Dig Dis Sci (2013) 58:2653–2660
DOI 10.1007/s10620-013-2691-0

ORIGINAL ARTICLE

Comparison of Performance and Safety of Endoscopic Retrograde Cholangiopancreatography Across Pediatric Age Groups

Berkeley N. Limketkai · Vinay Chandrasekhara · Anthony N. Kalloo · Patrick I. Okolo III

Received: 26 January 2013 / Accepted: 13 April 2013 / Published online: 26 May 2013

Abstract
Background and Study Aim Endoscopic retrograde cholangiopancreatography (ERCP) has been shown to be overall effective and safe in children, but its performance characteristics and safety profile have not been specifically evaluated according to age. We aim to compare the indications, findings, interventions, and safety outcomes of ERCP across pediatric age groups.
Methods A retrospective cross-sectional study of pediatric patients (ages 17 or below) who underwent ERCP between October 1998 and April 2011 at a tertiary-care academic center. Data on indications, findings, technical success, and adverse events of ERCP were collected and compared according to age groups (0–6, 7–12, or 13–17 years).
Results There were 289 procedures performed in 154 children (mean age, 11.5 years). The number of patients undergoing ERCP increased with age; teenagers constituted the largest group (52.6 %) and had the most procedures (49.8 %). Children aged 0–6 years had an equal distribution of biliary and pancreatic cases; children aged 7–12 years had predominantly pancreatic indications. Most procedures in teenagers were for biliary indications. Overall, the technical success rates of ERCPs were similar across age groups ($P = 0.661$). Seventeen adverse events (5.9 % of procedures) were identified: post-procedure pancreatitis (12 cases; 4.2 %), hypoxia (3; 1.0 %), and hemorrhage (2; 0.7 %). The youngest group had more adverse events (12.0 %, compared to 6.3 and 2.1 % in other groups; $P = 0.049$), mostly due to mild pancreatitis.
Conclusion ERCP is generally safe in the pediatric population, although the risk of mild post-procedure pancreatitis may be higher among the youngest children.

Keywords Safety · Endoscopy · ERCP · Pediatrics · Pancreas

B. N. Limketkai · V. Chandrasekhara · A. N. Kalloo · P. I. Okolo III (✉)
Division of Gastroenterology, Johns Hopkins University School of Medicine, 1800 Orleans Street, Zayed Tower, Suite 7-125, Baltimore, MD 21287, USA
e-mail: pokolo2@jhmi.edu

B. N. Limketkai
e-mail: berkeley.limketkai@gmail.com

V. Chandrasekhara
e-mail: vinayc1@gmail.com

A. N. Kalloo
e-mail: akalloo@jhmi.edu

Introduction

Endoscopic retrograde cholangiopancreatography (ERCP) has long been established as an effective diagnostic and therapeutic modality for pancreaticobiliary disorders [1]. While the majority of the published literature have been in adults, emerging data have shown ERCP to be similarly effective and safe in children [2–12]. However, most pediatric studies have been limited by small cohorts, largely due to the lower incidence of pancreatic and biliary diseases in children and the higher threshold to pursue invasive procedures in this population.

Moreover, much less has been described with regards to the performance and safety characteristics of ERCP in very young children. Over half of pediatric ERCPs are performed in teenagers [4], whose physical attributes more closely resemble those of young adults. As previous studies have generally aggregated children of all ages in their analyses, the age-specific indications, diagnostic findings,

therapeutic successes, and adverse events of ERCP may be masked in younger children. There are special anatomic and physiologic considerations when performing ERCP in young children. Additionally, certain genetic conditions may be more manifest in very young patients, while older children may have disease processes more similar to those seen in adults.

As such, the aim of this study is to investigate the procedural indications, diagnostic, therapeutic, and safety outcomes of ERCP in a large pediatric cohort at a tertiary-care academic center, specifically across various pediatric age groups.

