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**Will necrosectomy be obsolete for infected necrotizing pancreatitis? Is a paradigm shift needed?**

Chang YC. Will necrosectomy be obsolete for infected pancreatic necrosis?

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# Abstract

In 1886, Senn stated that removing necrotic pancreatic and peripancreatic tissue would benefit patients with severe acute pancreatitis. Since then, necrosectomy has been a mainstay of surgical procedures for infected necrotizing pancreatitis (NP). No published report has successfully questioned the role of necrosectomy. Recently, however, increasing evidence shows good outcomes when treating walled-off necrotizing pancreatitis without a necrosectomy. The literature of NP published primarily after 2000 was reviewed; it demonstrates the feasibility of a paradigm shift. The majority (75%) of minimally invasive necrosectomies show higher completion rates: between 80% and 100%. Transluminal endoscopic necrosectomy (TEN) has shown remarkable results when combined with percutaneous drainage (PCD) or a metallic stent. Related morbidities range from 40% to 92%. Single-digit mortality rates have been achieved with TEN, but not with video-assisted retroperitoneal necrosectomy series. Drainage without necrosectomy procedures have evolved from PCD to transluminal endoscopic drainage (TED) with or without percutaneous endoscopic gastrostomy access for laparoscopic instruments. Most series have reached higher success rates around 79%-93%, and even 100%, using transcystic multiple drainage methods. It is becoming evident that TED treatment of walled-off NP without a necrosectomy is feasible. With further refinement of the drainage procedures, a paradigm shift from necrosectomy to drainage is inevitable.

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**Key words:** Walled-off pancreatic necrosis; Minimally invasive treatment; Transluminal endoscopic drainage/necrosectomy; Delay until liquefaction; Infected necrotizing pancreatitis

**Core tip:** A paradigm shift of timing from early, prompt surgical necrosectomy to delay-until-liquefaction has become the global consensus for the treatment of infected necrotizing pancreatitis, which allows drainage procedures and minimally invasive techniques to play a much more important role before definitive surgery. When the minimally invasive drainage procedures are refined, especially the transluminal endoscopic drainage (TED) and irrigation with a percutaneous gastrostomy access route, success rates are around 80%, and most series report single-digit mortality. Zero mortality using TED without a necrosectomy is a real possibility: it can be achieved. A paradigm shift from necrosectomy to drainage for the treatment of walled-off necrotizing pancreatitis should be considered.

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**Introduction**

Bradley[1] described the original 19th-century dispute between Senn and Fitz about the value of necrosectomy for necrotizing pancreatitis. In 1886, Senn[2] claimed that removing necrotic pancreatic and peripancreatic tissue would be beneficial for patients with severe acute pancreatitis (AP). Fitz[3], however, was convinced that the prognosis of an individual episode of acute pancreatitis was determined only by the pathological findings and not based on whether surgical debridement had been performed. But even Fitz[4], who initially considered the operation useless and hazardous, later suggested that the “the sooner the operation was carried out, the better for patients with AP”. Until about 1925, Senn’s views held sway, and debridement was common practice before AP surgery. Moynihan[5] expressed the prevailing surgical opinion of the time: “recovery from the disease, apart from operation, is so rare that no case should be left (surgically) untreated. However, few survived surgical intervention. After the development of an amylase assay, the therapeutic pendulum swung away from surgery toward nonsurgical management and surgical intervention was contraindicated. Even though this conservative approach spared the majority of patients with mild or moderate acute pancreatitis surgical intervention, many patients with severe acute pancreatitis still died. In an attempt to confront persistent high mortality rates from nonsurgical management of severe acute pancreatitis, the concepts of surgical approaches were advocated and surgical mortality often exceeded 50%”[5].

Since then, the rationale of AP surgery evolved from exploratory laparotomy to total pancreatectomy in severe AP in the late 1960s and 1970s, to early immediate surgical intervention in the 1980s when the pancreas was proved to be infected, to the notion, in 1993, of 100% mortality if AP were treated non-operatively[6], to the present concept, expressed in 2007[7], that patients with severe necrotizing pancreatitis (NP) complicated with infection benefit from delayed necrosectomy and drainage.

Surgical necrosectomy was the mainstay of NP treatment a decade ago, especially when non-surgical approaches failed. However, from serendipitous antibiotic treatment[8] for infected NP, non-surgical therapy for sterile NP[1], and no debridement with minimally invasive left-flank drainage[9], to the dual drainage[10] of endoluminal and percutaneous approaches, more evidence has been reported of successfully treating the infected NP (INP) without a necrosectomy. This resurrects the same question 125 years later by the author and by Smadja and Bismuth[11]: Is necrosectomy a “useless and hazardous approach” for acute pancreatitis? The same dispute occurred between Bradley[12] and Warshaw[13] over sterile NP but not INP. Bradley[12] concluded: “However, surgical debridement and drainage remains the preferred approach for infected pancreatic necrosis despite occasional anecdotal reports of successful management by transcutaneous or endoscopic means.”

