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Pancreatic Surgery in Children: Complex, Safe, and Effective

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Objective: The aim of this study was to assess indications for and report outcomes of pancreatic surgery in pediatric patients.

Background: Indications for pancreatic surgery in children are rare and data on surgical outcomes after pediatric pancreatic surgery are scarce.

Methods: All children who underwent pancreatic surgery at a tertiary hospital specializing in pancreatic surgery between 2003 and 2022 were identified from a prospectively maintained database. Indications, surgical procedures, and perioperative as well as long-term outcomes were analyzed.

Results: In total, 73 children with a mean age of 12.8 years (range: 4 mo to 18 y) underwent pancreatic surgery during the observation period. Indications included chronic pancreatitis (n = 35), pancreatic tumors (n = 27), and pancreatic trauma (n = 11). Distal pancreatectomy was the most frequently performed procedure (n = 23), followed by pancreatoduodenectomy (n = 19), duodenum-preserving pancreatic head resection (n = 10), segmental pancreatic resection (n = 7), total pancreatectomy (n = 3), and others (n = 11). Postoperative morbidity occurred in 25 patients (34.2%), including 7 cases (9.6%) with major complications (Clavien-Dindo ≥ III). There was no postoperative (90-d) mortality. The 5-year overall survival was 90.5%. The 5-year event-free survival of patients with chronic pancreatitis was 85.7%, and 69.0% for patients with pancreatic tumors.

Conclusion: This is the largest single-center study on pediatric pancreatic surgery in a Western population. Pediatric pancreatic surgery can be performed safely. Centralization in pancreatic centers with high expertise in surgery of adult and pediatric patients is important as it both affords the benefits of pancreatic surgery experience and ensures that surgical management is adapted to the specific needs of children.

Keywords: Chronic pancreatitis, pediatric pancreatic surgery, pediatric surgery, pediatric pancreatic tumors, pancreatic trauma

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Indications for pancreatic surgery in children are diverse, complex, and rare,[1–5] ranging from neonates with uncontrollable hypoglycemia due to congenital hyperinsulinism and young children with chronic pancreatitis or traumatic pancreatic rupture, to adolescents with malignant pancreatic tumors.

Because of of the rarity of these procedures, evidence on indications and outcomes of pancreatic surgery in children is scarce, and data on ideal surgical management are limited by low caseloads in most centers.[6] Therefore, mostly small case series have been published thus far largely offering only snapshots of actual characteristics of this distinct patient population.[3,6–13] Previous evidence from these publications suggests that pancreatic surgery in children is associated with lower risks than in adult patients.[3,5,6,8,9] However, study results differ considerably, and complication rates vary from 15% to 60%.[5,8–10,14–16]

The aim of this study was therefore to analyze indications and outcomes of children undergoing pancreatic surgery in a high-volume pancreatic surgery center.

METHODS

This is a retrospective cohort study of all consecutive pediatric patients undergoing pancreatic surgery between January 1, 2003 and January 31, 2022, at the Department of General, Visceral, Transplantation, and Pediatric surgery at the Heidelberg University Hospital. The study is reported according to the strengthening the reporting of observational studies in epidemiology recommendations. The completed strengthening the reporting of observational studies in epidemiology checklist is provided as supplemental file with the submission of this article (Supplemental Digital Content 1, http://links.lww.com/SLA/E917). Pediatric patients were defined as those of 18 years of age or younger.[2,3,7,9,16–19] Data on all patients ≤ 18 years were extracted from our institutional, prospectively maintained pancreatic surgery registry. Approval for data collection and conduction of the present study was granted by the institutional review board of the Medical Faculty of the University of Heidelberg (S07/2013). Preoperative, intraoperative, and postoperative data were analyzed. Postoperative complications occurring within 90 days after surgery were classified according to the Clavien-Dindo classification.[20] Comprehensive Complication Index (CCI)[21] was also calculated. After discharge, patients were followed throughout the early postoperative period as well as long-term, according to the surgical department's protocol.[22] Pancreatic surgery was performed using standardized techniques that have been previously described.[23–27]

The following surgical procedures were carried out: distal pancreatectomy (DP),[28] pancreatoduodenectomy (PD),[27] duodenum-preserving pancreatic head resection (DPPHR),[25]

