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2019 SSAT PLENARY PRESENTATION

Complications of Percutaneous Drainage in Step-Up Approach for Management of Pancreatic Necrosis: Experience of 10 Years from a Tertiary Care Center

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Abstract

Introduction Percutaneous catheter drainage (PCD) as initial intervention in necrotizing pancreatitis has led to improved outcomes and obviated need for surgery in a significant proportion. However, there can be difficulty in accessing deep-seated necrotic collections by percutaneous catheter and complications are likely.

Methods The present study involves a retrospective analysis of a prospectively maintained database of patients with necrotizing pancreatitis managed by a step-up approach. All patients who underwent PCD were studied for catheter-related complications.

Results A total of 707 PCD catheters were used in 314 patients (median 2, interquartile range IQR 1–3). The total number of interventions were 1194 (median 3, IQR 2–5). Enteric communication was seen in 8.9%, of which colonic fistula occurred in 71.4%, duodenal in 17.8%, and jejunal in 10.7% of patients. Majority (78.5%) of the fistulae were managed conservatively by withdrawal of the drain. Operative management was required in 30% of colonic and 40% of duodenal fistulae. Need for surgery, length of hospital stay, and mortality were not significantly different between patients with and without fistulae. Bleeding complications were seen in 7.3% of patients, out of which 34.7% were managed conservatively, 21.7% required angioembolization of pseudo-aneurysms, and 34.7% needed surgery. Patients with bleeding had significantly higher requirement for surgery and mechanical ventilation compared to those with no bleeding. There was no significant increase in hospital stay, ICU stay, and mortality.

Conclusion Hollow viscus and vascular injuries are important complications seen with catheter drainage of necrotic collections. Majority of patients with enteric communication were managed conservatively, with no added morbidity or mortality. Bleeding complications related to PCD had higher requirement for surgical intervention, but mortality rates remained similar to those of patients with no bleeding complications.

Keywords Necrotizing pancreatitis · Percutaneous catheter drainage · Intestinal fistula · Bleeding complications · Pseudoaneurysms · Ultrasound guidance · CT scan guidance · Infected pancreatic necrosis, Sterile pancreatic necrosis

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Introduction

Acute necrotizing pancreatitis (ANP) is a severe form of acute pancreatitis with necrosis of pancreatic parenchyma and peripancreatic tissues.[1] In the past, management of pancreatic necrosis involved necrosectomy with open or closed packing and drain placement.[2,3] However, this approach was associated with high mortality and morbidity, such as secondary organ failure, incisional hernia, enterocutaneous fistula, and pancreatico-cutaneous fistula.[4,5] Hence, a multidisciplinary approach involving percutaneous, endoscopic, and minimally invasive surgical techniques is now favored for treatment of ANP.[6–8]

In the landmark PANTER study,[9] a minimally invasive "step-up" approach led to a lower rate of major complications and death compared to primary open necrosectomy. Percutaneous drainage (PCD) or endoscopic drainage of necrotic collections is the first step in this approach. Percutaneous or endoscopic drainage aims to evacuate infected fluid and loose necrotic tissue. Necrosectomy is reserved for patients who fail to respond to initial drainage.

Percutaneous drainage of necrotic collections is reported to be technically feasible in > 95% of patients, often via a left-sided retroperitoneal route.[10] However, there is a risk of complications like bleeding, non-target puncture, and bowel perforation. In the "step-up" arm of the PANTER study,[9] enterocutaneous fistula was seen in 14% whereas significant bleeding was reported in 16%. In a systematic review of PCD in ANP,[11] the pooled complication rate of PCD was 21.4%. The impact of PCD-related complications on the course of the disease and outcome has not been presented before. Also, no treatment strategy has been suggested previously. Hence, this study aimed to evaluate the incidence, clinical presentation, management, and outcome of complications in patients with necrotizing pancreatitis who were treated with PCD as a part of a step-up approach.

Materials and Methods

Design and Setting

The study population was comprised of patients of necrotizing pancreatitis seen in our division at a large tertiary care referral teaching hospital of North India. We performed a retrospective analysis of patients undergoing PCD of necrotic collections as a part of a "step-up" approach. Patients with PCD who sustained visceral or vascular complications were the focus of this study. The period of the study was from April 2008 to December 2017. The study was approved by the institutional ethics committee.

