Childhood constipation: new insights in testing, treatment and cost
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Comparison of Solid State and Water Perfused Catheters to measure Colonic Motility

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ABSTRACT

Background
SS manometry catheters with portable data loggers offer many potential advantages over traditional WP systems, such as prolonged recordings in a more physiologic ambulatory setting and the lack of risk for water overload. The use of SS catheters has not been evaluated in comparison to perfused catheters in children.

Aim
To compare data provided by SS (SS) and WP (WP) catheters in children undergoing colonic manometry studies.

Methods
A SS catheter and a WP catheter were taped together such that their corresponding sensors were at the same location. Simultaneous recordings were obtained using SS and WP catheters (both 8 channels, 10 cm apart) in 15 children with severe defecation disorders referred for colonic manometry. Signals were recorded for a minimum of 1 h during fasting, 1 h after ingestion of a meal and 1 h after administration of bisacodyl. SS signals from the data logger were analyzed against the perfused signals. All high amplitude propagated contractions (HAPC), the most recognizable colonic motor event, were evaluated for spatial and temporal features including their durations, amplitudes and propagation velocities.

Results
A total of 107 HAPCs were detected with SS and 91 with WP catheters. All WP-HAPC were also observed with SS. Linear regression analysis showed that SS catheters tended to give higher readings in the presence of amplitudes <102 mmHg and lower reading with amplitudes >102 mmHg. An opposite trend was found for duration of contractions. No significant difference was found for HAPC velocity.

Conclusions
SS catheters are more sensitive in recording HAPC in children with defecation disorders compared to the more traditional WP assembly. There is a difference in measurements of amplitude between the two systems. SS catheters offer potential advantages over WP catheters in children, being portable, safer to use and may provide data over a more prolonged period.
INTRODUCTION

Changes in intracolonic pressure, resulting from contractions of the colonic muscle can be detected using intraluminal manometry. Colonic manometry is a diagnostic test used by pediatric motility centers for the evaluation of children with defecation disorders unresponsive to medical and behavioral management. Based on results from colonic manometry, recommendations to change medical treatment are made in 81% of patients. 1 Colonic manometry is also helpful in predicting the success of antegrade enemas via cecostomy. 2

The current standard in pediatric colonic motility testing is to use water-perfused catheters. These open tipped catheters are connected to a pneumohydrolic infusion pump that ensures constant flow of water and are attached to cumbersome recording equipment. Due to the size of the recording equipment, the requirement for constant water infusion, studies are performed in a laboratory with the child in supine position and do not last more then 4-5 hours. 3

Developments in microtransducer technology have allowed the production of manometry catheters incorporating miniaturized strain gauge transducers. These catheters allow recording of gastrointestinal motor activity on portable solid-state data logging devices. 4-6 They are not connected to an infusion pump and permit manometry measurement in ambulant patients offering an attractive alternative to traditional stationary manometry. In children, ambulatory manometry has proven to be a useful screening tool for infrequent and unpredictable motility events when evaluating esophageal function. Diagnostic yield (detection of abnormal esophageal body motility) is higher for ambulatory studies when compared to stationary water-perfused manometry. 7 Prolonged ambulatory manometry has the additional advantage of assessing motility during normal activities (eating/fasting, sleeping/awake, active/resting) and of correlating motility abnormalities with infrequent symptoms. Because patients are allowed out of bed during ambulatory testing, such studies are better tolerated by children.

However, there have been no studies which directly compare solid-state catheters and water-perfused catheters in a simultaneous head-to-head manner in colonic manometry. A previous study was performed in dogs that underwent laparotomy and involved catheters much larger diameters (1cm) than currently used with only 2 sensors. 8

The present study aimed at comparing solid-state (SS) to the water-perfused manometry (WP), with particular attention to the detection and measurement of high amplitude propagating contractions (HAPCs).
METHODS

Subjects
This was a prospective study performed at Nationwide Children’s Hospital in Columbus, OH. Children between the ages of 6 - 18 years with defecation disorders, who were already scheduled to undergo colonic manometry, were invited to participate. The study was approved by the local Institutional Review Board.

Manometry assembly and catheter design
A multi-lumen WP motility catheter with eight pressure sensors spaced 10cm apart was used (MUI, Ontario, Canada). The catheter was perfused using a pneumohydraulic infusion system (Dentsleeve, Mississauga, Canada), connected to a polygraph and computer software (Medtronics, Minneapolis, MN). The SS catheter (Unisensor AG, Switzerland) incorporated eight strain gauge microtransducers, spaced 10cm apart and was 3.5mm in diameter. Recording from this catheter was captured in a portable recording device, known as a datalogger with a sampling rate of 8Hz and 32Mb flash card memory capacity.

The two catheters were taped together using parafilm such that ports were at the same location facing outwards and simultaneous recordings were obtained using the two catheters.

Calibration
The WP system was calibrated according to the manufactures’ recommendations with the use of a sphygmomanometer coupled to the external pressure transducers of the perfusion pump. SS catheter calibration was performed using a manometer connected to cylindrical chamber to which known pressures were applied.

