Diagnostic and Therapeutic Endoscopy

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3.1 Introduction

3.1.1 Pre-procedure Preparation

Physiologic issues (the emotional and psychosocial well-being of both patients and their caregivers) have an important role in preparation for endoscopy in pediatric patients. Informed consent should be obtained from a parent or guardian or from older children when appropriate. According to the American Academy of Pediatrics (AAP), a pre-procedure health evaluation specific to elective procedures should be obtained, and it includes a health history, American Society of Anesthesiology score of physical status, medication history, allergy assessment, age, weight, and baseline vital signs. A physical examination including a focused assessment of the heart, circulation, lungs, head, neck, and airway should be performed. Laboratory tests are not required in the pre-procedure assessment and need only be performed for clinical indications.

Endocarditis prophylaxis should be considered in patients with congenital heart disease; in particular, those with significant valve lesions and those with surgically placed shunts or artificial material in their circulation. Routine endoscopy with or without biopsy does not warrant antibiotic prophylaxis.

The AAP guideline on sedation in pediatric patients, with presumed normal gastric emptying, advises fasting for a minimum of 2 h after ingesting clear liquids, from breast milk for 4 h and from formula, nonhuman milk, and solids for 6 h before elective sedation. The risks of sedation without appropriate fasting in emergent cases must be weighed against the necessity for the procedure and the expected benefit.

3.1.2 Intra-procedural Sedation and Monitoring

Almost all gastrointestinal (GI) procedures in children are performed using endoscopist-administered moderate sedation or anesthesiologist-administered deep sedation and general anesthesia to ensure patient safety and comfort. Premedication with either oral (0.5 mg/kg) or intranasal (0.2 mg/kg) midazolam allows easier intravenous line

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placement and division from parents particularly in selected group of children with a high level of anxiety before sedation.

Routine oxygen supply is a low-cost, high-benefit practice because data suggest that a significant number of children could have transient apnea and oxygen desaturation during sedation for endoscopy.

Although the short duration of most endoscopic procedures does not contribute to dehydration or hypothermia, children should be well draped, and room temperatures should be appropriately adjusted to avoid these possibilities.

Neurologically impaired patients can be particularly susceptible to benzodiazepines and opiate/benzodiazepine associations. Administration of sedation in children should always be weight based and usually titrated by response, allowing adequate time between doses to assess effects and the need for additional medication. Higher relative doses may be finally required in the preschool, elementary, and pre-teenage groups compared with teenage patients.

The AAP guidelines recommend continuous pulse oximetry and heart rate monitoring at all levels of sedation by a dedicated trained attendant who is specifically assigned to monitor the patient's vital signs. Most pediatric gastroenterologists are well trained and certified to provide moderate sedation, and most procedures can be safely performed outside the operating room. However, because the high frequency of progression to deep sedation, personnel trained specifically in pediatric rescue maneuvers including airway management and pediatric advanced life support should be readily available.

All supplies necessary to rescue any child experiencing cardiovascular complications during a procedure should be readily available in any unit performing pediatric procedures.

3.1.3 Post-procedure Monitoring and Discharge

After conclusion of endoscopic procedures, children should be monitored for adverse effects of the endoscopy or sedation. Vital signs and oxygen saturation should be monitored at specific intervals. The child should be easily awake, protective reflexes should be intact, and speech and ambulation appropriate for age should have returned to pre-sedation levels. Patients who have received reversal agents (e.g., flumazenil, naloxone) may require longer periods of observation as the half-life of the sedative may exceed that of the reversal medication leading to resedation.

Before discharge, specific written and verbal instructions and information should be given to a parent, legal guardian, or other responsible adults. This should include signs and symptoms of potential adverse events, steps to follow in the event of an adverse event, and a phone number at which 24-h coverage is available. Special instructions to observe the child's head position to prevent airway occlusion should be given in cases in which the child will travel in a car seat. In such cases, it may be preferable to have more than one adult who accompanies the child on the day of the procedure.

In this chapter, we will describe technique, indication, and potential complications of the main diagnostic and therapeutic endoscopic procedures available for pediatric population [1–3].

3.2 Esophagogastroduodenoscopy

3.2.1 Indications and Contraindications

Common indications for esophagogastroduodenoscopy (EGDS) in children are summarized in Table 3.1. Diagnostic EGDS may be specifically indicated to evaluate common pediatric conditions such as allergic, infectious, or peptic esophagitis, infectious or inflammatory gastritis, and celiac disease. Infants and children are unlikely to localize their symptoms to the upper GI tract; a number of nonspecific signs and symptoms (failure to thrive, unexplained irritability, and anorexia) may motivate upper endoscopy in young children.

Two other common pediatric diseases that may require endoscopy are the ingestion of

Table 3.1 Common indications for upper endoscopy in children

Diagnostic
Dysphagia
Odynophagia
Intractable or chronic symptoms of GERD
Vomiting/hematemesis
Persistent epigastric pain
Unexplained irritability
Anorexia
Weight loss/failure to thrive
Anemia (unexplained)
Diarrhea/malabsorption (chronic)
Gastrointestinal bleeding
Caustic ingestion
Therapeutic
Foreign-body removal
Stricture dilation
Esophageal variceal ligation
Upper GI bleeding control

Adapted by Ref. [1]

foreign bodies and caustic substances. The protocol for endoscopic evaluation of foreign body ingestion is similar to that in adults and has been well described elsewhere. Compared with standard practice in adults, it is generally recommended that foreign body removal in children should be done while they are under general anesthesia with endotracheal intubation to protect the airway from aspiration. Emergent foreign body removal in children is indicated for any symptomatic esophageal foreign body and for asymptomatic esophageal button batteries because of the high risk of esophageal tissue necrosis and risk of fistula formation. Another increasingly common indication for emergent foreign body removal in children is ingestion of powerful magnets, often manufactured as toys. Ingestion of two or more magnets has been associated with significant risks of obstruction, perforation, and fistula development of the upper and lower GI tracts, necessitating surgical intervention and even bowel resection. An algorithm to assist emergency department physicians and gastroenterologists in providing timely care, including endoscopic removal of magnets, was recently published and endorsed by the North American Society of Pediatric Gastroenterology, Hepatology, and Nutrition.

In cases of witnessed ingestion of caustic substances in which patients are manifesting symptoms, upper endoscopy should be performed to assess for esophageal, gastric, and duodenal injury. Universal performance of EGD in the setting of unwitnessed caustic ingestion without evidence of oropharyngeal injury is controversial, especially in asymptomatic patients. However, there is a well-recognized lack of correlation between symptoms of caustic ingestion and degree of esophageal injury. Endoscopy within 24 h of caustic ingestion is usually considered safe and provides important prognostic information.

EGDS is usually not recommended in infants for the evaluation of uncomplicated gastroesophageal reflux disease (GERD) or congenital hypertrophic pyloric stenosis. It is also generally not indicated in older children for evaluation of functional GI disorders, including self-limited abdominal pain.

Upper endoscopy is a safe procedure in otherwise healthy children 1 year of age and older, although discharge instructions should address sore throat and hoarseness, which may occur after the procedure in as many as one third of patients.

There are few contraindications to perform endoscopic procedures in children. The size of the patient is rarely a contraindication, and upper endoscopic examinations can be performed safely in neonates as small as 1.5–2 kg. Relative contraindications include coagulopathy, neutropenia, and unstable cardiopulmonary disease. In patients with these conditions, it is important to ascertain whether the benefits of performing the procedure outweigh its risks.

3.2.2 Equipment Requirements

The technical aspects of performing upper endoscopy are essentially the same in children and adults. The main difference is the smaller endoscopy equipment necessary to evaluate the smaller and more angulated anatomy of infants

Table 3.2 Neonatal and pediatric gastroscopes

Manufacturer	Model	Insertion tube (length/diameter, mm)	Definition/magnification/color enhancement	Biopsy channel (diameter, mm)
Olympus	GIF-N180	1100/4.9	Standard/none/NBI	1/2.0
	GIF-XP 180N	1100/5.5	Standard/none/NBI	1/2.0
Fujinon	EG530N	1100/5.9	High-definition/zoom/	1/2.0
	EG530NP	1100/4.9	High-definition/zoom/	1/2.0
Pentax	EG1690K	1100/5.4	Standard/zoom/iSCAN	1/2.0
	EG1870K	1050/6.0	Standard/zoom/iSCAN	1/2.0

Adapted by Ref. [2]
NBI narrow-band imaging

Table 3.3 Equipment compatible with pediatric endoscopes

Small biopsy forceps
Small polyp snare
Pediatric roth net
Small alligator forceps
Small rat-tooth forceps
Small injection needle
Small argon plasma coagulator probe
Two-prong graspers

Adapted by Ref. [2]

and young children. The newborn esophagus measures 8–10 cm in length and approximately 5 mm in diameter. In addition, the antrum and proximal duodenum may be more angulated in young children. Although standard adult endoscopes are generally safe in children weighing more than 25 kg, there are a number of commercially available endoscopes less than 6 mm in diameter with the necessary tip deflection that should be used in infants and children weighting less than 10 kg (Table 3.2). Gastroscopes ≤6 mm are recommended in children below 2.5 kg and preferred in children below 10 kg. Standard adult gastroscopes may be considered in children of 2.5–10 kg only if endotherapy is required. In children above 10 kg, standard adult gastroscopes can be tolerated. The main limiting factor with all pediatric endoscopes is the small working channel (2.0 mm) that makes suctioning more difficult and limits their use for therapeutic maneuvers. Table 3.3 lists equipment compatible with most of pediatric endoscopes.

3.2.3 Technique

The patient lies on the left side with the chin tucked against the chest and the bite guard placed between the teeth. Several methods can be used to insert the endoscope. The safe way is under direct vision.

Under direct vision (Fig. 3.1a, b), the instrument tip is advanced to the larynx, and the open glottic aperture is visualized (Fig. 3.1c). A slit can be recognized between the posterior wall of the hypopharynx and the cuneiform and corniculate tubercles (Fig. 3.1d). This slit leads to the upper esophageal sphincter, which curves gently around the posterior side of the cricoid cartilage. The instrument tip should pass a little to the left or right of the midline (Fig. 3.1e), taking care not to deviate into either piriform recess. The esophageal lumen becomes visible for a brief moment, and the tip is advanced into the esophagus (Fig. 3.1f).

In the blind insertion method, the endoscope is first passed over the base of the tongue toward the hypopharynx under external visual control. Care is taken that the endoscope tip is not retroflexed toward the nasopharynx and does not deviate to the left or right into the piriform recess. The instrument tip can be gently advanced just to the introitus of the upper esophageal sphincter. Following initial resistance, a distinct "give" is felt as the endoscope slips into the upper esophagus. Once the instrument tip is within the esophagus, the insertion is continued under endoscopic vision.

In both methods (blind and direct vision insertion), there is always a short segment of the esophagus that must be traversed without vision.

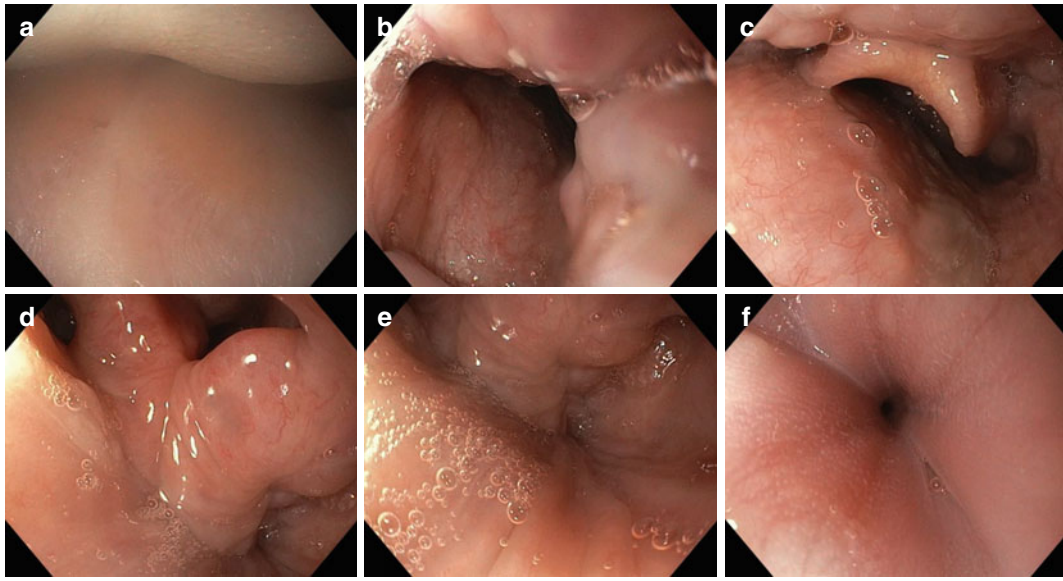

Fig. 3.1 Endoscopic view showing the different phases of the under vision insertion method

The upper esophageal sphincter appears as a lip-shaped eminence surrounding a transversely oriented, slit-like lumen. The cervical esophagus is a straight, collapsed tube that appears largely featureless at endoscopy. Air insufflation distends it to a round, symmetrical lumen that is affected very little by respiratory movements.

The aorta indents the middle esophagus from the lateral side and runs almost horizontally as it crosses the esophagus. The left main bronchus indents the esophagus from the anterior side just below the aortic arch. In the endoscopic image, it runs obliquely downward in a counterclockwise direction. The aorta and bronchus could not be always recognized. Unusual shapes are occasionally noted in thin patients.

The retrocardiac esophagus appeared just below the middle esophageal constriction. This portion of the esophagus is compressed anteriorly by the left atrium and posteriorly by the aorta, resulting in an elliptical lumen. Distinct pulsations could be documented.

The lumen of the distal esophagus again appears round and symmetrical. The lower esophageal constriction is visible in the distance. The muscular contraction and accompanying venous plexus create a typical endoscopic picture of longitudinal folds with concentric luminal narrowing.

Endoscopy is the best procedure to evaluate the gastroesophageal junction. The endoscopist identifies and evaluates the sphincter itself, the diaphragmatic hiatus in relation to the incisor teeth, and the transitional region between the squamous epithelium of the esophagus and the columnar epithelium of the stomach, which are separated by a visible junction called the Z-line. It has an important role to assess whether the lower esophageal sphincter is competent or incompetent, although this assessment varies considerably among different examiners.

The first region that is seen after entry is the junction of the fundus and body of the stomach. To improve vision, air is insufflated, the lesser curvature being on the right and the angulus in distance. When liquids are present, suction is used to reduce aspiration risk. At this point, it is better to rapidly progress in the duodenum to avoid traumatic lesions and the overinflation required for retrovision. Progression is made with a clockwise rotation of 90°, bending the tip upward (Fig. 3.2a). This double maneuver brings the pylorus into view. To put the pylorus in the antrum axis, the tip is angled down. The shaft is then advanced toward the pylorus, which will open with the help of air insufflation. The intubation of the pylorus is achieved with the tip slightly bent down and right. A view of pale mucosa of

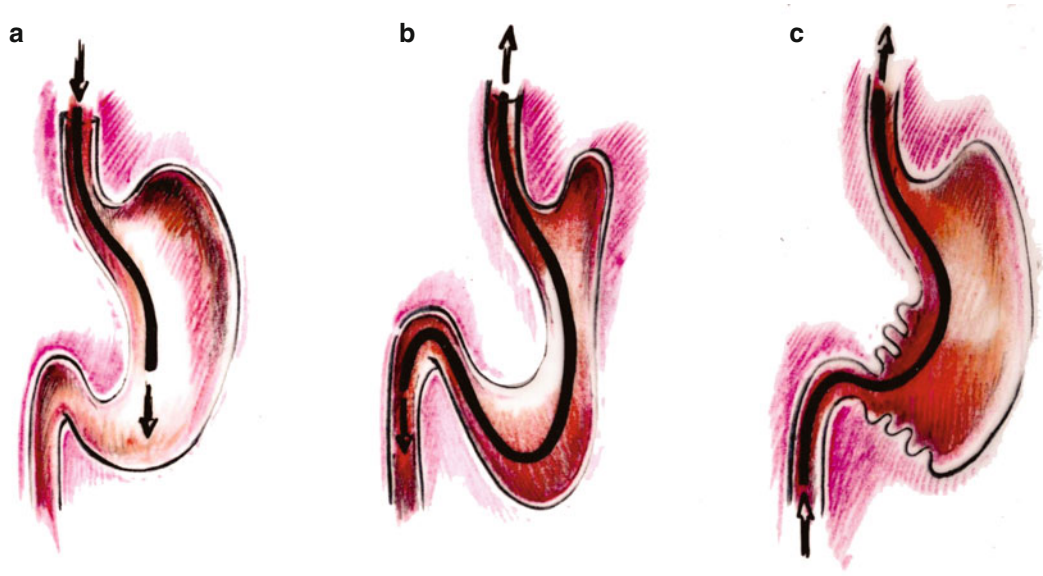

Fig. 3.2 Schematic view of the endoscopic maneuvers required for advancing the endoscope in the stomach and duodenum. (**a**) Progression is made with a clockwise rotation of 90°, bending the tip upward; (**b**) pushing will bring the tip in front of the duodenal angle; it is then bent to the right and up; (**c**) withdrawal is necessary to obtain an optimal view, because of the paradoxically progression of the endoscope owing to the straightening of the gastric loop

the bulb is achieved by withdrawal and air insufflation, the anterior wall placed to the left and the posterior wall to the right. The superior duodenal angle is visualized before passage to the second portion of the duodenum. This progression is usually carried out blindly because of the sharp angle and needs to be made with care. Pushing will bring the tip in front of the duodenal angle; it is then bent to the right and up (Fig. 3.2b). At last, withdrawal is normally necessary to obtain an optimal view, because of the paradoxically progression of the endoscope owing to the straightening of the gastric loop (Fig. 3.2c). Sometimes, rectification of the last maneuver is needed with deflection of the tip upward and to the left.

During the withdrawal, a careful mucosal examination is performed using circumferential movements with air insufflation to provide a well-distended mucosa and to improve visualization of possible small lesions. A retrovision maneuver in the stomach is the best way to fully visualize the fundus, the lesser curvature, and the cardia (Fig. 3.3). While it is in the back portion of the proximal antrum, a 180–210° angulation is necessary to bring into the view the angulus and the lesser curvature (Fig. 3.3a). Keeping the angulation, a 180° rotation around the shaft's axis will permit visualization of the greater curve and the fundus (Fig. 3.3b–e). A key difference between pediatric and adult diagnostic procedures is that routine tissue sampling (usually performed during the withdrawal phase) is performed in children from at least the duodenum, stomach, and esophagus during EGDS. It is standard pediatric endoscopy practice to obtain biopsy specimens, even in the absence of gross abnormalities, because the risks of sedation and performing repeat endoscopy in pediatric populations are considered to outweigh the risks of obtaining biopsy specimens. Several studies have also shown that it may be particularly difficult to rule out clinically significant disease based only on endoscopic appearance of the upper GI tract in children, and biopsies during pediatric EGDS are generally considered necessary even in the absence of any macroscopic endoscopic findings.

