




Review

Pediatric Endoscopy, Update 2020

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Abstract: Optimal management of pediatric endoscopy requires a multidisciplinary approach. In most hospitals, endoscopy in pediatric patients is performed by conventional gastroenterologists and only a few centers have specialized pediatric gastroenterologists. This is due to the fact that the number of pediatric gastroenterologists is limited and not all of them are experienced in endoscopic techniques. However, there are also some pediatric centers offering a high-quality and high-volume endoscopy service provided by very experienced pediatric gastroenterologists. Up to now, the literature on pediatric endoscopy is rather sparse. In this article, we describe current knowledge and practice of endoscopic procedures in pediatric patients, which should be relevant for both the adult and pediatric gastroenterologists.

Keywords: guidelines; gastroscopy; colonoscopy; EUS; ERCP; celiac sprue; foreign body

1. Introduction

1.1. Who Should Perform the Procedure?

Pediatric endoscopy has been established during the last 20 years (PE). PE should be performed by endoscopists, especially trained in pediatric diseases and in pediatric endoscopy. The main advantage of doing so is due to the special knowledge of pediatricians regarding the behavior of their patients and the different appearances of the diseases in younger age groups [1,2]. However, pediatric doctors nearly never gain the experience based on case numbers and numbers of procedures in children that gastroenterologists can reach in adults. Subsequently, gaining experience in more complex endoscopic procedures is difficult for pediatricians due to the limited exposure. It is common knowledge that the outcome of a procedure is connected to the frequency it is performed [2]. Especially in very complex procedures, involvement of an experienced endoscopist, even if he/she is not a pediatrician, should be considered. For example, it would be advisable that a pediatrician performs a diagnostic colonoscopy but hands over to a gastroenterologist to perform a polypectomy if required, because this task is very uncommon in children but daily practice in adults [3]. Another example might be the performance of an ERCP or hemostasis techniques in variceal bleeds.

1.2. Initial Considerations and Indications

In pediatric endoscopy, the age and weight of the patient, the patient's history, the aim of the investigation, and the experience and skills of the endoscopist have to be taken into consideration. In contrast to the best clinical practice in adults, the NASPGHAN guidelines recommend to take routine biopsies from the esophagus, stomach, duodenum, ileum, and colon during endoscopy in children to avoid repeated examinations [2,4,5]. This recommendation balances the procedural risk in relation to waste of resources due to unnecessary biopsies. This is similar to situations in adult medicine, when biopsies are taken without macroscopic visible pathology, e.g., in suspected *Helicobacter* infection or microscopic colitis. A relative contraindication to the procedure is a clotting disorder, neutropenia, or instable cardiopulmonary disease. No further specifications are published [6–8].

Pediatric endoscopy can be performed as an outpatient procedure even though one-third of the patients complain about hoarseness and mild swallowing problems afterwards. In Germany, however, most pediatric endoscopic procedures are performed for inpatients, mainly due to the complex diseases the patients have.

1.3. Nil by Mouth

To minimize the aspiration risk, a period of fasting is mandatory before endoscopic procedures. However, for children this period should be as short as possible. Two hours fasting for water, 4 h fasting for breastmilk, and 6 h fasting for solids has been recommended before endoscopy [9,10].

1.4. Who Should Inform the Patient?

The pediatrician is usually the physician who knows the patient and his/her family best and has requested the endoscopy based on the presenting symptoms and medical history. Therefore, the pediatrician seems to be the appropriate person to explain the procedure, its benefits and risks, and potential alternative management options. Whenever possible, the patient and parents should meet the endoscopist to avoid stress and misunderstanding, especially in case of complications. At least the one informing the patient's parents or guardians should have profound knowledge on the procedure. Having an additional explanation from a gastroenterologist can sometimes be confusing. If special risks or techniques are involved that need detailed explanation by a gastroenterologist, it is helpful to arrange a meeting to talk to the child and the parents together to avoid misunderstandings.

It is important to know that the consent can only be taken from the parents or legal representation of the child; however, if the child is able to understand the risks involved, the child has to give its consent as well. Age and specifics depend on the legal authorities of the respective countries.

1.5. Sedation

1.5.1. Premedication

Sedation in all children is mandatory by anesthetists for all children in the UK and in some other countries whereas pediatricians sedate under certain circumstances. Sedation by an anesthesiologist in newborns and toddlers is recommendable but not always required. Often, a premedication with benzodiazepine makes the procedure easier for the patient and the endoscopist. An application of a plaster coated with a local anesthetic medication is able to improve the child's comfort for inserting a necessary IV line.

1.5.2. ASA Classification

In most of the cases, where children have to be sedated to perform an endoscopy, the ASA classification is negligible. However, the classification should be known to the endoscopist to avoid an unnecessary risk because of an unsafe sedation procedure. ASA I equals a healthy child, ASA II equals a child with an underlying disease not relevant for sedation, and ASA III equals a chronic

disease with a relevant impact to the sedation process. From ASA III, the sedation should be performed by an anesthesiologist [11–13]. ASA IV equals a life-threatening condition with an unclear outcome of the procedure and requires an anesthesiologist as well as a special consent if it is not an emergency procedure.

