Surgery for Acute Pancreatitis

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Abstract Surgery for acute pancreatitis has undergone significant changes over the last 3 decades. A better understanding of the pathophysiology has contributed to this, but the greatest driver for change has been the rise of less invasive interventions in the fields of laparoscopy, endoscopy and radiology. Surgery has a very limited role in the diagnosis of acute pancreatitis. The most common indication for intervention in acute pancreatitis is for the treatment of complications and most notably the treatment of infected walled off necrosis. Here, the step-up approach has become established, with prior drainage (either endoscopic or percutaneous) followed by delay for maturing of the wall and then debridement by endoscopic or minimally invasive surgical methods. Open surgery is only indicated when this approach fails. Other indications for surgery in acute pancreatitis are for the treatment of acute compartment syndrome, non-occlusive intestinal ischaemia and necrosis, enterocutaneous fistulae, vascular complications and pseudocyst. Surgery also has a role in the prevention of recurrent acute pancreatitis by cholecystectomy. Despite the more restricted role, surgeons have an important contribution to make in the multidisciplinary care of patients with complicated acute pancreatitis.

Keywords Acute pancreatitis · Pancreatic necrosis · Infected necrosis · Laparostomy · Minimally invasive · Percutaneous drainage · Necrosectomy

Introduction

There have been dramatic changes in the role of surgery for acute pancreatitis (AP) over the last 20 years, and some have predicted its demise. While it is true that open surgery now has a more restricted role in patients with severe and critical AP, there are still a range of indications for which surgery remains an important and sometimes life-saving treatment (Table 1). The most common indication for intervention is for infected local complications of AP, and these have recently been re-defined (Fig. 1) [1]. Other indications for intervention include complications of acute pancreatitis, and these may require surgery alone or combined with other treatment modalities, including interventional radiologic and endoscopic techniques. The purpose of this chapter is to provide a current overview of the role of surgery in AP, in the context of these wider changes in intervention.

Surgical Diagnosis of Acute Pancreatitis

Acute pancreatitis is now rarely diagnosed by surgery in advanced healthcare systems. The situation where this might still be the case is when patients with AP present late, and there is a non-diagnostic elevation of serum pancreatic enzyme concentration. The other indication is when a patient presents with signs of severe peritonitis, warranting an urgent laparotomy. If these patients can be stabilised, cross-sectional imaging will usually allow the radiological diagnosis of acute pancreatitis, avoiding the need for surgical diagnosis.

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Table 1 Indications for surgery in acute pancreatitis

1. Surgery for diagnosis
2. Surgery to treat complications of pancreatitis
 - a. Abdominal compartment syndrome
 - b. Infected necrosis
 - c. Non-occlusive intestinal ischaemia and necrosis
 - d. Enterocutaneous fistulae
 - e. Vascular complications
 - f. Pseudocyst
3. Surgery to prevent recurrent acute pancreatitis

Surgical Treatment of Abdominal Compartment Syndrome

The incidence of intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) in AP appears to be related to a more aggressive resuscitation strategy [2]. The consensus definition of IAH is a persistent increase of intra-abdominal pressure (IAP) >12 mm Hg, and ACS is defined as the combination of IAP >20 mm Hg and new-onset organ dysfunction [2]. Pressures are usually measured by a catheter in the bladder, but this is far from routine practice. In patients with AP, ACS is associated with extensive pancreatic necrosis, multi-organ failure, a longer stay in ICU and hospital and higher mortality [3]. In a combined series of 6 studies comprising 93 patients with ACS the mortality ranged from 25 to 75 % [4]. Patients with IAP exceeding 25 mm of Hg within the first 14 days in the ICU have been shown to have a mortality rate of more than 50 % [4]. Early recognition and prompt treatment of ACS help to decrease morbidity and improve patient survival.

Although IAH is associated with a significantly higher APACHE II and multiple organ dysfunction (MODS) scores in patients with severe acute pancreatitis (SAP), a causal relationship between ACS and MODS has not been established [5]. It has been found that the duration of IAH is of greater importance than the absolute increase in intra-abdominal pressure. The mechanism by which IAH affects end-organs such

as the heart, lungs and kidneys has not been established. The gut-lymph hypothesis [6] is a plausible explanation, with impairment of gut microcirculation leading to a breakdown of the gut barrier and the generation of toxic gut lymph which bypasses the liver entering the circulation immediately upstream of the organs affected [7].