3.2.4 Complications

Although about one third of pediatric patients presented sore throat or hoarseness after EGDS under general anesthesia, all other reported complications are uncommon particularly (less than

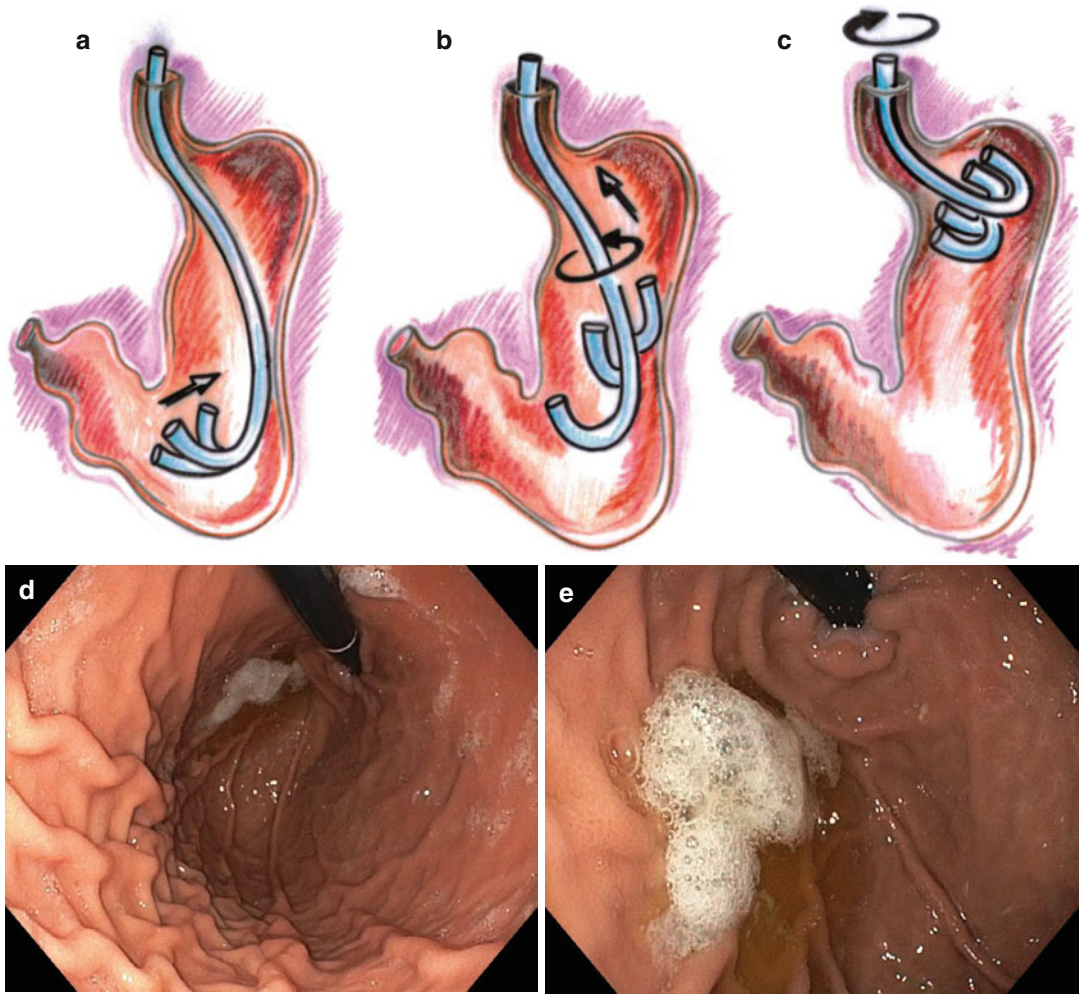

Fig. 3.3 Schematic (**a**, **b**, **c**) and endoscopic view (**d**, **e**) of the retrovision maneuver

1 %) when performed by well-trained pediatric equip. They are mostly related to the anesthesia and infrequently to the procedure itself. Hypoxic episodes and aspiration are always possible under deep sedation. Allergic patients could react to the medications or to the latex. Finally, rare complications are hypotension, arrhythmia, and malignant hyperthermia.

Complications related to the endoscopic procedure include perforation, parietal hematoma, embolism, and infection. Perforation principally involves the esophagus; it is due to therapeutic endoscopy and its signs could appear with some delay. To minimize this risk, it is mandatory to never push forward without vision. In case of suspected perforation, surgical referral is urgent to choose a conservative or a surgical approach. Intramural duodenal hematoma has been described after endoscopic biopsies and occurs more frequently in children than in adults. The clinical presentation mimics abdominal occlusion, it is frequently associated with pancreatitis and always resolves spontaneously between 4 days and 2 weeks with fasting nasogastric suction and fluid replacement. Surgical drainage is unnecessary and therefore contraindicated. Fatal massive embolism has been reported in two children with Kasai procedure because of potential vessel leakage. Infectious complications can result from the patient's own flora, from patient

to patient by the endoscope and between the patient and the staff. This seems rare and can be seen in cardiac-risk patients; therefore, prophylactic antibiotics are suggested only to selected patients [4, 5].

3.3 Colonoscopy

3.3.1 Indications and Contraindications

In the last years, colonoscopy has become a routine procedure also for pediatric patients. It is safely used in all groups of children, including newborns. Common indications for colonoscopy are shown in Table 3.4. There is no pediatric colon cancer screening guideline, and therefore patient volume of pediatric colonoscopies at the population level is far lower than that of adults. Uncommon, but nevertheless critically important, indications for colonoscopy in children include surveillance for neoplasia in children with long-standing inflammatory bowel disease and hereditary polyposis syndromes as well as for graft-versus-host disease.

Colonoscopy is not recommended in children with acute self-limited diarrhea, stable recognized irritable bowel syndrome, chronic nonspecific abdominal pain, constipation with or without impaction, and inflammatory bowel disease that is responding to treatment.

There are few contraindications to perform colonoscopy in children. The size of the patient is rarely a contraindication, and lower endoscopic examinations can be performed safely in neonates as small as 1.5 to 2 kg. Diagnostic colonoscopy is absolutely contraindicated in anyone with fulminant colitis, toxic megacolon, or suspected perforated bowel. Recent intestinal resection represents a possible contraindication to the examination. Relative contraindications include coagulopathy, neutropenia, and unstable cardiopulmonary disease. In patients with these conditions, it is important to ascertain whether the benefits of performing the procedure outweigh its risks.

Table 3.4 Common indications for colonoscopy in children

Diagnostic
Chronic or profuse diarrhea
Lower GI bleeding
Polyposis syndrome (diagnose and surveillance)
Failure to thrive/weight loss
Lower GI tract lesions seen on imaging studies
Rejection of intestinal transplant
Abdominal pain (clinically significant)
Therapeutic
Polipectomy
Stricture dilation
Hemostasis
Foreign-body removal

Adapted by Ref. [1]

3.3.2 Equipment Requirements

Although the instruments are similar, pediatric colonoscopy is different from adults in many aspects such as preparation, sedation, technique, and spectrum of therapeutic manipulations. First at all, in contrast to adults, endoscopic examinations in children are usually performed under deep sedation or general anesthesia to reduce emotional stress caused by separation from parents and the preparation for the procedure itself. Moreover, in children, colonoscopy is usually performed by specialized pediatric gastroenterologists. However, surgeons or adult gastroenterologists may be consulted for advanced or therapeutic endoscopy in pediatric patients. Knowledge of the equipment available for use in smaller patients, primarily those weighing less than 10–15 kg, is required.

Pediatric colonoscopes have variable insertion tube lengths (133–170 cm), shaft diameters (9.8–11.8 mm), and channel size (2.8–3.8 mm). Pediatric colonoscopes with a shaft that can be stiffened as needed are also available. These variable-stiffness colonoscopes were designed to improve the ease of insertion by reducing looping in more mobile sections of bowel with the ability to maintain flexibility in more fixed sections. There are no published data to support colonoscope choice in children, but

recommendations based on experience state that the lower weight limit for the use of a standard adult or pediatric colonoscope is 12–15 kg. In children weighing between 5 and 12 kg, colonoscopy can be performed by using infant or standard adult gastroscopes. Children weighting less than 5 kg may undergo successful ileocolonoscopy with ultrathin gastroscopes, although this can be technically challenging because of the flexibility of the insertion tube. Pediatric colonoscopes with a working channel of 2.8 mm will not accommodate larger accessories (e.g., jumbo biopsy forceps).

3.3.3 Bowel Preparation

Bowel cleansing for colonoscopy in pediatric patients must prioritize safety and compliance and should take into account patient's age, clinical status, and anticipated willingness or ability to comply. To date, bowel preparation regimens for children have not been standardized and vary greatly among medical centers and individual practitioners. Ingestion of clear liquids for 24 h and a normal saline solution enema (5 mL/kg) may be sufficient for infants younger than 2 years of age. For children older than 2 years of age, cleansing can be accomplished with intestinal lavage by using osmotic agents, such as polyethylene glycol solutions with and without electrolytes, dietary restrictions, and stimulant laxatives, such as senna and bisacodyl, and/or enemas.

Polyethylene glycol with electrolytes is used as the primary agent for bowel cleansing; most children will require approximately 80 mL/kg of the solution. Most will also be unlikely to ingest sufficient volume because of its noxious taste. Administration of polyethylene glycol with electrolytes via a nasogastric tube in a hospital setting for 24 h before the procedure is a safe and appropriate treatment, especially in children younger than 6 years of age. PEG-3350 without electrolytes in doses as much as 10 times higher than those recommended for standard treatment of constipation is emerging as the preparation of choice in many pediatric units. Several studies have reported on the safety and efficacy of 4-day bowel preparations by using PEG-3350 without electrolytes in children.

We have recently confirmed that low-volume PEG preparations and sodium picosulphate plus magnesium oxide plus citric acid preparations (NaPico + MgCit) are a good alternative to the standard PEG solutions for bowel preparation in children due to their comparable safety and efficacy profile. Moreover, NaPico + MgCit-based preparations appeared to be more tolerated, representing a promising regimen for bowel preparation in children [6, 7].

3.3.4 Technique

Patient is placed in the left lateral decubitus position. Complete colonoscopy can be performed successfully in the majority of children. Many factors can influence and complicate the procedure, e.g., redundant large intestine, improper preparation, or previous surgeries. General principles of a safe and effective colonoscopy include:

- The intubated colon adopts configuration and shape according to manipulations and movements with the colonoscope, and the pattern of these changes are predictable, as well as the direction in which the colonoscope tip should be moved.
- Rotation, twisting, withdrawal, deflation, and simultaneous to and from movements of the shaft will prevent formation of big loops (Fig. 3.4), mesenteric stretching, and related abdominal pain and discomfort.
- Excessive insufflation leads to overdistension and diminishes ability to telescope the bowel.
- Excessive pushing forward creates more problems than benefits.

The principles of pediatric colonoscopy are similar to those in adults, but should be more acute because of the child's small stature and angulations. In the child, it is frequently possible to palpate a loop of the scope in the abdomen, a clue that instrument withdrawal and straightening are needed. Meticulous attention to technique

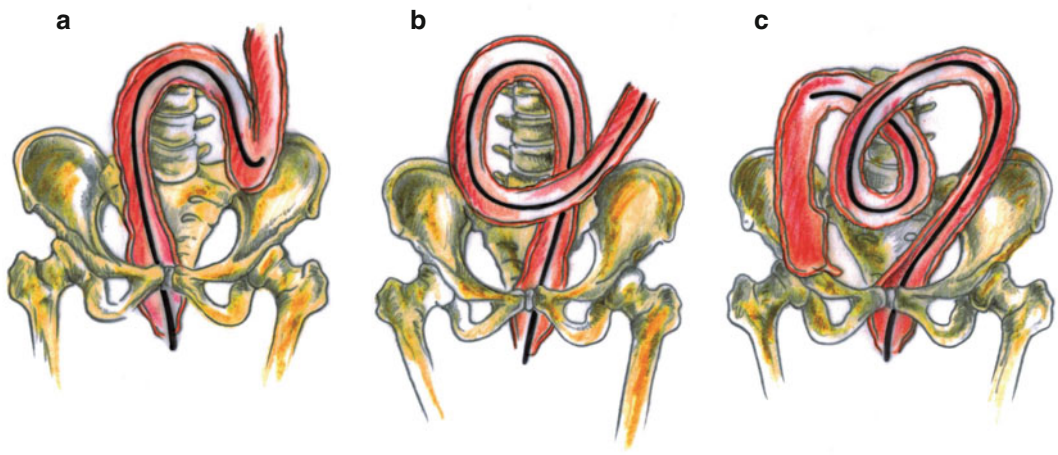

Fig. 3.4 Schematic view of the loops that may form during colonoscopy. N-loop (**a**), alpha-loop (**b**) and gammaloop (**c**)

is required in children because the colon wall is thin, and, in the presence of anesthesia using propofol, there should not be any noticeable feedback from the patient that would provide a clue as to pain or discomfort from an overstretched mesentery or overdistended bowel.

The key to effective colonoscopy is to minimize pain and discomfort. It is critical to try and keep the lumen of the bowel in sight knowing where the tip of the colonoscope is and trying to keep the colonoscope straight with avoidance of loops.

The mucosal pattern of the colon is best studied as the instrument is slowly withdrawn. However, we believe that it is important to carefully pay attention at the mucosa while advancing forward, since trauma could sometimes occur to the mucosa with the passage of the instrument, and, if abnormalities are not identified beforehand, one is always left wondering whether what one sees is due to colonoscopy vs. the underlying pathology.

An additional difference between pediatric and adult diagnostic procedures is that routine tissue sampling is performed in children from at least from the colon and terminal ileum.

3.3.5 Complications

The potential risks and complications of colonoscopy include bleeding, perforation, infection, and difficulties with sedation (such as paradoxical reaction to the agent used).

Bowel perforation and hemorrhage related to pediatric colonoscopy are serious but rare complications. During diagnostic colonoscopy, the estimated frequency of colonic perforation, most commonly in the sigmoid, is in the range of 0.2–0.8 %. The frequency is higher with therapeutic colonoscopy procedures such as polypectomy but is still comparatively rare ranging from 0.5 to 3 %. Mortality is extremely low and should be substantially less than 0.2 %.

3.4 Capsule Endoscopy

3.4.1 Introduction

Since 2001, when it was introduced, capsule endoscopy (CE) has become widely adopted as a clinical tool in the evaluation of small bowel disease. Though the first pediatric studies were initiated in that year, marketing clearance for CE in pediatric patients 10 years of age and older by the US Food and Drug Administration, the Health Canada, and the European Medical Agency did not occur until 2003. Supported by additional experience in children as young as the age of 10 months, the Food and Drug Administration

(FDA) expanded the role for CE for the use in children ages 2 years and older in 2009, approved the use of a patency capsule for this same age group, and has now approved mucosal healing as an additional indication.

Because CE avoids ionizing radiation, deep sedation, or general anesthesia required by other imaging methods, CE has the potential to be particularly valuable in pediatrics. Most of the small bowel has been inaccessible for mucosal evaluation, and much of our knowledge of small bowel disorders has been dependent on laboratory manifestations which are often surrogate markers, radiographic studies which provide indications of more advanced disease and surgical/pathological teachings that provide much information about severe conditions but a limited understanding of their prelude and potential for medical treatment. The recent developments with deep enteroscopy are difficult and invasive in children and as yet insufficiently evaluated with the indication for their use often abnormalities that are initially seen on the less invasive CE.

In many ways, this first decade of small intestinal CE has presented the equivalent of the expansion of knowledge that occurred when traditional endoscopy was introduced. Then, clinicians began to realize the different visual manifestations of gastroduodenal and colonic diseases that could not be appreciated radiologically or pathologically. Additionally, visual findings were gradually able to be explained and then associated with known conditions. The same appears true now for capsule endoscopy. Suspicious nonspecific lesions and bulges seen with CE are being further explained when pathologic samples are obtained with biopsy or surgical removal.

3.4.2 Small Bowel Capsule

3.4.2.1 Indications and Contraindications

Guidelines have been promulgated regarding the indications for CE use by societies such as the American Society for Gastrointestinal Endoscopy.

In pediatrics, the suspicion of CD and evaluation of existing inflammatory bowel disease (IBD) are the most common indications, followed by obscure/occult gastrointestinal bleeding (OGIB), abdominal pain/diarrhea, and polyposis (Fig. 3.5). Even within the pediatric population, clinical indications are age-stratified (Table 3.5). The approved indications for the pediatric and adult populations may expand as the broader utility of the capsule is recognized. Already, the capsule is useful to diagnose allergic disorders, a newly recognized enteropathy in cystic fibrosis, and to evaluate unrecognized causes of abdominal pain. The capsule could be used in monitoring medical therapy in Crohn's disease and graft-versus-host disease. The finding of jejunal lesions in ulcerative colitis and the use of the capsule to differentiate patients thought to have indeterminate colitis (IBD-U) and nonspecific colitis prove to be valid uses of CE especially before a colectomy is performed. Though

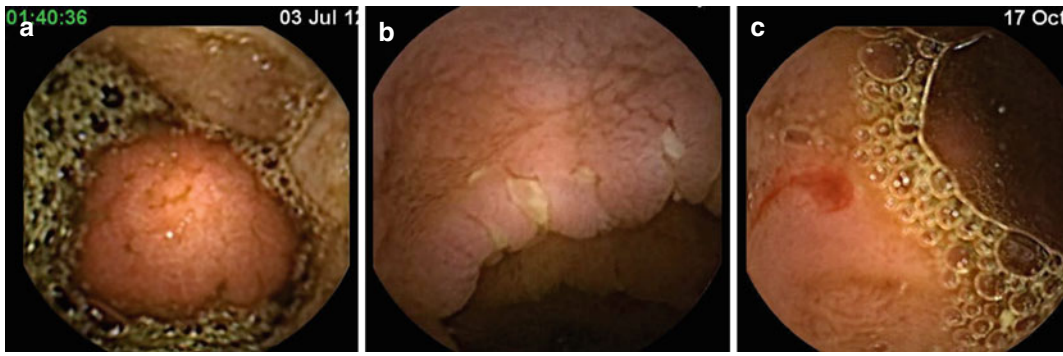

Fig. 3.5 Capsule endoscopic findings of small bowel polyp (**a**), ulcers (**b**) and active bleeding from Angiodysplasia (**c**)

Table 3.5 Clinical indications for CE by age

	Adult	Pediatric	Age <8 years
Procedures (*n*)	22,840	1013	83
OGIB + IDA (%)	66	15	36
CD/UC/IC (%)	10	63	24
Abdominal pain (%)	11	10	14
Polyps/neoplasms (%)	3	8	-
Others (%)	10	4	25

CD Crohn's disease, *IDA* iron deficiency anemia, *OGIB* obscure gastrointestinal bleeding, *IC* indeterminant colitis, *UC* ulcerative colitis

CE may not change the decision regarding surgery (though it has done that), CE may alter the type of surgery that is performed. Additionally, diagnostic algorithms based on CE results have been employed in selected intestinal motility disorders and suggest that wider application of CE are likely, expanding the thoughtful use of this modality.

CE is contraindicated in pregnancy, patients with known or suspected gastrointestinal obstructions, strictures or fistulas, Zenker's diverticula, small bowel motility abnormality, documented surgical ending blinding loop, cardiac pacemakers, or other implantable electromedical devices. Despite this last indication, recent studies have shown that the clinical use of capsule endoscopy is safe in patients with implantable cardioverter defibrillators (ICDs), and even when the capsules were in closest proximity to the ICDs, no interference was observed.

The main limitations of CE include its lack of therapeutic capabilities (including biopsy), the inability to control its movement, its high rate of incidental findings, difficulty in localizing identified lesions (because of the impossibility to wash out the lesion or reexamined it), and the potential to miss single-mass lesions. Certain segments of the SB, such as the second portion of the duodenum or the terminal ileum, may not be seen well by the capsule and therefore have limited diagnostic accuracy. Accuracy can be also decreased by the obscuration of the lens by food, bile, or stools. Moreover, despite the expected life span of ~8 h, the capsule battery may run out before the entire small bowel is visualized, particularly in cases of delayed small bowel transit time.

3.4.2.2 Technical Aspects

CE is a painless noninvasive diagnostic procedure that is performed by swallowing a capsule.