1.5.3. Special Aspects of Sedation

Sedation of children should follow guidelines especially made from the pediatric and anesthesiological society [14–16]. It should be noted that painful procedures require a deeper sedation compared to adult patients. Therefore, special knowledge in sedation of children is recommended.

Before sedation, any kind of mobile orthodontic appliances and jewelry such as nose ring, tongue, and cheek piercing must be removed to avoid the risk of aspiration or swallowing.

The physician who is responsible of the sedation must not be the person who is performing the endoscopy. Most of the children can be sedated by using the principles of analgosedation performed by a pediatrician, only in case of severe problems by an anesthesiologist. The necessity of general anesthesia should be made dependent from the age of the child, comorbidity and kind of procedure [15,17,18]. The indication for performing the procedure under general anesthesia is also influenced by local individual factors like availability and technique. Special rules should be applied for newborns and infants. This age group does not necessarily need general anesthesia. However, long procedures with the risk of prolonged air insufflation should be performed under general anesthesia (per example ERCP). Rectal biopsies for the diagnosis of Hirschsprung disease can be taken under analgosedation; on the other hand, dilatation (bougienage) of the esophagus in case of esophageal atresia should be performed under general anesthesia. It is also recommended to perform a general anesthesia in children with a physical handicap (per example for placing of a transabdominal feeding tube). However, even this is performed differently in different hospitals [12,15,17,19].

Nurse administration of propofol sedation should not be used in children. Pre-oxygenation is recommended in all sedation procedures. In contrast to adult sedation, the reaction of children to the medication can be sudden and unexpectedly strong. Therefore, experience is necessary to be able to respond immediately and appropriately. The most common sedative is propofol in children, and it can be safely administered by specifically trained non-anesthesiologists. The addition of midazolam, fentanyl, remifentanyl, and/or ketamine to propofol may increase effectiveness without creating more adverse events [15]. One study shows the sedation protocol with propofol was safe and efficient. The administration of midazolam provided no additional benefit in propofol-based sedation [20].

The selection of the sedation method should account for the possibility of a psychological trauma for the child. In any case, the physician should be prepared for an unexpected emergency during the procedure. A common complication is the laryngospasm. The ESGE/ESPGHAN guidelines suggest to perform OGD under general anesthesia, and only if general anesthesia is not available, under deep sedation in a carefully monitored environment. However, they state that this presents a weak recommendation based on low quality evidence [7,8].

1.6. Technical Requirements

The endoscopy suite and the necessary equipment do not differ from the requirements of endoscopy in adults. A basic life monitor with the opportunity of measuring pulse oximetry, ECG, and blood pressure should be available. Special newborn and children-sized blood pressure measuring cuffs are important to avoid misinterpretations. The child should be placed on a stretcher, which can be moved in height. Emergency drug medications should be prepared as well as a breathing bag sized to the right age of the child. An HD monitor system for video endoscopy is advisable. Standards of endoscope cleaning procedures and storage of endoscopes should be followed, which do not differ from the standards in adults. Standard accessory tools and equipment should be at hand, for example hemostatic devices such as needles or clip systems. Special attention should be paid that small diameter

instruments of less than 2 mm diameter are also available when the small channel neonatal scopes are used.

2. What is Different in Pediatric Endoscopy

Being a pediatrician requires a special skill and experience in dealing with children. Apart from a special knowledge about the different appearance of diseases in children, a great portion of empathy, patience, and some psychological skills are required. This is true for dealing with the patients as well as with their parents. Before endoscopy, a detailed patient's history, ASA score, history of the intake of medications, allergic disposition, age, weight, and vital parameters has to be taken [9,15]. Relevant prognostic factors are: Sepsis, shock, body fluid, and electrolyte disturbances, acute and chronic respiratory diseases, and cardiovascular diseases like congenital heart diseases or neurological diseases. Prevalent liver or kidney failure should be known. The question of endocarditis prophylaxis is complex and therefore it is not further discussed here [21,22].

2.1. Endoscope

Special pediatric endoscopes with a diameter of less than 6 mm are commercially available from different companies and should be primarily used in children less than 10 kg body weight or younger than 1 year. The colon of a newborn is approximately 60 cm long. Recently the current available endoscopic material for pediatric endoscopy was published [17,23].

The problem of the very small endoscopes is the small working channel of <2 mm. The small channel is limiting the versatility of the endoscopes especially in its suction function and for instruments bigger than 1.8 mm. However, special pediatric forceps are available for histologic investigations, but the branches of the forceps are also limiting the size of the specimen (Table 1). Even in children of less than a year or less than 10 kg weight, standard endoscopes can be considered if endotherapy is required. It is advisable to use a standard gastroscope for colonoscopy as well until the age of 10, because in nearly all cases, the caecum can be reached with a standard gastroscope. A special pediatric colonoscope is not necessary but can make the procedure easier in the age range of 5 to 12. The nasal endoscope can be used in newborns to avoid trauma. There are experiences with ultra slim colonoscopy as well. It is already used as a rescue in situations where standard colonoscopies have failed [24]. Endoscopic ultrasound is seldom performed in children because in almost all cases there are excellent percutaneous ultrasound conditions. If necessary, there is a special longitudinal diagnostic Pentax probe with an instrument diameter comparable to a standard gastroscope. Newborns can be easily investigated with help of an endobronchial endoscopic ultrasound probe [25–31].

