NASPGHAN Capsule Endoscopy Clinical Report

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ABSTRACT

Wireless capsule endoscopy (CE) was introduced in 2000 as a less invasive method to visualize the distal small bowel in adults. Because this technology has advanced it has been adapted for use in pediatric gastroenterology. Several studies have described its clinical use, utility, and various training methods but pediatric literature regarding CE is limited. This clinical report developed by the Endoscopic and Procedures Committee of the North American Society of Pediatric Gastroenterology, Hepatology and Nutrition outlines the current literature, and describes the recommended current role, use, training, and future areas of research for CE in pediatrics.

Key Words: capsule endoscopy, GI bleeding, medical education, pediatric gastroenterology, pediatrics, small bowel endoscopy

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What Is Known

- Wireless capsule endoscopy is a bowel imaging modality used to visualize the gastrointestinal mucosa without the use of radiation.
- Small bowel capsule endoscopy is Food and Drug Administration approved for children older than 2 years of age and has been performed in children >7.9 kg.
- Further research regarding its use, extent of clinical utility, and training for this endoscopic technique is needed in pediatric gastroenterology.

What Is New

- This clinical report outlines current pediatric research, clinical utility, training methods, and practice of capsule endoscopy in pediatric gastroenterology as agreed upon by the NASPGHAN (North American Society for Pediatric Gastroenterology, Hepatology and Nutrition) Endoscopy and Procedures Committee.

Wireless capsule endoscopy (CE) to visualize the entire small bowel with or without anesthesia was first described in 2000 (1). The US Food and Drug Administration (FDA) approved small bowel (SB) CE for use in adults in 2001. FDA approval for pediatric patients followed in 2003 and 2009 for patients 10 to 18, and >2 years of age, respectively (2). More recently, safe and

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TABLE 1. Manufacturer, size, field of view, battery life, and frame rate

Manufacturer	Size, mm	Field of view	Frame rate, frames/s	Recording time, h
Covidien Imaging/Pillar SB3	11.4 × 26.2	156°	2–6 (adaptive)	12
MiroCam/MC1000-W/MC1000-WM/MC1000-WG	10.8 × 24.5–25.5	170°	3	8–12
Olympus/MAJ-2027	11 × 26	160°	2	12

SB = small bowel.

successful passage of the CE has been reported in patients younger than 1 year (7.9 kg) (3–6).

Currently 3 manufacturers have FDA approval for SB CE systems, the PillCam SB2 and SB3 (Covidien Ltd, Dublin, Ireland), Endocapsule (Olympus America, Inc, Center Valley, PA), and MiroCam (IntroMedic Company Ltd, Seoul, Korea). Each system includes the capsule recording equipment (sensing pads or belt, data recorder, and battery pack), and proprietary software for data analysis. The capsule endoscope is designed to be disposable and is approximately 11 × 26 mm in size and is designed to be disposable. Through an optical dome, images are captured by a complementary metal-oxide semiconductor (PillCam, MiroCam) or charge-coupled device (Endocapsule) image sensor, aided by a lens and white light-emitting diode illuminating sources. The images are then transmitted to the external data recorder by various novel radio transmission systems. Slight differences exist between the available CE in size, weight, field of view degree, image capture rate, resolution (pixels), and battery life (Table 1) (6).

This North American Society for Pediatric Gastroenterology, Hepatology and Nutrition (NASPGHAN) Clinical Report reviews the use of CE and special considerations in children. The available literature on CE training and certification, indications, preprocedure consent and preparation, data interpretation, and potential adverse events are also reviewed. We conclude with a discussion of future research goals and opportunities.

Special Considerations for Pediatric Capsule Endoscopy

CE represents an important and attractive diagnostic imaging modality in pediatrics given the lack of ionizing radiation and potential to complete the study without anesthesia. It is one of several modalities that can assess the SB mucosa. Generally it is well tolerated in pediatric patients because children can attend school or go about their daily activities during the examination, but there are several important differences in the use of CE between adult and pediatric patients that should be noted (7).

One of the important considerations before undertaking CE in a child is to ascertain the patient's ability to swallow the large capsule endoscope. This is a particularly common problem especially for young children. To help patients learn to swallow the capsule, patients may be instructed to practice swallowing candies such as large jelly beans (8). For individuals unable to swallow the capsule, or patients with severe dysphagia or swallowing disorders, the study can be safely undertaken by introducing the capsule endoscopically (9). Endoscopic placement of the capsule can, however, be difficult in children with small oral or pharyngeal anatomy.