Currently, the management of NP has undergone a paradigm shift toward minimally invasive techniques for necrosectomy, obviating the need for open necrosectomy in most cases[14]. There is increasing evidence that minimally invasive approaches, including a step-up[15] approach that incorporates percutaneous catheter or endoscopic transluminal drainage followed by video-assisted retroperitoneal or endoscopic debridement, are associated with improved outcomes over traditional open necrosectomy for patients with INP. A recent international multidisciplinary consensus conference[16] emphasized the superiority of minimally invasive approaches over standard surgical approaches.

Yet, a minimally invasive necrosectomy is still used, according to most reports. Recently, increasing evidence of the efficacy of endoscopic technique includes reports of successes without a necrosectomy when treating NP, which raises the same old question of whether necrosectomy is obsolete.

# Purpose: Author’s questions

Is necrosectomy mandatory for treating necrotizing pancreatitis? Can we avoid it? If necrosectomy can be avoided, then a paradigm shift may allow us to move toward minimally invasive drainage procedures. Our aim is the same as that of Traverso and Kozarek[17], who said that the word “necrosis” induced a “knee-jerk response to perform necrosectomy”. They claimed that, given time, the necrosis would dissolve (“necrolyse”) or become infected. Even though INP indicates surgical debridement in most medical centers worldwide, they first perform percutaneous drainage, which, they say, has “drastically lowered the need for pancreatic necrosectomy to less than 10%” and the mortality rate to “single digits”.

# Data Collection

The outcomes of NP, primarily INP, treated using conservative treatment, open necrosectomy, interventional drainage, and minimally invasive methods, and reported after 2000, were reviewed. Morbidity, mortality, the reoperation rate, the pancreatic fistula rate (for surgery), endoscopic sessions, the completion rate for endoscopic methods, and the success rate for drainage methods were compared to see whether there has been a paradigm shift from surgery to minimal invasive—especially drainage—alternatives.

# Outcomes

Even for INP, completely conservative treatment (Table 1) with antibiotics without mortality was possible in 3 reports[8,18,19]. Surgery could be avoided in from 67% to 87.5% of cases. For sterile NP, the mortality of conservative treatment remained between 0% and 5.3% (Table 1), which is the same as reported before 2000.

Despite some studies’ reports of single-digit mortality[20-23] using surgical necrosectomy, high mortality (about 20%-63.9%) is reported in the majority of series (Table 2). Except in a few centers, surgical outcome has not changed much, and the surgical risk is high. A nationwide study in the United States of 1783 patients[24] from 1998 to 2010 indicated that the incidence of pancreatic debridement decreased from 0.44% to 0.25% (*P* < 0.01) and that PD in-hospital mortality (overall 22.0%) decreased from 29.0% to 15% (*P* < 0.05).

In the majority (75%) of the included series on minimally invasive necrosectomy (MIN), higher completion rates between 80% and 100%[10,25-38] are reported (Table 3). MIN, mainly transluminal endoscopic necrosectomy (TEN) with drainage, has shown remarkable results combined with percutaneous drainage (PCD)[10,26,29,34] or using a metallic stent[28,32]. Related morbidities ranged from 40% to 92%[11,26,30,33,34,36,39,40]. Single-digit (0%-10%) mortality rates have been achieved in the majority of the TEN group, but not in the video-assisted retroperitoneal drainage (VARD) group. The PEG (percutaneous endoscopic gastrostomy) access route was used in three series[25,32,34] (Table 3).

The success rate of PCD varies (Table 4). Some series[41-43] report that it remains unchanged at around 35%-49%, but most[17,19,20,41] have reached a higher success rate of about 76%-93%. The TED rates are about 80%[19,44], and even 100%[45] when using single transluminal gateway transcystic multiple drainage (SGTMD) methods. Single-digit mortality was reported in most series[19,20,41,44-47], and zero mortality is a reality[19,20,41,45,47].

