrelli O, Smith VV, Rampling D, Köglmeier J, Shah N, Thapar N, Curry J, Lindley KJ. High-resolution colonic manometry accurately predicts colonic neuromuscular pathological phenotype in pediatric slow transit constipation. *Neurogastroenterol Motil* 2013; **25**: 70-78.e8-9 [PMID: 23030503 DOI: 10.1111/nmo.12016]
12 **Werth B**, Meyer-Wyss B, Spinas GA, Drewe J, Beglinger C. Non-invasive assessment of gastrointestinal motility disorders in diabetic patients with and without cardiovascular signs of autonomic neuropathy. *Gut* 1992; **33**: 1199-1203 [PMID: 1427371 DOI: 10.1136/gut.33.9.1199]
13 **Picciariello A**, Papagni V, Martines G, De Fazio M, Digennaro R, Altomare DF. Post-operative clinical, manometric, and defecographic findings in patients undergoing unsuccessful STARR operation for obstructed defecation. *Int J Colorectal Dis* 2019; **34**: 837-842 [PMID: 30783740 DOI: 10.1007/s00384-019-03263-9]
14 **Lopez VK**, Berrocal VJ, Corozo Angulo B, Ram PK, Trostle J, Eisenberg JNS. Determinants of Latrine Use Behavior: The Psychosocial Proxies of Individual-Level Defecation Practices in Rural Coastal Ecuador. *Am J Trop Med Hyg* 2019; **100**: 733-741 [PMID: 30675841 DOI: 10.4269/ajtmh.18-0144]
15 **Naniwa K**, Sugimoto Y, Osuka K, Aonuma H. Defecation initiates walking in the cricket Gryllus bimaculatus. *J Insect Physiol* 2019; **112**: 117-122 [PMID: 30468738 DOI: 10.1016/j.jinsphys.2018.11.004]
16 **Bove A**, Pucciani F, Bellini M, Battaglia E, Bocchini R, Altomare DF, Dodi G, Sciaudone G, Falletto E, Piloni V, Gambaccini D, Bove V. Consensus statement AIGO/SICCR: diagnosis and treatment of chronic constipation and obstructed defecation (part I: diagnosis). *World J Gastroenterol* 2012; **18**: 1555-1564 [PMID: 22529683 DOI: 10.3748/wjg.v18.i14.1555]
17 **Burns AJ**, Roberts RR, Bornstein JC, Young HM. Development of the enteric nervous system and its role in intestinal motility during fetal and early postnatal stages. *Semin Pediatr Surg* 2009; **18**: 196-205 [PMID: 19782301 DOI: 10.1053/j.sempedsurg.2009.07.001]
18 **van den Berg MM**, Di Lorenzo C, Mousa HM, Benninga MA, Boeckxstaens GE, Luquette M. Morphological changes of the enteric nervous system, interstitial cells of cajal, and smooth muscle in children with colonic motility disorders. *J Pediatr Gastroenterol Nutr* 2009; **48**: 22-29 [PMID: 19172119 DOI: 10.1097/MPG.0b013e318173293b]
19 **Bassotti G**, Clementi M, Antonelli E, Pelli MA, Tonini M. Low-amplitude propagated contractile waves: a relevant propulsive mechanism of human colon. *Dig Liver Dis* 2001; **33**: 36-40 [PMID: 11303973 DOI: 10.1016/S1590-8658(01)80133-X]
20 **Mesin L**, Merletti R, Vieira TM. Insights gained into the interpretation of surface electromyograms from the gastrocnemius muscles: A simulation study. *J Biomech* 2011; **44**: 1096-1103 [PMID: 21334627 DOI: 10.1016/j.jbiomech.2011.01.031]