A variety of accessories have been used to deliver the capsule endoscope to the stomach or small intestine. Standard polypectomy snares (off label) and nets (off label) can be used to deliver the capsule into the duodenum (10–12). The AdvanCE (US Endoscopy, Mentor, OH) allows endoscopic delivery of the capsule. The system is a disposable catheter with a sheath diameter of 2.5 mm that can be preloaded through the appropriate accessory channel. It is recommended that the capsule be deployed into the duodenum rather than the stomach to decrease the possibility of gastric retention (13).

Another important consideration for pediatric patients is the limiting age or size that will permit the capsule endoscope to pass through the pylorus or ileocecal valve (14). Traditionally in adults, a patency capsule (PC) is swallowed before the formal CE study to establish luminal patency and minimize risk of capsule retention. In pediatrics, younger children cannot swallow the PC and sedation solely for endoscopic placement of the PC is not recommended. Previous studies have used a barium SB study, computed tomography, or magnetic resonance imaging to assess SB patency. In both adults and children, however, no formal guidelines reflect as to whether or not luminal patency should be assessed in all patients before CE. Risk of capsule retention will be discussed in a separate section.

Training/Certification

Currently no universally agreed upon, evidence-based, training exist guidelines for CE or pediatric CE. Although pediatric gastroenterology training programs now routinely teach CE, most programs do not have a structured CE curriculum and only 4% have a formal CE module (15,16). A large number of in-person and online training courses are available that are endorsed by national or international gastrointestinal (GI) societies; however, no data are published validating the efficacy of such training. Two recent studies have shown that the minimum number of cases required

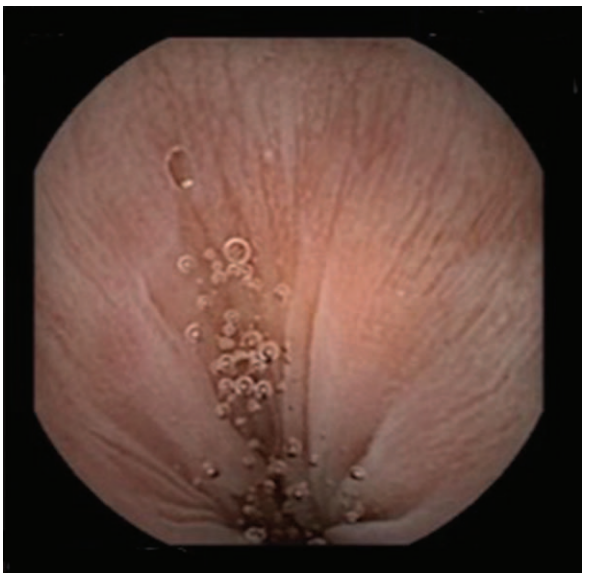

FIGURE 1. Normal esophagus.

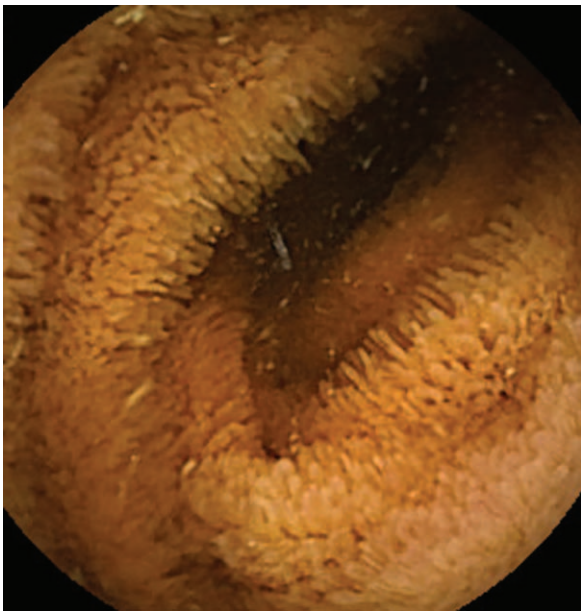

FIGURE 2. Normal small bowel.