Table 1. Accessories.

Accessories
Small biopsy forceps
Polyp snare
Small alligator forceps
Small injection needle
Small argon plasma coagulation probe
2-prong grasper
Pediatric Roth net

ERCP is rarely indicated. If necessary, a 7.5 mm duodenoscope should be used in children under the age of 1 year or weighing less than 10 kg. In elder children the therapeutic duodenoscope with 4.2 mm working channel can be taken for ERCP (ESGE guidelines) [14,16,32–34].

The standard adult colonoscope has a diameter from 11.7 to 13.0 mm and can be used in teenagers. It is useful to know that the colon in younger age tends to be mobile therefore loop forming of the colonoscope is very common. Children under sedation are easily examined in a supine position

with the legs slightly apart. The advancing end of the endoscope is often palpable or visible under trans-illumination through the thin abdominal wall of the child. Special attention should be given to the resolving of those loops because of the risk of perforation. The use of scope-guide is advisable; this technology works without X-ray but exploits magnetic pulses generated from the movement of electromagnetic coils incorporated along the shaft of the colonoscope in a low-intensity magnetic field. The precise position and orientation of the colonoscope within the colon can be displayed as three-dimensional image on a monitor. This information is extremely helpful to avoid loop formation and can guide supporting external pressure or loop solving.

2.2. Air-Insufflation

Special attention has to be given to the amount of air, which is insufflated into a child during endoscopy. Even small amounts of additional gastrointestinal air are able to lead to a lung compression in newborns and to a worsening of the respiratory situation. Compromising on optimal endoscopic views, the endoscopist should only insufflate air as absolutely necessary. Special attention should also be given to the suction, especially in the process of removing the endoscope. In case of respiratory problems, the endoscope should be removed immediately under suction of the inflated air and secretions. CO₂ insufflation instead of air insufflation can reduce such problems as it is much faster absorbed and exhaled and therefore should be preferred whenever possible.

3. Indications of Pediatric Endoscopy

In general, the indications for endoscopy in children and adults differ. The cancer prevalence is extremely low in the pediatric population while other diagnostic indications are similar. Many therapeutic procedures are age related; e.g., removing of hyperplastic polyps or juvenile polyps are very rare in children [35,36], the same is true for esophageal polyps [37]. Common indications in children are: Chronic diarrhea (51%), impaired growth (41%), therapy refractory reflux symptoms (27%), and rectal bleeding (9%) [38]. Rare diseases include gastrointestinal stroma tumors. Congenital diseases of the pancreatic and bile duct system are usually picked up and visualized by non-invasive cross-sectional imaging but might require a therapeutic ERCP that are mostly performed by a skilled endoscopist with interventional experience in adults.

Therapeutic Indications

Esophageal strictures in children are almost never malignant and mostly based on accidental ingestion of caustic substances. Other reasons are: Congenital webs and strictures, achalasia, a Schatzki-ring, eosinophil esophagitis, and problems after surgery (like esophageal atresia). Crohn's disease can—although rarely—also be the cause of an inflammatory stricture of the esophagus.

Endoscopic dilatation techniques include balloon and bougienage. The TTS balloon requires the use of a standard endoscope as it will not fit through the 2 mm working channel of the neonatal endoscope. If a standard endoscope cannot be used, the balloon should be placed over a guide wire under X-ray guidance. The perforation rate for endoscopic balloon dilatation is given in the literature somewhere in between 0.1%–0.4% [1,2,39,40]. Gastrointestinal bleeding is rare in children. All common endoscopic hemostatic techniques can be applied, for example: Injection methods, clip methods, coagulation methods, ligature, and obliteration of varices. Experience in the application of hemospray is sparse.

4. Esophago-Gastro-Duodenoscopy

4.1. Equipment and Techniques

It is advisable to use extra thin instruments (4–6 mm) for diagnostic in newborns. CO₂ should be used to insufflate the gastrointestinal tract. In case it is not available, special attention should be given to minimize air insufflation. Modern standard endoscopes can be used from 10 kg body weight

or from one year on [2,7]. The same suggestion about endoscopes comes from ESGE guidelines that recommend making the choice of the gastroscope on the child's weight and age 8.

4.2. Anatomical Differences Unique to Children

The anatomy of the children is comparable to adults, just different in size. An esophagus of a newborn is approximately 8–10 cm in length and 5 mm in diameter. The passage of the instrument into the duodenum is slightly different to adults because of the greater angle. Therefore, the instrument has to be pushed deeper into the antral area and the straightening of the instrument is more pronounced after the passage of the pyloric area. In other words, passage of the pylorus will require some looping at the greater curve in the antrum and subsequently more straightening after intubation of the duodenum. This maneuver has to be gently performed to reduce the risk of vagal response and bradycardia.