The original mouth to anus (M2A) capsule endoscope (PillCam SB, Given Imaging) has three components: a capsule "endoscope" an external receiving antenna with attached portable hard drive, and a customized PC workstation with a dedicated software for review and interpretation of images M2A capsule which weights 3.7 g and measures 11 mm in diameter × 26 mm in length. The slippery coating of the capsule allows easy ingestion and prevents adhesion of lumen contents, whereas the capsule moves via peristalsis from the mouth to the anus. The capsule includes a complimentary metal oxide silicon (CMOS) chip camera of 256 × 256 pixels, a short focal length lens, 4–6 white light-emitting diode (LED) illumination sources, two silver oxide batteries, and a UHF band radio telemetry transmitter.

Image features include a 140° field of view, a 1:8 magnification, a 1–30 mm depth of view, and a minimum size of detection of about 0.1 mm. The activated M2A capsule provides images at a frequency of two frames per second until the battery expires after 7 ± 1 h, which enables the device to take up to 55,000 .jpg images during 8-h procedure. The pictures are transmitted via an eight-lead sensor array, arranged in a specific fashion on the patient's belly, to a recorder, which is worn on a belt. The recorder is downloaded into a Reporting and Processing of Images and Data computer workstation and seen as a continuous video film.

Now in its second generation, PillCam SB 2 has the same dimension as the previous PillCam,

but it has an angle of view of 156°. The wider angle of view permits to cover more than double the visualized mucosal surface area; therefore, the entire circumferences of the intestinal folds can be visualized.

Moreover, the second-generation capsule includes a three-lens system, an automatic light exposure sensor to improve the optics. An improved method to process the digital information produces images with uniform exposure to light with a higher image resolution and a better sharpness of the mucosal detail, as well as an increase in the depth of view. The software also has additional support systems as a localization system, a blood detector, a double and quadri picture viewer, a quick viewer, a single picture adjustment mode, an inflammation (Lewis) scoring system, and an atlas to assist the interpreter. By now, there are five CE systems: the PillCam SB2 (Given Imaging, Yokneam, Israel), the Endo Capsule (Olympus America, Center Valley, PA), the OMOM capsule (Jinshan Science and Technology, Chongqing, China), the MiroCam (IntroMedic, Seoul, Korea) and CapsoCam Plus (CapsoVision, Saratoga, CA, USA).

The patient fasts overnight, and, on the morning of the procedure, a comfortable belt containing sensors is fitted at the patient's waist, with easy-fasten straps for quick adjustments and removal. The camera is activated by the removal of the capsule from its magnetic holder, and it is given to the patient with a glass of water. After the patient has successfully swallowed the capsule, then the capsule is passively moved along by peristalsis. Two hours after ingestion, the patient is allowed to drink, while eating is allowed after 4 h. During the procedure the patient may carry on with his daily activities. After 8 h, the patient will return to the physician's office to return the sensor belt and data recorder. The PillCam video capsule passes naturally with a bowel movement, usually within 24 h. The physician will then download images from the data recorder for review.

The data recorder is a small portable recording device that communicates with the capsules as the capsule passes through the GI tract. The data recorder is placed in the recorder pouch which is attached to the belt around the patient's waist. Actually there is a RAPID real-time device that enables real-time viewing during a PillCam procedure.

In patients who are unable to swallow the capsule as younger children, or patients with difficulty in swallowing, the examination is carried out placing the capsule with the endoscope directly in the duodenum. Many different techniques to deliver the capsule have been described even for the pediatric population with different device as a foreign body retrieval net alone, a retrieval net and translucent cap or translucent ligation adaptor, a polypectomy snare, and the others with or without an overtube.

Before the procedures, all parents or legal guardians have to give informed consent for their children, and this consent was given in full oral explanation and in writing, above all for the risk of retention.

Upper and lower endoscopies are necessary before performing capsule endoscopy, to exclude lesions from the upper and lower gastrointestinal tract.

3.4.2.3 Patient Preparation

The presence of intestinal contents or a delayed gastric or intestinal transit may cause the failure of the complete visualization of the intestinal mucosa. Despite several studies have examined the possibilities of improving bowel cleanliness and shortening transit time with different medication, small bowel preparation is still a controversial issue. Capsule manufacturer recommend a bowel preparation with a 12-h fast. From European guidelines, there is evidence for a benefit from bowel preparation for capsule endoscopy, but there is so far no consensus on the preparation regimen.

3.4.2.4 Adverse Events

Capsule retention is defined as having a capsule that remains in the digestive tract for more than 2 weeks. Causes of retention cited in the literature include: NSAID strictures, Crohn's disease, small bowel tumors, intestinal adhesions, ulcerations, and radiation enteritis. The frequency of this problem varies: in some studies in adults, it has been

reported in less than two percent of all capsule endoscopy in adults. In a recent pediatric review, the percentage of capsule retention was reported to be variable from 0 % up to 20 %. Prior to the development of the patency capsule, gastroenterologists were dependent on clinical history and radiographic studies to determine the safety and utility of CE. Radiographic studies to evaluate the potential safety for CE have been misleading because capsule retention has been documented in patients with normal small bowel radiography, and conversely safe capsule passage has been described in patients with strictures identified radiographically (see section "Patency Capsule"). It is important to underline that in some circumstances, capsule retention is permitted to identify the exact localization of lesions that needed surgery anyway. In our experience, this happened in a patient in whom the capsule was retained in a blinding surgical ending loop with multiple mucosal ulcerations and a gut wall dilatation. The surgeon found immediately the lesions because of the capsule retention. It appears that the risk of retention is dependent upon the clinical indication and not on the age difference. The highest risk factors for capsule retention include known IBD, previous SBFT demonstrating small bowel CD, and a BMI <5th percentile combined with known IBD, though retention occurred despite the absence of stricture on SBFT. Rare cases of perforation, aspiration, or small bowel obstruction have been reported in adults with none reported in children. However, children have suffered mucosal trauma when capsules have been placed with the Roth net. As a result, specific capsule placement devices are now being used.

3.4.3 Patency Capsule

The majority of capsule retentions have occurred in patients with normal small bowel radiological studies, yet functional patency may be present in patients with radiologically documented strictures. To avoid this concern, an identically sized patency capsule (PC) containing a mixture of barium, lactose and a radiofrequency identity tag was developed. The currently available version has dual timer plugs that gradually implodes if passage does not occur within 30 h. The PC can serve as a useful guide and may lessen the likelihood of CE retention, particularly in known CD where the risk of retention is greatest.

3.4.4 Colon Capsule

Colon capsule endoscopy represents an innovative noninvasive, painless, swallowed "colonoscope" that is able to explore the colon without requiring sedation and air insufflation. The US FDA did not approve it yet, but it is available in Israel and in part of Europe.

Theoretically, all patients with suspected or known colonic disease, referred for conventional colonoscopy are potentially candidates for a colon capsule examination including suspected lesions detected at a previous exam, gastrointestinal bleeding, unexplained iron deficiency anemia, positive fecal occult blood test, clinically significant diarrhea of unknown origin, surveillance for colonic neoplasia, colorectal cancer screening, chronic inflammatory bowel disease, etc.

But we know from adults study that colon capsule should not be considered alternative to conventional colonoscopy but complementary to traditional colonoscopy in case of incomplete colonoscopy, when conventional colonoscopy is contraindicated or in patients who are unwilling to undergo colonoscopy. There are also several studies for the utilization of the colon capsule for screening of colorectal cancer, but to date there are not reasonable results because of the low sensitivity in identifying patients with colonic polyps as compared with standard colonoscopy. Although colon capsule endoscopy represents a reliable system that is not invasive and well tolerated, there are no studies in children.

3.4.4.1 Technical Aspects

There are some differences between the small bowel and colon that make the evaluation of the colon more difficult. First of all, the colon has a much wider diameter. This allows the capsule to flip around its own axis and change directions preventing, full visualization of the mucosal surface.

This problem has been partially solved by adding another camera, allowing both ends of the capsule transmit images. The first generation of the colonic capsule had two cameras on both heads, taking four frames per second. It is 5 mm longer than the small bowel capsule (dimension 11 × 32 mm).

Moreover, the angle of view from each imager is 156°, and it permits greater imaging coverage of the larger cross-sectional diameter of the colon. The second problem is that the capsule has to travel through the stomach and the small bowel to reach the colon and this journey is time consuming. Two changes were made to solve this problem. First of all, a third battery and a sleep mode were added to economize on energy. The transmission of images ceases for an hour and a half after ingestion to allow travel to the target area. With increased energy stores (third battery) and decreased energy consumption (sleep mode), the capsule transmits images from the entire colon. It acquires images at a rate of four frames per second (two for each imager) and has a total operating time of 10 h, approximately. Images transmitted by CCE are recorded in a portable, external recorder (DR2C) specifically developed for colon capsule, and then the images are downloaded in a workstation and visualized.

Recently a second-generation colon capsule has been developed to improve the sensibility of the examination. The new colon capsule is slightly longer than the previous (31.5 mm versus 31 mm), and the angle of view has been increased from 156° up to 172° for each camera, thus offering a panoramic view of the colon (360°). In order to conserve battery energy, the capsule is equipped with an adaptive frame rate, and it captures 35 images per second when in motion and four images per second when it is virtually stationary.

This specific image rate is controlled in real time by the new data recorder which both stores the images and analyzes the capsule images. The data recorder is able to recognize the localization of the capsule, and to save more battery, colon capsule 2 works at a low rate of images per minute during its journey into the stomach and the small bowel, and then when images from small bowel are not anymore detected, then it switches into the adaptive frame rate.

The possibility to identify the site of the capsule permits to notify at the patient by a sounding signal and by a vibration that the capsule is still into the stomach, and the preparation protocol needs to be continued with prokinetic agents. In the small bowel, a beeping sound, a vibration, and a message on the display inform the patients to finish the preparation with a laxative to accelerate the small bowel transit. Transfer of the recorded images to the workstation and review of the videos with rapid software are similar to small bowel capsule. The new rapid software does however now include a simple graphic interface tool for polyp size estimation.

Another difference between the small bowel and colon is that the colonic surface is covered by fecal material and the mucosa of the colon will not be visualized by the capsule. The bowel cleansing has to be superior to the cleansing process applied for conventional colonoscopy since no suction of liquid is possible during capsule endoscopy so if colon is unclear the bowel mucosa may not be seen by CCE. Therefore, novel colon preparation regimens were developed to provide a clean colon and to promote CCE propulsion through the entire colon to the rectum.

By now, there is not any study to determinate the optimal bowel preparation for children, and also for adults, the optimal bowel preparation has yet to be determined. For adults, the most widely used preparation regimen includes an oral preparation of polyethylene glycol (PEG) osmotic solution, boost doses of sodium phosphate solutions, and prokinetic agents.

With this regimen, colonic preparation was judged adequate in a median of 77 % (range 35–89 %) of cases, and the rate of complete examination appears to be very close to the ≥95 % rate recommended for screening colonoscopy.

In children, the preparation protocol is similar to adults, including for three days before the examination patients take a diet without fibers, the day before a clear liquid diet with or without a small breakfast (only milk), and 2–4 L (50 ml/kg) of split dose polyethylene glycol (PEG), half on the previous evening and half in the morning until 2 h prior to capsule ingestion.

A written informed permission is signed by parents' patients to carry out the procedure. Twenty minutes before capsule ingestion, patients take prokinetic agents as domperidone at the dose of 10–20 mg, and the capsule is then swallowed with water. By real-time modalities, it is possible to check when the capsule reaches the duodenum. If, after an hour from ingestion, the capsule is still in the stomach intramuscular prokinetic is administered. Once the capsule arrives to duodenum, the physician activates the capsule and the patient can go home.

Patients or their parents were asked to inform the physician when the capsule was passed in the stools [8–11].

3.5 Enteroscopy

3.5.1 Introduction

Evaluation of small intestinal mucosa has an important role in the treatment of children with different gastrointestinal disorders. Although, for many years small bowel contrast studies were the only practical and effective diagnostic tools on the basis of the length and tortuosity of the small intestine.

Complete visualization of the small bowel mucosa has been obtainable since the introduction of capsule endoscopy (CE) in 2001. Whereas CE has revolutionized diagnostic approach to small bowel disorders, inherent limitations of CE exist. The main limitations of capsule endoscopy include an inability to control the capsule and direct the viewing in real time, as well as inability to perform biopsies or therapeutic intervention and the possible risk of retention. In addition, for some children, voluntary ingestion of the CE can be daunting or impossible, and the capsule should be endoscopically inserted with dedicated device.

Historically, push enteroscopy or surgically assisted enteroscopy was used to further evaluate or treat detected lesions. However, the lack of efficacy and the invasive nature of these procedures, respectively, indicated a need for new methods.

Device assisted enteroscopy (DAE) has recently been reported as an effective method to achieve deep small bowel intubation allowing histologic evaluation and therapeutic intervention and has replaced push and surgically assisted enteroscopy. This advancement has assisted in the care of not only adults but also children and adolescents, although indications and number of application of these techniques may differ because of disease frequencies.

3.5.2 Indications and Contraindications

Indications for enteroscopy are well known in adults. International societies have published algorithms for the different clinical indications clarifying the role of this invasive and potentially dangerous technique in each clinical setting. Main indications and contraindications in children are listed in Table 3.6.

Table 3.6 Common indications and contraindications for enteroscopy in children

Indications
Obscure gastrointestinal bleeding
Suspected or known Crohn's disease
Polyps
Altered intestinal anatomy (e.g., Roux-en-Y)
Eosinophilic gastroenteropathies
Contraindications
Absolute
Intestinal perforation
Peritonitis
Patient toxicity
Cardiovascular instability
Relative
Patient size/age
Severe neutropenia
Severe thrombocytopenia or coagulopathy
Recent digestive surgery
Partial or complete bowel obstruction
Extensive intra-abdominal adhesions
Toxic megacolon
Connective tissue disorders
Intra-abdominal vascular aneurysm
Pregnancy

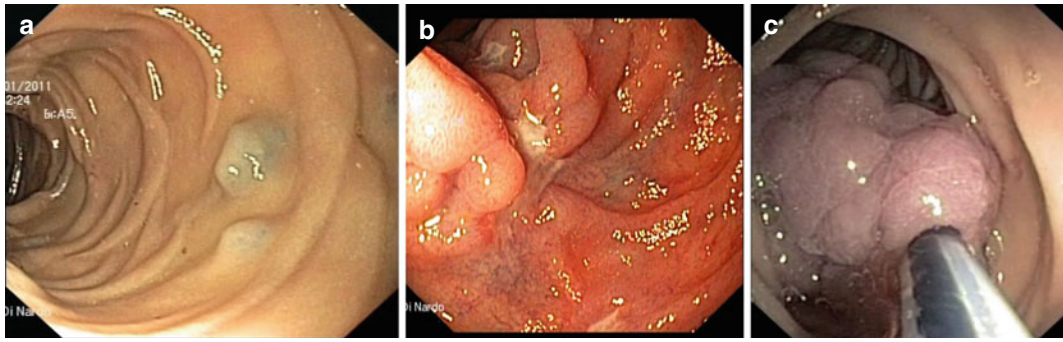

Fig. 3.6 Vascular malformation (**a**), deep ulcer (**b**) and giant jejunal polyp (**c**) detected during Single Balloon Enteroscopy

OGIB is the most common indication for enteroscopy in children. To date, considering the published pediatric case series, a total of 84 patients were studied for OGIB, and it was diagnostic in 62 patients (73.8 %). Diagnoses were Meckel's diverticulum (16.6 %), vascular lesions (15.4 %) (Fig. 3.6a), Crohn's disease (13 %) (Fig. 3.6b), ulcer (5.9 %), and polyps (5.9 %) (Fig. 3.6c). Endoscopic therapeutic procedures were described in 11 patients (13 %), although the published data did not evaluate the outcome.

Only in our recent study, CE has been systematically performed (including second look with CCE-2) before enteroscopy in children with OGIB, and this combined approach significantly increased the overall diagnostic yield (86 %) as compared to previous pediatric data.

In conclusion, enteroscopy has a high diagnostic yield in diagnosing the cause of OGIB in children with the advantage of therapeutic intervention and histologic diagnosis. Nevertheless, future prospective studies are needed to establish the correct place of enteroscopy in the diagnostic algorithm of children with OGIB.

In children with suspected Crohn's disease (CD), DAE is recommended when conventional studies including EGDS, ileocolonoscopy, imaging of small bowel, and CE have been undetermined and histological diagnosis and/or therapeutic procedure would alter disease management (Fig. 3.7). In the setting of established CD, DAE is indicated when endoscopic visualization and biopsies of the small intestine beyond the reach of EGDS or ileoscopy is necessary in order to exclude an alternative diagnosis (lymphoma, tuberculosis, or carcinoma) or undertake a therapeutic procedure including dilation of small bowel stricture, removal of retained capsule, and treatment of bleeding lesions (Fig. 3.8).

Small bowel polyps may cause intermittent bleeding, obstruction, intussusception, or progression to malignancy. Polypectomy might reduce the risk of multiple or urgent laparotomies with intestinal resection, which can result in morbidity and mortality. In published pediatric case series, 50 pediatric patients underwent enteroscopy for surveillance and treatment of small bowel polyps; 98 procedures and at least 318 polypectomies were performed. Not all the procedures allowed a complete evaluation of the small bowel. Although further studies are needed to assess the role of enteroscopy in the management algorithm of children with suspected or established small bowel polyps, it is an effective and safe alternative to surgery for the treatment of isolated and easy accessible small bowel polyps in children.

Contraindications for DAE are listed in Table 3.6.