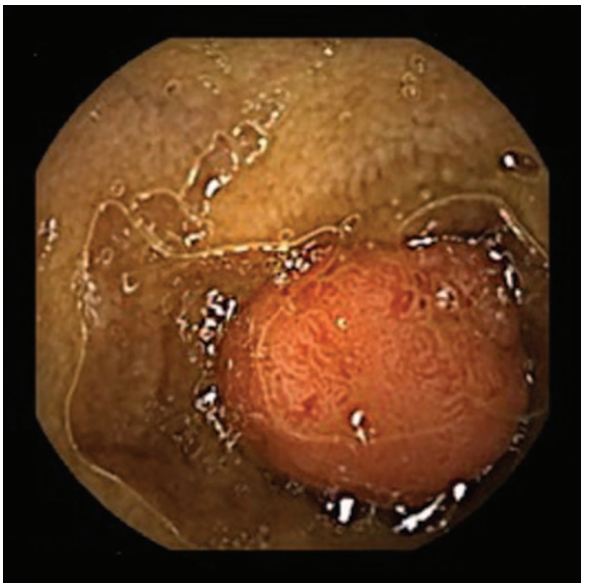

FIGURE 4. Small bowel polyp.

for trainees to attain competence in CE ranges from 10 to 30 cases for trainees learning CE within the context of a structured CE curriculum (17,18). Sidhu et al found that trainees with limited endoscopy experience (medical students) could less accurately interpret CE studies as compared with trainees with experience (GI fellows), suggesting prior endoscopy experience is valuable (19). In addition, computer-aided curricula have shown benefit in developing trainee competence in interpreting CE (20).

Increasingly application of objective criteria, when possible, is being recognized to determine competence rather than solely basing competence on the number of procedures being completed. Objective measures for assessment of competence have, however, not been defined (21,22). The 2007 GI core curriculum defines 25 CE studies within the context of a GI fellowship as the threshold for assessing competence (23). The American Society of Gastrointestinal Endoscopy credentialing and training guidelines recommend formal instruction in CE. These guidelines includes didactic tutoring and a minimum of 20 CE studies, supervised by an experienced faculty member and completed within the context of a GI fellowship training program, (eg, passing a formalized in-service examination or >90% correlation rate of significant findings compared with a credentialed capsule endoscopist) (21,24). The American Society of Gastrointestinal Endoscopy recommends that CE training completed outside the context of a fellowship program should include completion of a hands-on course endorsed by a national or international GI society (minimum 8 hours of Continuing Medical Education followed by review of at least 10 CE

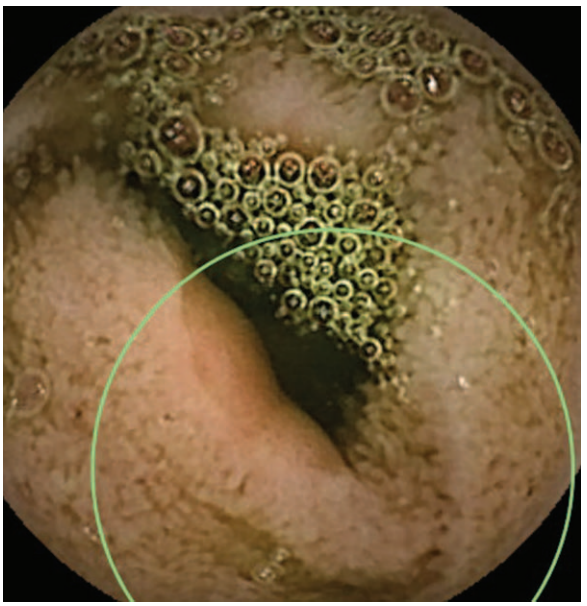

FIGURE 3. Eosinophilic gastroenteritis.

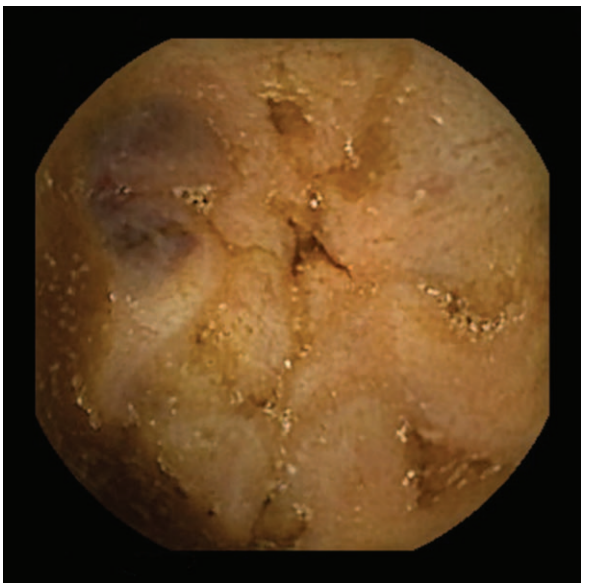

FIGURE 5. Venous malformation.