Methods

The protocol for this retrospective research study was approved by the Johns Hopkins Institutional Review Board. Consecutive ERCP procedures performed in all patients under the age of 18 at the Johns Hopkins Hospital between October 1998 and April 2011 were included. All procedures were performed by endoscopists with expertise in ERCP. Prior to each procedure, informed consent was obtained from the patient's parent or guardian. Data regarding patient demographics, procedure indications, findings, interventions, adverse events, and post-procedure course were abstracted from the electronic medical records and retrospectively analyzed.

Successful cannulation was defined as the ability to cannulate and inject radiopaque contrast into the biliary and/or pancreatic duct of interest. Technical success was defined as the ability to complete the intended therapeutic procedure, such as stone extraction, sphincterotomy, or stent placement. Patients who developed immediate or early adverse events following the procedure were admitted for observation and treatment. Data on these intra- and post-procedure adverse events were available in the electronic medical records. Adverse events that were assessed included evidence of sustained respiratory depression (as clinically determined and recorded by the anesthesia provider), hemorrhage, perforation, pancreatitis, and mortality, as defined by consensus criteria [13].

Patients were divided into 3 age groups based on their age at the time of the procedure (0–6, 7–12, or 13–17 years). Pre-adolescence was defined as an age younger than 13 years old. Teenagers were defined as being 13 years or older. Categorical data were compared using the χ^2 or Fisher exact test. Individuals with missing data for a particular variable of interest were not included in the corresponding analysis. A P value less than 0.05 was considered statistically significant. All statistical analyses were performed using Stata SE version 12 (Stata, College Station, TX, USA).

Results

Patient Demographics

During the 13-year study period, 154 children underwent 289 ERCP procedures (Table 1). The median patient age at the time of ERCP was 12 years (interquartile range 8–15; range 1–17 years). There were 68 boys (44.2 %) and 86 girls (55.8 %), of whom 87 (57.2 %) were White and 47 (30.9 %) were Black. The remaining 18 (11.8 %) included pediatric patients of Hispanic, Asian, or other ethnic origin. When stratified into age groups (0–6, 7–12, and 13–17 years), genders were equally distributed among the pre-adolescent children. There were more girls (53; 65.4 %) than boys (28; 34.6 %) in the teenage group. The proportions of each race were similar among age groups. The number of patients who underwent procedures increased with age. Teenagers constituted the largest age group at 52.6 % of the pediatric population.

ERCP Indications and Findings

Of the 289 ERCP procedures performed on children, 138 (47.8 %) were primarily for biliary indications and 151 (52.2 %) for pancreatic indications (Table 2). Teenagers had the most number of cases (144; 49.8 %), mirroring the large size of this age group. There were shifting distributions of biliary and pancreatic indications for each age group. The youngest children had an equal distribution of biliary and pancreatic cases. On the other hand, the majority of cases in the 7–12 years age group were for pancreatic indications, and the majority of cases in teenage patients were for biliary indications.

The most common indications for biliary procedures for all age groups were suspected choledocholithiasis (18.0 %), elevated transaminases of unclear etiology

Table 1 Patient demographics according to age group

	Age group			
	0–6 years	7–12 years	13–17 years	All years
Patients (*n*)	33	40	81	154
Procedures (*n*)	50	95	144	289
Sex				
Male (%)	17 (51.5)	23 (57.5)	28 (34.6)	68 (44.2)
Female (%)	16 (48.5)	17 (42.5)	53 (65.4)	86 (55.8)
Race[a]				
White (%)	20 (60.6)	20 (50.0)	47 (58.0)	87 (57.2)
Black (%)	8 (24.2)	12 (30.0)	27 (33.3)	47 (30.9)
Other (%)	5 (15.2)	7 (17.5)	6 (7.4)	18 (11.8)

[a] Race information for one patient in the 7–12 year group and one in the 13–17 year group were missing

