Colon High-Resolution Manometry: Using Pressure Topography Plots to Evaluate Pediatric Colon Motility

*Khalil I. El-Chammas, *Neelesh A. Tipnis, †Pippa M. Simpson, and *Manu R. Sood

ABSTRACT

Objectives: Colon manometry is usually performed using the 8-pressure sensor water-perfused manometry system. High-resolution manometry (HRM), using closely spaced solid-state pressure recording sensors, provides more detailed information of gut luminal pressure changes, and, by displaying the HRM data as a pressure topography plot (PTP), helps with data interpretation. Our aim was to compare the colon and rectal luminal pressure data obtained using 8 pressure sensors and displayed as conventional line plot (CLP) with data obtained using a custom-made solid state manometry catheter with 36 pressure recording sensors and displayed as PTP.

Methods: We evaluated colon manometry patterns during fasting, response to meal, and bisacodyl stimulation in 10 patients with constipation and stool expulsion disorders. The data from 8 pressure sensors were displayed as CLP and data from 36 pressure sensors as PTP. Two gastroenterologists independently interpreted these studies. We calculated variability in interpreting colon, rectal, and anal manometry data.

Results: Intermode, interobserver, and intraobserver reliability were good to excellent for recognizing colon contraction patterns when data are displayed as PTP compared with when displayed as CLP, whereas the reliability for recognizing anal contractions were poor to excellent.

Conclusions: Colonic and anal manometry patterns are easily recognized when HRM data are expressed as PTP. Obtaining information of colonic luminal pressure changes with rectum and anal pressure changes using HRM can help better understand the pathophysiology of pediatric constipation and stool expulsion disorders.

Key Words: constipation, high-resolution manometry, pressure topography plots

(*JPGN* 2014;59: 500–504)

Received September 24, 2013; accepted May 12, 2014.

From the *Department of Pediatrics, Division of Pediatric Gastroenterology, Medical College of Wisconsin, Milwaukee, and the †Section of Quantitative Health Sciences, Children's Research Institute, Children's Hospital of Wisconsin, Milwaukee.

Address correspondence and reprint requests to Manu R. Sood, Division of Pediatric Gastroenterology and Nutrition, Medical College of Wisconsin, 8701 Watertown Plank Road, Milwaukee, WI 53226 (e-mail: msood@mcw.edu).

This article has been developed as a Journal CME Activity by NASPGHAN. Visit *http://www.naspghan.org/wmspage.cfm?parm1=742* to view instructions, documentation, and the complete necessary steps to receive CME credit for reading this article.

M.R.S. has received a research grant from Takeda Pharmaceuticals, and spouse works for Abbott Laboratories. The other authors report no conflicts of interest.

DOI: 10.1097/MPG.0000000000000442

Colon manometry is used to evaluate children with chronic intractable constipation (1,2) and differentiate between functional constipation and colon neuromuscular disease (3). It can also help to make decisions regarding surgical intervention in children with chronic constipation (4). Conventional colon manometry studies, using the 8-pressure sensor manometry system and data expressed as conventional line plots (CLPs), are usually sufficient to evaluate colon contraction patters, especially high-amplitude propagating contractions (HAPCs). Evaluating gastrocolic reflex (GCR), however, is more challenging (2,5). Furthermore, the typical colonic manometry catheter has limited resolution, with sensors spaced 10 to 15 cm apart. This prevents detailed evaluation of regional differences in motility patterns because only 1 or 2 pressure sensors may be present in a particular colonic segment. A large proportion of children with chronic intractable constipation have neuromuscular abnormalities restricted to the left side of the colon; therefore, detailed information about the motility of this region of the gastrointestinal tract may help clinical decision making (3,6).