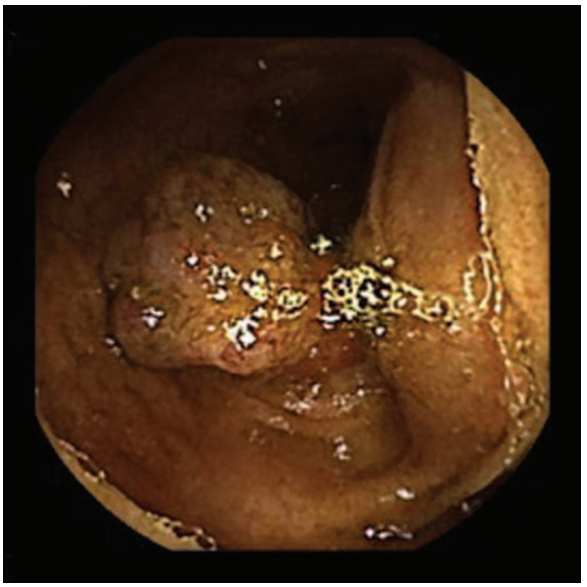

FIGURE 6. Blue rubber bleb nevus syndrome.

studies by a credentialed capsule endoscopist (21). Currently no pediatric-specific CE training and credentialing guidelines are available and as with other pediatric adaption of adult performed procedures pediatric-specific training research and guidelines are needed.

Although the number of CE cases required to attain competence and certification may vary among pediatric training programs, curricula should aim to assess pre- and post-training level of competence. This should include evaluation benchmarks with regards to procedure- and equipment-related knowledge, patient preparation and assessment, lesion recognition, documentation, interpretation, and management. Because of the variation in procedural volume and need to maintain competence our recommendation is that a practice has designated capsule endoscopists. These studies ideally should be read by a pediatric capsule endoscopist and/or, if further developed, by an individual who completed a pediatric gastroenterology CE training program or met training guidelines.

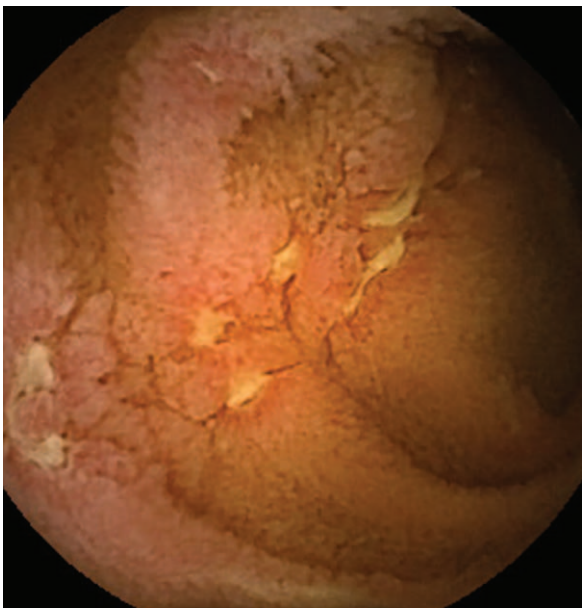

FIGURE 7. Inflammatory bowel disease.

Indications and Diagnostic Yield

CE is most commonly used to assess SB mucosa (Figs. 1-7). With the endoscopy-assisted placement of the CE, studies have been successfully performed in children as young as 10 months and 7.9 kg (2,3,5,9,25). In a meta-analysis performed by Cohen and Klevens (26), which reviewed 740 CE procedures performed from January 2001 to May 2010, the pediatric indications for CE were for suspected Crohn disease (54%), obscure gastrointestinal bleeding (OGB) and undiagnosed anemia (17%), abdominal pain and diarrhea (13%), polyposis (11%), and other small intestinal pathology (5%). Cohen (7) also reported a positive CE study in up to 77% patients; however, only 54% of these with abnormalities located in the SB. When compared with double balloon enteroscopy and positive histological findings, Danialifar et al (27) showed CE to be highly sensitive with an excellent negative predictive value in pediatric patients. The study also showed concordance compared with balloon enteroscopy varied by indication with concordance higher in polyps and OGB. Depending on the findings and yield of CE a follow-up referral to address the findings may be needed. This may include referral for SB enteroscopy, surgery, or further medical management.

Inflammatory Bowel Disease

CE has become a key tool to assist in the diagnosis and management of pediatric Crohn disease. The diagnostic yield of CE for the diagnosis of Crohn disease has ranged from 6% to 70% (3,4,28–34). CE is also used to assess the extent of intestinal involvement and surveying for recurrence of Crohn disease after treatment or postoperatively (4,28,29,31–33). Studies have shown CE correlates well with other imaging modalities for Crohn disease with CE revealing good sensitivity compared with magnetic resonance enterography (MRE) and computed axial tomography enterography (CTE), although specificity is not as strong (35–37). Although the diagnostic yield varies significantly among studies, establishing the presence or absence of SB Crohn disease has played a major role in determining management strategy.

