Nationwide Evolution of Pediatric Endoscopic Retrograde Cholangiopancreatography Indications, Utilization, and Readmissions over Time

Monique T. Barakat, MD, PhD[1,2,*], George Cholankeril, MD, MPH[2,*], Roberto Gugig, MD[1], and William E. Berquist, MD[1]

Objectives To analyze outcome and utilization trends over time of pediatric endoscopic retrograde cholangiopancreatography (ERCP) in an all-capture US population-level study.

Study design Using the National Inpatient Sample (2005-2014) and National Readmission Database (2010-2014), we identified pediatric (age <20 years) hospitalizations during which ERCP was performed and assessed ERCP-associated readmissions. *International Classification of Diseases, Ninth Revision, Clinical Modification* codes were used to identify hospitalization diagnoses, comorbidities, and patient/hospital characteristics. Multivariate logistic regression analyses were performed to determine significant predictors ($P < .05$) of 30-day readmission.

Results A total of 11 060 hospitalized pediatric patients underwent ERCP between 2005 and 2014. Most were female (n = 8859; 81%), aged 14-20 years (n = 9342; 84%), and white (n = 4230; 45%). Most (85%) of ERCPs were therapeutic, and leading indications were biliary (n = 5350; 48%) and pancreatitis (n = 3218; 29%). Thirteen pecent of patients were readmitted post-ERCP. Odds for 30-day readmission were highest for patients with a history of liver transplantation, age 0-4 years, male sex, and obesity ($P < .001$ for each). Patients in both urban teaching and urban hospitals had much lower odds than those in rural hospitals for prolonged length of stay associated with ERCP.

Conclusions These data represent a comprehensive study of nationwide trends in age-specific volumes and outcomes following ERCP in the pediatric population and provide important insights into trends in pediatric pancreaticobiliary disease management, as well as practice setting, patient characteristics, and patient comorbidities associated with pediatric post-ERCP outcomes, including readmission and length of stay. *(J Pediatr 2021;232:159-65)*.

See editorial, p 10

Endoscopic retrograde cholangiopancreatography (ERCP) has been well established as an endoscopic therapeutic modality for biliary and pancreatic disorders in the adult population and has been performed since the 1960s.[1-3] Up to 600 000 ERCPs are performed in the US annually.[4,5] The range of indications for the procedure has expanded, and utilization patterns have consequently shifted, with ERCP largely replacing high-risk biliary surgical interventions, such as bile duct exploration surgery, in adults.[4]

Experience with and utilization of ERCP in children and adolescents has historically been limited, owing to multiple factors. First, the incidence rates of diseases that are traditional indications for ERCP are comparatively lower in pediatric patients compared with adult patients. Second, there has been a lack of appropriate-sized duodenoscopes and accessories for infants and smaller children. The development of smaller-diameter duodenoscopes and accessories in the late 1980s contributed to the expanded use of ERCP in children; however, the impression that ERCP is technically challenging and risky in children has persisted, representing yet another factor that has limited its widespread utilization in pediatrics. Finally, the range of indications for ERCP, outcomes following ERCP, and safety of ERCP in children and adolescents have not been well defined.

Population-level studies of outcomes following ERCP in adults have defined the true risk associated with the procedure and highlighted opportunities for improved prevention of ERCP-associated adverse events, as well as detection and optimal management of these adverse events.[5] These all-capture studies have also investigated

ERCP	Endoscopic retrograde cholangiopancreatography
ICD-9-CM	*International Classification of Diseases, Ninth Revision, Clinical Modification*
LOS	Length of stay
MRCP	Magnetic resonance cholangiopancreatography
NIS	National Inpatient Sample
NRD	National Readmission Database
TCH	Total charge of hospitalization

From the [1]Division of Pediatric Gastroenterology, Hepatology, and Nutrition, Lucille Packard Children's Hospital at Stanford University Medical Center and [2]Division of Gastroenterology and Hepatology, Stanford University Medical Center, Stanford, CA

*Contributed equally.

The authors declare no conflicts of interest.

0022-3476/$ - see front matter.
https://doi.org/10.1016/j.jpeds.2020.11.019

endoscopist- and facility-level characteristics that are predictive of higher vs lower rates of unplanned healthcare encounters and adverse event rates following ERCP,[5,6] providing opportunities for education of patients and consideration of the optimal setting(s) in which adult ERCP should be performed.

