



Minimally invasive surgery of the pancreas: a narrative review of current practice

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Abstract: Minimally invasive surgery has moved from the fringe of pediatric surgery to the mainstream to address a variety of problems. Pancreatic pathology, though uncommon and complex, is frequently amenable to laparoscopic intervention. Indications for pediatric pancreatic operative intervention includes trauma, congenital hyperinsulinemia and neoplasm. Children may require distal pancreatectomy, subtotal pancreatectomy, enucleation, lateral pancreaticojejunostomy and pancreaticoduodenectomy. Of these operations, all but pancreaticoduodenectomy have been successfully described in children using a minimally invasive approach. Traumatic transection of the main pancreatic duct may require operative intervention if endoscopic techniques are unsuccessful. Distal pancreatectomy has been successfully utilized in this circumstance. Additionally, near total pancreatectomy may also be performed laparoscopically although successful reports are limited. Enucleation, especially with the use of intraoperative ultrasound may avoid a large laparotomy for isolated benign masses. Finally, chronic pancreatitis resulting in a dilated main pancreatic duct may benefit from a lateral pancreaticojejunostomy. This operation has also successfully been performed in children. Included is a review of pediatric pancreatic minimally invasive operations paired with corresponding pathology.

Keywords: Pancreas surgery; pancreas injuries; pancreas abnormalities

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Background

Minimally invasive surgery for children with pancreatic pathology is a topic that is covered sporadically in the literature, with most information limited to case reports or case series. Newer trials evaluating strategies for management aim to capture the relatively small volume of patients with these issues by capitalizing on multi-institutional data sets. The information may be organized by specific pathology or by the type of operation used to ameliorate the problem. Herein we limit the discussion to the pathology most amenable to laparoscopy: distal pancreatectomy, subtotal pancreatectomy, enucleation and

lateral pancreaticojejunostomy. The intent of this manuscript is to give the reader an overview of the newest information available for a minimally invasive approach to the pancreas. We present the following article in accordance with the Narrative Review reporting checklist (available at <http://dx.doi.org/10.21037/tgh-20-220>).

Methods

We conducted a literature search on PubMed using the terms “minimally invasive surgery pancreas,” “pancreaticojejunostomy,” “Puestow,” “solid pseudopapillary

tumor,” “pancreatic trauma,” and “hyperinsulinism” We included all manuscripts written in English spanning the time period between 1995 and 2020. Papers specific to children were selected for review.

Distal pancreatectomy

The minimally invasive distal pancreatectomy may be utilized in a number of clinical scenarios in the pediatric population including trauma, neoplasms and focal hyperinsulinism limited to the distal gland.

Traumatic pancreatic injury

In cases of traumatic transection of the main pancreatic duct following blunt injury, laparoscopic intervention may be utilized in the stable patient. Diagnosis of pancreatic injuries is typically a combination of cross-sectional imaging (MRI or CT) and endoscopic retrograde cholangiopancreatography (ERCP) or magnetic resonance cholangiopancreatography (MRCP). Pancreatic stents may be possible in transection of the mid-body of the pancreas, but more distal injuries are not well-suited to this intervention. These patients may recover faster following a definitive resection than with multiple failed interventions and pseudocyst formation. ERCP with stent placement that fails to traverse the point of ductal injury can lead to a functional island of pancreatic tissue distal to the transection. Further intervention such as distal pancreatectomy or cyst-gastrostomy may be indicated if the patient is symptomatic. Cyst-gastrostomy can be performed using endoscopic or laparoscopic techniques depending on the anatomic location of the cyst (1). Though non-operative management of solid organ injury is standard of care; the challenge is determining characteristics that predict failure of non-operative management. Major ductal disruption is particularly controversial. In their retrospective analysis of blunt pancreatic injuries treated at seven designated level 1 pediatric trauma centers in the US, Mattix *et al.* found that failure of non-operative management was significantly higher among patients with an injury grade III to V (2). Additionally, among patients with ductal injuries, those who failed non-operative management had significantly higher injury severity scores (2). The study was not sufficiently powered to detect a difference in recovery time between the two groups (2).

Non-operative management of pancreatic injuries in children is not without risk. In a series of 100 pediatric

patients with pancreatic injury, 42% developed organized fluid collections, over half of which ultimately required intervention (3). Another review of operative versus non-operative management of pancreatic injury in children demonstrated a significantly higher proportion of patients with pseudocyst formation in those with the non-operative approach (4). Eleven percent of patients who had a distal pancreatectomy developed a leak, however all were controlled with the surgical drain placed at the initial operation (4). The laparoscopic approach to pediatric pancreatic injury appears to be safe. When comparing minimally invasive intervention to the open approach among 21 patients treated at six level 1 pediatric trauma centers, Iqbal *et al.* concluded that there was no difference in operative time, duration of hospital stay, or post-operative morbidity (4).