Obscure Gastrointestinal Bleeding/Chronic Iron Deficiency Anemia

In children younger than 8 years, OGB was the most common indication for CE (22). Most reports suggest that CE is a useful diagnostic tool when esophagogastroduodenoscopy (EGD) and colonoscopy and imaging have failed to determine a source of intestinal bleeding (2,28,29,31,33). Although some studies have yields as low as 19%, a single prospective multicenter study performed by Fritscher-Ravens et al (28) found as high as a 53% diagnostic yield in 30 children, whereas Oliva et al (38) reported a diagnostic yield of 95% in 22 children with OGB in which 82% had successful therapeutic intervention with single-balloon enterosocpy (7).

Intestinal Polyposis

Few well-designed large studies have been reported that evaluate the use of CE to diagnose and survey for small intestinal polyposis. Mostly retrospective case series have shown CE to be an accurate diagnostic tool compared with SB follow through imaging

of the intestine (2,29,31,32). Gastineau et al (39) suggest that CE in patients with Peutz-Jeghers syndrome although useful as a diagnostic tool, may not be useful to predict future obstructive complications (39,40). CE can also be used as initial or follow-up surveillance method in juvenile polyposis syndromes, but one should be aware of the risk of possible obstruction as noted below (41).

Abdominal Pain and Diarrhea

Few studies evaluate the diagnostic yield of CE in patients presenting with abdominal pain and diarrhea. In a multicenter prospective study, 12 patients with abdominal pain were evaluated with CE; 3 patients were found to have intestinal Crohn disease, 2 had lymphonodular hyperplasia, 1 had blue rubber bleb lesions, and 6 did not have any pathology (28). In a case series by Antao et al (29) 2 patients had CE for recurrence of abdominal pain; with 1 case revealed an intussusception that spontaneously resolved, with no leading point identified.

Other Indications

Reports of other small intestinal pathologies evaluated with CE include malabsorption syndromes, protein-losing enteropathies, lymphangiectasias, celiac disease, graft versus host disease, allergic disorders (eosinophilic gastroenteritis) of the intestinal tract and as a complementary study to improve the therapeutic outcome of SB enteroscopy or surgery (28,29,42–45).

Esophageal and Colonic Capsule Endoscopy

CE of the colon is available but is not yet FDA approved in pediatrics. Production by certain manufacturers of the esophageal capsule has been discontinued. Few pediatric studies pertain to these forms of CE (46). A recent study by Oliva et al (47) surveying ulcerative colitis in 29 pediatric patients using second-generation colonic CE (CCE-2) reports the positive and negative predictive values of CCE-2 to be 100% (95% CI 85–100) and 85% (95% CI 49–97), respectively, for any active disease. The current approved indication for CCE in adults is an incomplete colonoscopy. The potential benefit of these forms of CE in pediatrics will be in patients who are unable to tolerate anesthesia and/or endoscopy and to reduce the need for sedated endoscopy for surveillance of known colonic and esophageal pathology.

Contraindications

The relative contraindications of CE include any condition in which obstruction, strictures, or fistulae are suspected, which could cause CE retention (Table 2). This may include such conditions such as bowel tumor, Crohn disease, pregnancy, and radiation or nonsteroidal anti-inflammatory drug–induced strictures. Radiographic screening, using modalities such as SB series radiographs, MRE and CTE can be used to help predict the risk of capsule retention, especially in high-risk patients. Normal imaging, however, does not obviate the risk of capsule retention because multiple studies have reported retention in patients with previously normal imaging is well-documented (48). The Agile (Covidien) PC, which generally dissolves within 72 hours may be used to evaluate patients before CE (25). Even this capsule has, however, been associated with subsequent PC retention in a pediatric patients (2), secondary obstructive ileus (49), and indissoluble PC (50).

Additional relative contraindications include swallowing disorders. This may include allergy to the materials, pacemaker, or implantable electromagnetic devices that do not allow the capsule to work effectively. Size of patient and the size of oral and pharyngeal tissues may also pose a limitation. Caution should be approached when placing CE in such small children. Generally speaking, in high-risk conditions in which a stricture, mass, or small size is suspected one should balance the risks of obstruction and capsule retention should be balanced with the benefits of obtained information.

TABLE 2. Contraindications and relative contraindications

Capsule endoscopy high risk for adverse events and contraindications
1. Suspected obstruction
2. Bowel stricture
3. Bowel fistula
4. Known obstructing bowel tumor or lesion
4. Smaller size of patient
5. Allergy to materials
6. Presence of pacemaker or other electromagnetic device that interferes with CE electronics

Per manufacturer information.
CE = capsule endoscopy.