Outcome studies of pediatric ERCP reported to date are largely single-center experiences and self-reported procedure outcomes in multicenter databases.[7-10] Pediatric ERCP differs from adult ERCP in both the most common indications for the procedure and patient/endoscopist characteristics. Nationwide practice patterns of pediatric ERCP are largely uncharacterized. We conducted the present all-capture population-level study of pediatric ERCP procedures performed in the US, free from endoscopist, single-center, or region-level bias, with the goal of evaluating the overall frequency with which ERCPs are performed for pediatric patients in the US and analyzing trends in utilization and outcomes over time.

Methods

We used data from the National Inpatient Sample (NIS) and the National Readmission Database (NRD), nationally representative databases developed by the Agency for Healthcare Research and Quality under the Healthcare Cost and Utilization Project, to study pediatric ERCP-related hospitalizations in the US.[11] Using the NIS, we identified all pediatric (age ≤20 years) hospitalizations during which ERCP procedures were performed in the US from 2005 through 2014. To assess readmissions related to ERCP procedures, we used the NRD from 2010 through 2014.

The NIS is the largest publicly available all-payer database of national hospital discharges in the US, containing a 20% stratified and weighted sample of US community and academic hospitals.[12] National hospitalization rates and outcomes can be reliably estimated using a pool of approximately 35 million discharges. The NIS contains deidentified medical information and other relevant details of each hospitalization, including patient demographic characteristics, admission details, comorbidities, discharge diagnoses, inpatient mortality, and cost of hospitalization. The NRD is drawn from the State Inpatient Databases from 27 states with reliable, verified patient linkage numbers to track patients across hospitals within the respective states. It accounts for 57.8% of the total US resident population and captures 56.6% of all US hospitalizations.[13] The NRD database does not contain information on whether sequential inpatient stays were related or unrelated, but it does provide information related to readmission analyses, including patient demographics, admission details with time between admissions, length of stay (LOS), discharge diagnoses, and cost of hospitalization. Because the datasets used in these analyses were deidentified, our study was deemed exempt by the Institutional Review Board at our institution.

International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure codes were used to identify hospitalizations during which diagnostic and therapeutic ERCP procedures were performed (**Table I**; available at www.jpeds.com). ICD-9-CM diagnostic codes were used to determine the primary cause for hospitalization, as well as comorbidities (eg, obesity, diabetes) and history of liver transplantation. Other patient and hospital characteristics studied included age, sex, race/ethnicity, hospital region, teaching status, elective procedure status, LOS, and total charge of hospitalization (TCH). TCH was adjusted for inflation in the year 2014.[14]

Statistical Analyses

Multivariate linear regression analyses were used to determine predictors for TCH and LOS. In the regression models for TCH and LOS, we standardized these variables so that a unit change was 1 SD of the mean TCH and LOS, respectively. Multivariate logistic regression was also used to analyze 30-day readmission (binary outcome). Using a stepwise variable-selection process, demographic and covariate predictors for TCH, LOS, and readmission were included in each separate multivariate regression models with the inclusion criteria set with a $P < .20$ on univariate analysis. Demographic data, including race/ethnicity, were included into the final model. All statistical analyses were performed using SAS 9.4 (SAS Institute).

Results

ERCP Volume and Characteristics over Time

Between 2005 and 2014, the NIS recorded 11 060 hospitalized pediatric patients who underwent ERCP. Patient and hospital characteristics are summarized in **Table II**. The annual number of procedures performed peaked in 2010 (n = 1224) and then steadily declined from 2011 through 2014. More than 90% of the pediatric patients had either Medicaid or private insurance; however, insurance type was not associated with odds of readmission.

Patient Profile

The majority of patients were female (n = 8859; 81%), aged 14-20 years (n = 9342; 84%), and white (n = 4230; 45%). Hispanics comprised more that one-third of the hospitalizations. Regionally within the US, the South and West accounted for nearly two-thirds of the ERCP procedures (n = 7072; 65%).

ERCP Procedural Details

Therapeutic ERCP accounted for 85% of the ERCP procedures performed during the study period. The leading indications for ERCP were gallbladder and biliary disease (n = 5350; 48%) and acute/chronic pancreatitis (n = 3218; 29%). The median number of hospital days before the ERCP procedure was 2 days (IQR, 1-3 days).