# Discussion

The pathophysiology of acute pancreatitis is usually divided into three phases. In phase one, trypsin is prematurely activated pancreatic acinar cells, which synthesize, store, and secrete digestive enzymes. Once trypsin is activated, it activates a variety of harmful pancreatic digestive enzymes. In phase two, intrapancreatic inflammation occurs through a variety of mechanisms and pathways. In phase three, extrapancreatic inflammation, including acute respiratory distress syndrome (ARDS), which is often fatal, occurs. In about 80% of patients, acute pancreatitis is mild; however, in 10%-20%, the pathways that contribute to increased intrapancreatic and extrapancreatic inflammation lead to SIRS (systemic inflammatory response syndrome), a complex response to infection, trauma, burns, pancreatitis, and a variety of other injuries. In some instances, SIRS predisposes a patient to multi-organ dysfunction, pancreatic necrosis, or both[7]. The following precepts have been proposed over the past 130 years: (1) 1886: removing necrotic pancreatic and peripancreatic tissue is beneficial for patients with severe acute pancreatitis (Senn[2]); (2) 1889: the sooner surgery is done, the better for patients with AP (Fitz[3]); (3) 1925: recovering from AP without surgery is rare; thus, no patient with AP should be surgically untreated (Moynihan[5]); (4) 1993: the mortality in non-operatively treated patients approaches 100% (Widdison and Karanjia[6]); (5) When the pancreas is infected, surgery is mandatory; (6) When the pancreas is infected, early necrosectomy and drainage are recommended; (7) Delay until demarcation: used for the era of open necrosectomy to delay the operation timing and to spare the viable pancreatic tissue from being sacrificed during debridement; and (8) 1996: Surgical debridement is rarely necessary in sterile pancreatic necrosis (Bradley[1]).

There is no reason to use immediate surgery for patients with mild acute pancreatitis. Infected pancreatic necrosis, however, is an indication for surgical intervention. Approximately 20% of patients develop necrotizing pancreatitis, which is has a mortality rate of 15%. The major cause of death, in addition to early organ failure, is extrapancreatic infection or infectious pancreatic necrosis, which leads to sepsis and multi-organ failure. Secondary infection of pancreatic necrosis develops in approximately 30% of patients with necrosis, which increases the mortality rate to approximately 39%. Infected necrosis is virtually always an indication for intervention[48]. Surgery within the first 14 d of the onset of INP should be avoided because early surgery is associated with increased mortality[49]. The conventional management of INP is open surgical debridement. Other surgical approaches have been used: single-stage and multistage methods with a variety of drainage and closure techniques. Necrosectomy is a relatively standardized technique used with a variety of methods to control drainage, for example, marsupialization of the lesser sac, wide closed-suction drainage, continuous lavage of the septic cavity, and a planned repeat necrosectomy with a delayed primary closure. Less invasive methods have also been reported, namely, using laparoscopic techniques and equipment along the track of existing percutaneous drains[49].

The term and concept of “delay until liquefaction” was developed by the author[9] for minimally invasive drainage from the left flank without debridement. At least 3 wk are normally needed for liquefaction of the retroperitoneal and peripancreatic tissue to reach the left flank. This permits a sump drain to be inserted from the left flank to the pancreatic head area without opening the abdomen. This strategy is currently commonly used for the timing of delayed management[7] with open or minimally invasive approaches for drainage and necrosectomy. Walling-off the liquefied necrotic tissue that has formed a secure attachment to the gastric or duodenal wall enables endoscopic drainage with or without a necrosectomy from the stomach, duodenum, or left retroperitoneum. A prolonged delay may cause unnecessary adverse events.

## Consensus ON necrotizing pancreatitis

Several important points were established at a one-day meeting held in conjunction with the annual meeting of the American Pancreatic Association in 2010[16]: (1) Sterile acute necrotic collections almost never require intervention early in the course of disease, and in the later phase (*i.e.,* after several weeks), only if there are disabling symptoms, such as abdominal pain, significant mechanical obstruction (*e.g.*, a gastric or biliary outlet), or both; (2) Infected acute necrotic collections may occasionally require early intervention, but because early open surgery is associated with high morbidity and mortality, it should be avoided whenever possible. Instead, radiological or endoscopic drainage should be used before surgery to treat infection and to postpone or obviate the need for surgical debridement; (3) Intervention by any method is optimal when infected necrosis is walled-off and demarcated with at least partial liquefaction and discrete encapsulation. This typically requires a delay of 4 to 6 wk; (4) Asymptomatic walled-off necrosis (WON) does not require intervention regardless of the size and extension of the collection; it may eventually resolve spontaneously, even in rare cases of infected necrosis; and (5) Symptomatic WON generally requires intervention late in the course (*i.e.*, after 4 weeks) if there is intractable pain, visceral obstruction (*e.g.,* the stomach or bile duct), or infection.