The diagnosis of acute pancreatitis was made by clinical, biochemical, or imaging criteria. Initial management was supportive with fluid resuscitation, analgesics, nutritional support, and organ support. Contrast-enhanced CT scan was performed at least 4 days after pain onset to assess the severity of necrosis and local complications. Patients who failed to improve on conservative management underwent PCD insertion. The interventions were carried out under supervision of an interventional radiologist (MK, UG) with substantial experience in abdominal image-guided interventions. Indications for PCD insertion included suspected infected pancreatic necrosis or sterile pancreatic necrosis, with clinical deterioration, pressure symptoms, or persistent unwellness. Seldinger's technique was used to place PCD under ultrasound or CT guidance in the necrotic collection via the most direct route, avoiding intervening bowel and solid organs. The initial diameter of the PCD inserted was 8 Fr or 10 Fr, and subsequently upsized as required up to a maximum of 28 to 32 Fr. Additional interventions like upsizing, repositioning, replacement, or insertion of additional catheters were done as indicated. The number of catheters placed in a cavity would depend on the size of the cavity and the response to index catheter drainage. Saline irrigation was employed in all cases using a Y-connector attached to a pigtail catheter. The volume of irrigation depended on patient tolerance and ranged from 0.5 to 4.0 L of saline/drain/day. The PCD was removed after clinical improvement (defervescence, resolution of organ failure, and sepsis reversal) and radiological resolution of the necrotic cavity. Necrosectomy was performed if there was no clinical improvement (i.e., persistent sepsis, worsening, or new-onset organ failure) after PCD. Surgical procedures included minimally invasive or conventional open necrosectomy with closed lesser sac drainage and lavage.

We focused on maintaining nutrition in these patients. Target caloric intake was 30–35 kcal/kg of body weight/day, with the fat intake being around 30% of total calories and protein intake of 1.2–1.5 g/kg of body weight/day. We preferred the enteral route whenever it was available. Patients were initially started on oral or nasogastric feeds with standard or peptide-based formulae. Nasoenteric feed via endoscopically placed nasojejunal tube was started in case of delayed gastric emptying persisting for more than 3 days. Parenteral nutrition was employed if patients were not able to tolerate the enteral route of nutrition for more than 3–5 days. We continued with PN till at least 75% of nutritional needs could be met by enteral route, and gradually tapered it off as the oral diet was advanced.

Management of patients with suspected enteric communication of PCD is detailed in Fig. 1. Enteric communication of PCD was suspected if there was bilious, enteric, or feculent discharge from PCD. Alternatively, it was suspected if patients complained of watery diarrhea after saline irrigation. Diagnosis was confirmed with CECT scan (with contrast through PCD) or tubogram through PCD. Patients were continued on conservative management if there were no signs of peritonitis, nutrition was maintained, and there was no other indication for surgical intervention. Conservative management included low residue diet, saline irrigation through PCD, and monitoring drain output. If a patient showed clinical improvement, PCD output became clearer, and drain fluid amylase was normal, PCD was gradually withdrawn by 1–2 cm daily. Check tubogram ± ultrasound was performed to monitor catheter position and size of cavity. Surgical intervention was performed if patients failed to respond to non-operative management.

Management of patients with bleeding complications is detailed in Fig. 2. As a first step, the tip of the catheter was withdrawn by 1–2 cm and patients were monitored closely.