Non-operative strategies [8] to prevent and reverse IAH in the setting of AP should be initially considered, with surgical intervention usually reserved for the setting of persistent organ dysfunction. Medical interventions to lower IAP target three important contributors: (1) distension and volume of hollow organs (such as with paralytic ileus), (2) space occupying lesions (such as ascites, blood and fluid collections) and (3) conditions that limit abdominal wall expansion (such as agitation or incomplete relaxation in ventilated patients). The levels of sedation and analgesia should be optimised to avoid agitation and increased abdominal wall tone. A brief trial with neuromuscular blocking agents helps to decrease abdominal muscular tone and increases abdominal wall compliance thus reducing IAP. Enteral decompression with nasogastric or rectal tubes can be helpful in managing ileus and gastric dilation. Prokinetic agents such as erythromycin and metoclopramide may help mitigate paralytic ileus. Another drug, neostigmine, a parasympathomimetic agent, has been used for treatment of ACS related to acute colonic pseudo-obstruction (ACPO) after conservative measures have failed. It exerts its effect by two mechanisms: increasing the amount of available acetylcholine and indirectly stimulating nicotinic and muscarinic receptors in the smooth muscles of intestine. Valle et al. [9] concluded from a meta-analysis that the effectiveness to resolve ACPO with a single dose of neostigmine was 89.2 %. The use of neostigmine in AP is not included in any current guidelines [10]. Percutaneous drainage of ascites and/or fluid collection(s) should be considered as a useful intervention to reduce intra-abdominal pressure.

Currently, there is no consensus regarding the optimal timing for surgical decompression of ACS or the best technique in patients with AP. The most commonly used method for surgical decompression is a midline laparostomy extending from the xiphisternum to the pubis. This approach allows an inspection of bowel viability and the diagnosis of ischaemia. Although early complications, such as intestinal fistulas, have been greatly reduced with careful management and improved understanding of the open abdomen, there is still the medium-term requirement of skin grafting and longer-term requirement for elective repair of the ensuing incisional ventral hernia. Another approach is to use transverse bilateral extended incision below the costal margins to form a full-thickness laparostomy. This incision is more likely to achieve primary closure than the midline incision. A third option is subcutaneous vertical linea alba fasciotomy which is achieved through three short horizontal skin incisions. This allows the linea alba to be split,

Content	Acute (<4 weeks, no defined wall)		Chronic (>4 weeks, defined wall)	
	No infection	Infection	No infection	Infection
Fluid	Acute pancreatic fluid collection	Infected APFC	Pseudocyst	Infected pseudocyst
Solid ± fluid	Acute necrotic collection	Infected ANC	Walled off necrosis	Infected WON

Fig. 1 The local complications of acute pancreatitis defined by chronicity, infection and content (adapted from Windsor JA, Petrov MS. Acute pancreatitis re-classified. Gut 2013; 62: 4–5)

sometimes using a laparoscope for visual control although the least effective for decompression is associated with less complications, such as fistulae [11].

The judicious use of intravenous resuscitation fluids improved non-operative management, and the wider use of percutaneous drainage for collections has resulted in a decrease in the incidence of ACS in patients with AP. Although surgical decompression results in prompt recovery from ACS, it is associated with a significant morbidity including intra-abdominal bleeding, persistent infection, development of post-operative fistulas, and hernias [12].