TCH and LOS

The median TCH for each patient undergoing ERCP was $34 856 (IQR, $22 454-$54 893). Factors associated with an

increased (SD) TCH are shown in Table III. Multivariate regression analysis identified increasing age as a significant predictor for TCH, particularly among those aged ≥14 years, who had nearly a 5-fold higher odds of increased TCH compared with patients aged ≤4 years (OR, 4.95; 95% CI, 2.88-5.41). Compared with males, females were more than twice as likely to have increased TCH (OR, 2.41; 95% CI, 1.95-3.00). Compared with the Northeast region of the US, the Midwest and South regions were associated with higher odds for increased TCH, and the West was associated with a lower odds for TCH. In addition, each advancing calendar year was associated with a 10% lower probability of TCH.

The median LOS for each patient undergoing ERCP was 4 days (IQR, 3-6 days) per ERCP. Factors associated with increased LOS are shown in Table IV. Similar to the findings for TCH, patients aged ≥14 years (OR, 4.88; 95% CI, 3.64-6.55) and females (OR, 2.34; 95% CI, 1.91-2.87) had the highest probability of increased LOS. Obesity (OR, 1.89; 95% CI, 1.24-2.97) was also associated with an increased odds of prolonged LOS. In contrast to the TCH model, each year was associated with a slight increase in LOS (OR, 1.05; 95% CI, 1.01-1.09). In the LOS model, both urban teaching hospitals and urban hospitals had a much lower odds than rural hospitals for prolonged LOS, with urban teaching hospitals having a 72% lower odds for LOS.

Post-ERCP Readmission

Between 2010 and 2014, a total of 5177 hospitalized pediatric patients (unweighted) underwent ERCP and were captured in the NRD, of whom 686 (13%) were readmitted within 30 days (Table V). Analysis of readmission diagnoses reveals that a substantial proportion of the patients who were readmitted were admitted with diagnoses consistent with ERCP-associated adverse events (eg, pancreatitis, bleeding, infection). Compared with females, males had a higher rate of readmission within 30 days (18% vs 12%; $P < .001$). Among the 4 age groups, those aged 5-9 years had the highest rate of readmissions within 30 days (31%; $P < .001$).

Table VI (available at www.jpeds.com) presents factors associated with 30-day readmission after the initial hospitalization for ERCP. In our multivariate regression analysis, history of liver transplantation (OR, 2.01; 95% CI, 1.79-2.25; $P < .001$), age 0-4 years (OR, 1.95; 95% CI, 1.93-1.97; $P < .001$), male sex (OR, 1.17; 95% CI, 1.16-1.18; $P < .001$), and obesity (OR, 1.10; 95% CI, 1.07-1.14; $P < .001$) were associated with increased odds for 30-day readmission after undergoing ERCP during initial hospitalization.

Table II. Clinical and demographic characteristics of pediatric patients hospitalized for ERCP in the US, from the NIS 2005-2014

Characteristics	Values
Total procedures	11 060
Sex, n (%)	
Males	2077 (18.99)
Females	8859 (81.01)
Age, y, n (%)	
0-4	494 (4.47)
5-9	472 (4.27)
10-13	752 (6.8)
≥14	9342 (84.47)
Race/ethnicity, n (%)	
White	4230 (44.66)
Black	1202 (12.69)
Hispanic	3323 (35.08)
Asian	163 (1.72)
Other	554 (5.85)
Procedure indication, n (%)	
Acute/chronic pancreatitis	3218 (29.10)
Gallbladder biliary tract disease	5350 (48.37)
Comorbidities, n (%)	
Obesity	1508 (13.63)
Diabetes	138 (1.25)
History of liver transplantation	62 (0.56)
ERCP urgency, n (%)	
Elective	1516 (13.73)
Emergent	9525 (86.27)
Type of ERCP, n (%)	
Therapeutic	9456 (85.49)
Diagnostic	1604 (14.51)
ED visit, n (%)	6019 (67.03)
Hospital region, n (%)	
Northeast	1713 (15.71)
Midwest	2117 (19.42)
South	3723 (34.15)
West	3349 (30.72)
Type of hospital, n (%)	
Rural	560 (5.09)
Urban	3772 (34.28)
Urban teaching	6673 (60.64)
TCH, $, median (IQR)	34 856 (22 454-54 893)
Hospital LOS, d, median (IQR)	4 (3-6)
In-hospital mortality, n (%)	12 (0.11)
Days to procedure, median (IQR)	2 (1-3)
Payer insurance type, n (%)	
Medicaid	5507 (49.79)
Private Insurance	4886 (44.18)
Self-pay	667 (6.03)
Year of procedure, n (%)	
2005	1009 (9.12)
2006	1072 (9.69)
2007	1037 (9.38)
2008	1227 (11.09)
2009	1255 (11.35)
2010	1224 (11.07)
2011	1178 (10.65)
2012	1039 (9.39)
2013	1034 (9.35)
2014	985 (8.91)