Informed Consent/Refusal

Informed consent in procedural-based medicine is the manner by which the physician/caregiver speaks to the patient or patient's surrogate (parent in this case) to inform them about a procedure and subsequently obtain legal and ethical permission to have that procedure done to an individual (Table 3). Significant variations in institutional consent exist regarding CE. Some institutions document a formal consent process, whereas others have a less formalized physician discussion before a nurse visit to facilitate capsule swallowing and placement. For purposes of this clinical report it is recommended that some process discussing the general indications, methods, risks, benefits, and alternatives to CE be disclosed to the subject and/or appropriate surrogate/caregiver. How that information is disclosed and documented is variable.

The information that should be disclosed to the patient includes the appropriate indication(s) as noted above. The benefits of doing CE compared with other alternatives should be discussed including avoiding anesthesia, avoiding full bowel preparation, and possibly evaluating the bowel more extensively. The conversation could include a discussion of its limitations of diagnosis and chance of finding the suspected condition. Alternatives to the procedure should be discussed and may include not performing the procedure, further laboratory or radiologic testing, undergoing SB enteroscopy, CTE, MRE, or exploratory laparoscopy (51). Finally the risks of CE should be disclosed to the family. These may include capsule retention, aspiration, skin or mucosal irritation, vomiting, pain, sore throat, missed lesion, repeat study, or equipment malfunction. If a capsule delivery device is used, then the risks of standard endoscopy are also present (52). Per one of the capsule manufacturers, hypertension, respiratory, and cardiac arrest or arrhythmia are also possible with use or sedated endoscopic placement (53). Discussion regarding the relatively benign or life-threatening nature of these complications as relative risks should be included. Once this information is shared the patient and/or surrogate family member has the option to give an informed consent or informed refusal. How each physician documents the conversation or a formal consent process is subject to institutional policies and state laws and is outside the scope of the clinical report.

TABLE 3. Informed consent components, indications, risks, and alternatives

Indications	Methods	Risks	Benefits	Alternatives
1. Evaluation of small bowel for purposes of (a) Investigating Crohn disease; (b) investigation of obscure GI bleeding; (c) evaluation of polyps/ tumors; (d) other: (celiac, diarrhea, etc)	(1) Swallowing of capsule and recording of data into a recording device through wireless transmission; (2) Placement of capsule endoscopy into small bowel via capsule delivery system attached to endoscope	(1) Pain; (2) nausea; (3) vomiting; (4) obstruction-capsule retention (2.3%); (5) need for surgical or endoscopic removal; (6) bruising; (7) bleeding; (8) mucosal/skin irritation; (9) aspiration; (10) risks associated with EGD; (11) missed lesion; (12) incomplete Study; (13) need for repeat study; (14) equipment malfunction	More thorough investigation of small bowel mucosa for lesion of interest	(1) Not doing procedure; (2) surgical evaluation; (3). MR/CT enterography; (4) small bowel enteroscopy; (5) serological/stool testing

GI = gastrointestinal; MR/CT = magnetic resonance/computed tomography.

Preparation

Before administration of the CE necessary evaluation of the patient must be done to best assure that the capsule can pass the necessary anatomy of the esophagus, stomach, or large bowel. As noted above a stricture is a contraindication. Evaluation of the bowel should be done as described in previous sections.

Providers have several options to prepare patients for CE to optimize capsule images. CE manufacturers recommend a patient only need to be on clear liquids and nothing per os (NPO) the night before a CE. Yet several studies have evaluated bowel preparation before CE with laxatives, prokinetics, and/or simethicone used alone or in combination to improve diagnostic yield, visualization, and completion rate. Studies have been mixed, but most studies demonstrate improvement of the diagnostic yield of CE with bowel preparation (54–56).

Most studies on laxative bowel preparation focus on the effectiveness of polyethylene glycol (PEG). Other agents studied include sodium phosphate and magnesium citrate. PEG is effective in improving image quality when compared to clear liquid diet and NPO 12 hours before the CE (57). The recommended volume of PEG required to achieve optimal bowel preparation also varies, with adult studies evaluating 500 mL to 4 L with reports of 2 L being adequate for optimal bowel preparation (54,58–60). Alternatively, bowel preparation with magnesium citrate has not been shown to improve visualization or completion time for CE (61,62). Bowel preparation with sodium phosphate also has not shown to improve diagnostic yield, gastric transit time, or SB transit time (63,64).