Table 2 Major ERCP indications according to age group

	Age group				
	0–6 years *n* (%)	7–12 years *n* (%)	13–17 years *n* (%)	All years *n* (%)	*P* value[a]
Primary biliary cases	27 (54.0)	30 (31.6)	81 (56.3)	138 (47.8)	0.001
Major biliary indications[b]	29	30	81	140	<0.001
Choledocholithiasis	8 (16.0)	10 (10.5)	34 (23.6)	52 (18.0)	0.033
Elevated transaminases of unclear etiology	5 (10.0)	9 (9.5)	11 (7.6)	25 (8.7)	0.754
PSC	5 (10.0)	1 (1.0)	10 (6.9)	16 (5.5)	0.031
Stent removal	1 (2.0)	5 (5.3)	6 (4.2)	12 (4.2)	0.734
Cholangitis	1 (2.0)	1 (1.0)	5 (3.5)	7 (2.4)	0.605
Stricture	2 (4.0)	3 (3.2)	2 (1.4)	7 (2.4)	0.398
Bile leak	0 (0.0)	1 (1.0)	5 (3.5)	6 (2.1)	0.324
Choledochal cyst	6 (12.0)	0 (0.0)	1 (0.7)	7 (2.4)	<0.001
Chronic abdominal pain of unclear etiology	1 (2.0)	0 (0.0)	7 (4.9)	8 (2.8)	0.090
Primary pancreatic cases	23 (46.0)	65 (68.4)	63 (43.8)	151 (52.2)	0.001
Major pancreatic indications[b]	29	88	76	193	<0.001
Recurrent or chronic pancreatitis	19 (38.0)	50 (52.6)	41 (28.5)	110 (38.1)	0.001
Stent removal	5 (10.0)	12 (12.6)	16 (11.1)	33 (11.4)	0.909
Pseudocyst	0 (0.0)	8 (8.4)	10 (6.9)	18 (6.2)	0.092
Stone	2 (4.0)	10 (10.5)	2 (1.4)	14 (4.8)	0.005
Acute pancreatitis	2 (4.0)	4 (4.2)	3 (2.1)	9 (3.1)	0.588
Stricture	0 (0.0)	2 (2.1)	1 (0.7)	3 (1.0)	0.583
Duct disruption	1 (2.0)	1 (1.0)	0 (0.0)	2 (0.7)	0.251
Pancreatic mass	0 (0.0)	1 (1.0)	1 (0.7)	2 (0.7)	0.999
Post-operative pancreatic fistula	0 (0.0)	0 (0.0)	2 (1.4)	2 (0.7)	0.671

Percentages are calculated across all cases within the same age group

ERCP endoscopic retrograde cholangiopancreatography, *PSC* primary sclerosing cholangitis

[a] *P* value is calculated for particular indication across age groups

[b] Forty-one cases were classified as having two equally relevant indications for ERCP (e.g., recurrent pancreatitis and stone). Two cases were classified as having three ERCP indications. One teenage patient with gallbladder agenesis was not included in the table

(8.7 %), and suspected primary sclerosing cholangitis (PSC) (5.5 %). Choledocholithiasis and PSC were less common in the 7–12 years age group, while evaluation of choledochal cysts was more common in the youngest children. Distributions of the remaining biliary indications were otherwise similar across age groups. One 13-year-old girl with no previous history of cholecystectomy underwent ERCP to confirm possible gallbladder agenesis after a hepatobiliary iminodiacetic acid (HIDA) scan, and magnetic resonance imaging demonstrated the absence of a gallbladder.

The most common pancreatic indications included recurrent or chronic pancreatitis (38.1 %) and stent removal (11.4 %). Procedures for recurrent pancreatitis and suspected pancreaticolithiasis were significantly more common in the 7–12 years age group, while all other pancreatic indications were otherwise similar among age groups.