The introduction of solid-state manometry catheters with multiple, closely spaced pressure sensors, termed high-resolution manometry (HRM), has helped to better define the intraluminal pressure environment when used to evaluate sphincter physiology of the esophagus and the anorectum (7,8). Esophageal HRM data, expressed as color gradient scale pressure topography plots (PTP), have helped with data interpretation and improved diagnostic accuracy of esophageal motility disorders (7,9). A novel approach has been used to evaluate colon manometry in adults using a fiber Bragg grating–based manometry catheter design (10). This technology enables pressure sensors to be placed 1 cm apart and fluid infusion is not required. One potential disadvantage of this manometry catheter for pediatric use is the lack of central lumen, which is usually required for guidewire-assisted colon manometry catheter placement and drug administration during the study.

The aims of our study were to compare the colon and rectal luminal pressure data from 8 pressure sensors displayed as CLP with data obtained using a custom-made solid state manometry catheter with 36 pressure recording sensors and data displayed as PTP, and to evaluate the variability in interpreting colon manometry data displayed as CLP and PTP.

METHODS

We used a custom-designed solid state colon manometry catheter with 36 pressure sensors; the proximal 20 pressure sensors were 4 cm apart, and the distal 16 pressure sensors were 2 cm apart (Fig. 1). The catheter had a central lumen for a guidewire, which was used for endoscopy-assisted catheter placement and administration of medications during the study. We used a standardized protocol for colon manometry studies that included evaluation of fasting motility, response to a meal, and bisacodyl stimulation. All drugs known to affect the gastrointestinal motility were

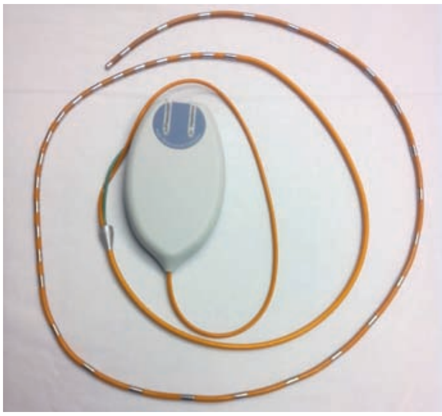

FIGURE 1. Solid-state colon manometry catheter with proximal 20 pressure recording sites 4 cm apart and distal 16 pressure recording sites 2 cm apart.

discontinued at least 72 hours before the study. Following an 8-hour fast, patients underwent colonoscopy- and fluoroscopy-assisted colon manometry catheter placement.

We randomly identified 10 studies, which were performed using the solid-state pediatric colon manometry catheter. The data from each study were displayed as CLP with information from 8 pressure sensors spaced at an equal distance (pressure sensors 10–15 cm apart), and the same data were also displayed as PTP with information from all of the pressure sensors that were inside the patient (maximum 36 pressure sensors) (Fig. 2A and B) using software provided by Medical Measurement Systems (Enschede, the Netherlands). The studies were made anonymous, and 2 pediatric gastroenterologists independently analyzed these studies. We evaluated the intermode reliability of recognizing colon contraction patterns when the data were expressed as CLP or PTP. We also evaluated interobserver reliability of recognizing colon contraction patterns between the 2 observers for interpreting data expressed as PTP. To study intraobserver reliability, the studies were recoded, and the observers were asked to reinterpret the same studies 4 months later. The 2 observers used published criteria to define colonic contraction patterns including HAPCs (contractions with an amplitude of at least 60 mmHg propagating aborally over at least 3 adjacent recording sites) and GCR (2,5). Colon contractions, which propagated over at least 3 adjacent recording sites (12 cm) and had amplitude between 5 and 59 mmHg, were defined as low-amplitude propagating contractions (LAPCs) (11). Each observer reported presence of HAPCs during fasting, postprandial period, and following bisacodyl stimulation; presence of GCR; rectal propagating contractions; anal sphincter pressure and relaxation; and anal canal localization. A study was reported as abnormal if there were no HAPC, the HAPCs failed to propagate into the descending or sigmoid colon, or GCR was absent. These criteria were identical to our earlier publication (5).

To evaluate the rectal luminal pressure change and anal sphincter physiology, we randomly selected 20 additional studies that were evaluated by 1 pediatric gastroenterologist and he reported on rectal luminal pressure changes in relation to the colon and also evaluated anal pressure change.