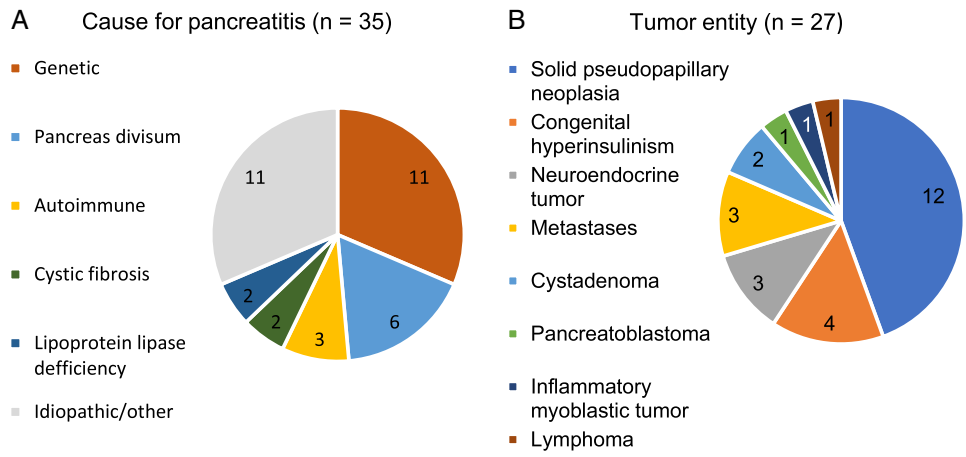

FIGURE 1. Underlying conditions for chronic pancreatitis (A) and types of pancreatic tumors (B).

segmental pancreatic resection/central pancreatectomy (SP),[26] total pancreatectomy (TP),[29] and drainage procedures with pancreato-intestinal anastomosis (DrainP).[30]

To standardize blood loss with respect to the circulating blood volume in children of different age groups and largely varying body weights, adjusted blood loss was calculated based on dividing the absolute intraoperative blood loss by the calculated circulating blood volume and expressed as percentage. The same strategy was followed to calculate intraoperative blood transfusion volume.[31,32] We used current definitions of postoperative pancreatic fistula (POPF), postpancreatectomy hemorrhage, and delayed gastric emptying (DGE).[33–35] The definition of DGE was adapted when applied to infants, with insufficient food intake defined as necessity of parenteral nutrition that has not been required before surgery.

For patients with chronic pancreatitis, event-free survival was calculated, and events were defined as recurrent episodes of pancreatitis. Disease-free survival was calculated for tumor patients, with the time from surgery until cancer recurrence defined as disease-free survival.

Statistical Analyses

Statistical analyses were performed using R (version 2022.07.2+576). Diagrams were compiled with either R or Microsoft Excel. For descriptive statistics, means with SDs were calculated for normally distributed data and medians with

TABLE 1. Patient Baseline Characteristics

	Study cohort, n = 73	Chronic pancreatitis, n = 35	Pancreatic tumor, n = 27	Pancreatic trauma, n = 11	*P*
Sex ratio (f:m)	43:30	18:17	18:9	7:4	0.532
Mean age (y) (SD)	12.8 (4.8)	12.5 (4.2)	13.3 (5.6)	12.6 (4.8)	0.278
Age range	4 mo–18 y	16 mo–18 y	4–18 y	4 mo–18 y	
Mean body weight (kg) (SD)	44.2 (18.4)	44.3 (17.6)	48.2 (15.1)	38.6 (15.8)	0.175
Comorbidity	17 (23.3%)	12 (34.3%)	1 (3.7%)	4 (36.4%)	0.009
ASA Score					
ASA I	11 (15.1%)	4 (11.4%)	6 (22.2%)	1 (9.1%)	0.335
ASA II	46 (63.0%)	26 (74.3%)	12 (44.4%)	8 (72.7%)	
ASA III	14 (19.2%)	4 (11.4%)	8 (29.6%)	2 (18.2%)	
ASA IV	2 (2.7%)	1 (2.9%)	1 (3.7%)	0	
Previous interventions					
Previous pancreatic surgery	16 (21.9%)	8 (22.9%)	5 (18.5%)	3 (27.3%)	0.969
Previous ERCP	17 (23.3%)	15 (42.9%)	0	2 (18.2%)	0.001
Preoperative biopsy	12 (16.4%)	1 (2.9%)	11 (40.7%)	0	< 0.001
Neoadjuvant chemotherapy	3 (4.1%)	0	3 (11.1%)	0	0.426
Preoperative imaging*					
CT	27 (37.0%)	9 (25.7%)	11 (40.7%)	7 (63.6%)	0.078
MRI	50 (68.5%)	27 (77.1%)	18 (66.7%)	5 (45.5%)	0.156
PET-CT	2 (2.7%)	0	2 (7.4%)	0	0.651
			Resection margin	AAST grade of pancreatic injury	
			R0: 24 (88.9%)	I:	
			R1: 3 (11.1%)	II:	
			Metastatic disease	III: 7 (63.6%)	
			6 (22.2%)	IV: 3 (27.3%)	
				V: 1 (9.1%)	

*Multiple in 1 patient possible.