For patients undergoing first-time ERCP, biliary indications were nearly twice as common as pancreatic indications (Fig. 1). First-time biliary procedures were predominantly performed for suspected choledocholithiasis and abnormal transaminases of unclear etiology. In contrast, repeat ERCPs were more likely to be performed for pancreatic indications and most commonly for evaluation of recurrent pancreatitis. The shift in indications reflects the high number of isolated cases for biliary duct disease, while patients with pancreatic disease had higher rates of repeated pancreatic interventions.

Successful cannulation was achieved in 272 (94.1 %) cases. Biliary and/or pancreatic findings were normal in 11.4 % of cases (Table 3). The most common biliary findings were choledocholithiasis (14.9 %), duct dilatation (11.4 %), and strictures (9.7 %). This pattern is consistent with suspected choledocholithiasis and abnormal transaminases as the most common biliary indications.

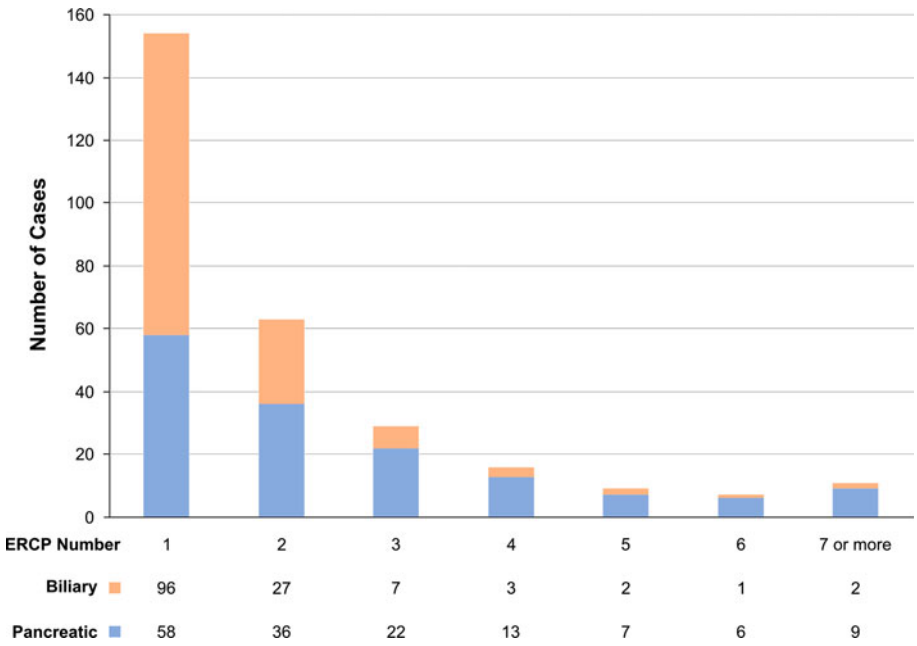

Fig. 1 Types of indications for first and repeat ERCPs

Choledocholithiasis was significantly more common at the time of procedure in the 0–6 and 13–17 years age groups compared with the 7–12 years age group. Although rates of the remaining biliary findings were statistically similar across age groups, there was a non-significantly greater incidence of bile leaks among teenagers. In the 7 cases of bile leak, 5 were iatrogenic after cholecystectomy and 2 were secondary to gunshot trauma.

The most common pancreatic findings were chronic pancreatitis (28.0 %), duct dilatation (19.0 %), pancreas divisum (17.0 %), and pancreaticolithiasis (7.3 %). These are anticipated results, as recurrent and chronic pancreatitis constitute the most common pancreatic indications for ERCP in children. Of the 3 age groups, pancreatic duct dilatation and pancreaticolithiasis were significantly more prevalent in the 7–12 years age group. This group had the most cases for recurrent pancreatitis and 80 % of repeat ERCPs were for pancreatic indications, compared to 64.7 and 60.3 % in the 0–6 and 13–17 years age groups, respectively. Abnormal pancreaticobiliary junction (APBJ) was found more often among the youngest children.