## 2013 updated guideline

The optimal management of necrotizing pancreatitis continues to evolve. A 2013 guideline[48] about debridement of necrosis and minimally invasive management of pancreatic necrosis, published by the American College of Gastroenterology, has says that the mortality of infected necrosis was falsely believed to be almost 100% in patients with IPN not given immediate surgery. There is ample evidence that antibiotic treatment alone can resolve the infection and, in some patients, preclude surgery. Therefore, the notion that immediate surgery is necessary for patients with IPN is no longer valid. Asymptomatic pancreatic and extrapancreatic necrosis do not require intervention regardless of size, location, and extension, because they are likely to spontaneously resolve, even if infected[16]. Unstable patients with infected necrosis should undergo urgent debridement. However, the current conventional wisdom is that IPN in clinically stable patients should be managed with antibiotics before surgery[16]. If the infected necrosis does not resolve, minimally invasive necrosectomy or open surgery is recommended once the necrosis is walled-off. Currently, a multidisciplinary consensus[16] favors minimally invasive methods over open surgery to manage PN. A randomized controlled trial[30] clearly showed endoscopic debridement was a better strategy than surgery. Despite advances in surgical, radiological, and endoscopic techniques, it is necessary to know that many patients with sterile pancreatic necrosis, and some patients with infected pancreatic necrosis, clinically improve sufficiently that they need no surgical intervention.

## Minimally invasive necrosectomy

Although minimally invasive approaches are currently advocated, they still have some related morbidity and mortality[30,50]. Bausch *et al*[50] compared the outcomes of minimally invasive retroperitoneal necrosectomy (*n =* 14) and endoscopic transgastric necrosectomy (*n =* 18) with the outcomes of open necrosectomy (*n =* 30). Postoperative problems were ongoing sepsis (29%, 11%, and 73%, respectively) and bleeding that required intervention (21%, 17%, and 26%, respectively). A specific complication of endoscopic transgastric necrosectomy was Gastric perforation into the peritoneal cavity during the procedure (28%), which required an immediate open pseudocystogastrostomy. A laparotomy was necessary in 21% of the patients after minimally invasive retroperitoneal necrosectomy and 28% after endoscopic transgastric necrosectomy because of specific complications or a persistent infection. The overall mortality rates were 21%, 6%, and 63% (*P* < 0.05). The highest rate was after open necrosectomy. Bausch *et al* concluded that morbidity and mortality remained high in acute NP, and that surgery should be delayed as long as possible to reduce them. Minimally invasive procedures can preclude laparotomy, but they can also cause specific complications that require immediate or secondary open surgery.

Bausch *et al*[50] also lower mortality in the TEN group than in the minimally invasive retroperitoneal necrosectomy group (6% *vs* 21%), which is similar to what is shown in Table 3.

Bakker *et al*[30] reported that the TEN group had significantly less proinflammatory response, complication (20% *vs* 80%), new-onset multiple organ failure (0% *vs* 50%) and pancreatic fistulas (10% *vs* 70%) compared to the VARD group. One gastric and one large intestine perforation occurred after VARD.

Ross *et al*[10] said that “Each treatment modality described for this application is a variation on a common theme - drainage of liquefied necrosis and debridement of necrotic tissue, either mechanically or by flushing and the passage of time.” The key to complete evacuation of necrotic material is creating a large access opening to the cavity[33]. However, related complications such as bleeding, perforation, fistula, and embolism are inevitable[26,33,35,37,38]. TEN needs to be used with caution, ideally in an interdisciplinary approach and within clinical trials.

## Drain first, but do it better

Earlier results of open or percutaneous drainage were not good enough as compared with the open surgical necrosectomy with drainage procedure and were unable to become the standard treatment of choice for the INP.

In 2011, Windsor[51] proposed “drain first, but do it better” for INP. He pointed out that open necrosectomy is not the standard of care in many leading centers and is not an absolute requirement for IPN. He concluded that PCD can be the only treatment for some patients with IPN, which avoids an unnecessary necrosectomy. However, it has not yet been determined whether PCD is best used when infection is suspected or confirmed, nor has it been established when PCD can be delayed. Some interventional radiologists have long advocated primary PCD, but it has not been widely adopted[52]. This might soon change, however: 56% of patients—those with sterile PN and those with infected PN—did not require a surgical necrosectomy after PCD, according to one review[53]. The role of PCD as the only treatment for IPN needs additional evaluation so that it can be done better.

Ross *et al*[10] discussed a key point of “how to do it better”, which is “the entry of the catheter into the collection was directed toward the dependent portion of the collection so that gravity could assist in drainage”. The entry is therefore the left flank. Another key point is a large caliber drain and a big skin outlet. The author[9] used a 3-5 cm left-flank incision to enable the one-time insertion of a large-caliber sump drain directly through a liquefied route to the pancreatic head area where the drain was fixed on one side of the skin but the wound was kept open to enable the liquefied discharge to freely flow along the drain in case the drain lumen was obliterated by the debris. The open wound was pouched using a colostomy bag.

Garg *et al*[54] concluded that with medical management (conservative + PCD), surgery could be avoided in 76.6% patients. Other gave an even higher estimate: about 83% (Table 4). However, PCD alone failed in a significant proportion of patients[18,42,43,52] and a higher mortality rate has been reported[42].