ASA indicates American Society of Anesthesiologists; AAST, American Association for the Surgery of Trauma; ERCP, endoscopic retrograde cholangiopancreatography; SD, standard deviation.

TABLE 2. Details on Surgical Procedures

	Study cohort, n = 73
Type of surgery	
DP	23 (31.5%)
PD	19 (26.0%)
DPPHR	10 (13.7%)
SP	7 (9.6%)
TP	3 (4.1%)
DrainP	11 (15.1%)
Surgical team	
Adult and pediatric surgeons	43 (58.9%)
Adult surgeons only	24 (32.9%)
Pediatric surgeons only	6 (8.2%)
Open surgery	69 (94.5%)
Minimal invasive surgery	4 (5.5%)
Laparoscopic	3 (4.1%)
Robotic	1 (1.4%)
Splenectomy	15 (20.5%)
Venous resection with reconstruction	2 (2.7%)
Arterial resection with reconstruction	1 (1.4%)
Intraoperative drain placement	64 (87.6%)
Multivisceral resection	9 (12.3%)
Liver resection	4 (5.5%)
Hemicolectomy	2 (2.7%)
Peritonectomy	2 (2.7%)
Gastrectomy	1 (1.4%)
Adrenalectomy	1 (1.4%)
Mean operative time (min) (SD)	226 (110)
Median absolute blood loss* (mL) (IQR)	300 (500)
Median weight-adjusted blood loss (IQR)	13.5% (16.8)
Intraoperative transfusion of RPBC (n)	7 (9.6%)

*For the subgroup of patients ≥ 40 kg.

DP indicates distal pancreatectomy; DrainP, drainage procedure; DPPHR, duodenum-preserving pancreatic head resection; IQR, interquartile range; PD, pancreatoduodenectomy; RPBC, red packed blood cells; SD, standard deviation; SP, segmental/central pancreatectomy; TP, total pancreatectomy.

interquartile range (IQR) for non-normally distributed data. Categorical data values are given as absolute and relative frequencies. Univariate differences between groups were analyzed by using the Kruskal-Wallis test followed by the post hoc Bonferroni test, as needed. For categorial variables, subgroups were compared with the χ^2 test followed by the post hoc Fisher exact test, as needed. Logistic regression was applied to identify univariate risk factors for the occurrence of any postoperative complication as a binary endpoint. Forward selection was used to select risk factors for a multivariate logistic regression model. The Kaplan Meier method was applied for calculating overall and event-free survival. Significance of survival difference between subgroups was tested with a 2-sided log-rank test. The level of significance was set at 5% for all tests in an exploratory meaning.

RESULTS

Seventy-three pediatric patients with a mean age of 12.8 years (SD: 4.8; range, 4 mo to 18 y) underwent pancreatic surgery during the study period. Chronic pancreatitis was the most common indication (n = 35; 47.9%), followed by pancreatic tumors (n = 27; 37.0%). Genetic disposition for chronic pancreatitis (mutations in PRSS1, SPINK1, and/or CFTR) was found in 11 of 35 children (31.4%) with pancreatitis and was the most common underlying reason for the condition (Fig. 1). The most common tumor entity was solid pseudopapillary neoplasia (SPPN; 12 of 27 patients (44.4%); Fig. 1). Eleven children (15.1%) underwent surgery for pancreatic trauma. Although sex was equally distributed in the pancreatitis subgroup, tumors were more often observed in female patients (18 females vs. 9 males). Comorbidities were significantly more common in patients with pancreatitis compared with other subgroups. Table 1 shows baseline characteristics of the entire patient cohort.

DP was the most frequently performed procedure (n = 23), followed by PD (n = 19) and DPPHR (n = 10; Table 2; Fig. 2). Mean operative time was 3 hours and 46 minutes. Open surgery was performed via median (n = 61) or transverse (n = 8) laparotomy. There were 4 minimally-invasive procedures, including laparoscopic DP (n = 3) and robotic PD (n = 1). Most patients received abdominal drains at the end of the operation (n = 64; 87.6%). Table 2 provides a summary of intraoperative data. Figure 2 compares the 6 different procedure types performed.