Discussion

ERCP is a complex and unique endoscopic procedure associated with the highest adverse event rate among endoscopic procedures. The adult gastroenterology literature underscores the importance of formal, rigorous endoscopic training and adequate ongoing annual procedure volume in maintaining competency to optimize success rates and minimize ERCP-associated adverse events.[6,15-19] This

Table III. Univariate and multivariate logistic regression analyses assessing for predictors for increased TCH for pediatric patients hospitalized for ERCP in the NIS database from 2005 to 2014

	Univariate		Multivariate	
Variables	**OR (95% CI)**	***P* value**	**OR (95% CI)**	***P* value**
Sex				
Male	Reference		Reference	
Female	3.65 (3.02-4.42)	<.0001	2.42 (1.95-3.00)	<.0001
Age				
0-4 y	Reference		Reference	
5-9 y	1.93 (1.30-2.86)	<.0001	2.01 (1.28-3.16)	.4006
10-13 y	3.11 (2.11-4.58)	.0716	3.41 (2.22-5.27)	.0045
≥14 y	5.91 (4.53-7.71)	.0575	4.95 (2.88-5.41)	<.0001
Race/ethnicity				
White	Reference		Reference	
Black	0.58 (0.44-0.76)	.0019	0.66 (0.49-0.88)	.9424
Hispanic	0.97 (0.78-1.22)	.5497	0.96 (0.74-1.23)	.9512
Asian	0.43 (0.25-0.74)	.0010	0.82 (0.46-1.49)	.9477
Procedure indication				
Acute/chronic pancreatitis	1.05 (0.82-1.28)	.5484	-	
Gallbladder/biliary tract disease	1.22 (0.93-1.49)	.6043	-	
Comorbidities				
Obesity	1.84 (1.31-2.59)	<.0001	1.49 (1.02-2.16)	.0377
Diabetes	0.38 (0.22-0.67)	.0007	0.45 (0.23-0.87)	.0167
History of liver transplantation	0.29 (0.14-0.62)	<.0001	0.75 (0.30-1.89)	.5392
ERCP urgency				
Elective	1.07 (0.81-1.41)	.6485	-	
Type of ERCP				
Therapeutic	1.04			
ED visit	1.35 (1.12-1.62)	.0017	1.09 (0.88-1.37)	.4362
Hospital region				
Northeast	Reference		Reference	
Midwest	1.47 (1.08-2.00)	.1522	1.23 (0.86-1.77)	.1426
South	1.64 (1.24-2.17)	.0023	1.36 (1.01-1.84)	.0026
West	1.11 (0.85-1.45)	.0633	0.70 (0.52-0.94)	<.0001
Type of hospital				
Rural	Reference		-	
Urban	0.55 (0.22-1.37)	.1546	-	
Urban teaching	0.14 (0.06-0.35)	.1522	-	
Year	0.88 (0.85-0.91)	<.0001	0.90 (0.86-0.94)	<.0001

depth of understanding of ERCP-associated adverse events has been derived largely from population-level data. Population-level data focused on ERCP outcomes and adverse events have been valuable in identifying the true rate of post-ERCP adverse events and characteristics associated with favorable and less desirable procedural outcomes in adults,[5,6] but similar studies have not been performed to examine pediatric ERCP practice patterns.

Pediatric ERCP has been performed since the mid-1970s, but at a much lower volume relative to the adult population owing to a variety of factors. The lower volume and more limited range of indications for pediatric ERCP has historically limited research focused on ERCP. Similarly, the smaller pediatric ERCP market share has limited pediatric-specific, size-appropriate ERCP device development, which in turn has limited the number of pediatric ERCPs performed. Outcome studies of pediatric ERCP reported to date are largely single-center experiences and self-reported procedure outcomes in multicenter databases.[7-10] The present study is a population-level study free from endoscopist, single-center, or region-level bias to provide a transparent view of nationwide pediatric ERCP practice patterns.