The data were analyzed using SPSS software, version 19 for Windows (IBM SPSS Statistics, Armonk, NY). The percentage agreement and kappa statistic were calculated to study the intermode, interobserver, and intraobserver reliability of recognizing colon contraction patterns. We considered the values 90% to 100% to indicate excellent agreement, 80% to 89% good agreement, 70% to 79% fair agreement, and values <70% poor agreement. The human research review board at Children's Hospital of Wisconsin approved the study.

RESULTS

The median (range) age of patients was 7.7 (0.9–21.7) years. A total of 17 of the patients were boys, median (range) fluoroscopic time was 1.2 (0.0–7.3) minutes, and there was no catheter coiling after placement. Of the 10 randomly selected studies, the tip of the colon manometry catheter was in the cecum in 7, at the hepatic flexure in 2, and in the transverse colon in 1 patient. There was no catheter migration during the study in any patient.

Intermode Reliability

The reliability of recognizing HAPCs and GCR between PTP and CLP is shown in Table 1. There is excellent agreement for recognizing fasting, postprandial, and bisacodyl-induced HAPCs when data are expressed as CLP and PTP. Agreement between CLP- and PTP-expressed data for identifying GCR and overall study conclusion, however, produced only fair to good agreement in 1 observer and poor agreement in the second observer. The second observer reported an absent GCR in 2 CLP but not in the corresponding PTP and absent HAPCs in 1 CLP but not in the corresponding PTP. The agreement between CLP- and PTP-expressed data for recognizing anal canal pressure and anal canal localization were poor.

Interobserver Reliability

The interobserver reliability of recognizing HAPCs and GCR when data are expressed as PTP is shown in Table 2. The interobserver reliability of recognizing HAPCs is excellent. Again, the agreement between the 2 observers for recognizing GCR is fair and study conclusion is poor. The 2 observers listed the same studies as abnormal for the same reason, which is the absence of HAPCs and GCR or lack of propagation of HAPCs in a region of the colon. Both the agreement between the 2 observers for recognizing anal canal pressure and anal canal localization were fair.

Intraobserver Reliability

The intraobserver reliability of recognizing data expressed as PTP and evaluated 4 months apart is shown in Table 3. There is excellent agreement of recognizing fasting, postprandial, and bisacodyl-induced HAPCs and GCR. The agreement for overall results of the manometry study produced fair agreement. The agreement for recognizing anal canal pressure was fair to excellent, whereas that for anal canal localization was poor to good.

Additional Information

LAPCs were noted in 50% of the HRM studies with data expressed as PTP, and 50% of conventional colon manometry studies with data expressed as CLP.

Rectal Motility and Anal Sphincter Observations

Rectal propagating contractions were observed in 7 patients (Fig. 2B). In 5 of the 7 patients, the rectal propagating contractions followed the termination of the HAPCs but preceded a bowel movement. The mean pressure of the rectal propagating contractions was 100 mmHg (range 50–150 mmHg), and these