Therapeutic Interventions and Adverse Events

As choledocholithiasis, duct dilatation, and strictures were the most common biliary pathologies detected, biliary sphincterotomy, stone extraction, and stent placement were similarly the most common therapeutic maneuvers performed (Table 4). For pancreatic pathologies, stent placement and removal, sphincterotomy, and minor papillotomy were the most common procedures.

Overall, ERCP performed well with a 90.7 % technical success rate among 289 attempted procedures; success rates were similar across age groups ($P = 0.661$). In the 148 first-time ERCPs without recurrent failures, the technical success rises to 95.9 %. Of the 27 (9.3 %) cases that were considered procedural failures, 17 were due to an inability to cannulate the duct of interest: biliary (6) or pancreatic (11). Technical failures despite successful cannulation occurred in 1 biliary case and 9 pancreatic cases. The biliary case was prematurely aborted due to inadequate sedation. The reasons for failure in the remaining pancreatic cases were pancreatitis-related duodenal obstruction (1), inability to retrieve an inwardly migrated stent (1), or inability to pass the guidewire through a discontinuous or obstructed pancreatic duct (7). One patient underwent surgical intervention after 3 ERCP attempts were unsuccessful in extracting a large pancreatic duct stone. Another patient had successful ERCP with pancreatic duct stone removal on the third attempt. One patient's pancreatic stone could not be traversed, but was no longer present on repeat ERCP.

Seventeen adverse events (9.7 % of patients, 5.9 % of procedures) were identified in this study population (Table 4). Mild pancreatitis was the most common adverse event, occurring in 12 cases (4.2 %) followed by hypoxia (3; 1.0 %) and hemorrhage (2; 0.7 %). The youngest children had higher rates of adverse events (12.0 vs. 6.3 and 2.1 %, $P = 0.049$), most of which were directly related to a higher rate of post-procedure pancreatitis. The pancreatitis rates for procedures with or without pancreatic stent placement were similar (4.6 vs. 4.0 %, $P = 0.736$).

Table 3 Major ERCP findings according to age group

	Age group				
	0–6 years *n* (%)	7–12 years *n* (%)	13–17 years *n* (%)	All years *n* (%)	*P* value[a]
Normal ERCP	6 (12.0)	7 (7.4)	20 (13.9)	33 (11.4)	0.297
Biliary duct					
Choledocholithiasis	9 (18.0)	5 (5.3)	29 (20.1)	43 (14.9)	0.003
Duct dilatation	7 (14.0)	14 (14.7)	12 (8.3)	33 (11.4)	0.257
Stricture	5 (10.0)	8 (8.4)	15 (10.4)	28 (9.7)	0.864
Sludge/debris	5 (10.0)	3 (3.2)	9 (6.3)	17 (5.9)	0.240
Papillary stenosis	0 (0.0)	6 (6.3)	12 (8.3)	18 (6.2)	0.082
PSC	2 (4.0)	2 (2.1)	13 (9.0)	17 (5.9)	0.070
Choledochal cyst	5 (10.0)	3 (3.2)	3 (2.1)	11 (3.8)	0.053
Bile leak	0 (0.0)	1 (1.1)	6 (4.2)	7 (2.4)	0.239
Pancreatic duct					
Chronic pancreatitis	13 (26.0)	33 (34.7)	35 (24.3)	81 (28.0)	0.201
Duct dilatation	6 (12.0)	26 (27.4)	23 (16.0)	55 (19.0)	0.030
Pancreas divisum	9 (18.0)	20 (21.1)	20 (13.9)	49 (17.0)	0.344
Stone	2 (4.0)	15 (15.8)	4 (2.8)	21 (7.3)	0.001
APBJ	8 (16.0)	3 (3.2)	4 (2.8)	15 (5.2)	0.003
Pseudocyst	0 (0.0)	5 (5.3)	8 (5.6)	13 (4.5)	0.220
Stricture	0 (0.0)	5 (5.3)	4 (2.8)	9 (3.1)	0.249
Sludge/debris	1 (2.0)	4 (4.2)	3 (2.1)	8 (2.8)	0.632
Duct disruption	1 (2.0)	2 (2.1)	4 (2.8)	7 (2.4)	0.999