3.5.3 Equipment

DAE was introduced for the first time in 2001 with double-balloon enteroscopy (DBE). Subsequently, single-balloon enteroscopy (SBE) and spiral enteroscopy have become available during the follow years. Unfortunately, no data reporting the use of spiral enteroscopy in children have been published to date, and the 16 mm outer diameter of the

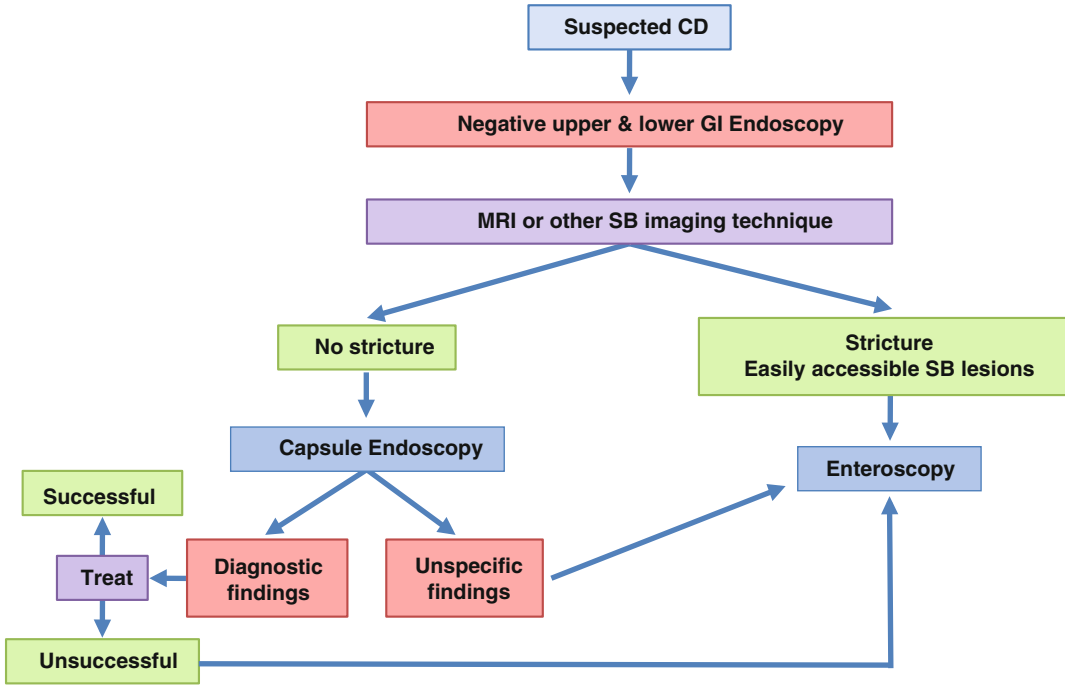

Fig. 3.7 Proposed algorithm in patients with suspected small bowel Crohn's disease. (Adapted by ref 16)

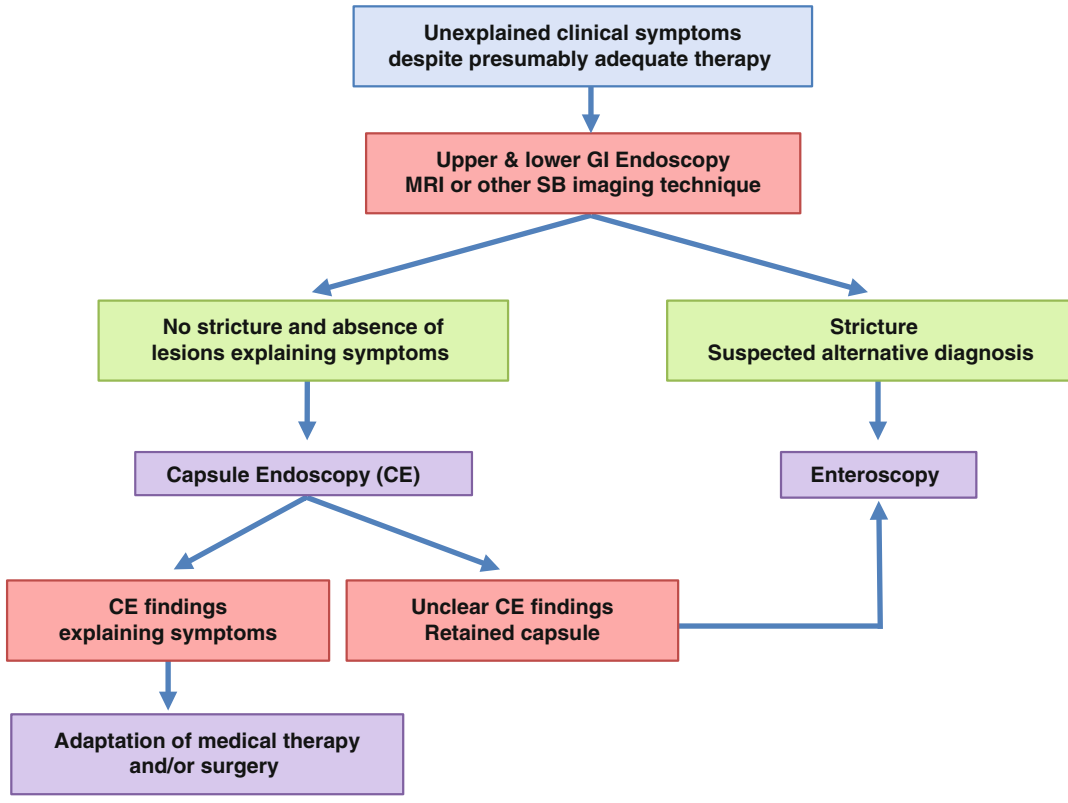

Fig. 3.8 Proposed algorithm in patients with established small bowel Crohn's disease. (Adapted by ref 16)

overtube currently makes this technique impractical for the majority of pediatric patients.

Commercially available since 2003, DBE (Fujinon Inc., Saitama, Japan) utilizes two primary models of endoscopes both with a working length of 200 cm (but with different outer diameters and channel diameters, 8.5 mm/2.2 mm and 9.8 mm/2.8 mm, respectively) plus a soft overtube, measuring either 12.2 or 13.2 mm in the outer diameter with a balloon located at the distal tip, and a length from 105 cm to 145 cm. The second balloon of the double-balloon system is located on the tip of the enteroscope and is inflated during overtube advancement to anchor the scope and prevent slippage.

Single-balloon enteroscopy (Olympus America Inc.) includes an enteroscope (outer diameter of 9.2 mm, channel diameter of 2.8 mm, working length of 200 cm) and a soft 13.2 mm outer diameter overtube (length of 140 cm) with a distal balloon designed to deeply intubate the small bowel. The overtube and the distal tip balloon are made of silicone rubber.

3.5.4 Technique

Balloon-assisted enteroscopy (BAE) including SBE and DBE is performed in children with the same technique described in adults. Obviously, there are some special considerations to take into account in performing BAE in children. The patient size could be the greatest limitation to the use of BAE in pediatric age. On data, DBE has successfully been performed from 2 years of age and SBE from 3 years of age, with a weight at least of 14 kg for both procedures. A smaller abdominal cavity, thinner intestinal walls, and a narrower intestinal lumen make BAE technically more difficult in younger children; thus, it requires a higher level of skill by the endoscopists. DBE is performed inflating the balloon that facilitates anchoring and shortening of the intestine, thus leading to straightening of the bowel yet to be examined and allowing deep advancement of the enteroscope. The bowel that has already been examined is "telescoped" onto the overtube during retraction. In this way, repeated advancement and retraction, or "pushing and pulling," ultimately leads to successful advancement throughout the small bowel. Complete small bowel viewing, from duodenum to cecum, is feasible although difficult. A combined antegrade and retrograde approach is often used to increase the amount of small bowel examined.

Regarding SBE, the primary difference with DBE is that there is no balloon on the tip of the enteroscope, which some feel makes it less complex to perform. In the past, DBE seemed to be able to achieve a greater depth of insertion compared to SBE. However, a recent randomized multicenter trial showed a similar depth of insertion and diagnostic yield in both techniques.

For both DBE and SBE, the patients need only to fast before the oral examination (approximately 12 h for solid food and 4 h for clear liquids). For retrograde examinations, a standard colonoscopy preparation is necessary. BAE in adults is usually performed either with conventional conscious sedation or with propofol based on local attitudes. General anesthesia with intubation is strongly recommended in children.

Depending on experience, radiologic fluoroscopy can be used as an aid in BAE, especially early on in the learning curve (Fig. 3.9); it can also be of usefulness when adhesions are expected because of prior abdominal surgery or massive SB involvement in children with Crohn's disease.

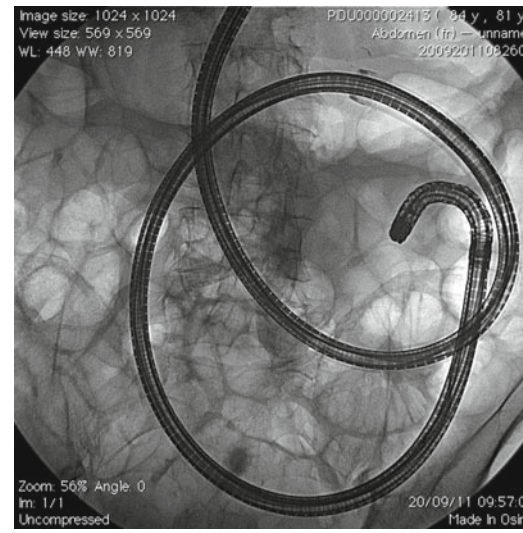

Fig. 3.9 Fluoroscopic view during oral enteroscopic approach

When stenosis is expected, radiology is certainly useful to assess stricture complexity.

Choice of oral versus anal approach is guided by the location of suspected disease. Several tools, including CE, MRI, and US, may be used to assist in localizing the lesion and direct the choice of the enteroscopic approach. In cases in which lesions are difficult or unable to be previous identified and located, both approaches can be considered. Complete small bowel assessment may at times be desired but in many cases is not necessary (e.g., primary lesion is encountered, obviating the need for complete examination) or unachievable. In many cases, the oral approach is chosen first due to the lower technical difficulty and consequently the greater depth of insertion when compared with the anal approach. Indeed, published series for DBE and SBE in adults and children have noted technical challenges to consistent passage through and beyond (proximally) the ileocecal valve. This can be explained by several factors inherent to normal anatomy, patient disease characteristics, and procedural difficulties. Total enteroscopy with BAE is defined as a complete evaluation of the small bowel, with either a single approach or a combined oral (anterograde)-anal (retrograde) approach. However, it may not be feasible in all patients; the reported success rate is 16–86 %. If the lesion is not reached with a single approach, an Indian ink tattoo performed at the deepest point of insertion is used to document a complete SB examination.

All therapeutic procedures available for traditional endoscopy can be performed during BAE using dedicated devices. On data, there are not specific and well-established learning programs for enteroscopy, especially for pediatric endoscopists.

3.5.5 Complications

In adult population, the rate of complications ranged from 1.2 to 1.6 %. Self-limited and mild post-procedure throat pain, abdominal pain, and discomfort were frequently described in both adult and pediatric patients. To date, only three major complications have been reported in the pediatric literature when endoscopic therapy has been performed. A laparoscopic-assisted DBE with the resection of several polyps was complicated by a pelvic abscess in the absence of perforation. One bleeding that was effectively treated endoscopically in a patient who had multiple resected polyps over a span of several endoscopic procedures. Finally, a jejunal perforation occurred in a child with Peutz-Jeghers syndrome who underwent two consecutive therapeutic DBE procedures within 18 days. The limited number of major complications in children would suggest a highly favorable safety profile. However, given the small number of patients studied, it may be premature to make definitive conclusions [12–16].

3.6 Cholangiopancreatography and Endoscopic Ultrasound

3.6.1 Introduction

Diseases requiring endoscopic retrograde cholangiopancreatography (ERCP) and/or endoscopic ultrasound (EUS) in children have a low incidence, thus limiting the experience and giving the impression that these procedures are more difficult in children. There is also lack of consensus about the indications to these procedures in the pediatric population. Generally, patients are referred to a tertiary care facility, and often the procedure is performed by an adult endoscopist.

3.6.2 Indications

ERCP is important in the evaluation of neonatal cholestasis to support a diagnosis of biliary atresia and other causes of biliary obstruction including choledocholithiasis. In recent years, indication to ERCP is mainly limited to therapeutic purposes, on the basis of the evolution of diagnostic imaging technique. During ERCP, a variety of therapeutic maneuvers could be achieved

including sphincterotomy, sphincteroplasty, stones extraction, stricture dilation, and stent placement. Most common indications to ERCP in the pediatric age are discussed below.

ERCP can be a less invasive approach to obtain a cholangiogram in children with suspected biliary atresia. According to several studies, ERCP could avoid unnecessary surgery by distinguishing biliary atresia from other causes of neonatal cholestasis. In one report of 140 infants with suspected biliary atresia, ERCP was successfully performed in 87 %. ERCP findings were confirmed by intraoperative cholangiogram in 80 % of the cases. In another series, ERCP was 86 % sensitive and 94 % specific for detecting biliary atresia and 100 % sensitive and 90 % specific for detecting choledochal cysts.

Biliary atresia was classified by Kasai into three main types depending on the level of biliary obstruction. In Kasai type I, the common bile duct is obliterated. In Kasai type IIa, the common hepatic duct is obliterated; in type IIb, there is atresia of the common bile duct, common hepatic duct, and cystic duct. In Kasai type III, the entire extrahepatic biliary tree is obstructed. Kasai types I, IIb, and III are indistinguishable based on ERCP findings because the obstructed common bile duct prevents visualization of the remainder of the biliary tree.

There is also a classification of ERCP findings:

- Type 1: Nonvisualization of the biliary tree
- Type 2: Visualization of the distal common duct and gallbladder
- Type 3: Visualization of the gallbladder and the complete common duct, with both hepatic ducts and visualization of biliary lakes at the porta hepatis

Caroli disease is a congenital disorder characterized by multifocal, segmental dilatation of large intrahepatic bile ducts. The condition is frequently associated with renal cystic disease of varying severity. Caroli initially described two variants, with (Caroli syndrome) or without (Caroli disease) hepatic fibrosis. ERCP is usually required only if other less invasive imaging studies, like ultrasonography or magnetic resonance cholangiography, failed to establish the diagnosis.

Cystic dilatations of biliary ducts originally were termed choledochal cysts, considering only cysts of the extrahepatic bile duct. Since 1977, a new clinical classification includes intrahepatic cysts. Biliary cysts are found by abdominal ultrasound, computed tomography (CT), or magnetic resonance cholangiopancreatography (MRCP). ERCP can be used as a supplementary test to confirm the diagnosis and categorize the type of cyst to facilitate surgical planning.

The Todani classification is based on site of the cyst or dilatation and includes five types of cysts:

- *Type I*: The most common (80–90 %), saccular, or fusiform dilatation of common bile duct (CBD)
- *Type II*: Diverticulum protruding from the CBD
- *Type III* (*choledochocele*): Dilatation of the duodenal portion of CBD
- *Type IVa*: Multiple dilatations of the intrahepatic and extrahepatic ducts
- *Type IVb*: Multiple dilatations of the extrahepatic bile ducts
- *Type V*: Cystic dilatation of intrahepatic biliary ducts, excluding Caroli disease

The Todani classification does not include type VI: An isolated cyst of the cystic duct (very rare). Only single case reports are documented in the literature.

Types I, II, and IV biliary cysts are associated with an increased risk of malignancy, and surgical excision is recommended.

Endoscopic sphincterotomy is indicated in the following types of cysts:

1. Fusiform bile duct dilation with a widely dilated common channel. In contrast to cystic dilation, fusiform dilation is more commonly associated with low-grade, short strictures located at or distal to the pancreaticobiliary junction.
2. Distal bile duct stricture, which typically occurs at the point of connection with the pancreatic duct. Up to 8 % of such patients

develop cystolithiasis (which may be multiple) involving intrahepatic and extrahepatic ducts.
3. Choledochocele (type III cyst).

Noteworthy, an anomalous pancreaticobiliary junction (APBJ) can present in up to 70% of patients with biliary cysts. It is characterized by a junction of the bile duct and pancreatic duct outside the duodenal wall with a long common duct channel. According to the Kimura classification, there are three types of APBJ:

1. Type B-P – Common bile duct joining the main pancreatic duct.
2. Type P-B – Pancreatic duct joining the common bile duct; this type is more likely to be associated with recurrent pancreatitis than the B-P type.
3. Long Y type – A long common channel, without common bile duct dilatation.

Sclerosing cholangitis in children is usually related with an underlying disorder, and approximately 14% of children with sclerosing cholangitis have underlying inflammatory bowel disease. The diagnosis of sclerosing cholangitis is usually established by magnetic resonance MRCP. The typical finding is pruning of the peripheral biliary tree with stenosis and dilation.

ERCP allows cytological sampling of the stenosis and therapeutic intervention in case of obstructive symptoms (Fig. 3.10). In case of dominant ductal strictures, according to the data of literature in the adult population, there is indication to endoscopic treatment with sphincterotomy and balloon dilation to relieve the obstruction.

Choledocholithiasis is rare in the pediatric population, and it is typically related with hemolysis, infection, chronic liver disease, or choledochal cyst. A review including 382 pediatric patients with gallstones found sickle cell disease, parenteral nutrition, and cardiac surgery as the most common risk factors with the highest frequency in infants, often without symptoms. The incidence of gallstones rises in girls during puberty. Ultrasonography does not always identify small stones in the biliary system. Thus, magnetic resonance cholangiopancreatography (MRCP) or endoscopic ultrasound (EUS) are often required to evaluate patients with a clinical suspicion.

The role of ERCP and the benefit of endoscopic sphincterotomy in children with choledocholithiasis have not been confirmed. Infants and children who presented no symptoms but have small common bile duct stones on an imaging study should usually be managed conservatively, since the stones (or sludge) are likely to pass spontaneously. Sphincterotomy generally should be reserved for symptomatic patients or those with underlying lithogenic disorders.

Malignant strictures of extrahepatic ducts are rare in children. There are few cases described in literature in which stenting successfully relieved the obstruction.

Bile duct complications after liver transplantation include bile duct strictures, leaks, and bile casts. The onset can be early or late (within or after 4 weeks from transplant). Diagnosis relies on MRCP, with ERCP playing only a therapeutic role.

The role of EUS is well established in adult GI and pancreatobiliary diseases. There is, instead, poor literature regarding the use of EUS in pediatric patients because usefulness of EUS in children has been only recently appreciated, and published papers often report few patients and single center experiences. Even if the pathology may differ between the two populations, EUS indications in children are similar to those described in adults. Also the reported results show a great impact of EUS in the management of disease in the pediatric population, in particular for what concerns pancreatobiliary disease (Fig. 3.11).

EUS could be used as a diagnostic tool to avoid more invasive procedure as ERCP in the evaluation of the common bile duct or the pancreatic duct. In children with clinical signs of CBD obstruction, EUS avoided diagnostic ERCP in the majority of cases. Also in pancreatic disease, EUS altered patient management or was used as a therapeutic tool in EUS-guided treatment.

There are few reports on interventional diagnostic or therapeutic pancreaticobiliary EUS in

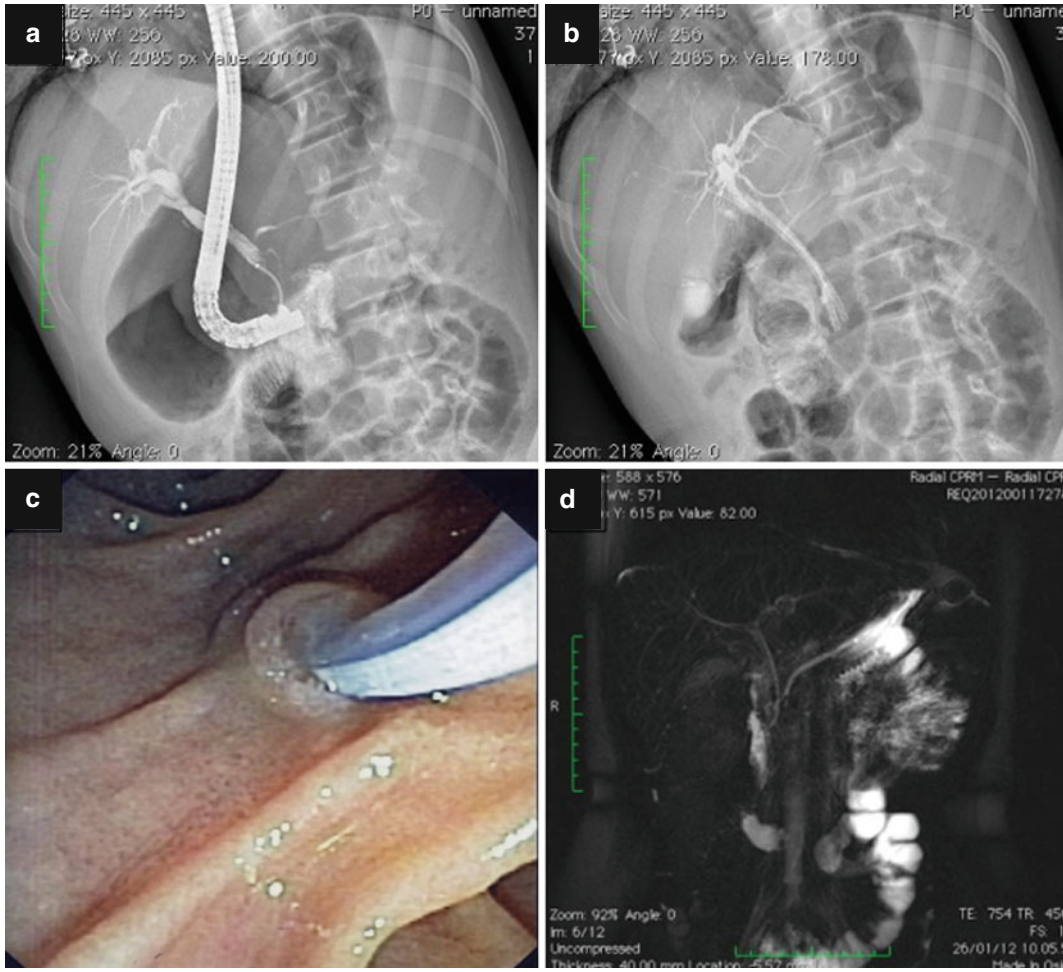

Fig. 3.10 Radiological (**a**, **b**) endoscopic (**c**) and MRI (**d**) findings of plastic biliary stents placed in a child with chronic pancreatitis associated to jaundice and choledochal dilation

the pediatric population. The principal described indications have been EUS-FNA and pancreatic fluid collection drainage. Despite the small sample size, in the pediatric population results of fine needle aspiration were similar to those achieved in adults in terms of success rate and diagnostic accuracy. In particular, the use of EUS-FNA could diagnose an autoimmune pancreatitis or could be useful in case of chronic fibrosing pancreatitis for a differential diagnosis from malignant masses. EUS-guided pseudocyst drainage has been used with high success rate in the pediatric population. In a case series published in 2013, a total of seven children underwent EUS-guided drainage of PFCs. The etiology was blunt abdominal trauma in five, hereditary pancreatitis in one, and idiopathic pancreatitis in one. Both technical and treatment success rates were 100 %. Two patients underwent repeat EUS-guided drainage due to lack of adequate resolution of pancreatic fluid collection on follow-up computed tomography. No immediate or delayed complications were reported. At a median follow-up of 1033 days, all of the children were doing well with no recurrence of the collections. EUS-guided rendezvous or ductal drainage has been occasionally reported. A case of pancreatic duct drainage by the rendezvous technique has been reported in a child and EUS-guided biliary drainage in a 13-year-old patient

