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WORD COUNT	2577	TIME SUBMITTED	02-APR-2025 11:15AM
		PAPER ID	115479695

Name of Journal: *World Journal of Clinical Pediatrics*
Manuscript NO: 104951
Manuscript Type: MINIREVIEWS

Paediatric digestive endoscopy: From conventional endoscopy to endoscopic ultrasound and endoscopic retrograde cholangiopancreatography

Paediatric Digestive Endoscopy

Abstract

Digestive endoscopy is now widely performed in clinical practice, including in children, and has revolutionized the diagnosis and treatment of many gastrointestinal disorders. Interventional procedures are increasingly utilized, particularly for hepatobiliary and pancreatic diseases. However, only a limited number of gastroenterologists are competent to perform endoscopic retrograde cholangiopancreatography and endoscopic ultrasound in pediatric patients. Although gastrointestinal endoscopic emergencies in children are rare, they can be severe. Their management is urgent and necessitates genuine teamwork, with close and continuous collaboration among gastroenterologists, anesthetists, and the pediatric team, especially in settings lacking pediatric endoscopists. This mini-review highlights current practices in pediatric digestive endoscopy and recent advances in interventional endoscopy compared to adult patients.

Key Words: Adult; Pediatric; Endoscopy; Endoscopic ultrasound; Endoscopic retrograde cholangiopancreatography

Okasha HH, El-Meligui A, Ghoneem E, Alyouzbaki AZ, Ait Errami A, Delsa H. Paediatric digestive endoscopy: From conventional endoscopy to endoscopic

ultrasound and endoscopic retrograde cholangiopancreatography. *World J Clin Pediatr* 2025; In press

Core Tip: Pediatric gastrointestinal endoscopy has revolutionised the diagnosis and management of gastrointestinal disorders, with the increasing use of interventional techniques for hepato-pancreatobiliary diseases. However, expertise in performing endoscopic retrograde cholangiopancreatography and endoscopic ultrasound in children remains limited. This minireview focuses on current practice, the growing role of interventional endoscopy, and the importance of gastrointestinal endoscopy in the management of gastrointestinal disease in children.

INTRODUCTION

Gastrointestinal (GI) endoscopy has gained increasing acceptance over the past decade, serving a growing range of diagnostic and therapeutic purposes. In expert centers, pediatric and non-pediatric endoscopists can perform these procedures[1]. Advances in endoscopic equipment and pediatric anesthesia have enhanced the safety and convenience of GI endoscopy for assessing various GI pathologies[2]. Currently, children can undergo nearly any type of gastrointestinal endoscopic procedure, including diagnostic and therapeutic upper and lower GI endoscopies, endoscopic ultrasound (EUS), and endoscopic retrograde cholangiopancreatography (ERCP)[3]. However, pediatric endoscopy has unique characteristics, such as the emotional impact of invasive procedures on children[2,4]. In addition, only some units can propose pediatric endoscopies due to a lack of pediatric endoscopists or experts in pediatric procedures. This mini-review highlights current pediatric GI endoscopy practices and advances in interventional endoscopy compared to adults.

FEATURES OF GASTROINTESTINAL ENDOSCOPY IN CHILDREN

GI endoscopy can be safely performed inchildren for various indications by qualified endoscopists trained in pediatricgastroenterology or adult gastroenterologists,

potentially assisted by a pediatricianwith expertise in pediatric GI disorders, whether for diagnostic orinterventional purposes[5]. Withtechnological advances in endoscope design and endoscopic devices, diagnosticGI endoscopy in children has become a routine procedure and is available inmost centers, except for EUS and CPRE, which require advanced expertise.According to guidelines published in 2017 by the European Society ofGastrointestinal Endoscopy (ESGE) and the European Society for PediatricGastroenterology, Hepatology and Nutrition (ESPGHAN), the type of endoscope (gastroscope, duodenoscope, colonoscope,and endoscopic ultrasound) should be selected based on the child's ageand weight (Table 1) to ensure safety and effectiveness[1]. Selecting an appropriate probe is particularlyimportant for infants under 10 kg or younger than age one year.

Each type of GI endoscopy has specificindications, including GI symptoms, colorectal pathology, and biliopancreaticdiseases. The selection ofappropriate GI endoscope depends on the presenting clinical features of the affectedchild, which might be followed by suitable endoscopic therapy. Based on ESGE/ESPGHAN recommendations [1–3], these indications aresummarized in **Table 1**.

All GI endoscopies are recognized as invasiveprocedures that can provoke anxiety in both the child and their parents. Sedationis essential to ensure the child's safety and comfort during the procedure. Thechoice of sedation depends on factors such as the child's age and health, the procedure'scomplexity, and the healthcare team's preferences. Comparedto adults, endoscopy in children is typically performed under generalanesthesia or deep sedation with careful monitoring.[2, 6].