21 **Shafik A**, El-Sibai O, Ahmed I. On the mechanism of colonic motility: the electric activation theory of colonic contraction. *J Surg Res* 2002; **103**: 8-12 [PMID: 11855911 DOI: 10.1006/jsre.2001.6308]
22 **Bharucha AE**, Anderson B, Bouchoucha M. More movement with evaluating colonic transit in humans. *Neurogastroenterol Motil* 2019; **31**: e13541 [PMID: 30681255 DOI: 10.1111/nmo.13541]
23 **Bassotti G**, Chistolini F, Marinozzi G, Morelli A. Abnormal colonic propagated activity in patients with slow transit constipation and constipation-predominant irritable bowel syndrome. *Digestion* 2003; **68**: 178-183 [PMID: 14671425 DOI: 10.1159/000075554]
24 **Bassotti G**, Chistolini F, Nzepa FS, Morelli A. Colonic propulsive impairment in intractable slow-transit constipation. *Arch Surg* 2003; **138**: 1302-1304 [PMID: 14662528 DOI: 10.1001/archsurg.138.12.1302]
25 **Prior A**, Fearn UJ, Read NW. Intermittent rectal motor activity: a rectal motor complex? *Gut* 1991; **32**: 1360-1363 [PMID: 1752469 DOI: 10.1136/gut.32.11.1360]
26 **Kumar D**, Thompson PD, Wingate DL. Absence of synchrony between human small intestinal migrating motor complex and rectal motor complex. *Am J Physiol* 1990; **258**: G171-G172 [PMID: 2301579 DOI: 10.1152/ajpgi.1990.258.1.G171]
27 **Qi H**, Brining D, Chen JD. Rectal distension inhibits postprandial small intestinal motor activity partially via the adrenergic pathway in dogs. *Scand J Gastroenterol* 2007; **42**: 807-813 [PMID: 17558903 DOI: 10.1080/00365520601127257]
28 **Xu J**, Dz Chen J. Effects of sibutramine on gastric emptying, intestinal motility and rectal tone in dogs. *Dig Dis Sci* 2008; **53**: 155-162 [PMID: 17510801 DOI: 10.1007/s10620-007-9837-x]
29 **Li Y**, Cong J, Fei F, Zhang Z, Yu Y, Xu C, Zhang X, Zhang S. Use of high-resolution colonic manometry to establish etiology and direct treatment in patients with constipation: Case series with correlation to histology. *J Gastroenterol Hepatol* 2018; **33**: 1864-1872 [PMID: 29791059 DOI: 10.1111/jgh.14287]
30 **Miner PB**, Camilleri M, Burton D, Achenbach H, Wan H, Dragone J, Mellgard B. Prucalopride induces high-amplitude propagating contractions in the colon of patients with chronic constipation: a randomized study. *Neurogastroenterol Motil* 2016; **28**: 1341-1348 [PMID: 27270968 DOI: 10.1111/nmo.12832]
31 **Smith TK**, Park KJ, Hennig GW. Colonic migrating motor complexes, high amplitude propagating contractions, neural reflexes and the importance of neuronal and mucosal serotonin. *J Neurogastroenterol Motil* 2014; **20**: 423-446 [PMID: 25273115 DOI: 10.5056/jnm14092]
32 **Hertz AF**. The ileo-caecal sphincter. *J Physiol* 1913; **47**: 54-56 [PMID: 16993234 DOI: 10.1113/jphysiol.1913.sp001612]