4.3. Indications

The most common indications are: Foreign body extraction, therapy-refractory reflux disease, and diagnostic of chronic inflammatory diseases [38,41–44]. Esophageal dilations are the most common indication for endoscopic therapy in children and can lead to perforations, which require prompt diagnosis and management [6]. Symptoms, which prompt an endoscopy request, are often impaired growth or dysphagia. Pediatric gastroscopy often diagnoses or rules out celiac disease, eosinophilic esophagitis, infectious esophagitis, or peptic ulcer disease. Very often, the disease is not related to distinctive symptoms; mostly, the symptoms are unspecific like impaired growth, irritability, loss of interest, and impaired activity. It has to be taken into account that a gastroscopy to diagnose unspecific symptoms mostly has a low impact in children [45,46]. Other indications are: Diagnostic of polyposis syndrome, Crohn's disease, dilatation of esophageal strictures, and insertion of feeding tubes (Table 2). Endoscopy is not indicated for diagnosis of hypertrophy pyloric stenosis or uncomplicated reflux disease. The indication for foreign body removal was recently discussed [44,47] by the authors. It should only be mentioned that a removal is indicated within 4 h of the ingestion or when the foreign body is stuck in the esophagus [48]. Congenital diseases might present in a broad variety, however the most common indication for a gastroscopy due to congenital disease is the therapy of esophageal strictures [39,49,50].

Table 2. Indications for endoscopy in the upper gastrointestinal (GI) tract.

Diagnostic Indications:
Dysphagia
Odynophagia
Chronic reflux disease without improvement through medication
Vomiting and hemorrhage
Chronic abdominal pain
Anorexia
Weight lost, impaired growth
Anemia
Diarrhea
Chronic malassimilation
Therapeutic Indications:
Foreign body ingestion
Acid and base ingestion
Dilatation of strictures
Esophageal varices and fundus varices

4.4. Complications

The complication rate of diagnostic endoscopy is lower than 1% [6,51]. The complication rate of therapeutic interventions is naturally higher. Common complications are: Bleeding, perforation,

and infection. In a prospective study in children, 249 complications within 72 h in 9577 endoscopic investigations have been reported. This indicates that a structured surveillance protocol after endoscopy is mandatory [52]. Considering procedural as well as sedation-related complications, adverse events can occur in up to 2.3% according to a study including 10,236 procedures [51]. Risk factors for complications are: Younger age, high ASA rating, female gender, and intravenous sedation.

4.5. Diagnostic

In contrast to endoscopy in adults, it is mandatory in children to take biopsies from all standard areas, even if there is no visible pathology. This should avoid unnecessary repeated procedures [53]. Duodenal biopsies should be taken to exclude celiac disease and stomach biopsies to investigate for *Helicobacter pylori* infections. A special small biopsy forceps should be considered in newborns to keep the traumatic lesion as small as possible [38,53]. Pediatricians recommend taking biopsies for *Helicobacter pylori* culture at the initial endoscopy because of the higher resistance rate of the *Helicobacter pylori* bacteria in children [45,53–57].

4.6. Intervention

All endoscopic interventions developed for adults can be performed in children as well. Detailed knowledge on endoscopic accessory material and some talent for improvisation and creativity is required to select the best suitable equipment. For example, special bile duct catheters from the adult ERCP equipment can be used for esophageal bougienage in newborns (7–10 French). Another interesting therapeutic procedure is the nasal insertion of an angioplasty catheter into the esophagus for the duration of 2–3 weeks. This allows a constant dilatation of an esophageal stenosis as an outpatient and therefore a better dilatation result. Astonishingly, the newborn adapts very well and can be fed with milk while the balloon is deflated. Although achalasia is rare in children, it is a very debilitating disorder and may present with similar characteristics to those of adults (dilated esophagus, absence of peristaltic waves, and lack of esophageal sphincter relaxation). Maselli et al. [58] described the first case of achalasia treated with POEM in a pediatric patient. Following this, other cases have been reported with high clinical success rate [59,60]; however, the procedure should be performed in expert hands.

4.6.1. Hemorrhage and Variceal Bleeding in Children

Esophageal variceal bleeding in children is rare but can occur, typically in the age range of 7–16 years [16,61–65]. Elective treatment of esophageal varices should only be performed in specialized centers. However, an acute variceal bleeding requires immediate endoscopic treatment in any hospital. As in adults, ligature therapy is the state of the art method to stop hemorrhage from esophageal varices.

Liver cirrhosis in children is rare, and a significant amount of children with esophageal and fundus variceal bleeding suffer from portal hypertension due to portal vein thrombosis or thrombosis of the splenic vein [66]. Overall, the endoscopic outcome of non-cirrhotic portal fibrosis is favorable. One-third of patients will have recurrence of esophageal varices and only a small proportion of bleeders will have poor outcome [67].