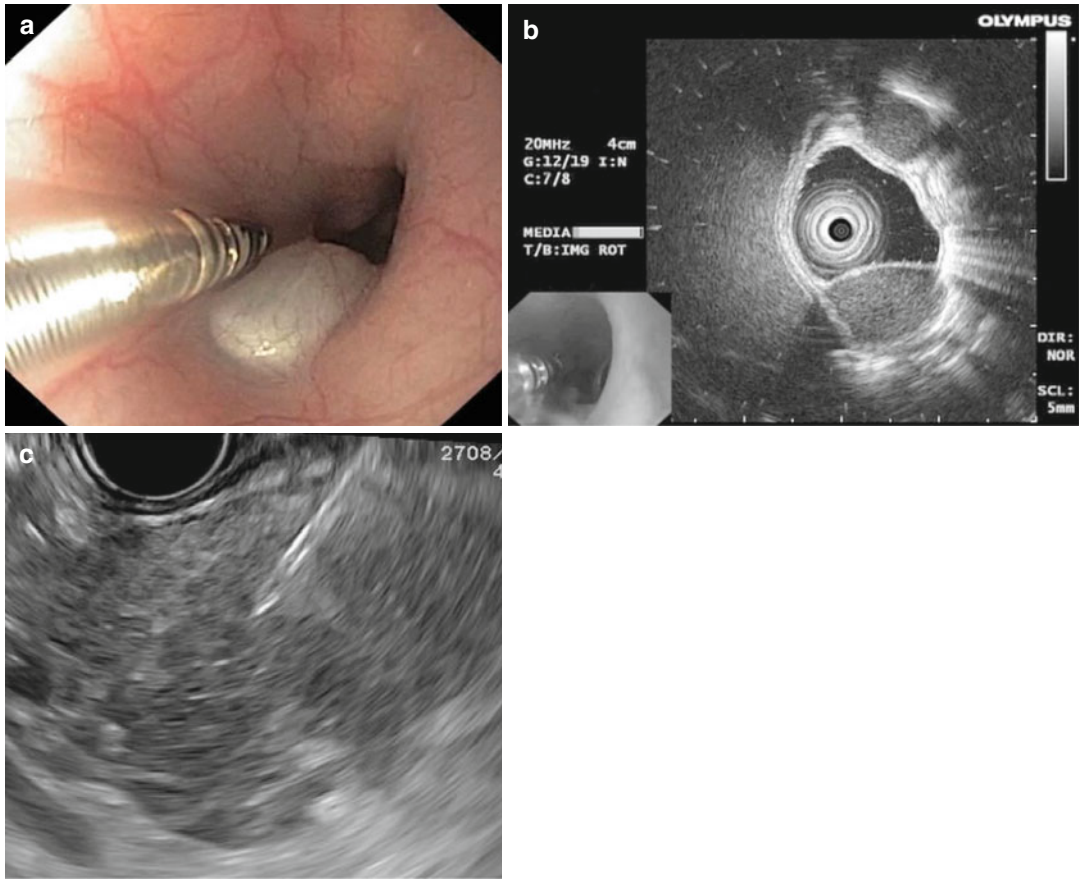

Fig. 3.11 Endoscopic (**a**) and EUS (**b**) appearance of esophageal duplication cyst. EUS-guided FNA of a pancreatic mass (**c**)

with metastatic rhabdomyosarcoma obstructing the biliary tract and involving the duodenum. This technique is rarely used even in the adult population.

Pediatric mediastinal masses represent a diagnostic and therapeutic challenge. They are a heterogeneous group of potentially life-threatening diseases. Transesophageal EUS with FNA allows assessment and biopsy of posterior and middle mediastinal lesions. The reported cases in literature are principally mediastinal nodes in which EUS-FNA was used for cytological diagnosis.

There are several reports about the use of EUS for the evaluation of esophageal, gastric, duodenal, or rectal disease. The technique and results are comparable to the ones in the adult population with a significant impact of EUS on the management of the patients. In the differential diagnosis of esophageal stenosis, EUS with miniprobes can diagnose the nature of the stenosis, thus guiding the further treatment. Subepithelial lesions or duplication cyst can be distinguished in the upper gastrointestinal tract by endoscopic ultrasound. Rectal ultrasound has been used in patients with anal fistulas and underlying Crohn's disease.

3.6.3 Patient Preparation and Sedation

The preparation and sedation of a patient undergoing ERCP/EUS is similar to that used for upper gastrointestinal endoscopy. In the case of pediatric setting, an adequate explanation of the procedure should be provided to the little patient and parents. If an adult endoscopist is perform-

ing the procedure, a close collaboration with a pediatric team should be implemented in order to provide an adequate care. Deep sedation with an anesthesiologist is highly recommended, since children cannot fully cooperate during procedures performed under conscious sedation. Post-procedure monitoring is not different than other endoscopic procedures requiring sedation. ERCP and EUS can be performed on an ambulatory basis when performed for diagnosis only. Therapeutic ERCP has a greater potential risk for serious complications, and overnight observation in the hospital may be indicated. Because ERCP is associated with a higher risk for bacteremia than diagnostic endoscopy, in selected cases, an antibiotic prophylaxis should be considered.

3.6.4 Equipment

For ERCP, a pediatric duodenoscope, with a diameter of 7.5 mm is mandatory in neonate and infants younger than 12 months and is preferred for children younger than 3 years. In older children and adolescents, a standard adult duodenoscope with a diameter of 11 mm can be used.

For EUS, thinner instruments are preferred in small patients. In children, 3 years of age or older a standard EUS equipment can be used.

3.6.5 Technique

ERCP is usually performed with the patient in the prone or semiprone position. The duodenoscope is inserted into the second portion of the duodenum and then is straightened in "short route" with a slow withdrawn. When it is not possible to perform this maneuver, the approach to cannulation of the papilla is performed with the "long route." In this case, the instrument stands along the greater curvature of the stomach. Cannulation technique in children is the same as in adults, but it is necessary to consider the narrower lumen of the children's duodenum that can add some difficulty. In neonates, deep selective cannulation of the bile duct is generally impossible because of the small duct diameter.

In children older than 1 year and adolescents, the rate of successful cannulation is more than 95 %, comparable to reports in adults. In neonates and young infants, the rate of successful cannulation of the common bile duct is often lower than in adults.

In EUS examination, the maneuvers are similar with the exploration of pancreatic head and uncinate accomplished from the duodenum while pancreatic body and tail visualized from the stomach. The experience of the endoscopists may account for a large part of the variability.

3.6.6 Complications

Complications of ERCP are pancreatitis, infection, hemorrhage, and perforation. A series of 329 ERCP for biliary or pancreatic indication reported a total of 32 complications (10 %), mostly pancreatitis with no deaths. The rate of post-ERCP pancreatitis seems to be higher in the patients undergoing pancreatic duct stent placement (7 of 28 procedures, 25 %). There is a very limited experience with EUS in the pediatric population. The complication rate not seems to differ from the adult series being very low especially for diagnostic examination [17–20].

3.7 Polypectomy

3.7.1 Introduction

Polypectomy is the most common endoscopic therapeutic intervention performed in children. In more recent decades, endoscopic polypectomy has endorsed continuous advances because of improvements in the endoscopic technology and techniques.

Polypectomy is difficult to learn, requiring a baseline level of skills in instrument handling including the ability to precisely and efficiently control the instrument tip and therapeutic devices.

3.7.2 Technique

Polyp shape and location both influence the success and technique of endoscopic polypectomy. Pedunculated polyps are much easier to remove than sessile and flat polyps, although they are still associated with a risk of postpolypectomy hemorrhage. The right colon, especially the cecum, is thinner walled than the left with consequent higher rates of complications after removing polyps from this colonic region. Polyps draped over the ileocecal valve are the most difficult to remove and are associated with the highest need for surgery. Rectal polyps are probably the easiest to resect, particularly if located in the lower half of the rectum that is extraperitoneal, minimizing the consequences of full-thickness electrocautery.

Different polypectomy snares are available with variable shape (oval, crescent, hexagonal), size (standard, mini, macro), and reusable vs. disposable. Before polypectomy, the snare should always be checked to make certain that the tip closes at least 1.5 cm into the plastic sheath. The point on the handle at which the snare has closed so that the snare has just entered the plastic sheath should also be marked, as this indicates when mechanical closure is complete and approximately the amount of tissue enclosed in the snare.

All kind of polyps should be captured in the "six o'clock position" because the snare enters the field roughly at this orientation; this can usually be accomplished by rotation of the colonoscope relative to the polyp or changing the patient's position. Because the optical element is located above the working channel of the endoscope, attempting to capture polyps at other orientations may result in losing the visual field against a fold prior to capture of the polyp. It is often easier to remove a polyp during the withdrawal phase of the examination because in this phase loops are removed and the polyp may be more easily snared because both torque and tip deflection are more responsive when the colonoscope is straightened. Additionally, advancing proximal to the lesion, deploying the snare, and dragging it over the polyp often facilitate placement of the snare.

Pedunculated polyps should be sufficiently manipulated to assure the colonoscopist that the snare is near the polyp's head but not around a portion of the head or normal tissue in order to leave a sufficient stalk for regrasping if immediate bleeding occurs. Once snared, the lesion should be lifted away from the colonic wall to minimize contact with the opposing colonic wall avoiding contralateral electrocautery injury. After transection, the stalk should be observed briefly to ensure that no immediate bleeding is occurring. In such a case, bleeding can be treated by regrasping the stalk and holding it for 5–10 min. Alternatively, injection of diluted adrenalin or application of clips has been reported as useful methods to stop immediate postpolypectomy bleeding. For large pedunculated lesions, additional strategies such as epinephrine injection (1:10,000) and attachment of a detachable loop snare (Fig. 3.12a, b) or of a metal endoclip (Fig. 3.12c–e) to the stalk prior to polypectomy should be considered to prevent postpolypectomy bleeding.

Sessile polyps can be removed by standard monopolar electrocautery using principles similar to those for pedunculated polyps. Transection in a single piece is generally feasible even for large polyps with a diameter within 2 or 3 cm. After grasping, the polyp is lifted or tented into the lumen in order to create an artificial stalk. In the right colon, it is advisable to partially deflate the lumen. Large sessile polyps represent a particular challenge to endoscopists because of the risks of hemorrhage, perforation, and inadequate polypectomy.

The submucosal injection technique has been proposed to make removal of large sessile colonic polyps easier and safer. Injection of fluids into the submucosa under the polyp increases the distance between the base of the polyp and the serosa, thus reducing the risk of bleeding, thermal injury, and perforation. The most commonly used fluid is saline (normal or hypertonic), with or without epinephrine. With time, this fluid will be reabsorbed; thus, other fluids have been used in an attempt to prolong the effect, including 10 % glycerol/5 % fructose, 50 % dextrose, sodium hyaluronate, and hydroxypropyl methylcellulose. Sometimes

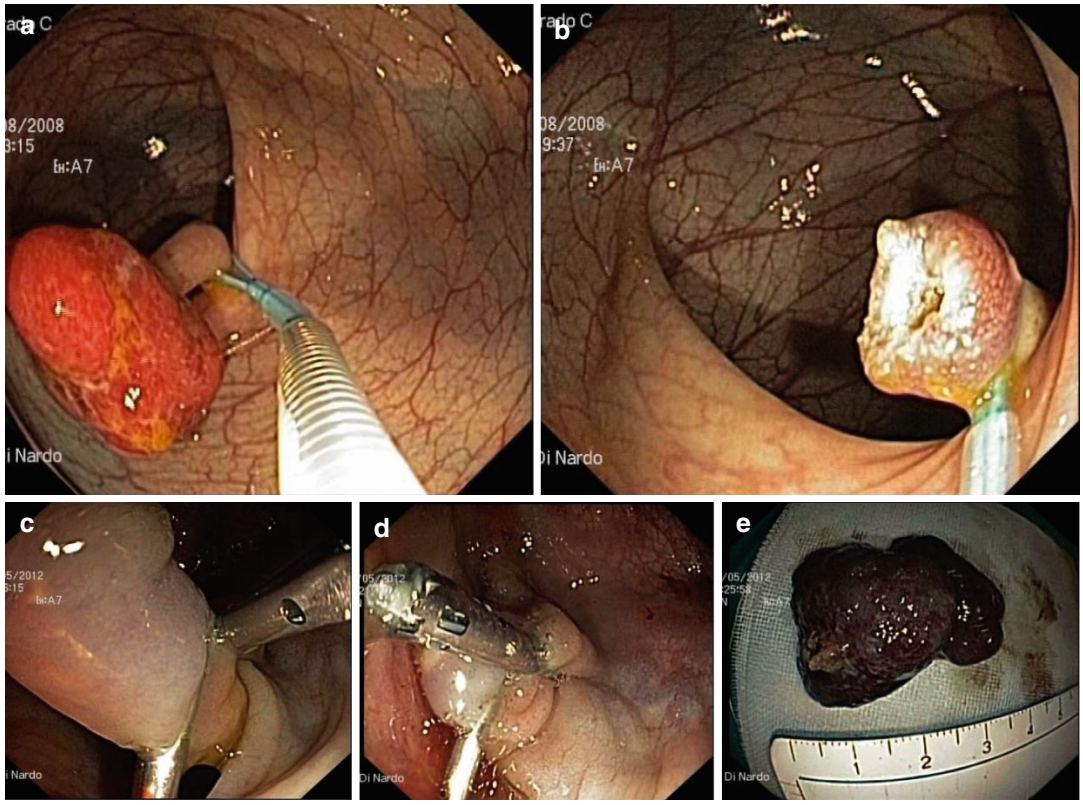

Fig. 3.12 Detachable loop snare (**a**, **b**) and metal endoclip (**c**–**e**) applied to the stalk of two giant pedunculated polyps to prevent postpolypectomy bleeding

few drops of methylene blue can be added to enhance visualization of polyp margins. Fluid is injected using a standard sclerotherapy needle. The needle may be placed into the submucosa at the edge of a polyp, or if the polyp is large and flat, multiple injections may be given around the periphery and directly into the center of the polyp. The desired elevation may require 3–4 mL of solution, although larger volumes can be injected safely. It is preferable to inject the proximal (far) aspect of the polyp first. If the distal aspect is injected first, the polyp can be tilted away from the colonoscope, making subsequent resection more difficult. If a bleb does not immediately form, slowly withdraw and lift the needle slightly while injecting until bleb formation is observed. However, if the polyp fails to elevate (the "non-lifting sign"), it may be an indication of infiltration of the lesion into the submucosa and muscularis propria. Alternatively, this phenomenon may also be caused by a prior attempt at polypectomy with healing and scarring of the layers, preventing this separation by fluid injection or by the needle penetration out of the colon wall, and so the fluid is being injected into the peritoneum.

Most (over 80–90 %) of the polyps encountered during routine endoscopy are less than 10 mm; therefore, techniques to remove these lesions must be optimized due to its important clinical consequences. These polyps can be resected using a number of different techniques, including hot or cold biopsy (with or without cautery), hot or cold minisnare, or cold biopsy followed by fulguration with a bipolar electrode. Cold snaring is the best technique for virtually all small (<10 mm) and most diminutive (<5 mm) polyps. Cold snaring allows efficient resection of polyp tissue in a single piece, with a margin of normal tissue to ensure complete eradication. Occasionally, polyps less than 10 mm are

narrow-based and bulky or pedunculated. In these occasional situations, hot snare resection may be warranted because of the higher risk of immediate bleeding with a more vascular pedicle.

The technique of cold snaring is fundamentally different from snaring with electrocautery. With cold snaring, the endoscopist advances the snare sheath, opens the snare, and encircles the polyp. The snare is then slowly and progressively closed, with the aim of capturing 1–2 mm of normal tissue around the polyp, until complete closure is achieved and the polyp is guillotined. Suction can help the snare to capture the polyp and surrounding tissue. The polyp can then be readily suctioned and retrieved.

3.7.3 Retrieval of Multiple Polyps

Retrieval of multiple polyps or multiple fragments of a big polyp could be a difficult challenge. A single snared polyp could be retrieved with the standard polypectomy snare; alternatively, a prolonged grasping device or wire basket may be used. In addition, dedicated Roth Net snare with a special net has been introduced for the removal of multiple fragments in one shot and has been proved to be safe and useful. The retrieval net could be particularly useful after piecemeal resection of large polyps in the proximal colon to avoid repeated introduction. Polyps as large as 7–8 mm in diameter could be aspirated and retrieved through the colonoscope using the commercially available filtered polyp suction trap. A useful trick for forced aspiration of larger polyp fragments is to remove the suction bottom valve, cover the opening with a finger, and wait.

3.7.4 Complications

Endoscopic polypectomy could be associated with complications, such as bleeding, perforation, and postpolypectomy coagulation syndrome. Most of these complications are self-limiting or could be readily managed conservatively and/or endoscopically. More rarely, they could be life threatening and/or require surgery. Risk factors for complications in this setting include multiple polypectomies, increased size, right colon location, and inexperienced endoscopist.

Bleeding, either immediate or delayed (usually within 1 week, but possible in up to 3–4 weeks), is the most frequently observed complication.

For small polyps, the immediate bleeding rate is 0.5–2.2 %, while delayed bleeding is rare (0.3–0.6 %). Most of the bleeding discovered in this setting is either self-limiting or easily treated in the same endoscopic session, with clip placement or adrenaline injection (1:10,000). Some of the proposed methods of preventing bleeding, such as prophylactic use of hemostatic clips or prophylactic argon plasma coagulation, on the polypectomy scar do not seem to be useful for preventing delayed bleeding in this setting.

Pedunculated polyps have an increased risk of bleeding. Epinephrine injection to both the stalk and the polyp head, as well as looping and clipping techniques, has been successfully deployed to prevent the risk of bleeding after hot snare polypectomy. Even though injection of epinephrine may only prevent immediate but not delayed bleeding, this is the most widely used preventive method.