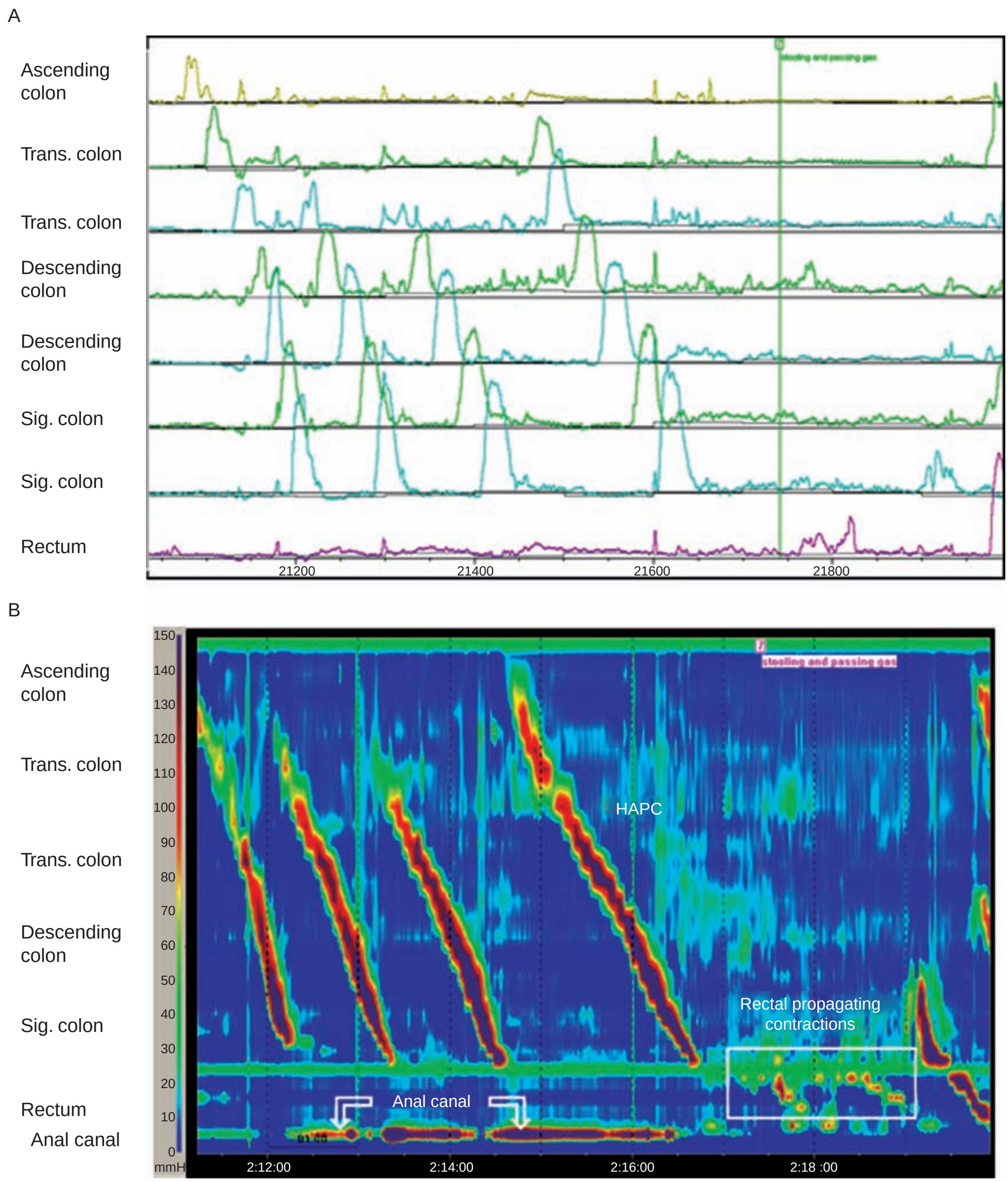

FIGURE 2. A, A 10-minute colon manometry panel with data from 8 pressure recording sites displayed as conventional line plot. B, The same colon manometry panel with data from 36 pressure recording sites displayed as isobaric pressure topography plot. The rectal propagating contractions are clearly seen with relaxation of anal canal during a bowel movement.

propagated over a distance of 4 to 6 cm. The anal pressure profile could be simultaneously evaluated at the time of the colon motility study in these 7 patients using HRM. There was, however, wide fluctuation in the anal pressure and in 6 patients the pressure was <10 mmHg just before or during the bowel movements, but at times the pressure would rise to 150 mmHg or higher.