Most of the bleedings are self-limiting and substitution therapy with fluids and sometimes blood products are sufficient. Medications like vasopressin, octreotide, and beta receptor blockade can be used accordingly to the therapy in adults (Table 3) [66,68]. Endoscopic intervention, however, should be first choice of the treatment options. The obliteration therapy with Polidocanol 1% is effective (positive results in 90%–95%) but is not recommended anymore due to complications such as post interventional strictures in 15%. Band ligation therapy has a higher efficiency in relation to post interventional bleeding and has a lower complication rate and lower costs with a higher overall survival [69]. TIPPS (Trans jugular intrahepatic portosystemic shunt) or shunt surgery can be used in therapy-refractory cases. Liver transplantation in children is not an option. In non-cirrhotic portal hypertension, most children will develop a spontaneous shunt over time. In those cases, all therapeutic intentions should

aim to bridge the time for nature to take over. The role of beta blockade therapy in children is not established yet.

Table 3. Additional medication in variceal bleeding.

Additional Medication in Variceal Bleeding
Octreotide: 1 mg/kg as flush injection (max. 50 mg), followed by 1 mg/kg/h
Somatostatin increase of dosage every 8 h possible to 4 mg/kg (max 250 mg within 8 h)
After successful stopping of the bleed, doses reduction of 50% in 8 h

A study suggested that antibiotic use within 48 h of admission in cirrhotic children with acute UGIB might have a positive impact on the percentage of children free of bacteremia and the readmission rate [70].

4.6.2. Foreign Body Ingestion

Foreign bodies often get stuck in anatomical areas with a relatively smaller diameter in the gastrointestinal tract. These areas are the three constrictions of the esophagus, the pyloric region, and the ileocecal valve. In the esophagus, the most common constriction is in the middle of the organ. The immediate risk to the patient ranges from negligible to life-threatening, depending on the ingested substance, its location, patient fitness, and time to appropriate therapy [71]. If there is a chance that a spontaneous passage of the foreign body might occur, endoscopy should be withheld. However, batteries and magnets should be removed as soon as possible. Already after a short time, complications like fistulas, ulcerations, and perforations can occur (up to 13%) [42,72–75]. Battery ingestion, particularly in the pediatric population, has become more common since the development of button batteries. Larger cylindrical battery ingestion is less common [76].

For the removal procedure, a variety of endoscopic equipment comes into play. A very useful tool seems to be a polyp recovery net. The net structure secures nearly every shape of a foreign body and can even protect the mucosa from sharp ends. Other tools like an alligator forceps or a single tooth forceps can be very helpful. In round and hard to pick up objects, a Dormia basket is recommendable. For soft objects, single wired snares are possibly the best removal tools. The physician should act with a great deal of inventiveness because no situation is equal to the next one. For instance, some objects with a small hole can be removed by insertion of a forceps through the hole and open the forceps behind. Simple and inexpensive devices such as Foley catheters and magnet-attached tubes can be used in emergencies [77]. The success rates for rigid esophagoscopy (100%) and flexible endoscopy (96.2%) were not significantly different ($p > 0.05$). Overall, rigid esophagoscopy had a higher complication rate than flexible endoscopy (10% versus 5.1%, $p > 0.05$), but this trend did not reach statistical significance [78]. An accurate history is of paramount importance to establish if the ingested body is an acid or a base. In case of acid or base ingestions, the indication to arrange an endoscopy is based on the symptoms. However, the impact of an early gastroscopy is not quite clear [17]. Every acid and base ingestion should be graded according to the mucosal defect because the grade of injury has a prognostic value (Table 4). The grades 1 and 2 have a relative good prognosis whereas grade 2b and 3 may lead to complications.

Table 4. Grading of injury after acid and base ingestion.

Grade	Description
Grade 0	normal
Grade 1	mucosal irritation, edema, and hyperemia
Grade 2a	trans mucosal (bleeding, exsudation, erosion, blisters, ulcerations)
Grade 2b	like grade 2a but with transmural ulcerations
Grade 3	deep ulcerations with necrosis and with or without perforation

Since the ingestion in children is usually incidental and not with intended self-harm as often in adults, immediate complications like aspiration and obstruction of the airways, which are more frequent in the adult, are rare in the children. Late complications like strictures are more frequent in children.

4.6.3. Esophageal Stent and Endoscopic Balloon Dilatation

The most common indications for endoscopic esophageal stent placement in pediatric population are benign diseases such as post-surgical or corrosive strictures and perforations. In the literature, the placement of fully covered metallic stent and plastic stents is described with good outcomes [79,80]. Also, the use of biodegradable esophageal stent in pediatric case is described in one case report [81]. Pyloric stenosis due to benign disorders can be effectively and successfully treated through endoscopic balloon dilatation in suitable patients [82].