TED and necrosectomy have currently been enormously pivotal in complementing the complete management of NP during this paradigm shift of intervention-timing from prompt surgical debridement to delay-until-liquefaction. Promising results have been published. A step-up technique after a PCD failure is, it seems, the best way to “do it better”. Repeated TEN[33] or TEN+TED showed an 80%-100% success rate (Tables 3 and 4); however TED is preferred because it avoids some complications of TEN.

Drainage with minimally invasive necrosectomy from transluminal endoscopy with or without a stent or from a trans-PCD sinus tract has its specific morbidities. The old important of whether the necrosectomy is required[3,11] still remains unanswered. Can a “drain only” strategy further reduce these morbidities but maintain the same outcomes? With the progressive evolution of a multiple transluminal gateway technique (MTGT)[47] for TED, single transluminal gateway transcystic multiple drainages (SGTMD)[45], or dual modality drainage[10], albeit in only a few case series, allow 100% success when drainage[10,43] without a necrosectomy is used to treat NP.

A transgastrostomy endoscopic procedure reported in 1993[55] (Table 3[25,28,32,34]) provides another feasible and easier access to further simplify the treatment. A double PEG technique developed by Raczynski *et al*[25] had been demonstrated to be an inspiring tool. The author suggests a “[one or two double-lumen transgastrostomy tube with jejunal arm (PEG-J)[32,56] method]” to offer jejunal feeding using a nasogastric tube, if needed, before the “delay until liquefaction” period, and an endoscopic or endoscopically assisted route for drainage later during the walled-off period. Creating a large access opening to the cavity[32] to complete evacuation of necrotic material is essential. One Foley tied with Penrose drains or two Foley drains keep the access open and offer irrigation.

## Surgery: A last resort

Within the last decade, TEN and TED have probably replaced most surgical roles in the treatments of walled-off NP except for the disconnected pancreatic duct syndrome[17]. Disconnected pancreatic duct syndrome (DPDS) is characterized by evidence of a main pancreatic duct cutoff, an inability to access the upstream pancreatic duct during an endoscopic retrograde cholangiopancreatogram (ERCP), and CT evidence of viable pancreatic tissue upstream (toward the spleen), in association with a persistent non-healing pancreatic fistula or pancreatic-fluid collection, despite a course of conservative medical management[57]. DPDS is an increasingly recognized complication of severe acute pancreatitis (SAP) and abdominal trauma, with reported prevalence rates that range from 10% to 31%. However, these figures are most representative of highly select populations of SAP in tertiary hospitals; the prevalence in all cases of acute pancreatitis remains unknown[58]. Although surgical management had been the consensus[59], there have been reports of success with initial endoscopic treatment[57]; 19 of 26 patients showed long-term improvement, 7 required surgery after treatment failed, the other 5 underwent immediate surgery: mortality was 0%. Sakaria *et al*[32] included 4 DPDS patients for a series in which they used esophageal stents to treat walled-off pancreatic necrosis. Complete resolution was achieved in 15/17 patients (88%). Two patients not specified as having DPDS required surgical intervention after endoscopic treatment failed. At least two of their patients did not need surgical rescue for DPDS. More effort should be focused on DPDS in the era of transluminal endoscopic treatment.

## Necrosectomy: obsolete

The answer to “Will necrosectomy be obsolete?” is now much more positive. A paradigm-shift from a surgical to a non-surgical approach, or to drainage as proposed by Windsor[51], whether the necrosis is infected or sterile, is waiting for additional randomized studies. Although not significantly different, endocrine (diabetes, *p* = 0.07) and exocrine insufficiency were lower in the endoscopic drainage group than in the surgery group[60]. Unnecessary necrosectomy procedures for the risky disease of NP should be prevented[5,17] and surgical management should be used as a last resort.

# Conclusion

With the recent successful outcomes of pure endoscopic and complementary endoscopic treatments for failed PCD, it is clear that drainage without a necrosectomy is feasible and should be the first choice of treatment for symptomatic sterile or infected walled-off NP and peripancreatic fluid collection. A paradigm shift from necrosectomy to drainage for the treating NP should be considered to eliminate potential complications.