DISCUSSION

The results of the present study show that colon, rectal, and anal luminal pressure changes can be detected simultaneously using a solid-state colon manometry catheter with 36 pressure recording sensors. The interobserver and intraobserver reliability for interpreting HAPCs produced good to excellent agreement when data were displayed as PTP, suggesting that HAPCs can be recognized when colon manometry data are expressed as PTP. Recognizing GCR by visual inspection, however, was relatively more difficult, with data displayed as either CLP or PTP, suggesting displaying data as PTP provides no additional advantage in interpretation of GCR. The second observer was able to recognize GCR when data were displayed as PTP and not when data were displayed as CLP. Interpreting the GCR is an inherent shortcoming of colon

TABLE 1. Intermode reliability, expressed as percentage agreement (kappa), for each observer when interpreting the data expressed as CLP and PTP (n = 10)

Characteristic	Observer 1, %	Observer 2, %
Fasting HAPCs	100 (1.00)	100 (1.00)
Postprandial HAPCs	100 (1.00)	100 (1.00)
Bisacodyl-induced HAPCs	100 (1.00)	90 (n/a)
Gastrocolonic response	70 (0.44)	60 (0.09)
Study conclusion	80 (0.62)	60 (0.09)
Anal canal pressure	30 (n/a)	70 (0.21)
Anal canal localization	30 (n/a)	50 (−0.32)

HAPC = high-amplitude propagating contraction; n/a = data not available.

manometry studies, and we have reported higher variability in interpreting GCR by 5 motility experts; the interobserver variability showed only fair agreement (5). The GCR is a more subjective interpretation of colon motility data and produces more variability compared with HAPCs, which is a relatively better defined colon contraction pattern and easier to recognize. In the present study, observer 2 showed 60% agreement regarding GCR and overall study interpretation, suggesting the main cause for suboptimal overall study interpretation was variability in interpreting the GCR instead of the manner in which the data were displayed. Problems in evaluating the meal response on bowel motility are not limited to the colon manometry; Connor et al reported a greater variability in evaluating postprandial hypomotility for antroduodenal manometry testing in children (12).

Although the kappa statistic is commonly used to assess reliability, caution is required when interpreting the magnitude of the kappa statistic because it is influenced by the prevalence of the rating (if the prevalence is high, chance agreement is also high and kappa is reduced accordingly) and by the bias (when there is a large bias, kappa is higher). When there is a high percentage of agreement, there can be a low or negative kappa statistic, especially when there is an imbalance of the margins (13). The extreme of this is where kappa cannot be calculated where the corresponding table has only 1 row or 1 column. Thus, the percentage agreements and kappa were calculated for the reliability of recognizing colon contraction patterns (HAPCs, GCR).

The main advantage of using the 36-pressure sensor manometry catheter is the ability to recognize the rectosigmoid motility pattern. The solid-state catheter used in the present study enabled us to study the motility of the rectosigmoid region using pressure sensors spaced 2 to 4 cm apart. Although there was poor agreement when recognizing anal canal data between CLP and PTP for both

TABLE 2. Interobserver reliability, expressed as percentage agreement (kappa), for the 2 observers interpreting data expressed as PTP (n = 10)

Characteristics	Interobserver variability, %
Fasting HAPCs	100 (1.00)
Postprandial HAPCs	100 (1.00)
Bisacodyl-induced HAPCs	90 (0.64)
Gastrocolonic response	70 (0.08)
Study conclusion	60 (0.39)
Anal canal pressure	70 (0.21)
Anal canal localization	70 (0.21)

HAPC = high-amplitude propagating contraction.

TABLE 3. Intraobserver reliability, expressed as percentage agreement (kappa), when the observers interpreted the data expressed as PTP 4 months apart (n = 10)

	Intraobserver variability	
Characteristics	Observer 1, %	Observer 2, %
Fasting HAPCs	100 (1.00)	100 (1.00)
Postprandial HAPCs	100 (1.00)	100 (1.00)
Bisacodyl-induced HAPCs	100 (1.00)	90 (n/a)
Gastrocolonic response	90 (0.74)	90 (0.62)
Study conclusion	70 (0.29)	70 (−0.15)
Anal canal pressure	70 (0.44)	90 (0.62)
Anal canal localization	60 (0.05)	80 (0.38)

HAPC = high-amplitude propagating contraction; n/a = data not available.