None of the currently available drugs, includingpropofol, fentanyl, ketamine, and midazolam, provide a consistent sedativeregimen when used alone or in combination[7,8]. Arecent study by Manivannan *et al*., involving 1,323 children sedated by a pediatricanesthetist during upper endoscopy (UE), identified a correlation betweenpropofol dosage, durationof endoscopy, and sedation. The study discovered a novel relationshipbetween sedation time and propofol dosage, determined by body mass index/bodysurface area rather than mg/kgbody weight[8]. However,

furtherprospective multicenter studies are necessary to validate these findings acrossdifferent GI endoscopy types.

In Kudo's study on pediatric bidirectionalendoscopy performed by pediatric gastroenterologists, propofol sedation wascompared with midazolam sedation. The findings suggested that same-day pediatricbidirectional endoscopy under propofol sedation offers advantages overmidazolam sedation, including reduced procedure time[9].

A well-functioning pediatric sedation team is essentialto ensure safe and effective sedation for pediatric patients. Such a team mustbe knowledgeable and skilled in managing various procedures, pediatricconditions, and sedative techniques[10]. In recent years, pediatric centershave increasingly adopted unsedated transnasal endoscopy (TNE) to assess uppergastrointestinal tract disorders[11].

Sedation-free endoscopy provides a safer, more efficient,and cost-effective approach by avoiding the risks associated with anesthesia,particularly in children[11]. Integrating an unsedated pediatric endoscopyprogram into a pediatric gastroenterology practice can benefit greatly.

The primary contraindication of GI endoscopy isgastrointestinal perforation, as the procedure poses significant risks,including bleeding and infection, in such cases[1].

PEDIATRIC UPPER AND LOWER GI ENDOSCOPIES

Esophagogastroduodenoscopy (EGD)

According to ESGE/ESPGHAN guidelines, EGD canbe performed safely in children for diagnostic and therapeutic purposes **(Figure 1).** Like adults,EGD is the method of choice for investigating numerous symptoms, includingupper GI bleeding, with indications summarized in **Table 1**[1,12,13].

In recent years, EGD has been proposedprior to bariatric surgery to assess anatomical or mucosal abnormalities, suchas hiatal hernia, *Helicobacter pylori*infection, esophagitis, or peptic ulcer disease, which may influence preoperativemedical management[14].

Even when no visible endoscopicabnormalities are observed during EGD, routine tissue sampling is advised for allchildren to exclude conditions such as eosinophilicesophagitis and celiac disease. The number and locationof biopsies vary based on the suspected disease. For eosinophilic esophagitis, atleast three biopsies should be obtained from the distal, mid, and proximal esophagus.For celiac disease, five biopsies are recommended: One from the duodenal bulband four from the second or third portion of the duodenum[1,15].

Currently, EGD is frequentlyperformed to retrieve foreign bodies, such as coins, magnets, and buttonbatteries, particularly in children prone to ingesting such objects[16].

Enteroscopy

The ESGE/ESPGHAN guidelines do not recommendthe routine use of enteroscopy for acute upper GI bleeding in children; however,balloon enteroscopy is reserved for therapeutic purposes only[1].

Ileocolonoscopy

An appropriate probe is recommended for children based on age and weight, utilizing an ultrathin or adult gastroscope and a pediatric colonoscope (11–12 mm)[16]. Although the indications for colonoscopy are well-defined (**Table 1, Figure 2**), bowel preparation remains challenging, with no standardized protocol. Completion of preparation may require a nasogastric tube[1,17].

The Watanabe meta-analysis suggested thatpolyethylene glycol (PEG) might be preferable for bowel preparation beforecolonoscopy in children[18]. However, a recent systematic review comparingdifferent administration regimens from various countries found that sodiumpicosulfate magnesium citrate (SPMC) and PEG were similarly effective for bowelcleansing and comparable in terms of adverse events. Split-dose administration waspreferred over the day-before regimen but could disrupt sleep on the day of thecolonoscopy, increasing stress and reducing compliance with

preparation[17,19]. Only a limited number of randomized trialshave assessed the effects of low-volume PEG preparations in children[17].

To reduce the proportion of incompletecolonoscopies, the use of direct suction and an irrigation pump can enhancevisibility and facilitate the completion of the procedure in children[16].

Several factors specific to children, such asthe use of smaller endoscopes, can make progression more challenging comparedto adults. Pediatric factors (increased colon elasticity, underdevelopedabdominal musculature, and reduced adipose tissue) can increase looping during pediatriccolonoscopy[20].