The range and distribution of indications for pediatric ERCP attest to the progressive rise in the prevalence of pediatric gallstone disease, with >48% of ERCPs performed for management of gallstone disease. The spectrum of pediatric biliary pathology has evolved over the past 2-3 decades.[15,20] Our data align with population-level studies and a North American pediatric endoscopy survey study demonstrating that the most common indication for ERCP in children is biliary obstruction resulting from choledocholithiasis.[21,22] Pediatric biliary pathology was previously rare and highly associated with congenital or hemolytic disorders; however, the incidence of pediatric gallstone disease has increased in parallel with the emerging pediatric obesity epidemic.[20,23] Recent estimates have indicated a prevalence of pediatric cholelithiasis as high as 4%,[20] and consequently, the prevalence of pediatric choledocholithiasis and need for pediatric ERCPs have increased as well.[22,24] The relatively high proportion of ERCPs performed in females is consistent with some recent reports of a female predominance of pediatric obesity, as well as an increased prevalence of gallstone disease in adolescents taking oral contraception.[25] Gallstone disease is most common in adult female patients, but the more diverse

Table IV. Univariate and multivariate linear regression analyses assessing for predictors for increased hospital LOS for pediatric patients hospitalized for ERCP in the NIS database from 2005 to 2014

	Univariate		Multivariate	
Variables	**OR (95% CI)**	***P* value**	**OR (95% CI)**	***P* value**
Sex				
Male	Reference		Reference	
Female	3.82 (3.21-4.56)	<.0001	2.34 (1.91-2.87)	<.0001
Age				
0-4 y	Reference		Reference	
5-9 y	1.85 (1.30-2.63)	.0148	1.91 (1.27-2.87)	.1961
10-13 y	2.73 (1.95-3.82)	.3168	2.85 (1.95-4.16)	.0611
≥14 y	7.11 (5.56-9.09)	<.0001	4.88 (3.64-6.55)	<.0001
Race/ethnicity				
White	Reference		Reference	
Black	0.54 (0.43-0.69)	<.0001	0.64 (0.50-0.83)	.0003
Hispanic	1.45 (1.15-1.82)	.0069	1.27 (0.99-1.61)	.7876
Asian	0.45 (0.27-0.76)	.0011	0.81 (0.46-1.43)	.0873
Procedure indication				
Acute/chronic pancreatitis	1.04 (0.74-1.32)	.6472	-	
Gallbladder/biliary tract disease	1.13 (0.95-1.31)	.4582	-	
Comorbidities				
Obesity	3.11 (2.10-4.60)	<.0001	1.89 (1.24-2.87)	.0030
Diabetes	0.54 (0.30-0.98)	.0414	0.50 (0.26-0.98)	.0422
History of liver transplantation	0.30 (0.15-0.61)	.0009	0.76 (0.33-1.74)	.5164
ERCP urgency				
Elective	0.94 (0.74-1.20)	.6216	-	
Type of ERCP				
Therapeutic ERCP	1.55 (1.25-1.93)	<.0001	1.06 (0.88 1.24)	.4562
ED visit	1.65 (1.39-1.97)	<.0001	1.01 (0.81-1.25)	.9460
Hospital region				
Northeast	Reference		Reference	
Midwest	117 (0.88-1.54)	.7457	-	
South	1.17 (0.91-1.29)	.6939	-	
West	1.52 (1.16-1.98)	.0024	-	
Type of hospital				
Rural	Reference			
Urban	0.73 (0.31-1.71)	.0068	0.85 (0.36-2.01)	.0631
Urban teaching	0.14 (0.06-0.32)	<.0001	0.28 (0.12-0.64)	<.0001
Year	1.07 (1.03-1.11)	<.0001	1.05 (1.01-1.09)	.0152

range of ERCP indications and the broad lifespan across which ERCP is performed in adults may account for the relatively lower proportion of ERCPs performed in adult females relative to the female predominance of pediatric ERCP.