5. Colonoscopy

Colonoscopy provides a valuable diagnostic tool for pediatric patients with gastrointestinal symptoms. The selection of appropriate management and the performance of colonoscopies are important in pediatric patients. The most common indication for rectoscopy and colonoscopy are rectal bleedings. Another indication is Hirschsprung disease. For confirmation of the disease, a new technique of endoscopic full thickness resection could be used [83,84]. Polyps can be seen in 6.1% of all colonoscopies in children and 12% of children with rectal hemorrhage [35,85,86]. Rectal bleedings in newborns are common although usually prompt parents to overreact. In contrast to adult colonoscopy, a rectoscopy for diagnosis in that age group is sufficient. The most common reasons are: Anal rhagades, polyps, chronic inflammatory diseases, or eosinophilic colitis.

5.1. Equipment and Technique

Special pediatric colonoscopes can be used from an age of 1–2 years. Newborns and babies should be investigated with a standard gastroscope. In principle, there is no difference to a colonoscopy of an adult. However, the movements have to be more delicate and an experienced nurse should support using external compression right from the beginning of the procedure to avoid loop formation. The instrument should be pulled back very often to correct loops but the alpha maneuver should be avoided.

Special instruments are required for polypectomy. For example, special age-related electrodes should be used for diathermy and the team must be experienced to manage post interventional bleedings. A recent randomized controlled trial [87] described a statistically significant reduction of post-colonoscopy abdominal pain, in children who underwent colonoscopy with CO₂ insufflation compared to colonoscopy with air insufflation (82% vs. 37% at 2 h and 95% vs. 63% at 4 h).

5.2. Anatomical Differences Unique to Children

Marked differences between mobile and fixated parts of the colon render the advancing of the endoscope difficult. This should be kept in mind to avoid unnecessary complications. The sigmoid colon is usually not fixated and mobile; therefore, the sigmoid passage can be quite challenging and use of scope guide imaging is recommended to avoid loop formation.

5.3. Indications

The indications are diagnosis of chronic inflammatory diseases (first diagnosis, complications), diagnosis of diarrhea, or rectal bleeding, hereditary polyposis syndromes [35,85,86], and diagnosis of graft-versus-host disease (Table 5).

Table 5. Indications for colonoscopy in pediatrics.

Diagnostic
Chronic diarrhea (increasing in severity)
Lower gastrointestinal bleeding
Unexplained anemia
Polyposis syndrome (diagnosis and follow up)
Impaired growth, weight loss
Perianal lesions (fistula, abscess)
Therapeutic
Polypectomy
Foreign body removal
Dilatation of stenosis/strictures
Lower gastrointestinal bleeding

5.4. Complication

The most common complications related to diagnostic colonoscopy are perforation and bleeding occurring with a very low frequency of 0.01% and less than 2.5%, respectively [88]. The rate of complication increases in the interventional colonoscopy. A large retrospective study reports 10.9% of complications after polypectomy in pediatric patients [6,88]. In another common interventional procedure, such as the dilation of benign colonic strictures, data regarding pediatric population are still lacking. In the past, colonoscopic perforations almost always required prompt surgical intervention [89]; nowadays, new endoscopic clipping techniques allow one to close the perforations in many cases with small perforations.

5.5. Bowel Preparation

There is no generally recommended standard for bowel preparation in children. The available cleansing protocols have to be used and adapted to the age and size of the child. In newborns and toddlers, mostly the ingestion of normal clear fluids (tea, water) and an enema (5 mL/kg) is sufficient [90,91]. Remaining feces can be flushed out endoscopically; a flushing pump connected to the endoscope and operated by a foot pedal is helpful. Osmotic substances like polyethylene glycol solutions should be used in children older than two years. Low-volume preparations are preferred in children. ESGE guideline statement suggests not using sodium phosphate for bowel cleansing in pediatric population because of the risk of kidney damage (strong recommendation; high quality of evidence) [7].

5.6. Diagnostic

Generally, the diagnostic colonoscopy does not differ much from the procedure in adults. Especially when thinner instruments with thinner working channels are used, the size of the equipment must be adapted to the size of the working channel. This is important for interventional procedures like polypectomies or hemostatic techniques. However, those materials are commercially available in smaller diameters for pediatric instruments.

5.7. Intervention

A common problem in clinical pediatric practice is the diagnosis of Hirschsprung's disease. A large full-thickness rectal or colonic biopsy in the area of the pseudo stenosis is necessary. Usually, this is performed by endoscopic biopsies as well as surgical removal of rectal tissue. Recently, a new device has been introduced for this purpose. The FTRD-system (full-thickness resection device) is able to resect tissue containing all rectal or colonic wall layers with simultaneous closure of the perforation of the bowel. This novel endoscopic procedure, which uses an over-the-scope-clip system, can replace surgery for that purpose [83,84]. The size of the instrument and its passage through the sigmoid

are still problematic. Stricture formation after clip application can occur. However, these problems can be overcome in experienced hands [92,93]. Another indication for therapeutic colonoscopy is stent placement. In the literature, one study including five pediatric patients reported this procedure. Authors described a very high incidence of complications, so the procedure is not suggested for children [94].