There was no postoperative (90-d) mortality. Overall 90-day morbidity occurred in 25 patients (34.2%). POPF was observed in 5 patients (7.1%), of which 4 had undergone DP and 1 had undergone DrainP. DGE was diagnosed in 7 patients (9.6%). No postoperative hemorrhage occurred. Seven patients (9.6%) had major complications (Clavien-Dindo ≥ III), including grade C POPF (n = 2), grade C DGE (n = 2), and intra-abdominal abscess (n = 1). Both patients with grade C POPF received a CT-guided drain insertion after DP and treatment at ICU was required for 19 and 5 days, respectively. For one of these 2 patients with grade C POPF, additional endoscopic retrograde cholangiopancreatography with stenting of the pancreatic duct was performed. These patients recovered without further problems after a prolonged hospital stay. The 2 patients with grade C DGE (one after TP and one after PD) underwent endoscopic dilation of the pylorus or the gastroenterostomy, after which the symptoms resolved. The patient with intra-abdominal abscess had undergone DP. After insertion of a CT-guided drain, the patient recovered without further interventions. Furthermore, 2 patients had major complications necessitating early reoperation: 1 patient underwent surgical closure of bile leakage after DP with packing of the liver for traumatic pancreatic rupture and AAST grade IV liver injury due to blunt abdominal trauma. The second reoperation was required for infected subcutaneous hematoma at the midline incision after PD. Median length of stay in intensive care was 1 day (range, 0–19). Median length of hospital stay was 9 days (IQR 4.8). There were 4 readmissions to the hospital: due to emesis with insufficient oral food intake (n = 1), postoperative pancreatitis (n = 1), and intraabdominal fluid collection (n = 2). The mean CCI was 7.2 (range, 0–43.6). Table 3 shows specific details of the postoperative course.

Risk Factors for Postoperative Complications

To identify risk factors of postoperative morbidity, logistic regression was performed to analyze influence factors on the occurrence of any postoperative complication. In univariate analyses, higher ASA score and multivisceral resection were significantly associated with postoperative complications. The procedure type SP was associated with fewer complications when compared to the reference procedure (DP). After a forward selection procedure, age, procedure type, and multivisceral resection remained in the multivariate model. Age and multivisceral resection were significantly associated with postoperative complication occurrence, whereas SP was associated with lower complications rates compared with DP. Table 4 shows details of the univariate and multivariate analyses.