APBJ abnormal pancreaticobiliary junction, *ERCP* endoscopic retrograde cholangiopancreatography, *PSC* primary sclerosing cholangitis

Percentages are calculated across all cases within the same age group

[a] *P* value is calculated for particular finding across age groups

The rates of peri-procedure respiratory depression and hemorrhage were low and similar in all ages. There were no cases of perforation or death.

Comparison with MRCP Findings

Magnetic resonance cholangiopancreatography (MRCP) was performed prior to 57 ERCP procedures (Table 5). Across age groups, the distributions of MRCP indications (biliary or pancreatic) and ERCP types (therapeutic or diagnostic) were similar. Nonetheless, most of these ERCPs were for pancreatic indications (64.9 %, $P = 0.001$) and had a therapeutic component (84.2 %, $P < 0.001$); only 9 procedures (15.8 %) were purely diagnostic. Findings were concordant in 32 cases (56.1 % of MRCP tests). Concordance rates were similar across age groups (biliary indication, $P = 0.838$; pancreatic, $P = 0.133$) and according to indication ($P = 0.134$). Of the 9 diagnostic ERCPs, there was agreement in only 6 cases, suggesting that ERCP would have still been helpful for diagnosis in a third of these cases.

Discussion

Several pediatric case series have demonstrated ERCP to be effective and safe in children [2–12]. However, these studies have generally aggregated children of all ages in their analyses, thereby masking the age-specific indications, diagnostic and therapeutic successes, and adverse events of ERCP across pediatric age groups. Age stratification is nevertheless important, because childhood covers a broad continuum of rapid physical development, where anatomic and physiologic considerations for endoscopy may dramatically vary among age groups. For instance, infants and toddlers have a greater theoretical risk of tracheal compression and oxygen desaturations during passage of the endoscope [14]. Likewise, younger children typically require deeper sedation and are more sensitive to weight-based medication dosing than teenagers or adults. A cross-sectional analysis of the PEDS–CORI (Pediatric Endoscopy Database System–Clinical Outcomes Research Initiative) database further showed an association between younger age and increased adverse event rates among

Table 4 Therapeutic interventions and adverse events according to age group

	Age group				
	0–6 years *n* (%)	7–12 years *n* (%)	13–17 years *n* (%)	All years *n* (%)	*P* value[a]
All procedures	50	95	144	289	
All therapeutic cases	36	81	130	247	
Dual sphincterotomy	2 (5.6)	3 (3.7)	8 (6.2)	13 (5.3)	0.729
Biliary duct					
Sphincterotomy	14 (38.9)	19 (23.5)	59 (45.4)	92 (37.3)	0.006
Stone extraction	13 (36.1)	8 (9.9)	33 (25.4)	54 (21.9)	0.002
Stent placement	4 (11.1)	14 (17.3)	24 (18.5)	42 (17.0)	0.636
Stent removal	3 (8.3)	9 (11.1)	14 (10.8)	26 (10.5)	0.960
Stricture dilatation	1 (2.8)	0 (0.0)	14 (10.8)	15 (6.1)	0.002
Pancreatic duct					
Stent placement	7 (19.4)	28 (34.6)	30 (23.1)	65 (26.3)	0.109
Stent removal	5 (13.9)	18 (22.2)	20 (15.4)	43 (17.4)	0.370
Sphincterotomy	3 (8.3)	11 (13.6)	5 (3.9)	19 (7.7)	0.031
Minor papillotomy	5 (13.9)	5 (6.2)	8 (6.2)	18 (7.3)	0.257
Stone extraction	2 (5.6)	10 (12.4)	4 (3.1)	16 (6.5)	0.025
Stricture dilatation	0 (0.0)	1 (1.2)	3 (2.3)	4 (1.6)	0.999
Papillary orifice dilation	0 (0.0)	0 (0.0)	1 (0.8)	1 (0.4)	0.999
Cystduodenostomy	0 (0.0)	1 (1.2)	0 (0.0)	1 (0.4)	0.474
Adverse events[b]	6 (12.0)	2 (2.1)	9 (6.3)	17 (5.9)	0.049
Pancreatitis	5 (10.0)	1 (1.0)	6 (4.2)	12 (4.2)	0.042
Hypoxia	1 (2.0)	0 (0.0)	2 (1.4)	3 (1.0)	0.421
Hemorrhage	0 (0.0)	1 (1.0)	1 (0.7)	2 (0.7)	0.999