Perforation (immediate or delayed) is the second most common complication of polypectomy. For small and diminutive polyps, the risk of perforation is nil when cold polypectomy is performed. Perforation in polypectomy has in fact been mostly associated with electrocautery, so this technique is no longer advisable. On the other hand, removal of large lesions is associated with higher perforation rates (0–1.5 %). Lesions larger than 50 mm, located at the proximal colon especially the cecum, are other important risk factors for perforation, since the colonic wall is thin, while rectal location is a protective factor against perforation since the wall is thicker and retroperitoneal. Patients suffering from severe persistent pain that is not diminished by the passage of flatus should undergo X-ray examination

to seek the presence of extraluminal air. A CT scan should also be considered. When the endoscopist is sure that perforation has occurred by virtue of seeing the peritoneal cavity or other organ, then immediate surgical exploration is required.

Postpolypectomy coagulation syndrome is a rare manifestation of peritoneal irritation because of electrocautery but without evidence of perforation on computed tomography scan. It occurs in 1.3–3.7 % of patients undergoing excision of large lesions (usually >2 cm), but requires hospitalization in only 0.07 %. Fever, abdominal pain, and increased inflammation markers characterize it. Symptoms may occur up to 5 days after polypectomy, but this syndrome has an excellent prognosis and is managed conservatively with medical therapy [21–23].

3.8 Hemostasis Techniques

3.8.1 Introduction

Therapeutic endoscopy is indicated for patients with active bleeding at the time of endoscopy and for patients with high-risk stigmata or lesions associated with a high rebleeding rate identified at endoscopy. High-risk stigmata associated with ulcers include an evidence of active bleeding, an oozing from beneath an overlying clot, and a nonbleeding visible vessel at its base. A visible vessel usually appears as a red, blue, or white plug or mound.

Gastroduodenal vascular malformations and Dieulafoy lesions (an isolated blood vessel protruding through a small nonulcer mucosal defect), although are a rare source of upper gastrointestinal bleeding, have a high risk of bleeding with a high complication rate if left untreated. The complication and rebleeding rates of these lesions significantly decrease with effective endoscopic therapy.

Diffused mucosal bleeding from duodenitis or gastritis is usually not responsive to endoscopic intervention, except for portal hypertensive gastropathy. Esophageal and gastric varices could also have endoscopic characteristics that are associated with a high rebleeding rate and will be discussed in a dedicated section. Colonic lesions amenable to endoscopic therapy include bleeding ulcers, vascular malformations, polyps, and bleeding polyp stalks. Colonic varices, either caused by portal hypertension or hereditary, are less amenable to endoscopic therapy than their upper tract counterparts because of their diffuse nature unless a discrete bleeding point is identified at the time of endoscopy.

3.8.2 Nonvariceal Gastrointestinal Bleeding

Three endoscopic techniques could be used to control nonvariceal gastrointestinal bleeding: injective, thermal, and mechanical. The specific technique used depends on equipment availability, site and type of bleeding lesion, and experience of the endoscopist.

Standard pediatric gastroduodenoscopes have a 2.0-mm operative channel, and consequently they will accommodate needles for injection therapy but will not allow the use of thermal and mechanical devices. Standard adult gastroduodenoscopes have a 2.8-mm operative channel sufficient for all devices; however, the outer diameter (8.6–9.8 mm) of these endoscopes cannot be used in children below 10 kg. Adult therapeutic gastroduodenoscopes have either one or two operative channels ranging in sizes from 2.8 to 3.8 mm, but their outer diameter (11.3–12.9 mm) usually precludes their use in children below 20–25 kg.

Pediatric colonoscopes have a 2.8–3.8-mm channel allowing the use of all hemostatic devices.

3.8.2.1 Injection Technique

This is an inexpensive and easy-to-learn method usually performed by injection of a liquid agent at three or four sites around an exposed bleeding vessel and then directly at the site of the vessel. The rationale for this technique is that a visible vessel is not an end artery and that for effective

Table 3.7 Selected endoscopic accessories for injective hemostasis

Type	Diameter/size	Min endoscopic channel required (mm)	Representative products and manufacturers
Injection needle	23G, 25G 21G	2.0 2.8	Various
Injection-coagulation catheter	7 F (25G) 10 F (25G)	2.8 3.7	Injection gold probe/Boston Scientific
Injection-polypectomy snare	3.0 mm (25G)	3.7	iSnare/US Endoscopy

Adapted by Ref. [24]

Table 3.8 Sclerosant agents for nonvariceal bleeding

Solution	Concentration	Volume/number of injections/location	Max total volume	Comments
Hypertonic saline-epinephrine combination	3.6 % saline + 1:20,000 epinephrine or 7.2 % saline + 1:20,000 epinephrine	3 mL 3–4 injections at base of bleeding vessel	9–12 mL	Repeat prophylactic injections if visible vessel present 24–48 h after first hemostasis
Epinephrine with normal saline	1 mL 1:1000 epinephrine + 9 mL normal saline	0.5–2.0 mL injected in multiple sites around bleeding vessel and into bleeding point itself	10 mL	Larger volumes in range for spurting vessels
Epinephrine followed by polidocanol	5–10 mL epinephrine 1:10,000 Polidocanol 1 % 5 mL	Inject epinephrine into submucosa directly around blood vessel to achieve hemostasis by compression/vasocostriction, then obliterate vessel with polidocanol	Epinephrine 5–10 mL Polidocanol 5 mL	May substitute bipolar coagulation for polidocanol
Thrombin in normal saline	100 IU thrombin in 3 mL normal saline	Inject into bleeding vessel 10–15 mL total volume	10–15 mL	
Epinephrine with normal saline for polypectomy	1 mL 1:1000 epinephrine + 9 mL normal saline	1.0–2.0 mL per injection injected in multiple sites (3–4) around polyp to be raised up	30 mL	Goal is lack of vascular markings within injection site

Adapted by Ref. [24]

hemostasis tamponade of the feeding vessel is required. Injection is most easily performed by injection of the proximal site of the lesion first and distally thereafter; this avoids that injection over the distal site of the lesion as creation of the submucosal bleb may lift the bleeding site away from the view. Hemostasis results from a combination of vasoconstriction, mechanical tamponade, and cytochemical mechanisms.

Injection needles consist of an outer sheath (plastic, Teflon, or stainless steel) and inner hollow-core needle (19–25 gauge). Using a handle on the end of the needle sheath, the operator can retract the needle into the sheath for safe passage through the working channel of the endoscope. When the catheter is placed near the target lesion, the needle can be extended out of the end of the sheath to a preset distance, and a syringe attached to the handle is used to inject liquid agents. A combined injection needle/multipolar probe and a combined injection needle/snare are available to allow for sequential injection and coagulation (Table 3.7).

Table 3.8 lists the most commonly used solutions, their concentrations, appropriate volumes, and recommended injection site. Except under unusual circumstances, injection therapy should

be confined to a single solution (single agent or a combination agent) during an injection episode to minimize the risk of ulcer extension or perforation.

The main criticism of injective technique is that it may only provide temporary control of hemorrhage. For this reason, it is generally used to stop or slow down active bleeding prior to application of conclusive therapy such as thermal or mechanical technique.

Complications are usually related to the substance injected (e.g., arrhythmias and hypertension after adrenaline, bowel ischemia, and perforation after sclerosing agent injection in the thinner walled duodenum or right colon) and rarely to inappropriate technique (e.g., increased bleeding, rebleeding).

3.8.2.2 Thermal Techniques

Thermal devices generate heat either directly (e.g., heater probe [HP]) or indirectly by passage of electrical current through tissue (e.g., multipolar electrocautery [MPEC] probes, argon plasma coagulator [APC]).

Heater probe consists of a Teflon-coated hollow aluminum cylinder with an inner heating coil. A thermocoupling device at the tip of the probe maintains a constant temperature. Probe activation results in delivery of a preselected amount of energy in joules to the probe tip. Once the pulse has been initiated, the duration of activation is predetermined. The probe is water perfused to prevent tissue adherence. Coagulation should be around the bleeding point or stigmata first and then directly upon it. If a twin-channel instrument is used, the endoscopist is able to tamponade the bleeding with the probe while simultaneously suctioning in the region of the ulcer base. The number of joules per pulse should be reduced, especially in right-sided colonic lesions. In 1–3 % of cases, perforation may occur after heater probe application for gastrointestinal bleeding because of the variable depth and extent of tissue injury after application. Precipitation of bleeding has been reported in up to 5 % of cases after heater probe application.

Because of these limitations, the bipolar probe or MPEC is more commonly used. In these devices, current is transmitted from one electrode on the probe to another electrode. Energy is delivered when any pair of electrodes is in contact with the bleeding target. MPEC probes may have six points through which current can be passed; contact between any two is sufficient, allowing for tangential contact. The maximal temperature achieved with this method is significantly less than that of monopolar coagulation, resulting in less tissue injury and also greater efficacy for vessels <2 mm. As with the heater probe, the correct technique is to compress the bleeding vessel first and then to coagulate. Pulses should be applied as short, multiple pulses (2 s long) or a single pulse as long as 6–10 s. In adults, up to 40 s total of electrocoagulation may be required.

Increased bleeding after bipolar coagulation has been reported in cases with a visible vessel; usually this bleeding is controllable with further bipolar coagulation, but on occasion surgery has been required. MPEC seems to be equally effective to heater probe in terms of hemostasis, incidence of rebleeding, transfusion requirement, and need for emergency surgery.

In addition to sequential combination therapy, a combination probe is available that allows for sequential injection and coagulation without the use of a dual-channel endoscope or catheter exchange.

The APC is a noncontact electrocoagulation device that uses high-frequency monopolar alternating current conducted to target tissues through ionized argon gas (argon plasma).

The probes, consisting of a Teflon tube with a tungsten monopolar electrode contained in a ceramic nozzle close to the distal end of the probe, are 2.3 or 3.2 mm in outer diameter and are available in lengths of 220 or 440 cm. Probes are available to direct plasma either parallel or perpendicular to the axis of the catheter (Fig. 3.13). Gas flow rates can be varied from 0.5 to 7.0 L/min, the power settings vary from 0 to 155 W, and the generator voltage ranges from 5000 to 6500 V. Argon gas passes through the coagulation probe with an electrode at its tip. The foot switch activates the electrode, resulting in a flow of electrically activated ionized gas from the probe to the tissue causing tissue desiccation at the interface.

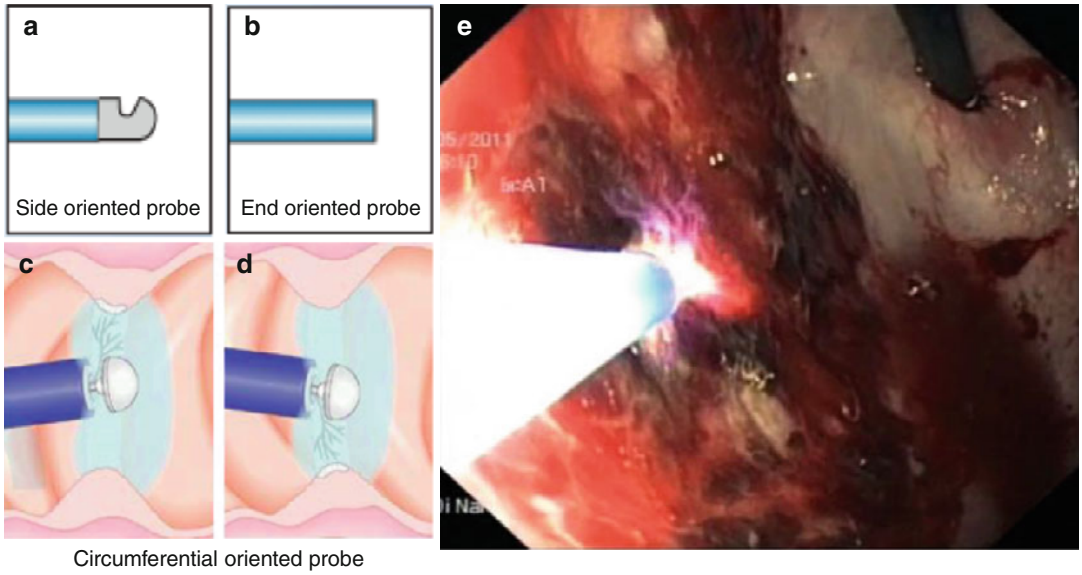

Fig. 3.13 Schematic representation of the available different oriented probe for Argon Plasma Coagulator (APC) application (**a**–**d**). Endoscopic view of APC treatment of a diffuse gastric bleeding (**e**)

If the catheter is not near target tissue (2–8 mm), there is no ignition of the gas, and depression of the foot pedal results only in flow of inert argon gas. After desiccation, the electrical resistance of the treated area increases, prompting the current to move to the untreated area of lower resistance. The depth of coagulation is dependent on the power setting, the gas flow rate, the duration of application, and the distance between the probe tip and the target tissue. The surface to be treated should be cleared of fluids, limiting the usefulness of the APC in cases of active bleeding. If the overlying surface is not clear, then a coagulated film may develop and the tissue beneath the surface may not be adequately treated. The correct technique is to put the probe to an optimal operating distance and to move the endoscope shaft to paint the confluent area to be coagulated. The noncontact nature of the technique makes it possible to treat large areas rapidly, in comparison with the heater probe or MPEC. The probe tip should not contact the tissue because this is a monopolar probe and deep tissue injury may occur with contact, although the safety of the technique is not forfeited by occasional inadvertent tissue contact. Care must also be taken to continuously aspirate the argon gas, which is flowing under steady pressure whenever the foot switch is activated during the procedure, because failure to do so can result in overdistension of the stomach or bowel, especially in smaller patients. Appropriate modifications will be required in pediatric patients, with current generators having minimum gas flow rates of 0.5 L/min and in right-sided colonic lesions that could be elevated with a saline cushion before treatment to reduce the risk of perforation.

Applications for the APC include hemostasis of vascular ectasias, treatment of bleeding ulcers, treatment of residual adenomatous tissue, and ablative therapy. The primary pediatric indication is likely to be treatment of symptomatic gastrointestinal vascular lesions (Fig. 3.13).

Complications have been reported in 0–24 % of patients in various adult series and include gaseous distension, pneumatosis intestinalis, pneumoperitoneum, pneumomediastinum, subcutaneous emphysema, pain at the treatment site, chronic ulceration, stricture, bleeding, transmural burn, and perforation.

3.8.2.3 Mechanical Techniques

Endoscopic clips consist of a metal double- or triple-pronged preloaded clip, a delivery deployment catheter, and a handle used to operate and

deploy the clip. Clips are available in a variety of jaw lengths and opening angles, they require a 2.8-mm endoscope channel for deployment, and triple-pronged clip requires a 3.2-mm endoscopic channel. A double-pronged clip with reopening and repositioning capability up to five times before deployment is available.

The preferred technique is to identify and clip the bleeding point first and then to apply additional clips around the bleeding point if necessary. Because this is a mechanical technique, secure clip deployment is achieved with maximal capture of tissue around the bleeding vessel. Optimal clip positioning is best achieved with the clip extended a relatively short distance from the endoscope tip. This allows for more precise clip application and allows for exertion of downward force on the clip during its placement. The correct technique is to position the clip slightly away from the arterial base, allowing for an en face or tangential approach, and to push the open clip downward while simultaneously applying suction. The clip should be slowly closed and, if optimally positioned, deployed. Reopening clips can be repositioned before deployment if required. The limitations of clip application relate to the location of the lesion and to size criteria. The proximal lesser curvature and gastric cardia may be difficult to approach for clipping directly or in the retroflexed position, and in some cases it is easier to carefully expose the clip before retroflexion. Duodenal ulcers involving the posterior wall of the duodenal bulb, fibrotic ulcers, and arterial vessel larger than 2 mm in diameter may be difficult to clip. In most cases, the clips dislodge spontaneously within 2–4 weeks and pass in the stool, although some have been in place for >1 year.

Although no adverse effects have been reported, magnetic resonance imaging may be contraindicated if clips are present. Clipping for acute nonvariceal hemostasis is associated with primary hemostasis rates in the range of 84–100 %, with low rebleeding rates, comparable with those achieved with injection, thermal, and combination therapies. As with thermal therapy, hemostatic clipping has been used as part of combination therapy in conjunction with epinephrine injection.

Clipping and other mechanical techniques have been shown to be more efficacious and are associated with a lower rebleeding rate than nonmechanical therapies for patients with Dieulafoy lesion, Mallory-Weiss tears, and colonic bleeding after biopsy, after polypectomy, from hemorrhoids, or from solitary rectal ulcer syndrome. Complications after clipping are extremely rare but include a case wherein a clip inadvertently perforated a gastric ulcer and was applied to the splenic artery, and a case of colonic perforation thought to be due to clip placement for postpolypectomy bleeding.

Detachable loops consist of a circular- or elliptical-shaped nylon loop preloaded onto a delivery system that includes a hook wire to which the loop is attached within a Teflon sheath and an opening handle. The outer diameter of 2.6 mm requires a 2.8-mm operative channel. Both reloadable and single-use preloaded devices are available. The loop is used in a manner similar to the technique of polypectomy snare placement. The maximal loop opening size is 30 mm. The loop is tightened with advancement of a silicon rubber stopper. The loop is then detached after hemostasis is achieved without transecting the lesion. The primary indication for loop placement is for the prevention or management of postpolypectomy bleeding. When the loop is applied before polypectomy snare placement, care must be taken to avoid entanglement of the loop in the polypectomy snare. Before polypectomy, detachable loop placement should result in change of the color of the polyp head without transection. If the loop is applied too tightly, amputation of the polyp may occur with resultant bleeding; if it is too loose, bleeding may occur after polypectomy. Hemostatic loop placement has also been effective in the management of bleeding Dieulafoy lesions and has been used for bleeding gastric varices.

3.8.3 Variceal Bleeding

Currently endoscopic variceal ligation (EVL) is the primary choice for the endoscopic management of variceal bleeding in children. However,

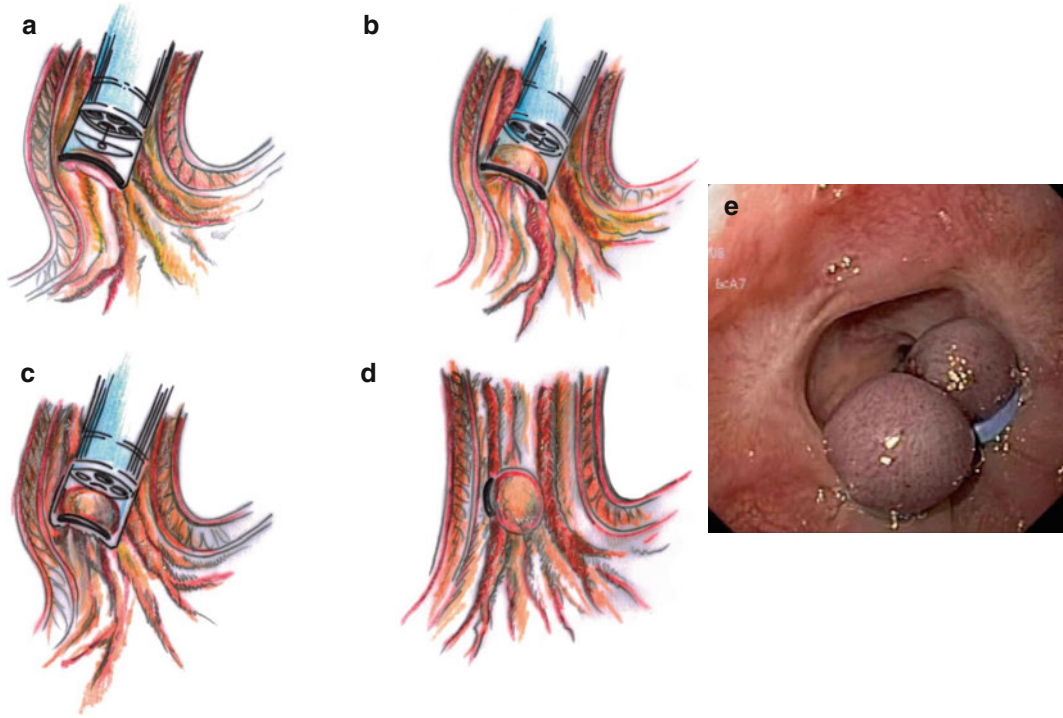

Fig. 3.14 Schematic representation of endoscopic variceal banding ligation (EVL) technique (**a**–**d**) and endoscopic view at the end of the procedure (**e**)

this treatment cannot be applied to small children due to technical limitations, and sclerotherapy is still recommended as an alternative approach in these cases. Primary endoscopic prophylaxis is only indicated in some children (i.e., patients who live in remote areas far from emergency medical care), and secondary prophylaxis is recommended for cirrhotic children, whereas a meso-Rex shunt operation is the first choice for prophylaxis in children with extrahepatic portal vein obstruction (EHPVO). Many of the current recommendations for the management of variceal bleeding have been adopted from case series in children and RCTs in adults.