33 **Hertz AF**, Newton A. The normal movements of the colon in man. *J Physiol* 1913; **47**: 57-65 [PMID: 16993235 DOI: 10.1113/jphysiol.1913.sp001613]
34 **Ritchie JA**, Truelove SC, Ardran GM. Propulsion and retropulsion in the human colon demonstrated by time-lapse cinefluorography. *Gut* 1968; **9**: 735-736 [PMID: 5718008]
35 **Moreno-Osset E**, Ballester J, Mínguez M, Mora F, Benages A. [Colonic transit time (segmental and total) in healthy subjects and patients with chronic idiopathic constipation]. *Med Clin (Barc)* 1992; **98**: 201-206 [PMID: 1560685]
36 **Moreno-Osset E**, Bazzocchi G, Lo S, Trombley B, Ristow E, Reddy SN, Villanueva-Meyer J, Fain JW, Jing J, Mena I. Association between postprandial changes in colonic intraluminal pressure and transit. *Gastroenterology* 1989; **96**: 1265-1273 [PMID: 2703114 DOI: 10.1016/S0016-5085(89)80013-7]
37 **Charepalli V**, Reddivari L, Radhakrishnan S, Eriksson E, Xiao X, Kim SW, Shen F, Vijay-Kumar M, Li Q, Bhat VB, Knight R, Vanamala JKP. Pigs, Unlike Mice, Have Two Distinct Colonic Stem Cell Populations Similar to Humans That Respond to High-Calorie Diet prior to Insulin Resistance. *Cancer Prev Res (Phila)* 2017; **10**: 442-450 [PMID: 28576788 DOI: 10.1158/1940-6207.Capr-17-0010]
38 **Chen JH**, Parsons SP, Shokrollahi M, Wan A, Vincent AD, Yuan Y, Pervez M, Chen WL, Xue M, Zhang KK, Eshtiaghi A, Armstrong D, Bercik P, Moayyedi P, Greenwald E, Ratcliffe EM, Huizinga JD. Characterization of Simultaneous Pressure Waves as Biomarkers for Colonic Motility Assessed by High-Resolution Colonic Manometry. *Front Physiol* 2018; **9**: 1248 [PMID: 30294277 DOI: 10.3389/fphys.2018.01248]
39 **Noelting J**, Ratuapli SK, Bharucha AE, Harvey DM, Ravi K, Zinsmeister AR. Normal values for high-resolution anorectal manometry in healthy women: effects of age and significance of rectoanal gradient. *Am J Gastroenterol* 2012; **107**: 1530-1536 [PMID: 22986439 DOI: 10.1038/ajg.2012.221]
40 **Rasijeff AMP**, Withers M, Burke JM, Jackson W, Scott SM. High-resolution anorectal manometry: A comparison of solid-state and water-perfused catheters. *Neurogastroenterol Motil* 2017; 29 [PMID: 28639425 DOI: 10.1111/nmo.13124]
41 **Lee TH**, Bharucha AE. How to Perform and Interpret a High-resolution Anorectal Manometry Test. *J Neurogastroenterol Motil* 2016; **22**: 46-59 [PMID: 26717931 DOI: 10.5056/jnm15168]
42 **King SK**, Catto-Smith AG, Stanton MP, Sutcliffe JR, Simpson D, Cook I, Dinning P, Hutson JM, Southwell BR. 24-Hour colonic manometry in pediatric slow transit constipation shows significant reductions in antegrade propagation. *Am J Gastroenterol* 2008; **103**: 2083-2091 [PMID: 18564112 DOI: 10.1111/j.1572-0241.2008.01921.x]
43 **Liem O**, Burgers RE, Connor FL, Benninga MA, Reddy SN, Mousa HM, Di Lorenzo C. Solid-state vs water-perfused catheters to measure colonic high-amplitude propagating contractions. *Neurogastroenterol Motil* 2012; **24**: 345-e167 [PMID: 22276915 DOI: 10.1111/j.1365-2982.2011.01870.x]
44 **Scott SM**. Manometric techniques for the evaluation of colonic motor activity: current status. *Neurogastroenterol Motil* 2003; **15**: 483-513 [PMID: 14507350 DOI: 10.1046/j.1365-2982.2003.00434.x]
45 **Mugie SM**, Perez ME, Burgers R, Hingsbergen EA, Punati J, Mousa H, Benninga MA, Lorenzo CD. Colonic manometry and colonic scintigraphy as a diagnostic tool for children with severe constipation. *J Pediatr Gastroenterol Nutr* 2013; **57**: 598-602 [PMID: 24177783 DOI: 10.1097/MPG.0b013e31829e0bdd]