The Thomson study evaluated loop types based onpatient characteristics. Younger children (less than 5 years old) were morelikely to develop reverse alpha loops and various repetitive and complex loops,while an elevated body mass index (BMI) was associated with a higher risk offorming alpha and deep transverse loops[21].

EUS IN CHILDREN

EUS is well-established as a diagnostic andtherapeutic procedure in the adult population. However, its role in thepediatric population with GI and pancreaticobiliary disorders remainsinsufficiently explored. In pediatrics, EUS is commonly performed for evaluatingpancreatic solid/cystic lesions (**Figure 3**), recurrent acute or chronic pancreatitis,suspected choledocholithiasis, subepithelial lesions such as duplication cystsand pancreatic rest, and benign or malignant lymphadenopathy (**Table 1**)[1]. Studies conducted on EUS in children have demonstrated a high positive impacton disease management, ranging from 44% to 98% [22–24]. With the growingindications for EUS in pediatrics, its adoption will likely expand[25].

Two types of echoendoscopes, radial andcurvilinear, can be used for EUS examinations. The radial echoendoscope providesa 360° view primarily for diagnostic purposes. In contrast, the curvilinearechoendoscope, offering a 120°–180° view parallel to the scope, has a workingchannel for interventional procedures such as fine needle aspiration or biopsy(FNA/FNB), stent placement, and guided radiofrequency ablation

of pancreaticneoplasms. A limitation of these echoendoscopes in pediatric use is their largesize, which restricts application in smaller children. Standard EUS scopescarry an increased risk of cervical esophageal perforation during intubationbut have been safely used in children as small as 15 kg, with reports ofsuccessful EUS in children under one year[22]. Mini probes or endobronchialultrasound (EBUS) with a 7.4 mm diameter are preferred for children under 15 kg or youngerthan three years (**Table 1**).

The incidence of acute pancreatitis inchildhood is increasing[26]. EUS is considered the most sensitive and specificdiagnostic tool for choledocholithiasis and microlithiasis, responsible for atleast half of all acute pancreatitis cases [26–29]. In a study by Téllez-Ávilaet al., three pediatric patients with acute pancreatitis underwent EUS, withone undergoing cholecystectomy after the first episode[30].

EUS-FNA is safe and feasible in pediatricpatients and has a significant clinical impact, often avoiding more invasiveand unnecessary procedures[24]. Varadarajulu *et al*. reported a significantclinical impact of EUS on 93% of pediatric patients with pancreaticobiliarydisorders[31]. Similarly, Raina *et al*. observed a clinical impact in 88% ofcases, and AlRashdan *et al*. found that EUS provided a different diagnosis in86% of cases[32,33]. Additionally, EUS-guided liver biopsy showed promise as asafe and effective alternative to percutaneous liver biopsy in evaluatingchildren with unexplained liver test abnormalities or biliary disorders[34].

Although guidelines endorse using EUS in pediatricpatients, its application has been reviewed in limited literature sources. EUShas proven safe and clinically impactful for diagnosing, managing, andfollowing up on common hepatopancreatobiliary and luminal pathologies in children.

ENDOSCOPIC RETROGRADE CHOLANGIOPANCREATOGRAPHY IN CHILDREN (ERCP)

Initially developed for adults and firstperformed in 1968, ERCP is a specialized procedurethat has become increasingly important in managing hepatobiliary and

pancreaticconditions in children[1,35]. Variations in anatomy, indications, and equipmentneeds make its use in children particularly challenging.

ERCP may be recommended in children, especially infants under one year of age when ultrasound or magnetic resonancecholangiopancreatography has not provided a definitive diagnosis or for therapeutic purposes. **Table 1** summarizes the main justifications for performingERCP in children[1,36,37]. Although somesymptoms are similar to those in adults, theprevalence of these conditions and their underlying causes differ in children.

Like other GI endoscopies, ERCP in children requires smaller probes and a more delicatetechnique to accommodatepediatric anatomy.Thin duodenoscopes (7.5–8.5 mm) should be used for neonates and children[3]. With narrower working channels (~2 mm), these scopes are designed to fit small anatomical structures whileenabling effective therapeutic interventions.

A well-established risk, post-ERCP pancreatitis (PEP), affects 5–12% of children, depending onthe procedure's complexity and rationale[38]. The risk is higher for younger children and in therapeuticERCP. Perforation, bleeding, and infection are less common complications[39]. Theuse of non-steroidal anti-inflammatory drugs, including rectal indomethacin,has been shown to reduce the incidence of post-ERCP pancreatitis in high-risk pediatric patients. Pancreatic duct stenting may prevent ductal obstruction in complex procedures[40].