An extensive experience with emergency sclerotherapy exists in children. A variety of agents have been used (sclerosants, chemically irritating compounds such as ethanolamine/tetradecyl sulfate). These sclerosants are injected either intra- or para-variceal, until bleeding has stopped. In the setting of emergency sclerotherapy, it is important to be aware of the significant incidence of associated bacteremia and to consider antibiotic prophylaxis in most patients. The effectiveness of sclerotherapy has been studied for both prevention and subsequent bleeding episodes. Considerably, whereas a band ligation device can only be used with an adult endoscope, an injection needle can be applied to every scope. Hence, sclerotherapy can be applied even to a neonate. It is also a very inexpensive method and is not technically difficult.

Although endoscopic sclerotherapy has been widely used with effective treatment of bleeding in neonates and children, side effects from the sclerosants can be significant, such as perforation, bleeding, ulceration, and stricture formation at the injection site. The range of complications associated with sclerotherapy has prompted the development of alternative endoscopic methods such as band ligation.

EVL can stop variceal bleeding through rubber band ligation of the variceal vessel and consequent mechanical strangulation (Fig. 3.14). After confirming the target varices that require ligation, the scope is advanced under direct vision until the banding cylinder is in full 360° contact with the

varix (Fig. 3.14a). After full contact is made, suction is applied by depressing the endoscopic aspiration control valve, which draws the varix and surrounding mucosa into the banding chamber (Fig. 3.14b). Once the chamber is completely filled by the varix, which is evident by a complete "red out" and loss of endoscopic visibility, the trip wire is pulled (Fig. 3.14c) to push the elastic band over the varix. The engorged varix is strangulated at the mucosal junction (Fig. 3.14d, e). Treatment begins with ligation of the most distal variceal columns in the esophagus just above the gastroesophageal junction, commencing with the bleeding varix, if one is present. Subsequent ligations of the remaining varices are performed at increasingly higher levels, proceeding upward in a spiral fashion to avoid circumferential placement of bands at the same level. Large varices should have additional bands placed more proximally within the distal 10 cm of the esophagus. A 2-cm mucosal bridge between adjacent bands is essential to minimize mucosal necrosis, rebleeding, and dysphagia. After banding, patients eat soft food for 2 days. Repeated treatments are performed at intervals of 2 or 4 weeks. On average 6–9 bands are applied at the initial session and progressively fewer at subsequent session. EVL may be a preferable approach because it is easier and safer. Direct comparisons of endoscopic sclerotherapy and variceal ligation both in adult and pediatric patients demonstrated similar rate of control of active bleeding and recurrence of hemorrhage with significantly lower overall complications and mortality rate for EVL. In addition, variceal ligation appears to lead to obliteration in fewer sessions. Potential concerns of this technique in children includes the impossibility to perform this technique in small children due to the scope and associated ligature attachment size as compared to the child's size (youngest described case was 4 years old) and the possible entrapment of the full thickness of the esophageal wall (esophageal wall is thinner than adults) by the rubber band with subsequent risk of ischemic necrosis and perforation.

For the endoscopic treatment of gastric variceal bleeding in adults, vascular occlusion with N-butyl-2-cyanoacrylate injection is recommended because sclerotherapy has shown a high rate of complications and band ligation shows a lower rate of therapeutic success and higher rate of rebleeding than vascular occlusion in these cases. The intravariceal injection of N-butyl-2-cyanoacrylate causes rapid occlusion of the varices when it makes contact with blood. To prevent damage in the working channel when applying this method, the radiographic contrast agent lipiodol is mixed with the N-butyl-2-cyanoacrylate to delay permanent hardening and enable radiologic observations after the procedure. If the N-butyl-2-cyanoacrylate is too dilute to travel through the vessels due to slow hardening, there is a risk of a fatal cerebral or pulmonary embolism developing. Small aliquots are thus recommended for these injections. Even though this technique may be considered in children, only a pilot study involving eight patients younger than 2 years old and weighing less than 10 kg who had gastroesophageal varices has been performed. Although glue injection (0.5–2 mL injected) was successful in all infants with immediate control of bleeding and a low rebleeding rate of 37.5 % requiring a second treatment with cyanoacrylate, this data is too small to properly evaluate this treatment modality in pediatric cases [24–26].

3.9 Dilation Techniques

Stricture dilation may be indicated when there is associated clinical impairment or a need to access beyond the stricture for diagnosis or therapy. Dilators used in gastrointestinal endoscopy can be allocated into two categories: fixed diameter push-type dilators (bougie dilators) and balloon dilators.

Bougie dilators are available in a variety of designs, calibers, and lengths and are usually reusable. They exert both radial and longitudinal forces when advanced through a stenosis and are used primarily in the treatment of esophageal and rectal strictures. Users should refer to the manufacturer's instructions for guidance on reprocessing.

Nonwire-guided bougie dilators (Hurst and Maloney dilators) are flexible push-type dilators

that do not accommodate a guidewire. They are available in a variety of diameters and are internally weighted with tungsten for gravity assistance. Hurst dilators have a blunt, rounded tip, whereas Maloney dilators have an elongated, tapered tip.

Wire-guided bougie dilators (Savary-Gilliard and America dilation system dilators) are flexible, tapered, polyvinyl chloride, and latex-free cylindrical solid tubes with a central channel to accommodate a guidewire. Tucker dilators are small (4–13.3 mm) silicone bougies tapered at each end; loops on each end can be pulled antegradely or retrogradely across strictures. A gastrostomy is required for use. These may be useful in the treatment of tortuous strictures secondary to caustic ingestion.

Balloon dilators are available in an array of designs, and lengths; calibers are marketed only for single use. They exert only radial forces when expanded within a stenosis and can be used in the treatment of all accessible strictures throughout the GI tract including small bowel strictures. They are designed to pass through the endoscope with or without wire guidance so that dilation can be observed. Balloon dilators are made of low-compliance inflatable thermoplastic polymers that allow uniform and reproducible expansion to their specified diameter at maximum inflation. The majority of balloon dilators allow for sequential expansion to multiple diameters. Dilating balloons are expanded by pressure injection of liquid (e.g., water, radiopaque contrast) by using a handheld accessory device. The hydraulic pressure of the balloon is monitored manometrically to gauge radial expansion force. Inflation with radiopaque contrast enhances fluoroscopic observation.

Achalasia balloon dilators are large-diameter (30, 35, and 40 mm) polyethylene balloon dilators specific for achalasia. All currently available achalasia balloon dilators are wire guided, single use and do not pass through the endoscope. They are positioned across the esophagogastric junction by using fluoroscopic guidance with visualization aided by the radiopaque markers on the balloon. Balloon insufflation with air is monitored manometrically.

3.9.1 Patients Preparation and Techniques

Patient preparation will depend upon the main cause and site of stricture. Patients with achalasia may require prolonged fasting and removal of food rests using a nasoesophageal tube. Adequate colon cleansing is needed for the treatment of lower GI tract stricture, and laboratory tests may be warranted in patients with blood dyscrasias or those taking anticoagulant therapy. Prior to endoscopy, all patients have to provide written informed consent, also with written information about the risk of perforation, and the possible need for surgery. General anesthesia is needed to perform dilation in children. After the procedure, patients should be observed for 24 h. Radiographic contrast examination is not performed routinely before dilation, but it is performed after dilation of achalasia or complex strictures to exclude perforation. Antibiotics are not used routinely before dilation. Anticoagulants should be discontinued. PPI therapy is recommended after esophageal dilation for peptic stricture.

Dilation can be performed with or without endoscopic, fluoroscopic, and/or wire guidance. Selection of different types of dilators depends on operator preference, type, and site of the stricture. Selection of the appropriate size is critical for safe and effective dilation. Techniques may need to be modified for complex strictures (e.g., length >2 cm, lumen diameter <12 mm, tortuous) and/or specific disease states and locations in the GI tract.

Wire-guided bougie dilators (Savary and American dilators) are passed over a guidewire endoscopically placed and subsequent endoscope removal (Fig. 3.15a). Nonwire-guided bougies (Hurst and Maloney) are passed blindly into the esophagus. These may have a higher rate of perforation in the presence of large hiatal hernias or complex strictures.

Balloon dilators in the GI tract may be passed with or without wire guidance. The balloon is positioned across the stenosis and inflated under direct endoscopic visualization. Nonwire-guided balloons are used in a similar fashion but are passed across the stenosis by using endoscopic visualization only (Fig. 3.15b).

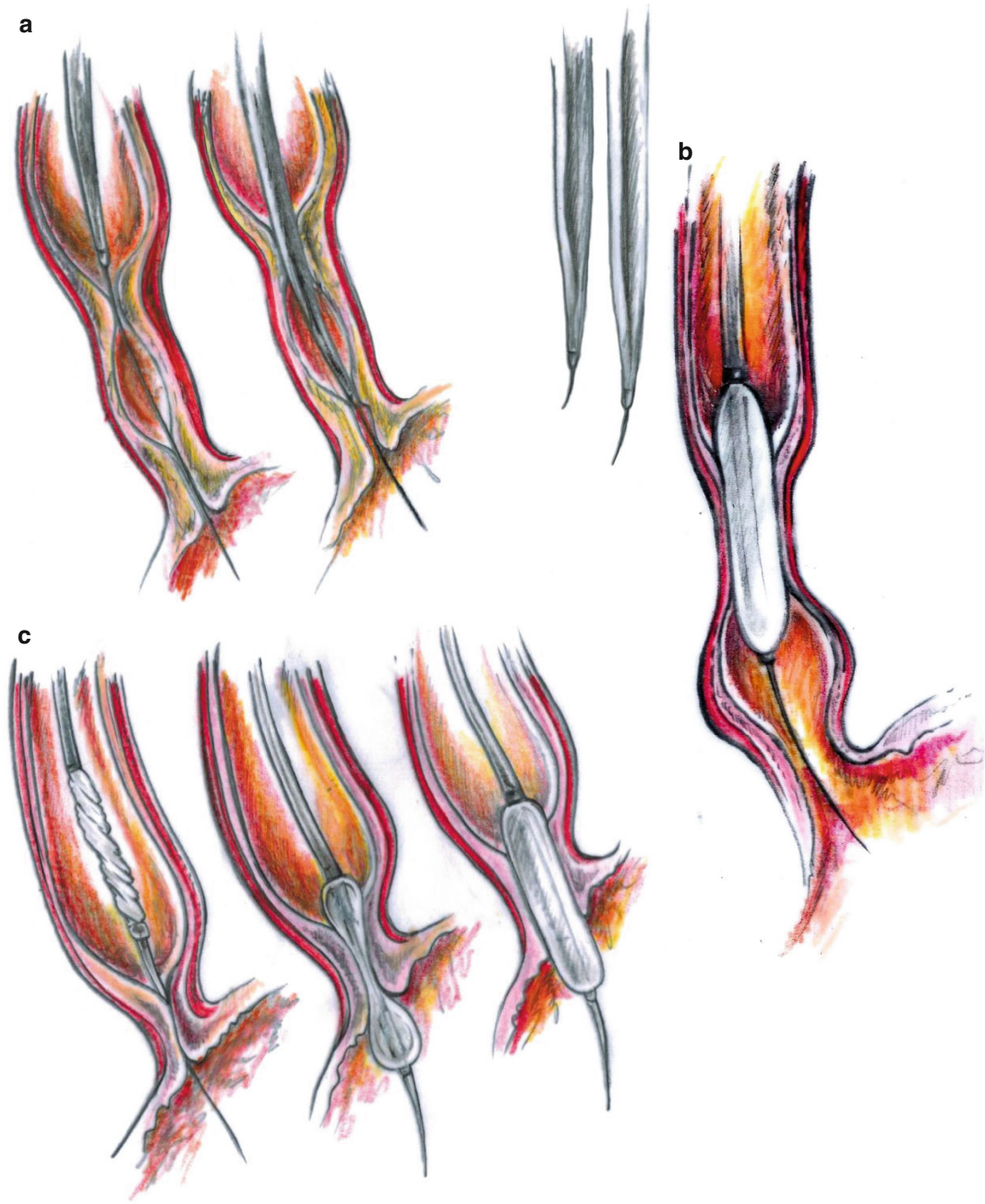

Fig. 3.15 Schematic representation of esophageal dilation performed with Wire-guided Savary dilator (**a**), with a nonwire-guided balloon (**b**) and with a large diameter wire-guided balloon in a case of Achalasia (**c**)

Pneumatic balloon dilation of the lower esophageal sphincter with a large-diameter wire-guided balloon is the mainstay of endoscopic therapy for achalasia (Fig. 3.15c). Dilation is generally performed over a wire endoscopically placed and under fluoroscopic guidance initially using a 30-mm balloon. Although nonfluoroscopically guided dilation using endoscopic visualization alone has been reported. A brief 6-s dilation, sufficient to obliterate the balloon's waist, was

shown to be as effective as the standard 60-s dilation.

Although the choice of dilatation device is left to the individual endoscopist, the "rule of three" has been the standard for bougie dilation. Specifically, the initial dilator chosen should be based on the known or estimated stricture diameter; serial increases in diameter are then performed. After moderate resistance is encountered with the bougie dilator, no greater than three consecutive dilations in increments of 1 mm should be performed in a single session. Although this rule does not apply to balloon dilators, most balloons allow a three-step inflation process, each of 1 mm, practically paralleling the "rule of three."

Current AGA recommendations for management of peptic esophageal stricture include consideration that steroid injection into benign strictures immediately before or after dilation has been advocated to improve outcome by decreasing the need for repeat dilations. This technique has also been successfully used to prevent stricture recurrence after balloon dilation in children with stenotizing Crohn's disease (Fig. 3.16).

Interruption of strictures (e.g., esophageal webs, Schatzki rings) with biopsy forceps or needle-knife electrocautery, either as the sole treatment or in conjunction with dilation, has been successfully demonstrated.

3.9.2 Complications

Perforation is the major complication associated with endoscopic dilation (0.1–1 %). It appears that perforations are common using a single

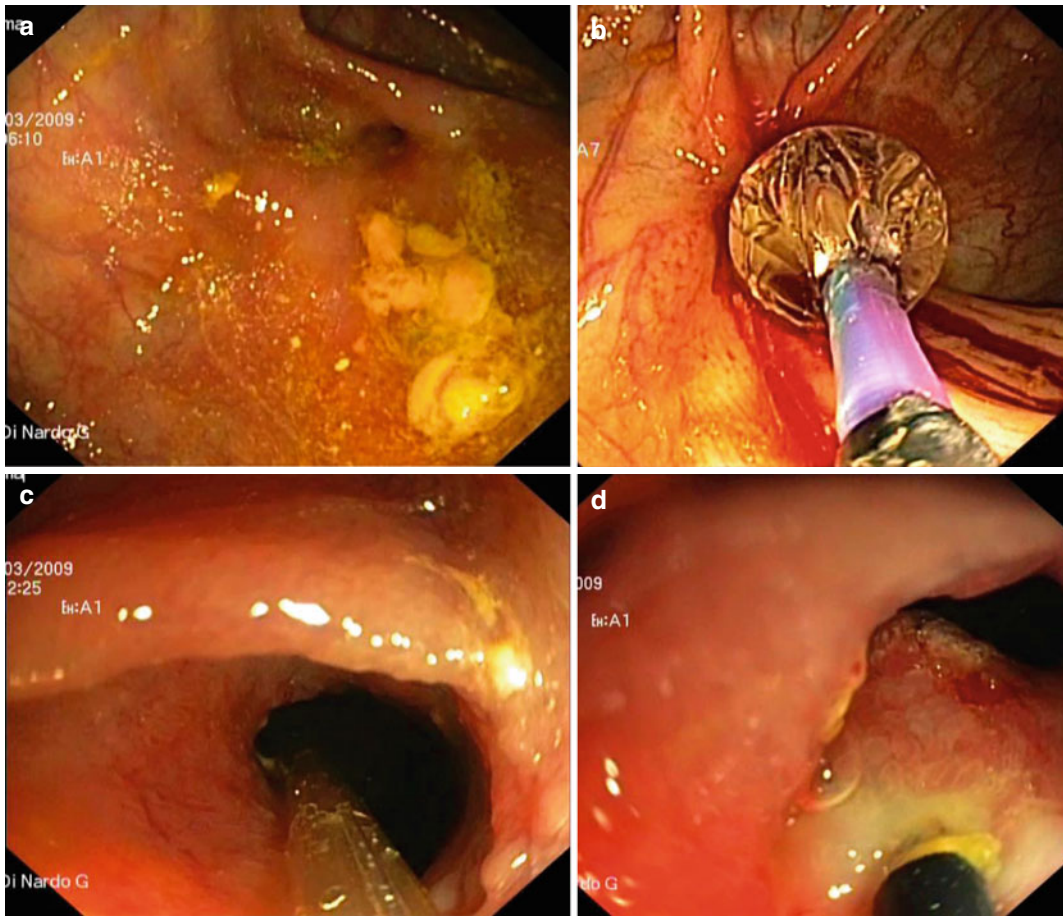

Fig. 3.16 Endoscopic view of ileocolonic stricture (**a**) balloon dilation (**b**, **c**) followed by intralesional steroid injection (**d**) in a child with Crohn's disease

nonwire-guided bougie size dilator particularly in children with complex stricture or with a large hiatal hernia. Other possible complications include chest pain, bleeding, and bacteremia.

The risk of perforation with balloon dilation in achalasia is in the range of 3–4 % with a mortality rate of <1 %. Other complications associated with achalasia dilation include prolonged pain and intramural hematomas. Open surgical repair with myotomy of early recognized endoscopic perforation offers an outcome similar to that of elective open myotomy. However, if endoscopic perforation occurs after pneumatic dilation, laparoscopic myotomy is usually not technically feasible. In patients with failed myotomy, pneumatic dilation could be safely performed.

Perforation after dilation usually occurs at the site of the stricture, but it could happen also in different site mainly related to the inappropriate use of nonwire-guided dilators and consequent creation of false track through the intestinal wall. Some experts recommend endoscopic inspection immediately upon completion of the dilatation procedure as the appearances may raise the possibility of perforation and prompt early treatment. Perforation should be suspected if severe or persistent pain, dyspnea, tachycardia, or fever develops. Physical examination may reveal subcutaneous crepitus of the chest or cervical region in cases of esophageal perforation. Although a chest or abdominal radiograph could show a perforation, a normal study result does not exclude this diagnosis and a water-soluble contrast esophagram or computed tomogram of the chest/abdomen may be necessary to disclose a perforation [27–29].

3.10 Percutaneous Endoscopic Gastrostomy

3.10.1 Indications and Contraindications

In children unable to take adequate oral nutrition reliably and safely for more than 1–3 months, placement of a gastrostomy should be considered to avoid complications of nasogastric tube feeding. Gastrostomy could be used not only as an enteral tube feeding but also for gastric decompression and/or to administrate medications.