Catheter placement and recordings
Catheters insertion was performed either by colonoscopy or with by the interventional radiologist guided by fluoroscopy as previously described. All medications known to affect colonic motility were withheld 48 hours prior to the studies. On the day before the study, the colon was prepared with a balanced electrolyte lavage fluid containing polyethylene glycol, administered via nasogastric tube (or gastrostomy if present). Colonoscopy was performed under general anesthesia, with guide wire and fluoroscopic control, to place the tips of the two catheters in the proximal colon. Catheters placement by the interventional radiologist was done under sedation.

The colonic manometry study was performed on the same day as the catheter insertion. After the child had fully recovered from anesthesia or sedation, both WP
colonic manometry and SS manometry were performed according to the standard protocol used in our hospital. This protocol consisted of recordings for a minimum of 1 hour during fasting, 1 hour after a meal and 1 more hour after the administration of bisacodyl (0.2mg/kg, max 5mg) via the central lumen into the colon.

Tracing analysis
SS signals from the datalogger were analyzed against the WP signals using GiPC Motility Software (RedTech, Inc. Calabasas, CA, USA). WP data was imported into the GiPC Motility software. The software enabled preprocessing such as artifact handling, filtering the data to remove noise and baseline adjustments. It provided for a variety of analyses such as amplitudes, durations, propagating velocity and motility index in both mouse-assisted and automatic modes. High amplitude propagated contractions (HAPC), the most important feature of normal colonic motility, were defined as three or more contractions recorded from adjacent recording sites with at least one contraction having an amplitude of 60 mm Hg or more, lasting at least 10 seconds. HAPCs were evaluated for spatial and temporal features including their durations, amplitudes and propagation velocities. Duration was measured as the time between the onset of the major upstroke of the wave and return to baseline. Amplitudes were recorded by subtracting the baseline pressure from the peak wave pressure. Velocity of contraction propagation was calculated by dividing the distance traveled by the time between wave peaks. The length of propagation was determined based on the number of recording sites over which the wave propagated. A colonic motility index was calculated by measuring the area under the pressure records for one 30-minute period before and two 30-minute periods after completion of the meal.

Statistics
Baseline characteristics of the tracings were analyzed in a descriptive way. For data analysis and interpretations, results are expressed as median and range. HAPC characteristics were compared using the Altman-Bland bias plot, which plots the difference between the two methods. Using univariate linear regression analyses the effects of average amplitude size, duration and velocity on difference of these characteristics between the two catheters was examined. To compare motility index we used the Kruskal–Wallis test and the Wilcoxon rank-sum test to examine overall differences between both catheters. A p value < 0.05 was considered statistically significant.
RESULTS

Demographics

Fifteen children (8 girls, age 5.6 – 16.3 years) participated to the study. Indications to perform colonic manometry were intractable constipation (n=12), symptoms of intestinal pseudoobstruction (n=1) and functional non-retentive fecal incontinence (FNRFI) (n=2). Using WP manometry, tracings revealed normal motility in 13 children (entire colon n=8, until distal colon n=5). One child showed low amplitude contractions (LAPCs) but no HAPCs and the patient with symptoms of intestinal pseudoobstruction showed barely any motility.

Catheter placement

In 12 children catheter placement took place in the OR and in three children placement was done by interventional radiology. The catheters were positioned with the tips in the cecum in 12 patients and in the remaining subjects in the transverse colon (n=1), splenic flexure (n=1) and descending colon (n=1).

HAPC frequency

A total of 107 HAPCs were detected with SS and 91 with WP. All 91 WP HAPC were observed with also with solid state. The median number of HAPCs per patient per study was 7 (range 1-24) using SS and 6 (range 1-19) using WP (p=0.03). The extra HAPCs were found in five patients who all, but one, showed other HAPCs that were detected by both catheters. For the 16 HAPCs that were only detected using SS, 11 of them were detected as low amplitude propagating contractions (LAPCs, amplitudes < 60 mmHg) on WP-tracings. Two SS-HAPCs did not fulfill HAPC criteria in the WP tracings as they propagated through only two channels. In two cases no contractions were seen at all in the WP tracing (Figure1).

HAPC characteristics

The median amplitude, velocity or distance of propagation of HAPCs detected by both SS and WP were not different. (Table1) Only the duration of SS-HAPCs was