Surgical Treatment of Non-occlusive Intestinal Ischaemia and Necrosis

A number of factors contribute to the risk of non-occlusive mesenteric ischaemia (NOMI) and intestinal infarction in patients with AP. Risk factors may include under-resuscitation with significant persisting reflex splanchnic vasoconstriction, the metabolic demand of early enteral feeding, non-selective inotropes and the development of intra-abdominal hypertension [13]. When NOMI occurs, it is usually an early event and within the first week of the onset of symptoms. When suspected, due to the development of an acute abdomen and a rising serum lactate, an urgent CT scan should be arranged. There may be evidence of *pneumatosis intestinalis* with intramural gas in the intestinal wall, and sometimes in the portal vein and liver. Occasionally mild NOMI can be managed conservatively by addressing the risk factors, but usually, it requires surgery and bowel resection [14]. As surgery is usually within the first week, the abdomen can be lavaged and any early collections drained, but the surgeon should not be tempted to expose, drain or debride the pancreas ('don't poke the skunk'). Probiotics have been shown to reduce infectious complications by limiting small-bowel bacterial overgrowth, restoring gastrointestinal barrier function and modulating the immune system. However, a double-blind randomised trial investigating probiotics failed to reduce infectious complications in AP and was associated with increase mortality related to NOMI (PROPATRIA Trial) [15]. Probiotic prophylaxis should therefore not be administered in this category of patients.

Surgical Treatment of Infected Acute Necrotic Collections and Walled off Necrosis

Historically, the most common reason for surgical intervention in patients with AP was to treat pancreatic necrosis, and it is this indication for surgery that has undergone the most change. There have been phases in the evolving role of surgery in AP, going from resection to debridement to drainage.

Another notable trend has been the move away from early to delayed intervention.

The early surgical mindset was to operate early to remove all necrotic tissue, both sterile and infected. The first successful total pancreatectomy for 'fulminant' AP was first reported by Watts in England [16], and this approach was subsequently adopted by other surgeons [17–19]. The logic was that without surgical intervention, the mortality would be close to 100 %, which might explain why there was an apparent acceptance of a 60 % mortality rate, at least for a time.

Open surgical debridement has been the standard treatment not only for the removal of infected pancreatic and peri-pancreatic necrosis but also for symptomatic sterile necrosis especially through the 1980–1990s. The trend for early intervention was not persisted with. A randomised trial was prematurely closed because the mortality associated with early surgery (within 2–3 days) was doubled (56 versus 27 %) when compared with more delayed surgery (after 12 days) [20]. Open necrosectomy is most performed using a pancreas preserving technique with gentle finger blunt debridement of demarcated non-viable tissue ('pancreatic sequestrum') with the avoidance of formal pancreatic resections and a reduced risk of bleeding, fistulae and avoiding the removal of viable pancreatic tissue. Different strategies were advocated following debridement, including closing the abdomen over packs, wide bore drains with postoperative irrigation or leaving the abdomen open to facilitate further debridements [21]. Irrespective of the approach, open necrosectomy was associated with an appreciable morbidity (34–95 %) and mortality (11–39 %) [22].

Open necrosectomy is no longer considered the standard of care for the management of infected APFC and WON. Less invasive techniques have been developed and implemented [23], and these have largely replaced the need for open procedures. The development of minimally invasive necrosectomy has been in the context of the trend towards less invasive treatments generally, and an increasing convergence of the technologies within the fields of laparoscopic surgery, interventional radiology and therapeutic endoscopy. Nine different minimally invasive intervention techniques, based on the method of visualisation (laparoscopic, endoscopic, nephroscopic) and the route of entry (transperitoneal, retroperitoneal and transmural) have been published [23]. A more comprehensive classification of interventions for AP, based on visualisation, route and purpose, includes the increasingly important contributions of interventional radiology [24]. Two other important trends have occurred, including the recognition that a delay in intervention allows a lesser procedure with better outcomes because it allows the development of a wall (i.e., inflammatory capsule) and for the necrosus to become demarcated. The other realisation is that there is a role for non-operative management in selected patients, including all unfit patients, most patients with sterile necrosis and some with infected necrosis.

The key development in this field was the first randomised controlled trial (PANTER) [25]. In this multicentre study, 88 patients with necrotising pancreatitis were randomly assigned to open necrosectomy or ‘step-up’ approach treatment. The major end-point was a combination of major complications and mortality. The results from this study have changed the surgical approach to AP. Just over a third of the patients who would have undergone open necrosectomy only required catheter drainage (radiologic or endoscopic) as the definitive procedure, although 44 % required another drainage procedure. Sixty per cent of patients who were drained went on to have a minimally invasive necrosectomy, and two patients required open necrosectomy out of 43 patients in the step-up arm. Another important finding was that new onset multi-organ failure was seen only in 12 % in the step-up group compared with 40 % in the open necrosectomy group. This study concluded that a minimally invasive step-up approach reduced the rate of major complications/death in patients with infected pancreatic necrosis, and this study established a new standard of care. The Dutch Acute Pancreatitis Group has since coined the 3 D’s approach to treatment: ‘Delay, Drain and Debride’ [26]. The principle of delay is now embedded within the latest guidelines [27].