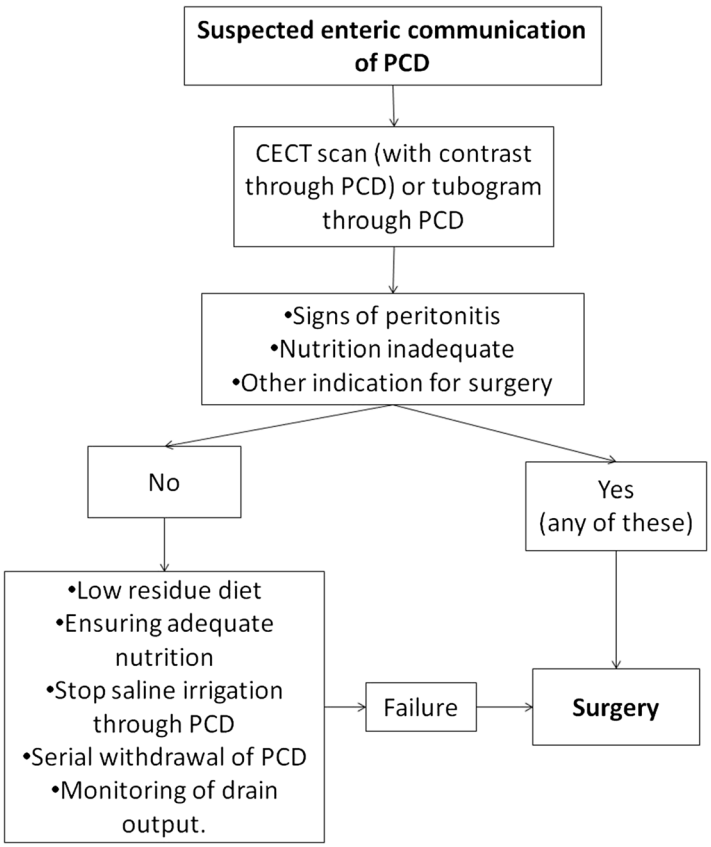

Fig. 1 Management of patient with suspected enteric communication of PCD

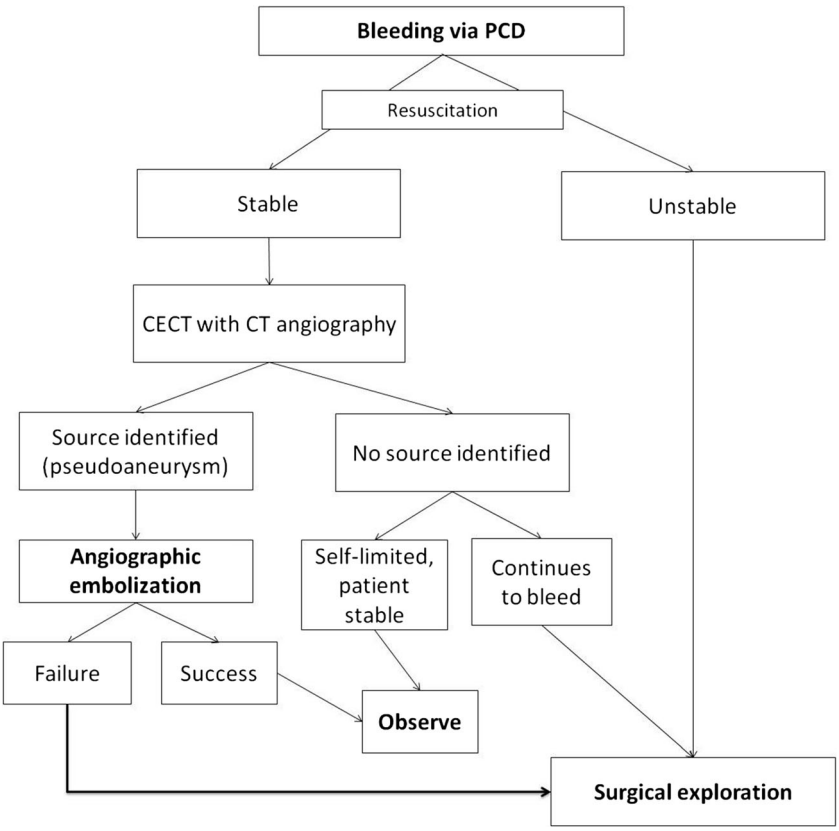

Fig. 2 Management of patient with bleeding via PCD

Patients with brisk bleeding through PCD were initially resuscitated and stabilized as per protocol for hypovolemic shock. Patients who were hemodynamically unstable and did not respond to resuscitation were taken up for emergency surgical intervention. Patients who were stable underwent emergency CECT with CT angiography. If a source of bleeding was encountered on CT angiography, urgent angiographic embolization or percutaneous thrombin injection was performed. If no source of bleeding and/or pseudoaneurysm was found, then the further decision was based on hemodynamic stability and ongoing bleed. Patients with continuing bleed from PCD underwent emergency laparotomy whereas those with self-limited bleed were observed.

Data Collection and Definitions

The definitions of terms used in the study were as mentioned in the PANTER study and our previous studies.[9,12] From our prospectively maintained database, data were retrieved on demographic characteristics [gender, age], etiology, and severity of illness [as per modified Atlanta classification, organ failure (OF) and Acute Physiologic and Chronic Health Evaluation II (APACHE II) scores, modified CT severity index (mCTSI)]. The interval between symptom onset and presentation, total hospital and total ICU stay, and need for mechanical ventilation were recorded. PCD characteristics were noted in detail. Details of visceral and vascular complications caused by PCD, detection, treatment, and eventual outcome were noted.