In contrast to adults, pediatric patients may be less likely to have associated intra-abdominal injuries (5). The increased frequency of isolated pancreatic injury in pediatric patients may relate to the difference in etiology. Children more frequently present after bicycle crashes whereas injuries in adults are more often a result of motor vehicle crashes (5). These isolated injuries lend themselves to minimally invasive surgical interventions. In a review of 200 pediatric patients with pancreatic injuries, the minimally invasive approach was shown to be a good diagnostic tool for patients with equivocal exam or imaging findings (6). Access to the abdomen is via the umbilicus and additional ports are oriented as for a splenectomy, since access to the splenic hilum is paramount to splenic preservation (*Figure 1*). Once the lesser sac is opened and the stomach retracted, key decision points include the method of taking the feeding venules between the posterior pancreas and splenic vein, the method of sealing the transected edge of the pancreas (stapler *vs.* sutures), whether to use of fibrin glue sealant and whether to leave a drain. The method of sealing the transected edge does not appear to influence the formation of postoperative pancreatic fistulas (7).

Neoplasia

Solid pseudopapillary neoplasm

In 2003 a group in France reported on a laparoscopic spleen preserving distal pancreatectomy for a solid pseudopapillary neoplasm (Frantz’s tumor). The report highlights the fact that this was felt to be cutting edge for the time, stating, “Although the role of laparoscopy in surgery of the pancreas is still controversial” it can still “be done safely, within a

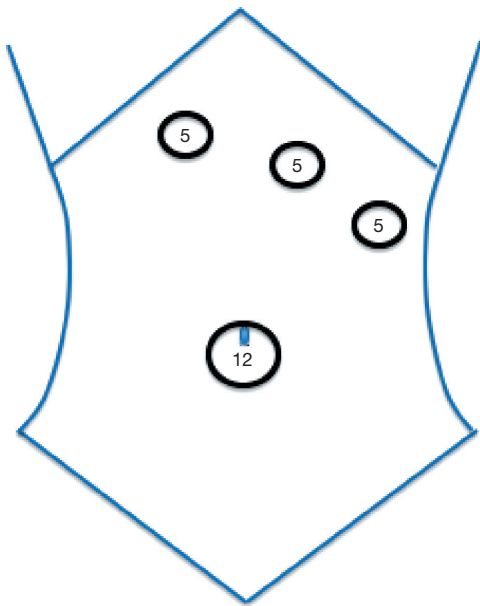


Figure 1 Port placement for laparoscopic distal pancreatectomy, with trocar size designated in each circle.

reasonable operative time, in children.” (8). Since then, there have been a number of case reports describing the success of this technique for pediatric patients with solid pseudopapillary neoplasms (9-14). There has also been a report of a successfully completed robotic-assisted, spleen-preserving, distal pancreatectomy for solid pseudopapillary neoplasm in a child (15). Technical details highlighted from these case series include using a split leg table for larger patients, creating a wide window through the gastrocolic ligament with elevation of the stomach, and dissection along the inferior border of the pancreas to expose the splenic vessels (9,16). Transection of the pancreas may be performed using an endoscopic linear stapler. If the lesion is located more proximally in the gland the pancreas may be divided with mono- and bipolar cautery, then over sewn with 5-0 PDS suture to accommodate for the thickness of the gland (11).

Pancreatic neuroendocrine tumor (pNET)

Insulinomas are the most common functional pNET causing hypoglycemia (17). Most are sporadic, solitary and benign. These factors make them favorable for the minimally invasive approach since they are amenable to parenchyma-sparing techniques such as enucleation (17). An important caveat to this is in the case of multiple endocrine

neoplasia type 1 where multifocal disease is more common, oftentimes requiring distal pancreatectomy. Su *et al.* performed a systematic review of adult patients undergoing laparoscopic versus open pancreatectomy for insulinomas and found that there was no statistically significant difference between the groups with regard to post-operative morbidity including pancreatic fistula, abscess formation, post-operative hemorrhage and reoperation (18). In this subset of patients post-operative development of diabetes mellitus is significant ranging from 12–56% (19). There is a paucity of data detailing the incidence of post-operative diabetes in children following distal pancreatectomy.

Splenic preservation

It is well known that the spleen plays an important role in immunologic function, especially in children. Therefore, with the advancement of minimally invasive techniques for distal pancreatic resection, ensuring splenic preservation is of paramount importance. The magnification imparted by the minimally invasive technique may aid in dissection of the splenic artery and vein off of the pancreatic parenchyma, however this remains a technically challenging component of the procedure. Strategies aimed at assisting in splenic preservation include straightening the splenic artery and vein to improve visualization during the dissection (20). Additionally, early identification of the vessels and medial to lateral dissection may be of benefit (14).