There are many approaches to minimally invasive necrosectomy [23]. The selection of the best approach depends on the availability of relevant expertise and the topography of the lesion to be treated. When the WON is central, transgastric approaches are the best approach. When there are prominent extensions into paracolic gutters, then flank percutaneous drainage is preferred, and the drain is used to access these more lateral lesions. This can be done by cutting down onto the drain to create a short transverse incision to facilitate extraction of the necrosus with blunt forceps and laparoscopic guidance, as in the videoscope-assisted retroperitoneal debridement (VARD procedure) [28]. This is an efficient method for debridement. An alternative approach is to use the approach used by urologists for percutaneous nephrolithotomy, with dilation of the drain track, insertion of an Amplatz sheath and high flow operating rigid nephroscope [29]. This less efficient method of debridement is often done as an adjunct to upsizing and placement of wide-bore drains (e.g., 32 Fr).

The diminishing role of open surgical treatment of infected local complications of AP and the rise of minimally invasive necrosectomy has almost been eclipsed by the evolution in the role of percutaneous drainage (PCD). Initially, PCD was an adjunctive treatment, being used to drain infected residual or recurrent collections after open surgery. To this has been the evolution of PCD as a primary treatment. This effectively buys time and this allows the systemic response to settle and for the maturation (encapsulation) of target lesions for later (and safer) definitive treatment. And now, PCD is being increasingly used as definitive and sole treatment, although there remains significant room for improvement [30].

In summary, several key points can be made about the surgical treatment of infected acute fluid collections and walled off necrosis.

1. Resection and early surgery are associated with prohibitive risk and mortality.
2. Debridement of sterile necrosis is rarely, if ever, indicated.
3. Treatment of infected acute fluid collections and walled off necrosis should be delayed as long as possible (by providing optimum intensive care support and drainage) to allow for encapsulation.
4. The step-up approach is the standard of care, with initial drainage (percutaneous or endoscopic) followed by minimally invasive necrosectomy (percutaneous or endoscopic), and open necrosectomy only if these approaches fail.

Surgical Treatment of Fistulae

The decrease in the use of laparostomy, open necrosectomy and packing for the treatment of AP has contributed to a decline in the incidence of enterocutaneous (small and large bowel) fistulae in these patients. The majority of these fistulas can be managed conservatively, using established principles [31]. This includes defining the anatomy, controlling sepsis, optimising nutrition and undertaking surgical resection after failed conservative management. Although fistulae increase the morbidity, they do not appear to increase the mortality of patients with necrotising pancreatitis [32].

Surgical Treatment of Pseudocyst

The reclassification of the local complications has led to a narrower definition of pseudocyst. It is now defined as an encapsulated collection of fluid with a well-defined inflammatory wall usually outside the pancreas with minimal or no necrosis [33]. And, it is only defined when it has been present for at least 4 weeks after the onset of interstitial oedematous pancreatitis. If the patient has necrotising pancreatitis, the collection will almost always contain necrotic pancreatic and sometimes peripancreatic tissue. This is not called a pseudocyst, but rather ‘walled off necrosis’ when present for 4 or more weeks (Fig. 1), determining the presence of absence of necrotic tissue within the collection with ultrasound or MR scanning. This is a limitation of CT scanning in AP patients. The majority of fluid collections and pseudocysts resolve spontaneously without active treatment. Those that persist and are associated with symptoms or complications should be treated. Persistence without symptoms or complications is not an indication for intervention, despite the widely held surgical opinion that a cysto-gastrostomy is required when a

pseudocyst of greater than 6 cm and present for more than 6 weeks [34]. In the absence of symptoms or complications, it is reasonable to take an expectant approach. Symptoms may develop, including early satiety, epigastric discomfort, impaired gastric emptying and gastro-oesophageal reflux [35]. Pressure on adjacent major veins can lead to portal and/or splenic thrombosis and segmental portal hypertension. The fluid content of a pseudocyst is enzyme-rich (including pancreatic elastase) and this can lead to weakening of blood vessels in the wall of the pseudocyst, leading to pseudoaneurysm formation and bleeding. Pseudocysts can also rupture leading to pancreatic ascites.