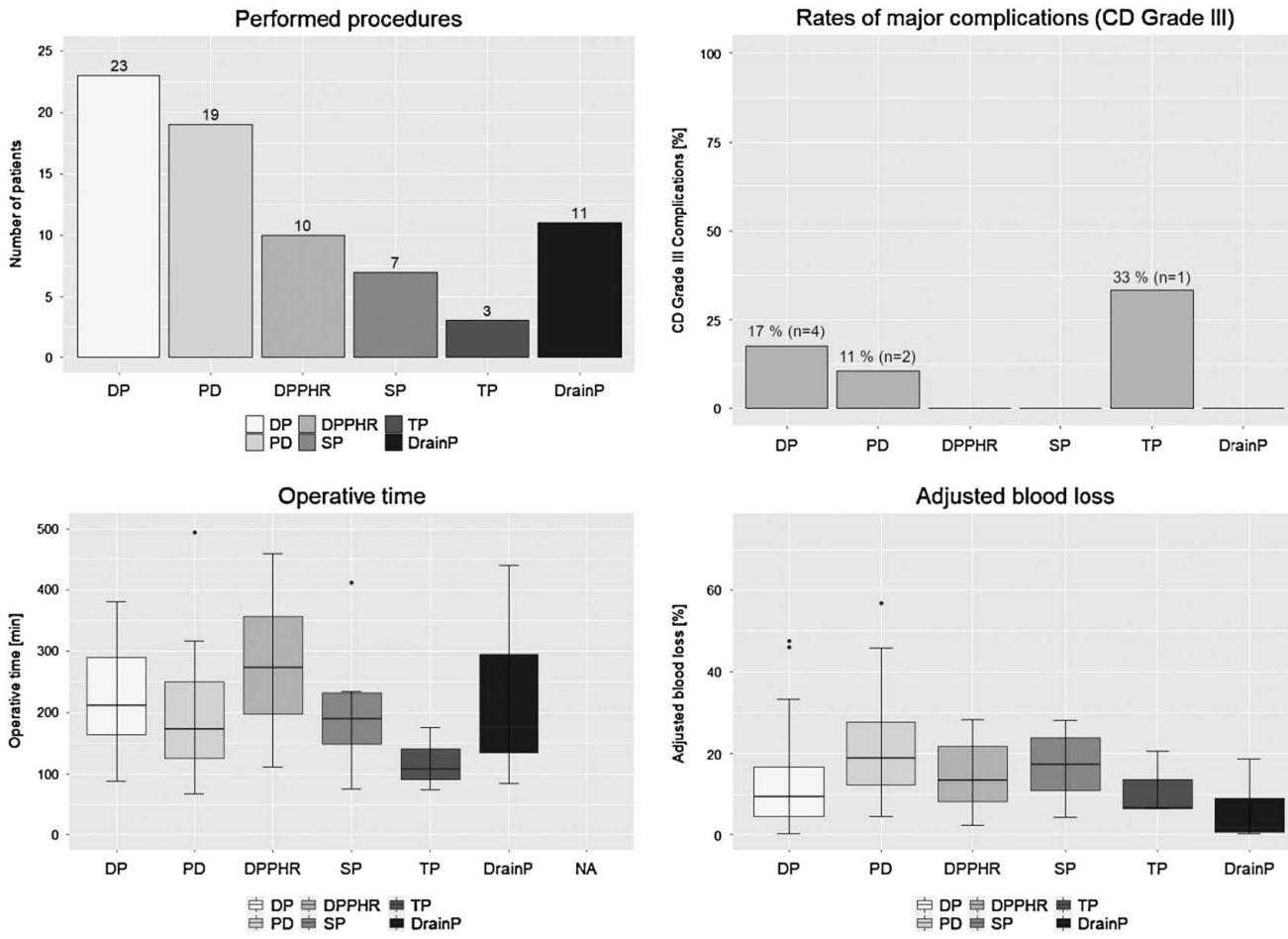

FIGURE 2. Numbers of all different procedure types performed (top left). Rates of major complications for each procedure type (top right). Box plots showing median operative times (bottom left) and median adjusted blood loss of different procedure types. CDC indicates Clavien-Dindo Classification; DP, distal pancreatectomy; DrainP, drainage procedure; DPPHR, duodenum-preserving pancreatic head resection; PD, pancreatoduodenectomy; SP, segmental/central pancreatectomy; TP, total pancreatectomy.

Follow-up With Long-term Outcomes

No surgery-related deaths occurred during the follow-up period. Median follow-up duration was 39 months (range, 3–203). Eleven patients (15.3%) were lost to follow-up. During the follow-up, 2 patients of the entire cohort required late pancreatic reoperations for a stenotic pancreaticojejunostomy after 10 and 24 months, respectively. Five of 35 patients (14.3%) with chronic pancreatitis had recurrent episodes of pancreatitis. Twenty-two of the 73 patients (30.1%) needed enzyme substitution therapy. Eight patients (11.0%) suffered from endocrine insufficiency and required insulin therapy. The 5-year event-free survival (EFS) of patients with pancreatitis was 85.7% (95% CI, 71.8–99.8). The overall survival (OS) of the entire study cohort at 2 years was 98.3% (95% CI, 95.0–100) and 90.5% (95% CI, 80.3–100) at 5 years (Fig. 3), respectively. The overall event-free survival for the entire cohort at 5 years was 81.1% (95% CI, 70.7–92.7).

No local recurrence was observed in any of the tumor patients. Six of the 27 tumor patients (22.2%) developed distant tumor metastases. Tumor entities of these 6 patients included pancreatoblastoma, pancreatic ductal adenocarcinoma, pancreatic neuroendocrine tumor, SPPN, and 2 sarcomas. Three of these 6 patients died during the observation period and 3 were in second remission. Twenty-four of the 27 tumor patients (88.9%) were alive at the time of the last follow-up. The 5-year estimated overall and disease-free survival of tumor patients was 75.0% and 69.0%, respectively (Fig. 3) (a table summarizing the follow-up data is provided in Supplemental Digital Content 2, http://links.lww.com/SLA/E917).

DISCUSSION

To our knowledge, this is the largest study on pancreatic surgery in children in a Western population. We show that pediatric pancreatic surgery is complex, effective, and safe. The whole spectrum of pancreatic surgery procedures, ranging from DP, PD, SP, DPPHR, and TP to DrainPs, is needed to adequately treat children with pancreatic disorders. The 5-year overall of 90.5% and the event-free survival of 81.1% were excellent, and there was no perioperative (90-d) mortality.

The complexity of pediatric pancreatic surgery is reflected by the wide spectrum of procedures required to appropriately treat our pediatric pancreatic patients. We classified pancreatic surgery in our cohort into 6 main procedure types, consisting of 23 DPs, 19 PDs, 10 DPPHRs, 7 SPs, 3 TPs, and 11 DrainPs. Our findings are in line with those of other series on pediatric pancreatic surgery, showing that a broad spectrum of pancreatic