We found an increased proportion of therapeutic compared with diagnostic ERCPs performed over the study period. Nonetheless, the rate of diagnostic ERCP is higher in the pediatric population compared with the adult population, perhaps reflecting underutilization of endoscopic ultrasound for pre-ERCP evaluation in pediatrics. Another contributing factor may be underutilization of diagnostic cross-sectional imaging modalities, such as magnetic resonance cholangiopancreatography (MRCP), in smaller pediatric patients. Limited studies have supported the value of MRCP for evaluation of pancreaticobiliary disease in children, and this modality has an emerging role in pediatric pancreas and biliary disorders.[26] However, interpretation of MRCP in children is associated with some limitations, including lower resolution for discerning ductal anatomy and abnormalities.[27] Additional studies to define pediatric-specific guidelines and recommendations for performance of ERCP could be highly beneficial in enhancing the uniformity of pediatric pancreaticobiliary endoscopic care.

Most children and adolescents in this study were hospitalized for 2 days before undergoing ERCP, with a cumulative median length of ERCP-associated hospitalization of 4 days. The median TCH for pediatric ERCP was $34 856, which is higher than the $20 022 reported median charge of ERCP-associated hospitalization for adult patients. In our multivariate analysis, children aged >14 years and females had prolonged hospital LOS relative to the other patients. Not surprisingly, the mean charges associated with these longer ERCP-associated hospitalizations were higher in children aged >14 years and female patients.

Following ERCP, just over 13% of patients were readmitted within 30 days of the procedure. Patient characteristics (ie, history of liver transplantation, obesity, age <4 years, and male sex) most significantly predicted an increased probability of 30-day readmission after undergoing ERCP during the initial hospitalization. Analysis of readmission diagnoses revealed that a substantial proportion of the patients readmitted were admitted with diagnoses consistent with ERCP-associated adverse events. Interestingly, older patients and females had a higher cost of hospitalization and longer LOS during their initial hospitalization, but these groups were less likely to be readmitted within 30 days after the

Table V. Clinical characteristics and demographic data of pediatric patients who had undergone ERCP during initial hospitalization and were readmitted within 30 days in the NRD, 2010-2014

	Pediatric ERCP readmissions, NRD 2010-2014	
Variables	**Hospitalizations**	**30-day readmissions, n (%)**
Total procedures	5177	686 (13.25)
Sex		
Male	1038	184 (17.72)
Female	4139	502 (12.12)
Age, y, n (%)		
0-4	133	34 (25.56)
5-9	141	44 (31.21)
10-13	287	48 (16.72)
≥14	4616	560 (12.13)
Obesity	956	94 (9.83)
Diabetes	66	17 (25.75)
Liver transplantation	8	3 (37.5)
ERCP urgency		
Elective	510	83 (16.27)
Emergent	4662	602 (12.91)
Type of ERCP		
Therapeutic	4444	607 (13.66)
Diagnostic	733	79 (10.78)
Payer insurance type		
Medicaid	2504	332 (13.26)
Private insurance	2391	280 (11.71)

The percentage of readmissions reported is calculated as the number of readmissions divided by the number of initial hospitalizations within each group.

ERCP. These data raise the question of whether a somewhat prolonged post-ERCP observation period may be advantageous and protective against future unplanned hospital readmission in the pediatric population.

A robust volume-outcomes relationship has been established for ERCP in the adult population, with endoscopists and facilities that have a higher annual ERCP volume exhibiting improved procedure-associated outcomes and lower rates of adverse events. We found that >60% of pediatric ERCPs are performed in urban teaching centers, ~34% are performed in urban centers, and ~5% are performed in rural settings. These 3 categories of practice settings for pediatric ERCP may be reasonably expected to correlate with facility volume, with urban teaching centers typically having the highest and rural centers having the lowest annual pediatric ERCP volume. Our regression analysis indicated that ERCPs performed in urban teaching centers and urban centers were associated with shorter duration of hospitalization relative to rural centers, consistent with the trend that would be predicted if a volume-outcomes relationship for pediatric ERCP exists and is similar to the relationship defined for adult ERCP.

Limitations of this study include inherent limitations of population-level administrative database studies and its focus on hospitalized patients. However, currently most pediatric ERCPs are performed on an inpatient basis. Owing to the low annual volume of pediatric ERCP procedures performed, national estimates on hospitalization could not be reliably ascertained. Due to specifics of inpatient hospital admission coding, our ability to accurately ascertain the indication for ERCP was limited for a subset of hospitalizations. Data on race or ethnicity were not captured in the NRD, and we were unable to assess the impact of race or ethnicity on readmissions. Because of inherent limitations of the NIS/NRD databases (data not available for all states) and ICD-9-CM diagnostic codes, and our desire to include comprehensive nationwide data in this initial pediatric study, we were unable to analyze facility or endoscopist characteristics predictive of post-ERCP adverse events. However, these limitations are balanced by the benefits of a national study and the ability to generalize these results to a larger population.