6. ERCP

Special duodenoscopes with a working channel of 2 mm are available for infants under the age of one year [32]. Normal duodenoscopes with a working channel of 2.7 mm can be used from the age of 1 and older. Special attention should be given to the X-ray equipment. X-ray of children has underlying special technical standards and regulations, which should be followed. Special endoscopic accessories for ERCP in newborns are available as well. There is the baby papillotome developed by Hans Seifert, which is suitable for working channels of every size and allows cannulation of the papilla as well as papillotomy. Interestingly, some indications of ERCP in childhood have still diagnostic purposes in contrary to the mostly therapeutic intentions in adults [14,16,32–34,95–101]. However, ERCP in children for diagnostic purposes should only be requested if non-invasive imaging including MRCP remains inconclusive.

6.1. Anatomic Differences Unique to Children

The passage of the duodenoscope into the duodenal region is similar to the endoscopy in adults. Sometimes, the higher position of the pylorus can be problematic. As most children will be under general anesthesia, the intubation of the instrument into the esophagus requires extra care and attention. Any application of force should be avoided. If the insertion into the esophagus is difficult, the instrument should be advanced with help of a laryngoscope and a Magill forceps. The working space in the duodenal region in newborns and infants is restricted because of the smaller size of the duodenum. This, together with the steep angle between the bile duct and the duodenum, renders the procedure more challenging than in adults. Due to the difficult anatomy, an unintentional contrast injection into the pancreatic duct can occur; a guide wire insertion first is highly advisable.

6.2. Indications

The main indication for ERCP in childhood is biliary disease which is not sufficiently explained by advanced non-invasive imaging such as MRCP. ERCP procedures in children are far less frequently performed than in adults. Malignant diseases of the biliopancreatic region are extremely rare. The main indications for ERCP in pediatrics are: Choledocholithiasis, primary sclerosing cholangitis, biliary strictures, cholangiocystic diseases, leakage of the bile duct after surgery (transplantation or cholecystectomy), bile plug syndrome [34,97,101], and parasitosis (fascioliasis, ascariasis). Pancreatic indications are: Recurrent acute pancreatitis, chronic pancreatitis, pancreas divisum, pancreas anulare, and pancreatic duct leaks after surgery or traumatic rupture of the pancreatic duct [14,16,33,34,43,97,101]. Genetic (CFTR, SPINK1, PRSS1, CTSC) and obstructive risk factors are the most common causes for the development of chronic pancreatitis in children. According to the INSPPIRE study, therapeutic ERCP was performed in 67% of children with chronic pancreatitis [102]. Patients with pancreas divisum (PD) may present with acute recurrent pancreatitis (ARP) or chronic pancreatitis (CP) [103].

6.3. Diagnosis

A diagnostic ERCP should be an extreme exception as most diagnostic questions can be answered by non-invasive imaging such as MRCP and the risks of ERCP are not justified [32].

6.4. Interventions

Treatment of common bile duct stones is the main indication for ERCP in children [97,104,105]. For such therapeutic intentions, small adult instruments (diagnostic duodenoscope) should be used instead of the baby duodenoscope because ERCP accessories such as baskets and balloons for stone removal are not available for baby endoscopes. The special regulations for X-ray use in children should be followed. There is a lack of experience with stenting of benign pancreatic biliary disorders in children. However, temporary stent placement can be accomplished safely and successfully, and this serves as a bridging therapy while awaiting surgical intervention [106].

6.5. Complications

The complications of ERCP in children are the same as in adults. Post ERCP pancreatitis occurs in 2.5% of cases; however, the course of the disease mostly remains benign and is rarely necrotizing [6,107].

7. Endoscopic Ultrasound

The indication for endoscopic ultrasound (EUS) in children is very rare as transabdominal ultrasound usually provides excellent views [108]. As during ERCP, particular attention should be given during esophageal intubation in order to avoid cervical esophageal perforation. If the procedure is at all necessary, the indications are the same as in adults [25–29,109–112]. Indications are: Staging and diagnosis of neoplasms in and around the upper and lower GI tract, detection of bile duct stones, and pancreatic diseases. Fortunately, pancreatic masses are an extremely rare indication for EUS in children. Surgical series demonstrate a difference in the histology of neoplastic masses in children compared to the adult population [113,114]. In particular, solid pseudopapillary neoplasms and pancreatoblastoma, followed by pancreatic neuroendocrine tumors (pNETs), are more frequent. The reported incidence of pediatric neuroendocrine Tumors (NETs) ranged from 1.14 to is 5.40 per 1 million children [115]. The localization of NETs in children is different from NETs in adults. In children, NETs are most commonly found in the appendix with ranges from 87.5% to 91.3% [116,117]. Pancreatic NETs are very uncommon. Diets et al. [117] reported only five patients with pancreatic NET on a total of 483 patients (1.04%). However, they also revealed that in the pediatric population NETs are more often associated with a suspected tumor predisposition syndrome and showed that pediatric pancreatic NETs in particular are associated with genetic syndromes.

In the diagnostic evaluation of pancreatic masses, EUS with biopsy is an important and safe procedure also in pediatric patients [118,119]. In pancreatic biliary diseases, the main endosonographic findings were microlithiasis in 25.9%, chronic pancreatitis in 16.7%, and pancreatic tumors in 11.1% of the patients [120].