TABLE 3. Postoperative Outcomes and Interventions

	Study cohort, n = 73
Median stay in intensive care (d) (IQR)	1 (1)
Median length of hospital stay (d) (IQR)	9 (4.8)
Overall postoperative 90-d morbidity	25 (34.2%)
90-d mortality	0
Readmission within 30 d after discharge	4 (5.5%)
Postoperative complications according to Clavien-Dindo Classification (CDC)	
CDC Grade I	10 (13.7%)
CDC Grade II	12 (16.4%)
CDC Grade III	7 (9.6%)
CDC Grade IV	0
CDC Grade V	0
Patients with any major complication (≥ CDC III)	7 (9.6%)
Postoperative pancreatic fistula (POPF)	
Grade B	3 (4.3%)*
Grade C	2 (2.9%)*
Delayed gastric emptying (DGE)	
Grade A	5 (6.8%)
Grade B	0
Grade C	2 (2.7%)
Postpancreatectomy hemorrhage (Grade A/B/C)	0
Chyle leak Grade A	2 (2.7%)
Postoperative interventions	
CT-guided drain insertion	4 (5.5%)
Endoscopy (+- papillotomy/stent)	3 (4.1%)
Early Reoperation (≤ 90 d postoperatively)	2 (2.7%)
Mean Comprehensive Complication Index (CCI)	7.2 (range 0–43.6, IQR 9)

*Rates refer to 70 patients, the 3 patients with TP were excluded.
IQR indicates interquartile range; TP, total pancreatectomy.

procedures is necessary to adequately treat children with pancreatic disorders.[2,3,6,36] For example, Casamassima et al[36], reporting on 21 pediatric patients with chronic pancreatitis, performed 4 longitudinal pancreatojejunostomies, 9 TPs, 2 TPs with islet autotransplantation, 2 sphincteroplasties, and 3 DrainPs. Analyzing their experience with pediatric pancreatic tumors, the same group reported 5 different procedures in 19 children, including 11 DPs, 4 PDs, 2 subtotal pancreatectomies, 1 SP, and 1 enucleation.[6]

Surgical treatment of pancreatic disorders was effective in our cohort, as mirrored by the high success rates of all 3 indication groups, also when compared to those of adult populations.[37–40] Lasting symptom relief was achieved in 30 of 35 patients (85.7%) with chronic pancreatitis, and only 11% of all patients (n = 8) developed new-onset diabetes during the follow-up period. Casamassima et al[36] reported on 20 children with pancreatitis undergoing surgery. They achieved symptom relief in 63%, TP was performed in 11 children (55%), and 70% were insulin dependent at last follow-up. Chinnakotla et al analyzed their experience with TP and islet autotransplantation in a cohort of 75 patients that included both children and young adults. Although postoperative morbidity was remarkably low and pain control was achieved in 80%, 63% of these patients were insulin dependent at the time of last follow-up, and 3 deaths occurred during the observation period.[41]

In our experience, TP can often be avoided while still achieving high rates of long-lasting symptom relief with targeted resections or drainage procedures.

We also demonstrated the efficacy of pancreatic surgery in children with pancreatic tumors, where no local recurrence was observed. Distant recurrences occurred in only 22.2%, and 24 of 27 patients (88.9%) were alive at the time of last follow-up. Considering that the 27 tumor operations in our cohort included 30% (n = 8) multivisceral and 7% (n = 2) vascular resections due to advanced disease, the efficacy of these procedures is further underlined. Rates of local and distant recurrence in the literature vary substantially, mainly due to the high heterogeneity of pediatric pancreatic tumors and consequently large variations among study populations. Lindholm et al[9] reported a recurrence rate of 58% and survival of 42% in pediatric patients undergoing pancreatic tumor surgery at Memorial Sloan-Kettering. Other studies reported rates of relapse between 7% and 24%.[5,6,11,18,42] Accordingly, absolute OS differed between 76% and 92% in these studies.[5,6,11,18] Complete resection rates (R0 resections) varied between 64% and 82% in previous case series on pancreatic surgery for tumors in children,[11,18,42] compared with 89% in our cohort. Focusing exclusively on SPPN, the most common pancreatic tumor in the pediatric population, distant relapse was observed in 1 of 12 patients (8.3%) in our cohort. This is in line with the rates reported by other studies on children undergoing surgery for SPPN. Reported recurrence rates range from 4% to 14%, with most studies reporting rates between 8% and 9%.[12,43–46]

In our 73 patients, there was no postoperative mortality. This is remarkable, given the broad spectrum of procedures performed, including all complex pancreatic operations, and even multivisceral and vascular resections. Whether or not the generally good condition of children with fewer comorbidities and better wound healing is responsible for these favorable perioperative outcomes remains unclear. Depending on the patient population investigated and the case volume of the centers, mortality rates in pancreatic surgery of adults vary between 3% and 10%.[38,47,48] Indeed, there seems to be a tendency toward lower perioperative mortality rates in previous series of pediatric pancreatic surgery compared with surgery in adult patients. Although most series reported mortality rates below 2%,[2,3,5,6,8–10,18,36] there is considerable heterogeneity in the literature, and mortality rates of up to 11% have been reported in children undergoing pancreatic surgery.[19] Rabinovich et al[2] reported a 2% mortality rate in a pediatric cohort undergoing pancreatic surgery for pancreatitis, tumor, or trauma. In a study on surgical management of pancreatic trauma in children at level 1 trauma centers in the United States, Mattix et al[49] reported a postoperative mortality rate of 8%. Yu et al[19] analyzed their experience with pancreatic tumor surgery in children at a pediatric center and reported a postoperative mortality rate of 11%. In summary, reported mortality rates of pancreatic surgery in children differ widely and are hardly comparable, as most studies comprise low case numbers,[6,8,12,42] included only select patients or procedure types,[9,10,13] or did not specifically report postoperative mortality.[14]