Few pediatric-specific devices are available, such as balloons, guidewires, and small cannulas. For instance, compared to adult equivalents, juvenile biliarystents are shorter in length and have a smaller diameter (4-5 Fr)[41].Single-use attachments and disposable scopes are becoming more popular choicesto improve safety and reduce the risk ofcross-contamination[42]. Developments in imaging technology, includingcontrast agents and high-definition fluoroscopy, are facilitatingprecision-guided procedures[43].

Pre-procedural assessment should consider the patient's age, weight, and comorbidities topersonalize the anesthetic regimen. General anesthesia is preferred for

ERCP in childrento ensure patient safety and immobility during theprocedure. A multidisciplinaryteam of pediatric gastroenterologists,anesthetists, radiologists, and surgeons provides comprehensive care. This type of collaborationimproves decision-making and maximizes outcomes[44].

A high level of technical skill is required for pediatric ERCP. ERCP has shown high success rates for both diagnostic andtherapeutic procedures in children, with 90% technical success in expertcenters[45]. Bridging the skills gap may befacilitated by training programs, including pediatric-specific ERCP simulations[46].

Efforts to develop pediatric-specific recommendations and standardized training are essential. Creating a pediatric ERCP registry with collaborativeresearch and databases will provide important information on the best techniques and outcomes[47].

PEDIATRIC INTERVENTIONAL ENDOSCOPY

Upper and lower endoscopies are increasinglybeing performed for interventional purposes, with the timing determined by thesituation. ESGE/ESPGHAN recommend early EGD for esophageal foreign bodies, withurgent removal of symptomatic blunt foreign bodies, button batteries, and coins,or impacted food from the esophagus (< 2 hours) and urgent (< 24 hours)for asymptomatic children. However, the removal of blunt gastroduodenal foreignbodies is recommended for symptomatic children or large bodies (2.5 cm in diameteror > 6 cm in length) or if they do not passspontaneously after 4 weeks. In contrast,sharp-pointed objects should be removed emergently (< 2 hours), even if locatedin the esophagus, stomach, or duodenum[1].

For button batteries, ESGE/ESPGHAN recommendsemergent removal (< 2 hours) if impacted in the esophagus due to theirpotentially significant damage. However, if located in the stomach, emergentremoval (< 2 hours) of button batteries is proposed for symptomatic childrenor those with known or suspected anatomical pathology in the GI tract (*e.g.*,Meckel's diverticulum). If the button batteries arelarger than 20 mm and located in the stomach, a follow-up by radiography isrecommended after 48 hours. Urgent endoscopicremoval (< 24 hours) is recommended for single cylindrical battery

ingestionif impacted in the esophagus and as soon as possible for symptomatic childrenelsewhere in the GI tract[1, 16].

Many different retrieval devices are available,including retrieval net graspers (alligator and rat tooth), and should bechosen according to the operator's experience. Some endoscopists, especiallywhen removing sharp objects, use an overtube to prevent injury[16].

As in adults, endoscopic variceal ligation isthe preferred treatment for variceal bleeding in children. However, due to theinability to attach the ligating device to a thinner pediatric endoscope,sclerotherapy can be proposed as an alternative treatment[48]. Combinedtreatment with epinephrine injection and thermal or mechanical techniques isrecommended for bleeding peptic ulcers and Dieulafoy's lesions in children[3].

EUS and ERCP are essential in managingcomplicated chronic pancreatitis and choledocholithiasis in adults andchildren. Endoscopic sphincterotomy may be necessary for the removal of bileduct stones (**Figure 4**), a procedure that issafe with a low rate of complications, even in children[49,50].

Therapeutic EUS has emerged as a potential toolfor treating several GI disorders in adults, and more recently in children, includingcystogastrostomy for drainage of pancreatic pseudocysts and walled-offpancreatic necrosis using double pigtail plastic stents and biflanged orlumen-apposing metal stents[51,52]. Furthermore, malignant and benign gastricoutlet obstruction can be successfully treated by EUS-guided gastrojejunostomy,even in children, as a non-operative alternative[53].

CONCLUSION

Digestive endoscopy has revolutionized diagnosing and treating many GI diseases and is now commonly used in children. Various established diagnostic and interventional GI endoscopy indications can be adapted to manage hepatobiliary and pancreatic diseases in children. These adjustments must account for the size of the probes, the tools used, and the procedure conditions. Successful implementation of pediatric endoscopy

requires true teamwork, with close and constant collaboration between gastroenterologists, anesthesiologists, and the pediatric team. Advances in interventional endoscopy will significantly benefit children with various GI disorders. To further improve this practice, it is crucial to establish an appropriate training program, particularly for ERCP and EUS, to increase the number of professional pediatric endoscopists.

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