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<th>Table 1. Characteristics of HAPCs in SS and WP</th>
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<td>Amplitude (mm Hg)</td>
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longer than compared to those measured with WP (29 vs. 23 s, P<0.01). The HAPCs that were only detected using SS had a significantly lower amplitude compared to the ones found with both catheters (72, 10 – 156 mmHg, p<0.01) but no difference in duration and velocity (28, 11-56 s, p=0.24 and 0.62, 0.36 – 2.78 cm s⁻¹, p=0.23). The Bland-Altman bias plot for HAPC-amplitudes showed a mean difference (SS – WP) of -1.2 mmHg with 95% limits of agreement from -76 to 74 mmHg (Figure 2). The plot seemed to show a negative trend of as the mean of amplitude increased. Regression analysis showed a linear relationship between the size of HAPC amplitude and the difference in amplitudes measured by both catheters. According to the model, SS measured higher values than WP at lower average amplitudes while the opposite was true for higher average amplitudes. At an average amplitude of 69 mmHg (P₂₅) SS measures 9 mmHg higher than WP. At an average amplitude of 127 mmHg (P₇₅) SS measures 7 mmHg lower than WP. For duration, the Bland-Altman plot showed a mean difference of 7s with 95% limits of agreement from -12 to 26s (Figure 1). Regression analysis showed a positive trend when duration increased. Bland-Altman revealed a 0.003 cm s⁻¹ bias for velocity with 95% limits of agreement from -1.16 to 1.17 cm s⁻¹. The plot did not seem to show a trend in the data when the velocity increased.
Motility index
Total fasting motility index was not different between the SS and WP tracings (103 vs. 99 mmHg·min in, p=0.321) and post prandial indices were also similar (147 vs. 120 mmHg·min, p=0.790).

Figure 2. Differences in HAPC characteristics measured by SS and WP manometers plotted against the average of both measurements. The 95% limits of agreement are shown by the dotted line. A linear regression line is drawn with its 95% limits of prediction shown by the dotted lines.
DISCUSSION

The present study shows that colonic manometry performed using a SS catheter provides colonic pressure measurements that correlate overall well with those obtained using a WP catheter. Importantly, the SS catheter did not miss any HAPCs detected by the WP catheter, given the clinician interest in detecting the presence of these patterns of contractions in colonic tracings. These data suggest that the SS catheter provides similar information and may be used as an alternative to WP catheter for colonic manometry. SS manometry did, however, identify several extra HAPCs, suggesting that it might even be more sensitive than WP catheters. Although these extra findings would not have changed the diagnosis in 4/5 children where the extra HAPCs were recorded, in one child the conclusion would have changed from “suboptimal amplitude of contractions in the more proximal part of the bowel” into “normal motility in the more proximal part of the bowel”. However, we are not able to comment on the ability to improve diagnosis since we did not attempt to prospectively compare manometric diagnosis made by the two systems. In this particular case it would not have changed the recommendations made by the treating physician.

While there are a few studies comparing SS catheters with WP catheters, this is the first study in humans to directly compare SS and WP catheters for colonic manometry. The previous study comparing both catheters in the colon used anesthetized dogs and showed a detection rate of 90% by perfused catheters and 81% for serosal strain gauges. 8 This study, however, used first generation catheters that only had 2 sensors each. Another study performed 20 years ago in the esophagus found lower mean amplitudes with the microtranducers than with perfused catheters but no difference in duration of contractions. They obtained significant correlations of $r=0.74$ and $r=0.51$ for amplitude and duration, respectively. 14

More recent studies have been performed in vitro using anorectal or sphincter of Oddi manometry. All studies found high correlation between amplitudes measured by both catheters (ranging from $r=0.97$ to $r=0.998$) with some reporting higher measurements with SS catheters although one study could not find a consistent pattern regarding the catheter that registered the higher pressure. 15-19

In our study the SS manometer read similar pressures on average to the WP manometer when recording HAPCs. The SS catheters tended to give higher readings with lower amplitudes while the WP catheter had higher readings at very high amplitudes. This may explain why the SS catheter picked up more HAPCs, as a proportion of contractions measuring >60mmHg by SS would not have reached this criterion with WP. In addition to the difference in sensitivity by both catheters we also found wide 95% limits of agreement, ranging from -77 to 74 mmHg. This
wide 95% limits of agreement would not be acceptable when we would only be interested in the absolute pressures.

One may hypothesize that this wide variance is due to the fact that the colon is a relatively large-diameter viscus. The SS catheter and WP catheter were attached such that both recording sensors were at the same height but not facing the same direction. Unlike areas of the digestive system with smaller diameters, such as the small intestine or esophagus, pressures measured at opposite sites might not be exactly the same, especially in areas such as the transverse colon where the lumen is almost triangular in cross section. Studies combining WP manometry and the barostat have shown that the sensitivity of manometric catheters in detecting phasic contractions decreases as the colonic diameter increases. 20 There are clear advantages and disadvantages with each system. The WP catheter is relatively cheap, robust and is fully autoclavable. Single use catheters are also available. Its major disadvantage is that the catheter has to be connected to a bulky pneumohydraulic infusion pump and recording equipment, making prolonged or ambulatory studies difficult to perform. Furthermore there are the dangers for water overload or water intoxication, especially in neonates and infants. The main advantage of SS catheters is that portable digital recorders make it possible to conduct prolonged studies with ambulant patients. The setup of SS manometry is also quicker and easier compared to the WP system. On the other hand, SS catheters are significantly more expensive and more fragile.

In conclusion, this study shows that solid state catheters connected to a portable data logger seem more sensitive in recording HAPC in children compared to the more traditional water-perfused assembly. Solid-state catheters offer potential advantages over water-perfused catheters in children, being portable, safer to use and may provide data over a more prolonged period of time. Further research should evaluate the cost benefit of SS vs. WP and the criteria for HAPC detection using solid state catheters, including newer catheters such as fiberoptic high resolution catheters. 21
REFERENCE LIST