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# Table 1 Results of nonsurgical or conservative treatment for necrotizing pancreatitis published mainly after 2000

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Ref.** | **Year** | **Case****NP** | **Type****(Intend)** | **Morbidity****(%)** | **Reoperation****Rate (%)** | **Mortality****(%)** | **Remark** |
| **Sterile** |  |  |  |  |  |  |  |
| Bradley[1] | 1991 | 40 | Nonsurgical |  |  | 10 |  |
| Ulmo *et al*[61] | 1996 | 146 | Nonsurgical |  |  | 9.5 | 1984-1993 |
| Baril *et al*[20] | 2000 | 26 | Antibiotics |  | 0 | 7 | 1993-1997 |
| Büchler *et al*[62] | 2000 | 56 | Conservative |  |  | 1.8 | 2 FN excluded |
| Zerem *et al*[41] | 2009 | 20 | Conservative |  | 15 | 0 | RCT |
| Garg *et al*[54] | 2010 | 137 | Conservative |  |  | 15.3 | 1997-2008 |
| van Santvoort *et al*[18] | 2011 | 386 | Conservative |  |  | 7.3 | 21 Dutch hospitals |
| Babu *et al*[46] | 2013 | 14 | Conservative |  |  | 7 | Step-up; 1 INP |
| **Infected** |  |  |  |  |  |  |  |
| Dubner *et al*[8] | 1996 | 3 | Antibiotics | 0 | 0 | 0 | Unstable or refused surgery |
| Baril *et al*[20] | 2000 | 6 | Antibiotics |  | 0 | 33 | 1993-1997 |
| Runzi *et al*[63] | 2005 | 16 | Antibiotics | 62 |  | 12.5 |  |
| Lee *et al*[19] | 2007 | 8 | Antibiotics | 0 | 0 | 0 | Non-RCT |
| Garg *et al*[54] | 2010Non-RCT | 71 | Conservativeor Pcd |  |  | 25.4 | 1997-2008 |
| van Santvoort *et al*[18]  | 2011 | 11 | Antibiotics | 0 | 0 | 0 | 21 Dutch hospitals |
| **Sterile + infected** |  |  |  |  |  |  |  |
| Büchler *et al*[62] | 2000 | 58 | Conservative |  |  | 5 | 2 FN |
| Garg *et al*[54] | 2010 | 208 | Medical |  |  | 18.8 | 1997-2008 |
|  | non-RCT |  |  |  |  |  |  |

NP: necrotizing pancreatitis; FN: False negative; INP: Infected necrotizing pancreatitis; PCD: Percutaneous drainage; RCT: Randomized controlled study.

# Table 2 Results of surgical necrosectomy for necrotizing pancreatitis published mainly after 2000

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Ref.** | **Year** | **Case****NP** | **Type****(Intend)** | **PF****(%)** | **Morbidity****(%)** | **Reoperation****rate (%) or****n/patient** | **Mortality****(%)** | **Remark** |
| **Sterile** |  |  |  |  |  |  |  |  |
| Baril *et al*[18] | 2000 | 1 | Open | 0 | 0 | 0 | 0 | 1993-1997 |
| Büchler *et al*[62] | 2000 | 1 | Closed + irrigation | ? |  | ? | 100 |  |
| Rau *et al*[64] | 2005 | 142 | Closed + irrigation | 23 | 61 | 43 | 23 | 1992-2001 |
| Howard *et al*[21] | 2007 | 23 | Planned relap |  | 78 | 30 | 9 | Symptomatic |
|  |  |  |  |  |  |  |  |  |
| Garg *et al*[54] | 2010Non-RCT | 9 | Closed + irrigation | > 30 |  |  | 55.5 | 1997-2008 |
| **Infected** |  |  |  |  |  |  |  |  |
| Baril *et al*[20] | 2000 | 11 | Open | NA | 91 | 45.5 | 9 | 1993-1997 |
| Büchler *et al*[62] | 2000 | 27 | Closed + irrigation | 29 |  | 22 | 18.5 | 2 un-OP excluded |
| Rau *et al*[64] | 2005 | 140 | Closed + irrigation | 30 | 78 | 27 | 27 | 1992-2001 |
| Howard *et al*[21] | 2007 | 66 | Surgery |  | 86 | 33 | 15 |  |
| Garg *et al*[54] | 2010Non-RCT | 36 | Closed + irrigation |  | 63 |  | 63.9 | 1997-2008 |
| van Santvoort *et al*[15] | 2010RCT | 45 | Closed + irrigation | 38 | 69 | 31 | 16 | 1 operation: 42%33% need + PCD |
|  |  | 24 | VARD |  | 65 |  | 17 |  |
| van Santvoort *et al*[18] | 2011 | 78 | VARD/TEN/OP |  | 64 |  | 18 | 21 Dutch hospitals |
| Babu *et al*[46] | 2013 | 27 | Closed + irrigation | 22.2 | 51.9 | 22.2 | 40.7 | Step-up |
| **Sterile+infected** |  |  |  |  |  |  |  |  |
| Smadja and Bismuth[11] | 1986 | 12 | Surgery, early |  |  |  | 100 |  |
|  | non-RCT | 15 | Surgery, late |  |  |  | 27 |  |
|  |  | 11 | Surgery, elective |  |  |  | 0 |  |
| Connor *et al*[39] | 2005 | 47 | Closed + irrigation | 1-9 | 95 |  | 39 | Infected 81% |
| Olakowski *et al*[65] | 2006 | 144 | Open packing |  | 43 | 3-8/patient | 21 | Infected 83% |
| Nieuwenhuijs *et al*[66] | 2003 | 38 | Open packing | 42 | 89 | 3-70/patient | 47 |  |
|  |  | 21 | Closed packing | 14 | 44 | 0-3/patient | 33 |  |
| Reddy *et al*[40] | 2006 | 118 | Closed + irrigation | 36 | 58 | 22.9 | 38.1 | Infected 65.3% |
| Howard *et al*[21] | 2007 | 102 | Planned relap |  |  |  |  |  |
|  | (1993-2001) | 59 |  | 49 | 89 | 67 | 18 | Infected 76% |
|  | (2002-2005) | 43 |  | 60 | 72 | 68 | 4 | Infected 72% |
| Rodriguez *et al*[67] | 2008 | 167 | Closed packing | 50 |  | 11 | 11 | Infected 72% |
| Garg *et al*[54] | 2010Non-RCT | 45 | Closed + irrigation |  |  |  | 48.9 | 1997-2008 |
| Babu *et al*[68] | 2010 | 28 | PCD + Surgery |  |  |  | 22 | 2000-2008 |
| Doctor *et al*[22] | 2011 | 61 | Open + Laprosc | 50.8 |  |  | 9.8 | 1998-2009 |
| (INP 83.6%) |  |  | (re-OP 8%) |  |  |  |  | s/p fistula 50.8% |
| Bausch *et al* [50] | 2012 | 30 | Closed + irrigation | 16.7 | 90 | 73.3 | 63.3 | Infected 83.3% |
| Madenci *et al*[23] | 2014 | 68 | Closed packing | 74.2 | > 74.2 | 14.7 | 8.8 | 2006-2009Infected 63% |
| Wormer *et al*[24] | 2014 | 1783 | Surgicaldebridement |  |  |  | 22.0 | 1998-2010Nationwide |