observers, there was fair agreement between both observers when using PTP. Furthermore, using closely spaced pressure sensors, we were able to recognize rectal propagating contractions in 7 patients. This was not possible using the 8-presure sensor data because there were only 1 or 2 pressure sensors in the rectum. Giorgio et al used a 20-lumen PVC water-perfused manometry catheter with recording sites 2.5 cm apart (maximum colon length studied was 50 cm) (14). They reported data in 18 children with slow transit constipation and 6 disease control patients. The number of postbisacodyl HAPCs in the descending colon and sigmoid region were lower in children with slow transit constipation, suggesting regional abnormalities, especially the distal colon. The number of LAPCs were reduced in the prebisacodyl period but increased in the postbisacodyl period in patients with slow transit constipation. Using a water-perfused 20-channel catheter would require a significant amount of fluid to be infused during the study, which would raise concerns for fluid overload, especially in young children having long studies. The solid-state manometry catheter we used enabled us to evaluate the rectosigmoid region motility with pressure sensor 2 cm apart and without the concern for fluid overload, because no fluid was infused through the catheter during the study.

We identified rectal propagating contractions in 7 patients. These were associated with a bowel movement in 5 patients. Periodic rectal motor activity is one of the patterns of human colonic phasic pressure activity (15,16). Adult studies show that rectal propagating contractions are present during the wake state, increase after a meal, and decrease during sleep (17,18). Rao and Welcher have shown that in healthy adults, only HAPCs associated with rectal propagating contractions resulted in a bowel movement (15). Rectal propagating contractions have not been reported in children but are likely to have similar physiological function as reported in adults. We speculate that children with dilated rectosigmoid colons may lack rectal propagating contractions, and this may hamper the ability to have a bowel movement during HAPCs. The ability to study colon and rectal motility using a 36-pressure sensor manometry catheter will help us better understand the role of rectal propagating contractions and its relation with anal pressure changes in children with chronic constipation. Future studies in a larger cohort of children with chronic constipation are needed to understand the role of rectal motility in childhood constipation.

We also identified anal sphincter relaxation during defecation in 6 patients. In 1 patient, we noted an increase in anal pressure during HAPCs. This patient complained of abdominal cramping, which we believe was an attempt to voluntarily withhold stool. In all of the patients, there were wide fluctuations in the anal pressure following bisacodyl stimulation, and at times, the pressure would increase to 150 mmHg or higher. We assume this was because of voluntary contraction of the pelvic floor by the patients. Because the catheter is taped to the child's thigh, we found the sensors tended to move in and out of the anal canal with hip movement. We have now started instructing the patients to minimize flexing their hips, especially at times when we are interested in evaluating anal pressure changes, for example, after administration of bisacodyl. We also ask the child to contract the pelvic floor muscles intermittently during the study to identify the anal canal. We are unable to reliably predict the anal pressure changes in our cohort, but we believe with the refining of this technique, future studies will be able to produce more reliable data.

Liem et al compared a water-perfused colon manometry catheter with 8 pressure recording sites with a solid-state manometry catheter that incorporated 8 strain gauge microtransducers spaced 10 cm apart (6). The solid-state catheter tended to give higher readings when the amplitude of colon contraction was $<$102 mmHg and a lower reading when amplitudes were $>$102 mmHg. An opposite trend was found for the duration of contractions. The solid-state catheter recorded more HAPCs compared with the water-perfused system. The authors concluded that solid-state catheters are more sensitive in recording HAPCs in children with defecation disorders compared with the more traditional water-perfused system and can be used for clinical evaluation of colon motility in children. The present study provides further support for using solid-state pressure sensors for the evaluation of colon manometry in children. Because solid-state catheters do not require perfusion of water or saline, we were able to use a catheter with 36 pressure sensors without concerns for fluid overload or electrolyte imbalance. We believe using solid-state colon manometry catheters makes these studies safer, especially in young children, and may also aid in the development of ambulatory colon manometry in the future.