Subtotal pancreatectomy

Hyperinsulinism

Subtotal pancreatectomy is primarily reserved for cases of congenital hyperinsulinemia. Without appropriate treatment, congenital hyperinsulinemia causes persistent hypoglycemia that can lead to irreversible neurologic damage. While clinically identical, congenital hyperinsulinemia may manifest as diffuse or focal disease, which significantly changes the operative approach. Focal lesions amenable to treatment with partial pancreatectomy may be determined using a combination of genetic testing and 18-fluorodopa PET/CT imaging. The most robust report of surgical intervention for congenital hyperinsulinemia was of 500 patients who underwent pancreatectomy at Children’s Hospital of Philadelphia in 2019 (21). However, all of these operations were performed using the open approach. As early as 2001, Blakely reported use of a laparoscopic

approach to the initial operation for hyperinsulinism (22). The operation, as described, is likely a 75% resection and proved inadequate due to continued hypoglycemia. However, at laparotomy 1 week later no adhesions were found and the completion pancreatectomy feasible (22). There have been a number of additional descriptions of the laparoscopic approach to near total pancreatectomy (23-25). Pierro *et al.* describes the laparoscopic technique for subtotal pancreatectomy in children with congenital hyperinsulinemia. Technical pearls include the use of a Nathanson retractor to elevate the stomach, a stay suture in the tail of the pancreas to assist with medial retraction and the use of a 3-mm hook cautery on high coagulation settings to divide the short vessels between the splenic vessels and the pancreas (26). The tail of the pancreas is first removed and sent for frozen section pathological review to confirm the diagnosis prior to proceeding with the remaining resection. Once confirmed, the head and uncinate process are removed leaving a rim of pancreatic parenchyma near the medial border of the duodenum preserving the common bile duct (26).

Enucleation

Enucleation of solitary, benign tumors may reduce the morbidity associated with more extensive pancreatic resections. This technique may be applied with cases of focal hyperinsulinemia, pNETs and small benign lesions that are remote from the main pancreatic duct (17,27). These tumors must be superficial, size less than 2 cm and at least 2 mm from the main pancreatic duct (28). This technique may shorten operative time, decrease blood loss and reduce post-operative pancreatic insufficiency, though robust data regarding these outcomes in children is currently lacking (28). Intraoperative ultrasound is helpful to delineate the relationship between the mass and vascular structures such as the portal vein and superior mesenteric vessels (29).

Lateral pancreaticojejunostomy (Puestow)

Pancreas divisum

One of the most common anatomical variants that leads to recurrent, chronic pancreatitis is pancreas divisum. This occurs when there is incomplete fusion of the dorsal and ventral anlage of the pancreas during fetal development.

The result is drainage of the two regions independently into the duodenum. Common features in pancreas divisum include stenosis (typically at the ampulla, but potentially at any branch point within the ductal system) and ectasia. This problem should be considered in any child who has a repeat bout of pancreatitis with no evidence of gallstone disease, though the diagnosis is elusive and not a top contender for consideration in most children with abdominal pain. Neblett *et al.* describe a single institution series of 130 children with acute, chronic, or relapsing pancreatitis (30). Of these, only 10 were attributed to pancreas divisum. The infrequency of the problem makes diagnosis and comprehensive study difficult. In their study, the average time between onset of symptoms and diagnostic ERCP was almost 6 years (30).

Diagnosis of pancreas divisum is secured with MRCP or ERCP, with the advantage of ERCP being the potential for a definitive, curative procedure performed concurrently. Treatment should be performed in a stepwise fashion, starting with the minimal intervention needed to achieve relief. This typically comes in the form of a sphincterotomy and stenting of the minor papilla, performed by an interventional gastroenterologist during ERCP. Re-stenosis of the minor papilla after removal of the stent is frequent; however, resolution of symptoms following stenting can be regarded as a predictor of success with surgical sphincteroplasty (31). If the minor papilla cannot be cannulated, a surgical sphincteroplasty can be performed. No descriptions of this procedure performed laparoscopically in children exist in the literature to date, likely because of the technical difficulty required to open the duodenum, isolate the papilla, and perform an effective sphincteroplasty. Finally, for patients with failed attempt or no improvement after sphincterotomy or sphincteroplasty, longitudinal pancreaticojejunostomy (Puestow procedure) may prove useful (32).

Description of longitudinal pancreaticojejunostomy using a minimally invasive approach in pediatric patients is limited. The first report in a child was in 2011 by Meehan *et al.* using a robotic technique (33). Later, in 2012, Zhang *et al.* described four pediatric patients who successfully underwent laparoscopic side-to-side Roux-Y pancreaticojejunostomy (34). Among the four patients, none had a pancreatic leak, pancreatitis or anastomotic stricture and the length of stay ranged from 4–6 days. Most recently, in 2018 Shah *et al.* reported two cases of laparoscopic pancreaticojejunostomy for chronic pancreatitis (35). While the second case required conversion to open, the authors concluded that the approach was safe and feasible.

Conclusions

As minimally invasive techniques evolve to become the standard of care among pediatric patients, its use in pancreatic surgery must be carefully examined. Drawing meaningful conclusions from limited pediatric data makes this especially challenging. Though laparoscopic pancreas surgery requires advanced technical abilities, many reports demonstrate its safety and efficacy in a variety of clinical conditions.

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