Laparosc: Laparoscopy; OP: Operation; un-OP: Not operated on; PCD: Percutaneous drainage; Relap: re-laparotomy; RCT: Randomized control study; TEN: Transluminal endoscopic necrosectomy; VARD: Video assisted retroperitoneal debridement.

**Table 3 Results of minimal invasive necrosectomy for walled-off necrotizing pancreatitis published after 2000**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Ref.** | **Year** | **Case****WON** | **Type****(Intend)** | **Sessions****(mean or****range)** | **Completion****rate (%)** | **Morbidity****(%)** | **Reoperation****rate (%)** | **Mortality****(%)** | **Remark** |
| **Infected** |  |  |  |  |  |  |  |  |  |
| Raczynski *et al*[25] | 2006 | 2 | TEND +irrigation | 3 | 100 | 0 | 0 | 0 | 2 PEG(1st report?) |
| Escourrou *et al*[26] | 2008 | 13 | TEND + irrigation | 1-3 | 100 | 46 | 0 | 0 | +PCD × 2 |
| Bala *et al*[27] | 2009 | 8 | Lt RPD + N+ irrigation | 3-17 | 87.5 | 25 |  | 12.5 | Stepped |
| Antillon *et al*[28] | 2009 | 1 | TEN + Stent |  | 100 | 0 | 0 | 0 | TransgastrostomyFoley irrigation |
| Will *et al*[29] | 2012 | 18 | TEN ± PCD | 3-8 | 100 | 16.6 | 0 | 0 | 1 unrelated death |
| Bakker *et al*[30] | 2012 | 10 | TEND | 2-6 | 100 | 20 | 0 | 10 | PF 10% |
|  | RCT | 10 | VARD/Lapar | 1-2 | 40 | 80 | 60 | 40 | PF 70% |
| Castellanos *et al*[31] | 2013 | 32 | VARD | 1 | 100 | 9.3 | 0 | 15.6 |  |
| Sarkaria *et al*[32] | 2014 | 17 | TEN + Stent ± PEG-J + irrigation | 5.3 | 88 | 5.9 | 11.8 | 0 | 8 PEG-J |
| **Sterile+infected** |  |  |  |  |  |  |  |  |  |
| Connor *et al*[39] | 2005 | 47(NS) | Lt. RPD + N | 1-9 |  | 92 |  | 19 | INP 81%(WON notspecified) |
| Voermans *et al*[33] | 2007 | 25 | TEND+ irrigation | NA | 92 | 40 | 4 | 0 | INP 76% |
| Papachristou *et al*[34] | 2007 | 53 | TEND ± PCD ± PEG + irrigation | 3 | 81 | 49 | 22.6 | 6 | INP 49% |
| Seifert *et al*[35] | 2009 | 93 | TEND | 6 | 80 | 26 | 11.8 | 7.5 | 1999-2005 |
|  |  | (NS) |  |  |  |  |  |  |  |
| Raraty *et al*[36] | 2010 | 137 | VARD |  |  | 75 |  | 19 | INP 64% |
|  |  | (NS) |  |  |  |  |  |  |  |
| van Santvoort *et al*[15] | 2010RCT | 43(NS) | Lt. RPD + N(Step-up) | 1-7 | 35 | 40 | 60 | 19 |  |
| Gardner *et al*[37] | 2011 | 104 | TEND | 1-14 | 91 | 14 | 2 | 2 | INP 39% |
| Bausch *et al*[50] | 2012 | 30 | PCD + N |  | 57 | 43 | 21 | 21 | INP 93% |
|  |  | 18 | TEND |  | 50 | 44 | 28 | 6 | INP 72% |
| Ross *et al*[10] | 2014 | 117 | TEND + PCD | NA | 100 | 4.2 | 0 | 3.4 | Dual modality |
| van Brunschot *et al*[38] | 2014SR | 455(NS) | TEN ± PCD | 4 (1-23) | 81 | 36 | 10 | 6 | INP 57% |