The overall morbidity in our cohort was 34.2% and the rate of major complications was 9.6%. These rates compare favorably with those reported in most larger studies of children undergoing pancreatic surgery. Jones et al[3] reported an overall morbidity of 40% in their institutional experience with pediatric pancreatic surgery for various indications in 46 children over a 19-year period. In a recent study from South Korea by Kwon et al[16], 28 children with SPPN underwent DP, with a postoperative morbidity rate of 57%, and major complications in 11%. Rabinovich et al[2] reported an overall morbidity rate of 33% in 62 children undergoing various types of pancreatic surgery performed by an interdisciplinary team of hepato-pancreato-biliary (HPB) surgeons for adult patients and pediatric surgeons. However, the

TABLE 4. Univariate and Multivariate Regression Analyses of Risk Factors for Postoperative Complications

Study cohort, n = 73

Dependent variable: occurrence of any postoperative complication

	Univariate		Multivariate	
Factors	**OR (95% CI)**	***P***	**OR (95% CI)**	***P***
Age	0.93 (0.84–1.02)	0.137	0.86 (0.75–0.98)	0.022
Procedure type (reference: DP)				
PD	1.16 (0.35–3.88)	0.804	0.79 (0.20–2.95)	0.725
DPPHR	0.20 (0.02–1.11)	0.067	0.22 (0.02–1.33)	0.103
SP	0.09 (0.01–0.85)	0.033	0.06 (0.01–0.70)	0.021
TP	9.00 (0.75–1262.13)	0.088	4.16 (0.23–632.98)	0.355
DrainP	0.34 (0.06–1.54)	0.166	0.24 (0.03–1.34)	0.108
Multivisceral resection	8.94 (1.95–64.01)	0.010	8.21 (1.71–53.46)	0.007
ASA (reference: ASA II)				
ASA I	1.85 (0.45–7.03)	0.376		
ASA III	4.04 (1.21–14.24)	0.023		
ASA IV	15.43 (1.15–2181.03)	0.038		
Comorbidity	2.04 (0.66–6.25)	0.208		
Indication group (reference: tumor)				
Pancreatitis	0.37 (0.12–1.07)	0.071		
Trauma	0.40 (0.08–1.74)	0.244		
Previous ERCP	1.33 (0.43–4.68)	0.632		
Previous pancreatic surgery	1.20 (0.36–3.75)	0.756		
Operation time	1.00 (0.99–1.00)	0.176		
Adjusted blood loss	1.03 (1.00–1.06)	0.081		
Vascular resection	1.96 (0.08–50.99)	0.640		
Splenectomy	0.36 (0.11–1.16)	0.087		
Intraoperative abdominal drain placed	1.64 (0.37–6.84)	0.494		

ASA indicates American Society of Anesthesiologists; CI, confidence interval; DP, distal pancreatectomy; DrainP, drainage procedure; DPPHR, duodenum-preserving pancreatic head resection; ERCP, endoscopic retrograde cholangiopancreatography; OR, odds ratio; PD, pancreatoduodenectomy; SP, segmental/central pancreatectomy; TP, total pancreatectomy.

percentage of high-risk procedures was lower in this cohort, with no multivisceral or vascular resections reported, and only 11% PD/TP compared with 30% in our cohort. Recent Chinese studies on pediatric pancreatic surgery reported overall complication rates of 51% and 54%.[14,15] In other studies, data on postoperative complications were often incompletely reported, and only major or selected complications were mentioned.[5,6,8,9,11,36]

POPF is among the most feared complications in pancreatic surgery.[33,50] Despite extensive research in pancreatic surgery of adults, it remains one of the major problems of these procedures and may cause life-threating sepsis or erosional bleeding. In our cohort, POPF occurred in 7% (n = 5) of all patients, and in 17% (n = 4) after DP. Remarkably, no POPF after PD, DPPHR, and SP was observed. Rates of POPF in pancreatic surgery of adult patients in our department and other