The present study represents a comprehensive assessment of the nationwide and regional trends in age-specific volumes and outcomes following ERCP in the pediatric population to date and provides insight into the evolution of ERCP volume and indications in children and adolescents over time, as well as patient characteristics and comorbidities predictive of post-ERCP readmission. These data may help shape pediatric ERCP practice and serve as a resource of data to share with patients and parents for risk stratification before the procedure. Further population-level studies of regional practices to ascertain the relationship between endoscopist and facility characteristics for pediatric ERCP would be of value for the pediatric endoscopy community. ■

Submitted for publication Aug 3, 2020; last revision received Oct 19, 2020; accepted Nov 10, 2020.

Reprint requests: William E. Berquist, MD, Professor, Department of Pediatrics, Division of Pediatric Gastroenterology, Hepatology & Nutrition, Stanford University Medical Center, 750 Welch Road, Suite 116, Stanford, CA 94305-5731. E-mail: berquist@stanford.edu

References

1. Adler DG, Baron TH, Davila RE, Egan J, Hirota WK, Leighton JA, et al. ASGE guideline: the role of ERCP in diseases of the biliary tract and the pancreas. Gastrointest Endosc 2005;62:1-8.
2. Cotton PB. Cannulation of the papilla of Vater by endoscopy and retrograde cholangiopancreatography (ERCP). Gut 1972;13:1014-25.
3. Cotton PB, Beales JS. The role of endoscopic retrograde cholangiopancreatography (ERCP) in patients with jaundice. Acta Gastroenterol Belg 1973;36:689-92.
4. Huang RJ, Thosani NC, Barakat MT, Choudhary A, Mithal A, Singh G, et al. Evolution in the utilization of biliary interventions in the United States: results of a nationwide longitudinal study from 1998 to 2013. Gastrointest Endosc 2017;86:319-26.e5.
5. Huang RJ, Barakat MT, Girotra M, Lee JS, Banerjee S. Unplanned hospital encounters following endoscopic retrograde cholangiopancreatography in 3 large North American States. Gastroenterology 2019;156:119-29.e3.
6. Varadarajulu S, Kilgore ML, Wilcox CM, Eloubeidi MA. Relationship among hospital ERCP volume, length of stay, and technical outcomes. Gastrointest Endosc 2006;64:338-47.
7. Yıldırım AE, Altun R, Ocal S, Kormaz M, Ozcay F, Selcuk H. The safety and efficacy of ERCP in the pediatric population with standard scopes: does size really matter? Springerplus 2016;5:128.
8. Giefer MJ, Kozarek RA. Technical outcomes and complications of pediatric ERCP. Surg Endosc 2015;29:3543-50.