Percentages are calculated across all interventions within the same age group

[a] *P* value is calculated for particular intervention across age groups

[b] Adverse events are calculated from all diagnostic and therapeutic ERCP cases

Table 5 Characteristics of ERCP cases with prior MRCP

	Age group				
	0–6 years	7–12 years	13–17 years	All years	*P* value
Indication					
Biliary, *n* (%)[a]	4 (36.4)	8 (40.0)	8 (30.8)	20 (35.1)	0.822
Pancreatic, *n* (%)[a]	7 (63.6)	12 (60.0)	18 (69.2)	37 (64.9)	0.822
ERCP					
Diagnostic, *n* (%)[a]	2 (18.2)	4 (20.0)	3 (11.5)	9 (15.8)	0.716
Therapeutic, *n* (%)[a]	9 (81.8)	16 (80.0)	23 (88.5)	48 (84.2)	0.716
Concordance					
Biliary, *n* (%)[b]	2 (50.0)	6 (75.0)	5 (62.5)	13 (65.0)	0.838
Pancreatic, *n* (%)[b]	2 (28.6)	9 (75.0)	8 (44.4)	19 (51.4)	0.133

ERCP endoscopic retrograde cholangiopancreatography, *MRCP* magnetic resonance cholangiopancreatography

[a] Percentages are calculated from the total number of MRCPs within each respective age group

[b] Percentages are calculated from the total number of corresponding MRCPs and ERCPs performed for each indication (biliary or pancreatic)

children who undergo esophagogastroduodenoscopy (EGD) [15]. Similarly, our age-stratified analyses of 289 ERCPs revealed notable differences in the indications, findings, and safety of ERCP use among various age groups.

Given the known lower incidence of pancreaticobiliary diseases in young children, the cross-sectional number of cases in our cohort appeared to increase with age. The youngest age group had the least number of procedures, while teenagers constituted the majority of patients and

ERCP cases. This trend was consistent with the age distribution of pediatric cases reported in another large study, where most ERCP procedures were performed in teenagers [4]. In our cohort, the distribution of biliary and pancreatic indications for ERCP also differed among the three age groups. ERCP to evaluate presumed congenital or genetic anomalies, such as PSC and choledochal cysts, were more common in the youngest children. Children aged 7–12 had predominantly pancreatic ERCPs and a higher rate of cases for recurrent pancreatitis. In contrast, over half the cases performed in teenagers were for suspected biliary pathologies. These age-varying observations may reflect a differential onset of diverse pancreaticobiliary disorders in children.

Anatomic anomalies (i.e., pancreas divisum, APBJ, and idiopathic duct dilatation) were commonly identified with ERCP. Unlike pancreatitis in adulthood, which mostly stems from alcohol use or choledocholithiasis, childhood pancreatitis is more commonly attributed to congenital anomalies, often requiring repeat endoscopic therapeutic intervention. Consequently, 68.4 % of procedures performed in pre-adolescent children were for pancreatic indications, 67.7 % of which were repeat procedures. The probability of needing to repeat an ERCP diminished with each successive procedure, presumably after having addressed the underlying causes of pancreatitis in some patients. It is possible that additional unrecorded ERCPs would have continued to occur after the study period. On the other hand, we believe the 13-year observational timeframe was adequate to capture longitudinal trends for recurrent procedures.