In summary, we have reported the results of our study using a custom-designed solid-state colon manometry catheter with 36 pressure recording sites and PTP to display colon intraluminal pressure change in children. We found that intermode, interobserver, and intraobserver reliability of interpreting HAPCs using PTP were excellent. As reported earlier, interpreting GCR and displaying the data are more challenging because PTP did not significantly improve interobserver or intraobserver agreement. The 2 main advantages of the solid-state manometry catheter are the ability to study the motility of the rectosigmoid region with closely spaced sensors and the elimination of the risk of fluid overload, especially in small children or during long studies.

Acknowledgment: We acknowledge the assistance and dedication of Karen Sherry, RN, during the motility procedures.

REFERENCES

1. Chumpitazi B, Nurko S. Pediatric gastrointestinal motility disorders: challenges and a clinical update. *Gastroenterol Hepatol (N Y)* 2008; 4:140–8.
2. Di Lorenzo C, Flores AF, Reddy SN, et al. Use of colonic manometry to differentiate causes of intractable constipation in children. *J Pediatr* 1992;120:690–5.
3. Villarreal J, Sood M, Zangen T, et al. Colonic diversion for intractable constipation in children: colonic manometry helps guide clinical decisions. *J Pediatr Gastroenterol Nutr* 2001;33:588–91.
4. Youssef NN, Pensabene L, Barksdale E Jr et al. Is there a role for surgery beyond colonic aganglionosis and anorectal malformations in children with intractable constipation? *J Pediatr Surg* 2004;39:73–7.
5. Sood MR, Mousa H, Tipnis N, et al. Interobserver variability in the interpretation of colon manometry studies in children. *J Pediatr Gastroenterol Nutr* 2012;55:548–51.
6. Liem O, Burgers RE, Connor FL, et al. Solid-state vs water-perfused catheters to measure colonic high-amplitude propagating contractions. *Neurogastroenterol Motil* 2012;24:345-e167.
7. Clouse RE, Staiano A, Alrakawi A, et al. Application of topographical methods to clinical esophageal manometry. *Am J Gastroenterol* 2000; 95:2720–30.
8. Jones MP, Post J, Crowell MD. High-resolution manometry in the evaluation of anorectal disorders: a simultaneous comparison with water-perfused manometry. *Am J Gastroenterol* 2007;102:850–5.
9. Kahrilas PJ. Esophageal motor disorders in terms of high-resolution esophageal pressure topography: what has changed? *Am J Gastroenterol* 2010;105:981–7.
10. Dinning PG, Hunt LM, Arkwright JW, et al. Pancolonic motor response to subsensory and suprasensory sacral nerve stimulation in patients with slow-transit constipation. *Br J Surg* 2012;99:1002–10.
11. Bampton PA, Dinning PG, Kennedy ML, et al. Spatial and temporal organization of pressure patterns throughout the unprepared colon during spontaneous defecation. *Am J Gastroenterol* 2000;95:1027–35.
12. Connor FL, Hyman PE, Faure C, et al. Interobserver variability in antroduodenal manometry. *Neurogastroenterol Motil* 2009;21:500–7e3.
13. Sim J, Wright CC. The kappa statistic in reliability studies: use, interpretation, and sample size requirements. *Phys Ther* 2005;85: 257–68.
14. Giorgio V, Borrelli O, Smith VV, et al. High-resolution colonic manometry accurately predicts colonic neuromuscular pathological phenotype in pediatric slow transit constipation. *Neurogastroenterol Motil* 2013;25:70–8.
15. Rao SS, Welcher K. Periodic rectal motor activity: the intrinsic colonic gatekeeper? *Am J Gastroenterol* 1996;91:890–7.
16. Prior A, Fearn UJ, Read NW. Intermittent rectal motor activity: a rectal motor complex? *Gut* 1991;32:1360–3.
17. Auwerda JJ, Bac DJ, Schouten WR. Circadian rhythm of rectal motor complexes. *Dis Colon Rectum* 2001;44:1328–32.
18. Orkin BA, Hanson RB, Kelly KA. The rectal motor complex. *Neurogastroenterol Motil* 1989;1:5–8.