Table 3.9 Indications and contraindications for PEG

Indications	*Underlying disorders*
Inability to swallow	Neurological disorders Multiple congenital malformations Oropharyngeal dysmotility Epidermolyis bullosa Others
Inadequate caloric intake	Cystic fibrosis Congenital heart disease Chronic respiratory failure Oncologic disease
Special feeding requirements	Unpalatable formula in multiple food allergies, metabolic diseases, or renal failure
Continuous enteral feeding	Short bowel syndrome
	Malabsorption
Contraindications	
Absolute Colonic interposition Severe and uncorrectable bleeding disorder Gastric varices Severe ascites Pharyngeal or esophageal obstruction	
Relative Hepatosplenomegaly Ascites Previous abdominal surgery Scoliosis Microgastria	

Adapted by Ref. [30]

The most common indications for percutaneous endoscopic gastrostomy (PEG) placement are listed in Table 3.9 and could be listed in four main groups: inability to swallow, inadequate caloric intake, special feeding requirements, and continuous enteral feeding.

There are a number of relative but few absolute contraindications to PEG placement (see Table 3.9). Uncorrectable coagulopathy and unfavorable anatomy resulting in lack of transillumination with inability to bring the anterior gastric wall in apposition to the abdominal wall are considered the main absolute contraindications for PEG placement. Careful patient selection and care in performing the procedure are known to reduce morbidity and mortality, which

are generally higher in patients with acute states of severe illness, such as heart failure.

3.10.2 Technique

PEG placement should be carried out in an operating room under general anesthesia. Prophylactic use of antibiotics (a single dose of broad-spectrum antibiotic administered before the procedure) is recommended to prevent local or systemic infection. An endoscopist together with an appropriately trained assistant, who is responsible for skin puncture and insertion of the guidewire, is warranted for PEG placement. Available PEG placement kits typically contain a gastrostomy tube with internal and external retaining devices, a skin trocar, a guidewire, and a plug adaptor for the tube. Gastrostomy tubes are made from polyurethane or silicone rubber and are available in a range of sizes from French gauge 9–24, with sizes 12–15 being suitable for most of the children.

The most popular technique of insertion is the "pull" technique because it has many advantages over the other techniques especially in young children. The patient is placed in the supine position, and the anterior abdominal wall is cleaned using an operative skin disinfection protocol. An endoscopic examination of the esophagus and stomach is then performed. The duodenum is not examined so as to minimize intestinal air distension.

The stomach is inflated however, so as to bring the anterior gastric wall in close contact with the abdominal wall. The endoscopist's assistant now identifies the correct skin puncture site (Fig. 3.17). The best option is to enter the stomach close to the junction of the gastric antrum and body. The site is located by using endoscopic transillumination (a bright point of light should be seen on the abdominal wall). If a clear point of transillumination cannot be identified, the assistant should not proceed with the puncture because this suggests the colon lies interposed between the stomach and the abdominal wall. When a good transillumination can be identified (Fig. 3.17c), the assistant applies digital compression at the proposed insertion site, and the endoscopist confirms that this is a suitable entry point in the stomach (Fig. 3.17a, b). The correct insertion point is usually midway between the umbilicus and the junction of the costal margin and left midclavicular line.

Some operators may first insert a needle so that the endoscopist can confirm the correct location (Fig. 3.17d). The assistant now performs the puncture by holding the trocar perpendicular to the abdominal wall and pushing it through into the inflated stomach. The endoscopist confirms entry of the trocar and its overlying plastic sheath (Fig. 3.17e). The trocar is withdrawn while leaving the sheath in situ to provide a secure track for the guidewire. The guidewire is passed through the plastic sheath (Fig. 3.17f), the endoscopist grasps it with the forceps (Fig. 3.17g–i), and the sheath is then withdrawn as the guidewire is slowly drawn into the stomach. The entire assembly including endoscope, forceps, and guidewire is then withdrawn. The guidewire now passes through the abdominal puncture, into the stomach, and out through the mouth. The proximal end of the guidewire is tied to a loop on the end of the gastrostomy tube (Fig. 3.17l). The distal end of the guidewire is gently pulled, drawing the tube and its internal bolster through the mouth, down the esophagus, into the stomach, and out through the puncture site, until the internal retaining device comes to lie on the anterior gastric wall (Fig. 3.17m). Sometimes it is necessary to make a small incision at the puncture site to facilitate passage of the gastrostomy tube out through the skin.

The distal end of the tube, still attached to the guidewire, is now cut off. An outer retaining device such as a disk is passed over the external tube, and this holds the tube at the abdominal wall so that it cannot slip back into the stomach. It is important to ensure that this external retaining device is not so loose as to be ineffective or so tight as to cause pressure damage. Local anesthetic may be injected around the incision point to reduce postoperative discomfort.

The tube is now cut to the desired length and the adaptor plug is inserted. A small amount of iodinated disinfectant may be applied to the external retaining device. A dry dressing is applied to the site for removal after 24–48 h. Finally, the endoscope should be reinserted to confirm that the inner retaining device is positioned correctly and to ensure that there is no bleeding (Fig. 3.17n).

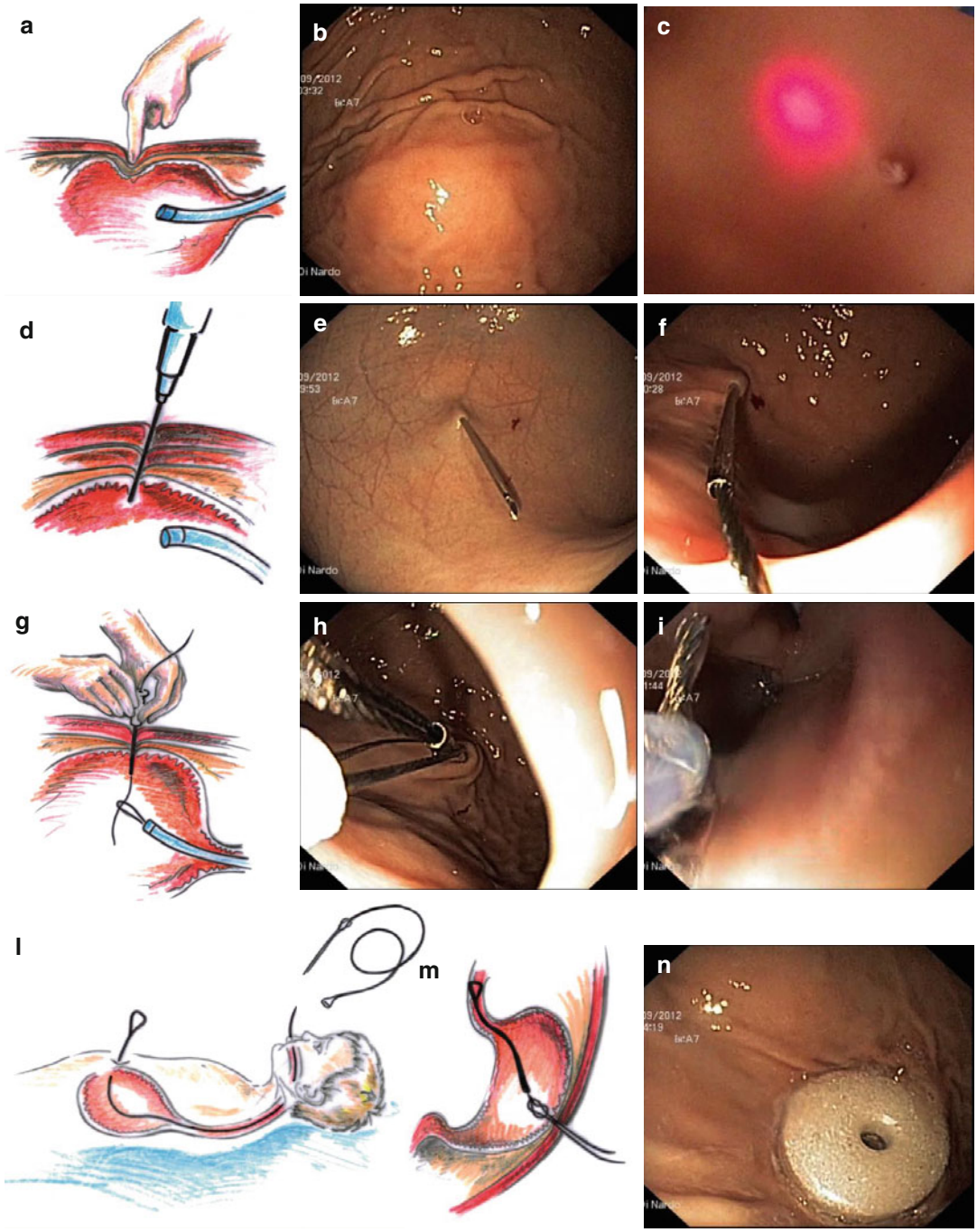

Fig. 3.17 Schematic representation and endoscopic view of the different PEG placement phases. (**a–c**) The endoscopist's assistant identifies the correct skin puncture site. (**d**) The assistant now performs the puncture by holding the trocar perpendicular to the abdominal wall and pushing it through into the inflated stomach. (**e**) The endoscopist confirms entry of the trocar and its overlying plastic sheath. (**f**) The guide wire is passed through the plastic sheath. (**g–i**) The endoscopist grasps it with the forceps and the sheath is then withdrawn as the guide wire is slowly drawn into the stomach. The entire assembly including endoscope, forceps, and guide wire is then withdrawn. (**l**) The proximal end of the guide wire is tied to a loop on the end of the gastrostomy tube. The distal end of the guide wire is gently pulled, drawing the tube and its internal bolster through the mouth, down the oesophagus, into the stomach and out through the puncture site, until the internal retaining device comes to lie on the anterior gastric wall (**m**). (**n**) Finally, the endoscope should be reinserted to confirm that the inner retaining device is positioned correctly and to ensure that there is no bleeding

Children should be admitted overnight to ensure adequate pain control and safe initiation of feeds. In the immediate postoperative period, the patient's general condition is monitored and the abdomen is examined for signs of peritonitis or significant pneumoperitoneum. Most of the children require some analgesia during the first 2 days. PEG should be used after 24 h starting with saline solution for few hours and then with designated liquid formula.

For 1 week, daily aseptic cleaning of the site is recommended and a sterile dressing can be applied. Subsequently, simple washing is sufficient and a dry dressing may be placed over the outer collar. Occlusive dressings are not recommended as they increase the risk of local infection.

After a period of 2–3 months or more, once the gastrostomy tract has healed, a more suitable device known as "gastrostomy button" can replace the gastrostomy tube. This device consists of a shorter (0.5–4.5 cm in length) and wider (e.g., 14–16 French) tube, just sufficient to traverse the fixed track, with some form of internal retaining device.

Their fixed length requires measurement of the formed track before insertion of the new device. This can be done with a graduated measuring device before selection of the correct length of device.

They can be inserted and removed quite easily, usually without need for sedation or general anesthesia. Only the first insertion of this device should be performed under endoscopic control to be sure that the balloon is correctly placed in the stomach and not in the colon as in the case of gastrocolic fistula. The only disadvantages are that they need to be changed every 4–6 months.

3.10.3 Complications

Complications may be classified as early and late.

Early complications as a direct result of PEG placement occur within 30 days of insertion and include pneumoperitoneum, colonic injury or gastrocolic fistula, small bowel injury, hepatic/splenic injury, bleeding, and stoma leak.

Pneumoperitoneum is a frequent postoperative finding identified radiologically in 5–50 % of patients. It is usually of minor clinical consequence, but could be a sign of iatrogenic bowel injury and hence should not be dismissed in the relevant clinical context.

Colonic injury or gastrocolic fistula is uncommon, but owing to the displacement of the transverse colon over the anterior gastric wall, it can lead to puncture of the colon during the blind insertion of the needle/trocar. Risk factors include under- or overdistension of the stomach, a left diaphragmatic hernia, and significant kyphoscoliosis. This complication could be detected early or late, frequently after many months, and even only during exchange of the PEG tube with gastrostomy button (Fig. 3.18). Clinical signs include the presence of undigested feed in stools, diarrhea immediately after feeding, feculent vomiting, or discharge from the gastrostomy track.

Small bowel injury is most common in children who have undergone prior abdominal surgery and occurs owing to adhesions that have fixed small bowel loops anterior to the liver, making them highly susceptible to injury during trocar insertion.

Stoma leak is common after PEG placement and may only need gentle tightening of the external fixation device to ensure close apposition of the internal bumper to the gastric wall. More persistent leaks may however lead to peritonitis.

Hemorrhage is an extremely rare complication resulting from gastric, peritoneal, retroperitoneal, and abdominal wall injuries. Hypotension without evidence of intraluminal bleeding is suggestive of parenchymal lesions (mainly liver and spleen) and should be promptly recognized and treated surgically. Puncture of abdominal wall vessels may present with bleeding from the PEG tract itself. Tightening the external and internal bumper may assist with hemostasis.

Late complications include local infection, granulation tissue, and buried bumper syndrome.

Peristomal wound infection is one of the most common complications of PEG (30–40 %). Prophylactic antibiotics are able to reduce stomal infection rates. If discharge occurs around site or erythema is present, the site could be swabbed

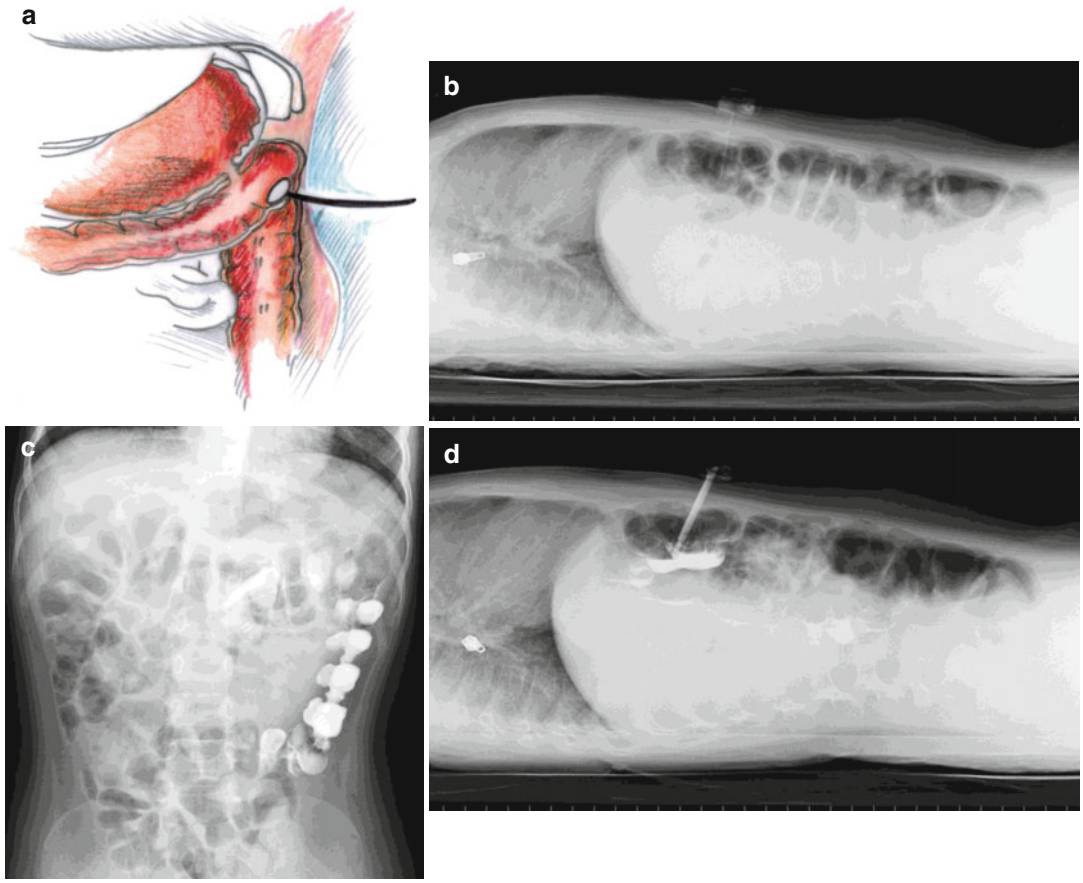

Fig. 3.18 Schematic (**a**) representation of a gastrocolic fistula as a complication of PEG. Radiographic study (**b**–**d**) with water-soluble contrast solution shows tip of tube in the lumen of trasverse colon

and evidence of colonization and antibiotic sensitivities obtained. The site is almost always colonized without causing tissue infection, although pain around the site and tissue swelling suggest bacterial invasion. Depending on clinical status, the child may need topical or systemic antibiotics. Less than 5 mm of erythema around the outer stoma site is common and is likely owing to local irritation by movement of the external bumper or minimal leakage.

Overgranulation at the gastrostomy site is seen as red/pink tissue at the stomal border that extends above the surrounding skin. This is a common complication that is usually owing to an ill-fitting device, wherein excessive movement or leakage leads to an excessive healing response. The granulation tissue has a tendency to bleed easily; it tends to discharge continuously and may cause local pain. Treatment options include silver nitrate, topical corticosteroids, cryotherapy, or surgical debridement. Silver nitrate does not cause any pain if applied only to the granulation tissue and is helpful to shrink down excessive granulation tissue.

Buried bumper is most common in the second year after insertion and occurs in approximately 2 % of children. The internal flange migrates through the gastric wall and potentially into the peritoneal space. Signs include difficulty in infusing fluid and feeds, with an increasing difficulty in moving and rotating the PEG during the weekly cares. This may be minimized by ensuring a correctly fitting device at regular review, particularly to ensure increasing tube length in line with weight gain.

If suspected, an upper endoscopy is warranted. Feeds should be discontinued until a diagnosis is made, as complications include sudden peritonitis and the formation of intraperitoneal or abdominal wall abscesses. In some cases, it is possible to pass a guidewire through the tube lumen under endoscopic control, gently dilate the tract with a dilator, and use the patent tract to insert a button.

3.10.3.1 PEG Care

It is quite normal to experience some clear or colored discharge from around the site for the first 7–10 days post placement while the site is healing. The site should be cleaned daily with warm soapy water; after cleaning, it is essential to ensure the area is fully dry. The use of creams and powders around the tube should be avoided as this may contribute to irritation and softening of the skin, which can lead to superficial skin infection.

In addition to the observation of the site for infection, a PEG requires daily care. One should also check and document any erythema, skin breakdown, granulation tissue, and pain, swelling, or offensive discharge.

Baths can be given once the incision site has healed. This is normally a minimum of 48 h after the gastrostomy has been placed. Swimming is permitted, but should not be encouraged for 2 weeks following gastrostomy placement. Dressings that cover, sit under, or occlude the gastrostomy are not recommended and usually not required. In specific circumstances, dressings may be helpful, such as silver dressings for the treatment of excessive granulation tissue formation and antimicrobial dressings in the presence of minor, superficial infection.

Flushing of the gastrostomy tube is essential to maintain tube patency, prevent tube blockages, and reduce bacterial overgrowth. Commonly, 20 mL of water is recommended, with smaller volumes used in certain circumstances, for example, if a child is fluid restricted and to avoid fluid volume overload. Caregivers should be instructed not to pull on the tube and to avoid any persistent tension as this may lead to progressive migration of the bumper into the abdominal wall, leading to "buried bumper syndrome." To prevent this complication, PEG should be carefully pushed into the stomach by 1–2 cm and then rotated once a week from day 7 postinsertion.

Teaching of all peoples involved in the care of the PEG begins before PEG placement and at the time of the decision to proceed to insertion. Teaching initially includes the demonstration of different devices and explanation of the planned surgical procedure. However, in addition to teaching the child and family, support for staff involved in caring for each patient in the community may be necessary. There are several key aspects of PEG use and care that should be taught. The family and caregivers should have the following competencies assessed to confidently be able to manage their child's PEG tube [30, 31].

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