Another indication of EUS is the characterization of stenosis and strictures in the gastrointestinal tract and the assessment of cystic structures such as duplications cysts or bronchogenic cysts. The use of the ultrasound mini probe or small caliber (7.4 mm diameter) EBUS scopes seems favorable for the diagnosis of stenotic or superficial processes in the gastrointestinal wall and for EUS in small children (<15 kg and <3 years). From the age of three years, standard radial or linear echoscopes can be used. EUS is useful for the characterization of subepithelial lesions. Rectal EUS can be used for diagnosis of malformations, fistulations with or without chronic inflammatory diseases, and staging of rectal neoplasms, although extremely rare in children [30,121]. The number of EUS performed in children might increase in future due to technical developments and adaptation of the equipment.

The use of interventional EUS has been described for drainage of pancreatic fluid collection [122–126]. In particular, Zaheer Nabi et al. described their experience in EUS-guided drainage of walled off necrosis using fully covered self-expanding metallic stents in 21 children with a technical and clinical success rates of 100% and 95%, respectively [127,128]. EUS-guided obliteration of portal venous collaterals with N-butyl-2-cyanoacrylate into feeding varices is possible, and an effective treatment for recurrent bleeding from varices that are not suitable for direct endoscopic treatment [129].

8. Capsule Endoscopy

The indications for capsule endoscopy in children are: Undiagnosed gastrointestinal bleeding, suspected small bowel Crohn's disease, celiac disease, and polyposis syndromes. In the United States, capsule endoscopy is approved from the age of 2 (FDA approval). If the capsule cannot be swallowed, endoscopic placement of the capsule can become necessary. A capsule retention in children is a rare side effect, reported in less than 1% of the procedures [130–133].

It is suggested that magnetic resonance imaging and wireless capsule endoscopy have a complementary role in the assessment of small bowel involvement in Crohn's Disease. Wireless capsule endoscopy detected small bowel diseases with a much higher specificity while magnetic resonance enterography had a higher sensitivity [134].

9. Balloon Enteroscopy

Enteroscopy with or without balloon technique is indicated when therapeutic interventions in the small bowel are needed. Children should have a minimum weight of 10 kg to undergo this procedure. If balloon endoscopy cannot be performed, intraoperative endoscopy should be considered [135–139].

10. Post Procedure Monitoring

Pediatric particularities should be considered in the post procedure monitoring. The following criteria and reactions should be assessed and documented: Alertness, reaction to reflexes, and evaluation of speech and behavior pattern. The documentation should follow the same standards as in adult recovery programs.

11. Nutrition

Percutaneous Endoscopic Gastrostomy (PEG)

The maintenance of oral nutrition is a main therapeutic target in children and infants. Twelve to 15 Chr. nutrition tubes should be considered in children with less than 50 kg body weight. The usage of 12 Chr. feeding tubes does not give any advantages compared to the placement of a 15 Charrier feeding tube because the inner ring of the PEG system has the same diameter. Therefore, there is no difference in procedural trauma; however, the child ends up with a smaller diameter to be fed through. In case of a narrow esophagus or an esophageal stenosis, the anchoring plastic plate of the PEG system can be modified by three radial cuts to make it more flexible. This is not recommended in the approved instructions of the PEG system; however, does not affect the functionality of the system or the stable positioning of the inserted tube according to our experience. Relative contraindications for PEG insertions are congenital malformations or children under 2 kg because of the possibility of breathing problems due to air insufflation during the procedure. Other relative contraindications are: Malrotation, situs inversus, ascites, previous surgical interventions in the abdomen, pathological enlarged liver or spleen, scoliosis, ventriculoperitoneal shunt systems, intraperitoneal dialysis shunt systems, and pathological enlarged vessels like in liver cirrhosis. To overcome the problem of ascites, transabdominal sewing devices can be used. Absolute contraindication is when trans illumination cannot be achieved, most often because of liver or large bowel interposition [140–143]. Preprocedural transcutaneous ultrasound should be considered since it might help to avoid complications.

12. Summary

The pediatric endoscopy is a challenging procedure that requires special skills [144] to offer a safe and valuable diagnostic tool to children of all ages including premature babies. Almost all endoscopic techniques known from adult endoscopy can be adapted to the pediatric setting when the special age dependent needs of pediatric patients are considered. The atmosphere during preparation, in the

endoscopy room, and in the recovery room must be calm, kind, and child-friendly, to minimize the perception of the trauma experienced by the child.

The knowledge of the correct indication of the endoscopic procedure is of utmost importance. According to the local expertise, the experience of the endoscopist and the kind of the procedure the endoscopy should be performed by an expert endoscopist, ideally by a pediatric gastroenterologist or pediatric surgeon because profound pediatric knowledge is mandatory to approach digestive endoscopic diseases in children. Interventions should be always performed by an endoscopist with therapeutic experience. Familiarity with the available equipment and competence in all endoscopic techniques is mandatory for a high-quality pediatric endoscopy service.

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