Most recent literature and guidelines do not show benefit for use of prokinetics for improved visualization, completion rate, or intestinal transit time (62,65–67). Prokinetics studied include oral erythromycin and metoclopramide.

Some studies using simethicone show improved CE visualization of the SB (68). Simethicone may also improve evaluation compared with bowel preparation consisting of clear liquid diet and NPO before the procedure or when used in combination with PEG (69–72). It may not, however, improve visualization when used alone compared with PEG bowel preparation (73).

One of very few randomized studies for bowel preparation in children by Oliva et al (74) evaluated standard clear liquid diet, low-volume (25 mL/kg up to 1 L) PEG, high-volume PEG (50 mL/kg up to 2 L), and simethicone with and without PEG. They found that low-volume PEG the night before the procedure and simethicone 30 minutes before the capsule deployment provided better visualization throughout the SB compared with no bowel prep or simethicone alone in pediatric patients. The low-volume PEG had similar efficacy compared with high-volume PEG; therefore, the authors recommend the low-volume PEG with simethicone as it has better tolerability compared with high-volume PEG (74).

Most adult studies and guidelines recommend the use of PEG as the agent for bowel preparation. But there is no consensus on the volume and timing of the medication.

Methods/Reading/Interpretation

Full instruction and training in CE is outside the scope of this report but basic methods will be reviewed here. The completeness and precision of the evaluation will vary based upon skills of the reader, the adequacy of the preparation, and use of the localization sensors (Table 4).

Before reading CE, the endoscopist should be familiar with the different options of reading the endoscopy via the computer software and should have completed training as suggested above (24). Software for CE continues to be updated and using the most updated software optimizes the ongoing advancing technology of CE (53). The reading principle may vary slightly depending on the capsule reader or the type of CE (esophageal, SB, colonic) that is being interpreted. The images that are created can be viewed in a single-image, 2-image, or 4-image sequence. Not only can one choose the number of images viewed at a time, but also choose the speed at which the video progresses. Each software package designates what setting is ideal for optimal viewing (53).

The time to interpret the capsule findings usually depends on the presence of abnormalities. The scan through the bowel can be done in an anterograde or retrograde fashion with images recorded at SB entry and exit to note SB transit time. Still image pictures can

TABLE 4. Endoscopy Committee consensus recommendations

Possible preparation options: (1) Low-volume polyethylene glycol with simethicone or (2) clear liquid diet day before study with nothing per os (NPO) after bedtime until study
High-risk populations: Strongly consider small bowel radiographic imaging before all capsule endoscopy studies to avoid higher risk of capsule retention: (1) Crohn disease; (2) occult GI bleeding; (3) prior bowel surgery; (4) suspected bowel tumor or mass

GI = gastrointestinal.

be taken and annotated to document findings throughout the study. Adequacy of visualization should be noted to document the quality of the capsule study. The final location of the CE at study completion should be noted for the clinician to follow-up possible SB capsule retention.

Atlases are available to assist readers with lesions that are difficult to interpret (75,76). A few scattered areas of erythema or a single aphthous lesions can be considered normal on a CE and are not necessarily diagnostic of a pathology and should be taken in clinical context (75,76). In an attempt to decrease variability of technique and readings, scoring systems have been proposed such as the Capsule Endoscopy Crohn's Disease Activity Index (Niv score) and the Lewis Score for inflammation. Adult studies that demonstrate these scoring systems improved inter-reader correlation and also make accurate correlations to inflammatory markers (77,78).

Adverse Events

CE is, in general, a well-tolerated and safe procedure. The adverse event that most studies attempt to address is capsule retention, which has been defined as a CE remaining in the digestive tract for 2 or more weeks or one that has required directed therapy to aid its passage (6). Two recent large adult studies reported overall capsule retention rates of 1.3 and 1.4% (79,80). A systematic review of 227 articles involving 22,840 adult patients revealed a pooled retention rate of 1.2%, 2.6%, and 2.1% for occult gastrointestinal bleeding, Crohn disease, and neoplastic lesions, respectively (79). The 2 largest pediatric studies, involving 207 and 284 cases, had retention rates of 1.4% and 1.8%, respectively (7,81). The pooled rate of retention in a review of 1013 pediatric procedures was 2.3% (22 patients, 18 intestinal, and 4 gastric retention), with retention occurring in CE performed for occult gastrointestinal bleeding, Crohn disease, and polyps occurring at rates of 1.4%, 2.2%, and 1.3%, respectively (7), and a 2011 meta-analysis of 740 CE studies in pediatric patients found a retention rate of 2.6% with the highest risk of SB retention in patients with known or suspected Crohn disease and a body mass index <5 (th)% (2). Retention usually relates to an intestinal stricture from inflammation (eg, Crohn disease, nonsteroidal anti-inflammatory drug enteropathy, and radiation enteritis), prior surgery (ie, adhesions or anastomosis), or small intestinal tumors (79). Retention associated with polyps has also been reported as a cause in pediatrics (7). Case reports in adults describe retention within diverticulum (Zenker, duodenal, jejunal, or ileal) (82–88), umbilical hernia, bowel fistula (89), eosinophilic enteritis, ischemic enteritis, cryptogenic multifocal ulcerous stenosing enteritis, and tuberculous enterocolitis (90,91).