46 **Stanton MP**, Hutson JM, Simpson D, Oliver MR, Southwell BR, Dinning P, Cook I, Catto-Smith AG. Colonic manometry via appendicostomy shows reduced frequency, amplitude, and length of propagating sequences in children with slow-transit constipation. *J Pediatr Surg* 2005; **40**: 1138-1145 [PMID: 16034759 DOI: 10.1016/j.jpedsurg.2005.03.047]
47 **Aburub A**, Fischer M, Camilleri M, Semler JR, Fadda HM. Comparison of pH and motility of the small intestine of healthy subjects and patients with symptomatic constipation using the wireless motility capsule. *Int J Pharm* 2018; **544**: 158-164 [PMID: 29678546 DOI: 10.1016/j.ijpharm.2018.04.031]
48 **Saad RJ**. The Wireless Motility Capsule: a One-Stop Shop for the Evaluation of GI Motility Disorders. *Curr Gastroenterol Rep* 2016; **18**: 14 [PMID: 26908282 DOI: 10.1007/s11894-016-0489-x]
49 **Stokes AM**, Lavie NL, Keowen ML, Gaschen L, Gaschen FP, Barthel D, Andrews FM. Evaluation of a wireless ambulatory capsule (SmartPill®) to measure gastrointestinal tract pH, luminal pressure and temperature, and transit time in ponies. *Equine Vet J* 2012; **44**: 482-486 [PMID: 22296404 DOI: 10.1111/j.2042-3306.2011.00533.x]
50 **Rao SS**, Camilleri M, Hasler WL, Maurer AH, Parkman HP, Saad R, Scott MS, Simren M, Soffer E, Szarka L. Evaluation of gastrointestinal transit in clinical practice: position paper of the American and European Neurogastroenterology and Motility Societies. *Neurogastroenterol Motil* 2011; **23**: 8-23 [PMID: 21138500 DOI: 10.1111/j.1365-2982.2010.01612.x]
51 **Koppen IJN**, Wiklendt L, Yacob D, Di Lorenzo C, Benninga MA, Dinning PG. Motility of the left colon in children and adolescents with functional constpation; a retrospective comparison between solid-state and water-perfused colonic manometry. *Neurogastroenterol Motil* 2018; **30**: e13401 [PMID: 30039585 DOI: 10.1111/nmo.13401]
52 **Chen JH**, Yu Y, Yang Z, Yu WZ, Chen WL, Yu H, Kim MJ, Huang M, Tan S, Luo H, Chen J, Chen JD, Huizinga JD. Intraluminal pressure patterns in the human colon assessed by high-resolution manometry. *Sci Rep* 2017; **7**: 41436 [PMID: 28216670 DOI: 10.1038/srep41436]
53 **Dinning PG**, Sia TC, Kumar R, Mohd Rosli R, Kyloh M, Wattchow DA, Wiklendt L, Brookes SJ, Costa M, Spencer NJ. High-resolution colonic motility recordings in vivo compared with ex vivo recordings after colectomy, in patients with slow transit constipation. *Neurogastroenterol Motil* 2016; **28**: 1824-1835 [PMID: 27282132 DOI: 10.1111/nmo.12884]
54 **Laouni J**, Scaillon M, Steyaert H, Segers V, Bruyninx L. [Diagnosis and management of a particular caseof intractable constipation]. *Rev Med Brux* 2017; **38**: 501-505 [PMID: 29318807]
55 **van der Doef HP**, Kokke FT, van der Ent CK, Houwen RH. Intestinal obstruction syndromes in cystic fibrosis: meconium ileus, distal intestinal obstruction syndrome, and constipation. *Curr Gastroenterol Rep* 2011; **13**: 265-270 [PMID: 21384135 DOI: 10.1007/s11894-011-0185-9]
56 **Rao SS**, Singh S. Clinical utility of colonic and anorectal manometry in chronic constipation. *J Clin Gastroenterol* 2010; **44**: 597-609 [PMID: 20679903 DOI: 10.1097/MCG.0b013e3181e88532]
57 **Rao SS**. Constipation: evaluation and treatment of colonic and anorectal motility disorders. *Gastrointest Endosc Clin N Am* 2009; **19**: 117-139, vii [PMID: 19232284 DOI: 10.1016/j.giec.2008.12.006]
58 **Gálvez Y**, Skába R, Vajtrová R, Frantlová A, Herget J. Evidence of secondary neuronal intestinal dysplasia in a rat model of chronic intestinal obstruction. *J Invest Surg* 2004; **17**: 31-39 [PMID: 14761826 DOI: 10.1080/08941930490269628]
59 **Sigurdsson L**, Reyes J, Kocoshis SA, Mazariegos G, Abu-Elmagd KM, Bueno J, Di Lorenzo C. Intestinal transplantation in children with chronic intestinal pseudo-obstruction. *Gut* 1999; **45**: 570-574 [PMID:

10486367 DOI: 10.1136/gut.45.4.570]

60 **Enríquez Zarabozo E**, Núñez Núñez R, Ayuso Velasco R, Vargas Muñoz I, Fernández de Mera JJ, Blesa Sánchez E. [Anorectal manometry in the neonatal diagnosis of Hirschsprung's disease]. *Cir Pediatr* 2010; **23**: 40-45 [PMID: 20578577]

61 **Martin MJ**, Steele SR, Mullenix PS, Noel JM, Weichmann D, Azarow KS. A pilot study using total colonic manometry in the surgical evaluation of pediatric functional colonic obstruction. *J Pediatr Surg* 2004; **39**: 352-9; discussion 352-9 [PMID: 15017551 DOI: 10.1016/j.jpedsurg.2003.11.026]

62 **Sintusek P**, Rybak A, Mutalib M, Thapar N, Borrelli O, Lindley KJ. Preservation of the colo-anal reflex in colonic transection and post-operative Hirschsprung's disease: Potential extrinsic neural pathway. *Neurogastroenterol Motil* 2019; **31**: e13472 [PMID: 30288858 DOI: 10.1111/nmo.13472]

63 **Bassotti G**, Morelli A, Whitehead WE. Abnormal rectosigmoid myoelectric response to eating in patients with severe idiopathic constipation (slow-transit type). *Dis Colon Rectum* 1992; **35**: 753-756 [PMID: 1643998 DOI: 10.1007/BF02050324]

64 **Rao SS**, Sadeghi P, Beaty J, Kavlock R. Ambulatory 24-hour colonic manometry in slow-transit constipation. *Am J Gastroenterol* 2004; **99**: 2405-2416 [PMID: 15571589 DOI: 10.1111/j.1572-0241.2004.40453.x]

65 **Pinna BR**, Herbella FAM, de Biase N, Vaiano TCG, Patti MG. High-Resolution Manometry Evaluation of Pressures at the Pharyngo-upper Esophageal Area in Patients with Oropharyngeal Dysphagia Due to Vagal Paralysis. *Dysphagia* 2017; **32**: 657-662 [PMID: 28528491 DOI: 10.1007/s00455-017-9811-5]

66 **Hila A**, Castell JA, Castell DO. Pharyngeal and upper esophageal sphincter manometry in the evaluation of dysphagia. *J Clin Gastroenterol* 2001; **33**: 355-361 [PMID: 11606849 DOI: 10.1097/00004836-200111000-00003]

67 **De Schryver AM**, Samsom M, Smout AI. Effects of a meal and bisacodyl on colonic motility in healthy volunteers and patients with slow-transit constipation. *Dig Dis Sci* 2003; **48**: 1206-1212 [PMID: 12870774]

68 **Dinning PG**, Hunt LM, Arkwright JW, Patton V, Szczesniak MM, Wiklendt L, Davidson JB, Lubowski DZ, Cook IJ. Pancolonic motor response to subsensory and suprasensory sacral nerve stimulation in patients with slow-transit constipation. *Br J Surg* 2012; **99**: 1002-1010 [PMID: 22556131 DOI: 10.1002/bjs.8760]

69 **El-Chammas KI**, Tipnis NA, Simpson PM, Sood MR. Colon high-resolution manometry: using pressure topography plots to evaluate pediatric colon motility. *J Pediatr Gastroenterol Nutr* 2014; **59**: 500-504 [PMID: 24840515 DOI: 10.1097/mpg.0000000000000442]

70 **Borrelli O**, Pescarin M, Saliakellis E, Tambucci R, Quitadamo P, Valitutti F, Rybak A, Lindley KJ, Thapar N. Sequential incremental doses of bisacodyl increase the diagnostic accuracy of colonic manometry. *Neurogastroenterol Motil* 2016; **28**: 1747-1755 [PMID: 27335210 DOI: 10.1111/nmo.12876]

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