D: Drainage; Lapar: Laparotomy; N: necrosectomy; NS: WON was not specified; PCD: Percutaneous drainage; PEG-J: Percutaneous endoscopic gastrostomy-Jejunal arm; PF: Pancreatic fistula; RCT: Randomized control study; RPD: Retroperitonium PCD; SR: Systemic review; S: Metallic stent; TE: Transluminal endoscopic; VARD: Video assisted retroperitoneal debridement.

**Table 4 Results of drainage without minimal invasive necrosectomy for necrotizing pancreatitis published mainly after 2000**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Ref.** | **Year** | **Case****NP** | **Type****(Intend)** | **Sessions****(range)** | **Success rate****(%)** | **Morbidity****(%)** | **Reoperation****rate (%)** | **Mortality****(%)** | **Remark** |
| **Sterile** |  |  |  |  |  |  |  |  |  |
| Baril *et al*[20] | 2000 | 13 | PCD |  | 92.3 |  | 7.7 | 0 |  |
| Zerem *et al*[41] | 2009 | 20 | Conservative | 1.5 |  |  | 15 | 0 |  |
|  | RCT | 20 | PCD | 1.4 | 85 |  | 15 | 5 |  |
| **Infected** |  |  |  |  |  |  |  |  |  |
| Freeny *et al*[52] | 1998 | 34 | PCD | 3.3 | 47 | 26 | 53 | 12 |  |
| Baril *et al*[20] | 2000 | 25 | PCD | 1.4 | 76 | 8 | 18 | 8 |  |
| Baron *et al*[44] | 2002 | 38 | TED + irrigation | 2 (1-6) | 79 | NA | 18 | 5 |  |
| Lee *et al*[19] | 2007non-RCT | 18WON | PCD + irrigation |  | 83.3 | 11 | 16.7 | 5.6 | PF 32% |
|  |  | 5 | TED |  | 80 |  | 20 | 0 | PF 6% |
| Bruennler *et al*[42] | 2008 | 80 | PCD | (1–14) | 43 | 29 | 25 | 34 | (10 + PCN)1999-2004 |
| Mortelé *et al*[43] | 2009 | 35 | PCD | 3.3 | 49 | 11 | 37 | 17 |  |
| van Santvoort *et al*[18] | 2011 | 130 | PCD | NA | 35 | 42 | 58 | 20 | 21 Dutchhospitals. |
| Mukai *et al*[45] | 2014 | 5 | SGTMD |  | 100 | 0 | 0 | 0 |  |
| **Sterile + infected** |  | WON |  |  |  |  |  |  |  |
| Traverso *et al*[17]  | 2005 | 73 | PCD | NA | 79 |  |  | 11 |  |
| Chang *et al*[9] | 2006 | 19WON | MIS Lt. flank | 1 | 84.2 | 10.5 | 5.2 | 15.8 | INP 80% |
| Babu *et al*[46] | 2013 | 29 | PCDStep-up |  |  | 20 |  | 6.8 | INP 86% |
| Varadarajulu *et al*[47] | 2011 | 48WON | TED |  | 52.1 | 10.4 | 35.4 | 6.5 |  |
|  |  | 12WON | MTGT |  | 91.7 | 0 | 0 | 0 |  |

INP: Infected necrotizing pancreatitis; MIS: Minimal invasive surgery; MTGT: Multiple transluminal gateway technique; PCD: Percutaneous drainage; PCN: Percutaneous necrosectomy; RCT: Randomized control study; SGTMD: Single transluminal gateway transcystic multiple drainage; TED: Transluminal endoscopic drainage.