Treating a pseudocyst by percutaneous drainage without first ensuring that there is no distal obstruction in the main pancreatic duct by MRCP is ill advised. The presence of a pancreatic duct stricture or stone increases the likelihood that percutaneous drainage will result in an external pancreatic fistula [36]. In this setting, it is best to perform internal drainage. Historically, this has meant performing a cystogastrostomy or Roux en Y cystojejunostomy, and more recently, these have been performed laparoscopically [35]. But today, it is preferable to consider treating a pseudocyst using an endoscopic transmural approach, either through the posterior stomach wall or medial duodenal wall. The insertion of a double pigtail stent, or multiple stents, is all that is required for a pseudocyst. This is in contrast to walled off necrosis, where it is best to use a purpose designed, wall-opposing, self-expanding metal stent that also permits endoscopic debridement [37]. Rarely, it is possible to successfully treat a pseudocyst by the placement of a transampullary drain directly into the pseudocyst cavity after first defining a communication between the main pancreatic duct and the pseudocyst cavity by endoscopic retrograde pancreatography [38].

A pseudocyst is more likely to persist and become symptomatic when there has been disruption of the main pancreatic duct by the necrotising process. Internal drainage of the ‘disconnected duct syndrome’ is advisable because conservative management will not achieve resolution of the pseudocyst. If an endoscopic approach is not feasible because of the location and topography of the pseudocyst, then a surgical approach is warranted [39].

Surgical Treatment of Gallstones

Patients with gallstone acute pancreatitis can present with associated cholestasis and cholangitis, suggestive of choledocholithiasis. While there is no longer any role for surgical exploration of the common bile duct in the acute setting, there is a well-defined role for urgent bile duct decompression by ERCP, biliary sphincterotomy and/or stenting. Too often, ERCP has been undertaken for predicted severe acute pancreatitis and for cholestasis. The inaccuracy of predicting severe

AP (70–80 %) results in unnecessary intervention in some patients and is no longer an indication for early ERCP. A recent meta-analysis finds that the primary indication for endoscopic treatment is concomitant cholangitis [40]. If the presentation of a patient with AP and cholangitis has been delayed beyond 72 h, it may be safer to decompress the biliary tree by percutaneous transhepatic biliary drainage since duodenal oedema and patient instability can significantly increase the risks of an endoscopic approach. Note that cholestasis *per se* does not require urgent endoscopic intervention; indeed, testing liver function tests over 48 h will often reveal improvement which suggests that the offending CBD stone has passed into the duodenum already.

Patients with gallstone acute pancreatitis warrant cholecystectomy. There is now significant body evidence indicating that this should take place during the same admission for those with mild and moderate AP [41]. There is a significant risk of recurrent AP if this is not done during the index admission. More challenging is the timing of cholecystectomy in those with severe and critical AP, especially when there has been significant inflammation and collections in the subhepatic space. Usually, the cholecystectomy is delayed until the patient has recovered and undergoes an interval elective cholecystectomy [42]. In patients who survive a severe episode of gallstone AP and are not fit enough for surgery, there is a trend to perform an endoscopic sphincterotomy as a definitive procedure on the basis that it reduces the risk of recurrent acute pancreatitis [43]. If these patients develop symptoms of biliary colic, an interval cholecystectomy will be required [44].

Conclusion

The role of the surgeon has diminished in the treatment of severe acute pancreatitis, but it has not disappeared. This chapter has highlighted the rise of less invasive approaches and the important roles played by interventional radiologists and therapeutic endoscopists. More than ever, the management of acute pancreatitis is multi-disciplinary, and the pancreatic surgeon remains a vital member of the team.

Compliance with Ethical Standards

Conflicts of Interest The authors declared that they have no conflict of interest.

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