9. Halvorson L, Halsey K, Darwin P, Goldberg E. The safety and efficacy of therapeutic ERCP in the pediatric population performed by adult gastroenterologists. Dig Dis Sci 2013;58:3611-9.
10. Issa H, Al-Haddad A, Al-Salem AH. Diagnostic and therapeutic ERCP in the pediatric age group. Pediatr Surg Int 2007;23:111-6.
11. Agency for Healthcare Research and Quality. Healthcare Cost and Utilization Project (HCUP). HCUP databases. Accessed January 10, 2020. https://www.hcup-us.ahrq.gov/nisoverview.jsp
12. Agency for Healthcare Research and Quality. Healthcare Cost and Utilization Project (HCUP). Overview of the nationwide readmissions database (NRD). Accessed April 28, 2020. https://www.hcup-us.ahrq.gov/nrdoverview.jsp
13. Agency for Healthcare Research and Quality. Healthcare Cost and Utilization Project (HCUP). Clinical classifications software (CCS) for ICD-10-CM/PCS. Accessed April 28, 2020. https://www.hcup-us.ahrq.gov/toolssoftware/ccs10/ccs10.jsp
14. US Bureau of Labor Statistics. CPI inflation calculator. Accessed December 20, 2019. https://www.bls.gov/data/inflation_calculator.htm
15. Moffatt DC, Coté GA, Avula H, Watkins JL, McHenry L, Sherman S, et al. Risk factors for ERCP-related complications in patients with pancreas divisum: a retrospective study. Gastrointest Endosc 2011;73:963-70.
16. Cotton PB. Are low-volume ERCPists a problem in the United States? A plea to examine and improve ERCP practice-NOW. Gastrointest Endosc 2011;74:161-6.
17. Disario JA. Hospital volume and ERCP outcomes: the writing is on the wall. Gastrointest Endosc 2006;64:348-50.
18. Kalaitzakis E, Toth E. Hospital volume status is related to technical failure and all-cause mortality following ERCP for benign disease. Dig Dis Sci 2015;60:1793-800.
19. Coté GA, Imler TD, Xu H, Teal E, French DD, Imperiale TF, et al. Lower provider volume is associated with higher failure rates for endoscopic retrograde cholangiopancreatography. Med Care 2013;51:1040-7.
20. Svensson J, Makin E. Gallstone disease in children. Semin Pediatr Surg 2012;21:255-65.
21. Kieling CO, Hallal C, Spessato CO, Ribeiro LM, Breyer H, Goldani HA, et al. Changing pattern of indications of endoscopic retrograde cholangiopancreatography in children and adolescents: a twelve-year experience. World J Pediatr 2015;11:154-9.
22. Barakat MT, Triadafilopoulos G, Berquist WE. Pediatric endoscopy practice patterns in the United States, Canada, and Mexico. J Pediatr Gastroenterol Nutr 2019;69:24-31.
23. Murphy PB, Vogt KN, Winick-Ng J, McClure JA, Welk B, Jones SA. The increasing incidence of gallbladder disease in children: a 20-year perspective. J Pediatr Surg 2016;51:748-52.
24. Hill SJ, Wulkan ML, Parker PM, Jones TK, Heiss KF, Clifton MS. Management of the pediatric patient with choledocholithiasis in an era of advanced minimally invasive techniques. J Laparoendosc Adv Surg Tech A 2014;24:38-42.
25. Koebnick C, Smith N, Black MH, Porter AH, Richie BA, Hudson S, et al. Pediatric obesity and gallstone disease. J Pediatr Gastroenterol Nutr 2012;55:328-33.
26. Arcement CM, Meza MP, Arumanla S, Towbin RB. MRCP in the evaluation of pancreaticobiliary disease in children. Pediatr Radiol 2001;31:92-7.
27. Li Y, Dillman JR, Anton CG, Crotty EJ, Smith EA, Abu-El-Haija M, et al. Secretin improves visualization of nondilated pancreatic ducts in children undergoing MRCP. AJR Am J Roentgenol 2020;214:917-22.

Table I. Procedure indication and readmission diagnosis codes

Indication	ICD-9-CM codes
Cholangitis	038, 576.1
Biliary stricture	576.2, 576.8
Gallstone disease	560.31, 574, 575
Pancreatic and hepatobiliary malignancy	155, 156, 157, 197.7, 235.3
Pancreatitis	577.0, 577.1
Pancreatic disease/pathology	211.6, 251.8, 251.9, 577.2, 577.8, 577.9, 751.7, 863.84
Abdominal symptoms	787.01, 787.02, 787.03, 787.99, 789, 793.4, 793.6
Abnormal laboratory studies	790.4, 790.5, 790.6, 794.8, 794.9
Sphincter of Oddi dysfunction	576.5

Table VI. Multivariate logistic regression analyses assessing for predictors of readmission for pediatric patients hospitalized for ERCP in the NIS database, 2005 to 2014

Variables	OR (95% CI)	*P* value
Sex		
Male	Reference	
Female	0.85 (0.84-0.86)	<.0001
Age group		
0-4 y	1.95 (1.93-1.97)	<.0001
5-9 y	1.13 (1.10-1.15)	<.0001
10-13 y	0.93 (0.91-0.98)	<.0001
≥14 y	Reference	
Obesity	1.10 (1.07-1.14)	<.0001
Diabetes	0.94 (0.91-0.98)	.0010
Liver transplantation	2.01 (1.79-2.25)	<.0001
ERCP urgency: elective	1.02 (1.00-1.03)	.0134
Type of ERCP: therapeutic	1.05 (0.89-1.14)	.9384
Year	1.01 (1.00-1.02)	.6282

Predictors with a univariate *P* value <.20 were included in the multivariate model.