The overall concordance rates between MRCP and ERCP were similarly marginal across age groups. Although not statistically significant, these rates were marginally lower with pancreatic findings compared to biliary findings, except in the 7–12 years age group. As this age group tended to have more ERCPs for recurrent pancreatitis, this deviation may be explained by induced concordance from repeated tests. Of the 57 ERCPs preceded by an MRCP, almost all (48) required therapeutic intervention; MRCP would presumably not have prevented the need for ERCP in these cases. However, there was likely a selection bias against individuals who did not require or undergo ERCP after having had a diagnostic MRCP. The role of MRCP for pancreaticobiliary diseases in this cohort should be further evaluated.

First-time ERCP was technically successful in roughly 96 % of patients, which is comparable to previously published reports [2, 3, 6, 9]. There were no differences in success rates across age groups. The overall adverse event rate (5.9 %) in our cohort was also comparable to those reported in several other studies [2, 4, 7]. However, after stratifying the patients according to age groups, the adverse event rate is seen to be moderately higher in the youngest children at 12.0 %. This proportion is almost twice that seen in teenagers and 6 times as high as the adverse event rate for the 7–12 years age group. One possible explanation for this difference in adverse event rates is the unique anatomical challenges found in very young children (i.e., small duodenal lumen, smaller papillary orifice, and narrow caliber pancreatic duct) that render cannulation of the intended duct and therapeutic interventions more difficult. Even among those who had successful pancreatic duct cannulation, the most common cause for overall failure of the procedure was the inability to pass the guidewire through a discontinuous or obstructed duct. Although cannulation times were not recorded, prolonged attempts at cannulation can contribute to a higher risk for post-procedure pancreatitis in the youngest children [16]. The placement of a pancreatic stent did not alter pancreatitis rates, but there may have been insufficient power to detect a difference. Our findings nonetheless highlight the need for additional studies examining procedure-related adverse events, particularly among the very young children. For children aged 7–12, on the other hand, there were numerically and proportionally more pancreatic cases, yet they had a high rate of ERCP success and the lowest rate of post-procedure pancreatitis (with or without prior sphincterotomy).

The study is limited by the inherent nature of retrospective observational analyses, having to rely on the quality and completeness of previously collected data. We assume that this has the greatest impact on identifying adverse events, such as transient intraprocedural events or adverse events that may not have been fully documented, although we reviewed all available documents in order to capture all data. Secondly, there were a limited number of patients, particularly younger children. Although this study is among the largest published cohorts to date, additional studies are needed in other settings before generalization of our findings can be made. Thirdly, there may be underreporting of post-procedure pancreatitis among children who undergo ERCP for recurrent or chronic pancreatitis. It would have been difficult to differentiate existent disease from a procedure-related adverse event. Nonetheless, even if more pre-adolescent and teenage children were recorded to have post-procedure pancreatitis, this observation would not obviate the association of technical difficulty and post-procedure pancreatitis in the youngest children.

Our study highlights the differences in the indications, findings, technical challenges, and adverse events of ERCP amongst different pediatric age groups. Pre-adolescent children were more likely to undergo ERCP for pancreatic indications, particularly repeat procedures for recurrent or chronic pancreatitis, while teenagers were more likely to undergo ERCP for biliary indications. Experienced

endoscopists can have good technical success and low adverse event rates with ERCP. Precautions should be taken during endoscopy to minimize duct manipulation, contrast injection, and duration of procedure. Adverse event rates appear to be higher in very young children, mostly due to post-procedure pancreatitis; however, ERCP is overall effective and safe in the pediatric population. The differences in procedural indications and adverse event rates among the various pediatric groups exemplify the importance in considering young children separately from teenagers when approaching ERCP and tailoring discussions of risks during the informed consent process.

Conflict of interest None.

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