Patient size is a concern unique to pediatrics. In absence of known or suspected inflammatory bowel disease preliminary studies indicate no correlation between body size and capsule retention (7,92). Further studies are needed.

Although most patients who experience capsule retention remain asymptomatic, CE can lead to bowel obstruction and onset may be quite delayed (93). In a study of 2300 adult patients, obstructive symptoms occurred in 19.4% patients (6 of 31 patients with retained capsules) and there was 1 with complications reported after acute surgical CE retrieval (80). Liao et al's (78) systematic review of 22,840 adult procedures revealed that 16 (15%) of 104 retained capsules were associated with partial or complete intestinal obstruction symptoms; importantly, 88 were asymptomatic. The incidence of obstruction in pediatrics has not been clearly established. In 1 study of 207 pediatric patients the incidence of capsule retention was 1.4% (3 patients) (81). Two of the patients required surgical intervention for obstructive symptoms. The third was symptomatic but passed the CE after steroid therapy. Sporadic cases of intestinal perforation from retention have also been reported in adults (94–100).

Documentation of CE passage is essential and patients and their guardians should be aware of the signs of obstruction to facilitate early recognition. In addition, patients and caregivers should be aware that retained devices are considered a contraindication to magnetic resonance imaging due to the risk of migration of the capsule and/or potential for bowel injury or perforation (101). If retention is suspected an abdominal film should be obtained after 1 to 2 weeks as the capsule may be retained for years before the development of symptoms (93). Emergent surgical removal is warranted in the context of acute obstruction. If a capsule endoscope has been retained, but no acute signs of obstruction are present, the patient could potentially be followed with an expectant approach. In most cases retrieval is desired, which can potentially be accomplished using medical, endoscopic, or surgical methods. Bowel cleanout or medical therapy aimed at the underlying cause of retention (eg, steroids for an inflammatory narrowing, prokinetic agents for dysmotility) have been used in pediatrics (81,92,102). If medical therapy fails, the capsule may be removed nonemergently by endoscopy or surgery open laparotomy has traditionally been the procedure of choice; however, laparoscopic removal has also been reported (103,104).

Aspiration is also a potential complication of CE reported in adults, particularly in individuals with neurological or swallowing disorders (105,106). Endoscopic placement of the CE in the duodenum can, in general, be used to avoid this risk. Minor mucosal trauma secondary to placement with a net has been reported as a rare complication in pediatric CE (28).

Future Research and Summary

Research in pediatric CE is limited and the Endoscopic and Procedures Committee of NASPGHAN is pursuing an agenda to further such research in pediatrics. Areas of interest include improving training, addressing size limitations, completion and diagnostic yield, automatic lesion detection, esophageal CE and CCE, and use in an acute or emergent setting.

The completion rate in both pediatrics and adults remains at roughly 85% and is often limited by the bowel transit time and visibility. Meta-analysis in adults has shown PEG prep before CE to increase the diagnostic yield versus fasting alone (64). Research is needed to further examine bowel preparation required for optimal viewing.

Effective CE interpretation is time intensive. Research is emerging in the development of software to automatically detect lesions using the contrast of pixels in a lesion compared with normal tissue to reduce the reading time and possibly increase the diagnostic yield (107,108).

Additional areas of research could occur regarding newer capsule technologies. As stated above, CE to specifically evaluate the colon (PillCam Colon, Given Imaging) has been developed, but only minimally reported as conference abstracts in pediatric patients and FDA approval is limited in adults. The PillCam Colon is currently being evaluated in Europe to detect polyps after incomplete colonoscopy and monitor colonic involvement of IBD (109).

Research regarding the limited use of CE to evaluate acute GI bleeding sources in the emergency department is emerging (110). This could be used to assist the endoscopist before performing emergent EGD and hemostatic procedure. Currently no pediatric studies have been published using CE technology in this setting.

In summary CE in pediatric is a rapidly advancing technology and has the potential to further transform the evaluation and management of SB disease. Although it has evolved significantly since 2000, it has many areas of further investigation that are needed.

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