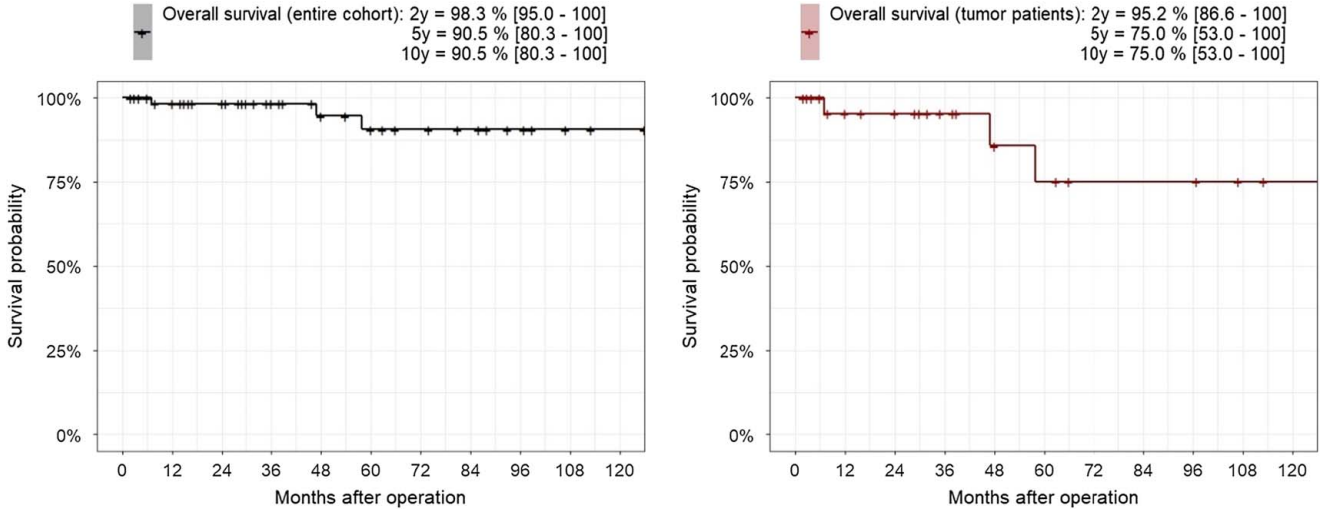

FIGURE 3. Overall survival of the entire cohort (left) and of the subgroup of tumor patients (right). Numbers in square brackets indicate 95% confidence intervals.

high-volume centers are usually higher and range from 10% to 30%.[51–54] On the one hand, this finding may be surprising, as the texture of pancreatic tissue in children is particularly soft and duct size is smaller, both factors that have been shown to be associated with higher risk of POPF in adults.[53,55,56] On the other hand, metabolic risk factors such as overweight and diabetes are less frequent in pediatric populations, which may partly explain the better outcomes of pancreatic surgery in children. Further studies are needed to investigate rates and risk factors of POPF in children.

Interestingly, there are purely pediatric centers that reported pancreatic surgery caseloads of less than 1 patient per year.[9,10,13,19] Under these circumstances, it seems to be problematic to acquire the expertise necessary to choose the best suited individualized procedures and to safely perform pancreatic operations in children in such low-volume institutions. In contrast, at our center 3.8 pediatric patients underwent pancreatic surgery each year. Furthermore, our institution performs more than 600 pancreatic operations in adults per year. We believe that these rare operations in children should therefore be centralized at specialized centers with high-volumes of adult (and pediatric) pancreatic surgery. In addition, close cooperation between HPB surgeons for adult patients and pediatric surgeons is mandatory to provide the best possible care and to ensure the best perioperative management tailored to the special needs of children. In our center, children with diseases of the pancreas are routinely evaluated in an interdisciplinary pancreas board, including HPB surgeons for adult patients and pediatric surgeons. The children that were decided to undergo surgery were operated in the operating rooms of the pancreatic surgery center for adult patients. Postoperatively, all children under 14 years of age were transferred to the pediatric surgery department. Neonates with congenital hyperinsulinism were treated at the neonatal intensive care unit. The older children stayed in the pancreatic center for adult patients after surgery. Using this approach and by taking advantage of the expertise at a high-volume pancreatic surgery center, pediatric pancreatic surgery can be performed safely, with virtually no mortality and low morbidity.

Limitations of this study include the retrospective study design. Children with different underlying diseases undergoing different procedures were included in the present analysis, making comparison and interpretation of outcomes more complex. Strengths of this study are the comparatively large sample size of children undergoing otherwise rare procedures.

CONCLUSION

This study reports the largest single-center series of children undergoing pancreatic surgery in a Western population. Pediatric pancreatic surgery demands a high level of experience. Therefore, centralization at specialized pancreatic centers with experts highly experienced in adult pancreatic surgery as well as pediatric surgical management should be aimed for. When these conditions are fulfilled, pancreatic surgery can be safely performed in children and achieves high success rates regarding pancreatitis symptom relief as well as long-term survival after tumor resection.

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