Statistical Analysis

Clinical parameters were compared between patients with and without PCD-enteric communication, and also between patients with and without bleeding complications. Normally, distributed data were expressed as mean ± standard deviation and were compared using the Student *t* test for 2 groups. Skewed data were expressed as median with interquartile range (IQR) and compared using the Mann-Whitney test for 2 groups. Proportions were compared using the χ^2 test or Fisher exact test. All statistical tests were 2-sided and performed at a significance level of $p < 0.05$. Statistical analysis was carried out using the IBM SPSS v.20 statistics software package (IBM SPSS Statistics, IBM Corporation, Armonk, NY).

Results

The study population consisted of 314 patients of acute necrotizing pancreatitis who were managed in our division during the study period. The mean age for the cohort was 39.6 ± 12.8 years. The cohort consisted of 238 males (75.8%) and 76 females (24.2%). Alcohol (176/314, 55.9%) and gallstones (80/314, 25.4%) were the predominant etiologies. Other causes were both alcohol and gallstones in 7 (2.2%), post-ERCP in 9 (2.9%), post-traumatic in 5 (1.6%), drug related in 3 (1%), hypercalcemia in 2 (0.6%), and idiopathic in 32 (10.2%). The median interval between symptom onset and presentation/referral to our center was 7 days (interquartile range (IQR) 1–16.25). Pre-referral initial treatment in the form of intravenous fluids, antibiotics, and organ support was received by 203 patients (64.4%). Patients who were referred to our center with PCD in place were excluded from the study.

When we looked at the severity of pancreatitis by modified Atlanta classification, 228 patients (72.6%) had severe disease and 86 patients (27.4%) had moderately severe disease. The median APACHE II score at presentation was 9 (IQR 6–12). Organ failure was seen in 228 patients (72.6%). Respiratory failure was seen in 215 patients (68.5%), acute kidney injury (AKI) in 92 (29.3%), and cardiovascular system failure in 55 (17.5%). Single organ system failure was present in 103 patients (32.8%), whereas 125 patients (39.8%) had multisystem organ failure. The median modified CT severity index (mCTSI) at first CECT scan was 10 (IQR 8–10). Mechanical ventilation for respiratory failure was required in 112 patients (35.7%), and median duration of ventilatory support was 8 days (IQR 3.25–14). The median total hospital stay was 40 days (IQR 25–60), and median total ICU stay was 15 days (IQR 7–27).

Patients underwent PCD at a median of 19 days (IQR 13–29) from the onset of illness. Median of 2 drains (IQR 1–3, range 1–8) were used per patient. A total of 707 PCDs were inserted in these patients, of which 373 (52.7%) were 10 Fr, 136 (19.2%) were 12 Fr, 142 (20.1%) were 14 Fr, and 56 (8%) were 16 Fr and above. A total of 1194 interventional procedures (drain insertion, repositioning, or upsizing) were carried out, with a median of 3 interventions per patient (IQR 2–5, range 1–12). Median duration of drainage was 35 days (IQR 20–60, range 2–235). Median time from PCD insertion to the identification of complication was 16 days (IQR 9.75–22.75 days). Bleeding complications were identified at a median of 13 days (IQR 4.5–18.5 days), while enteric fistulae were diagnosed at a median of 19.5 days (IQR 12–34.75 days). Bleeding complications occurred significantly earlier than bowel complications ($p = 0.03$).

Bowel Complications of PCD

Twenty-eight of 314 (8.9%) patients had enteric communication of PCD. Considering each PCD insertion as a separate intervention, the complication was noted in 3.9% of all PCD insertions (28/707). Median time from PCD insertion to identification of complication was 19.5 days (IQR 12–34.75 days). On CT scan/contrast tubogram, PCD communication with the colon was noted in 20 patients (71.4%), with the duodenum in

5 (17.8%), and with the jejunum in 3 (10.7%). All patients were managed as per the protocol detailed in Fig. 1.

Among 20 patients with colonic communication of PCD, conservative management with graded PCD withdrawal was successful in 14 patients (70%) (illustrated in Fig. 3a, c, d). Six patients required operative management for worsening sepsis. In these patients, surgery was performed at a median of 66 days (IQR 46–85) after the onset of pain. In 4 patients (20%), open necrosectomy with diversion of fecal stream by loop ileostomy was performed and no attempt was made to resect the part of the colon bearing the fistula. In 2 patients (10%) with communication of PCD with the right colon (cecum in one patient and hepatic flexure in another) (illustrated in Fig. 3e, f), necrosectomy with right hemicolectomy was performed with end ileostomy and distal mucus fistula.

In five patients, PCD communication with the duodenum was noted. All patients underwent nasojejunal tube placement and graded PCD withdrawal, which was successful in 3/5 patients. One patient needed surgical intervention for uncontrolled fistula. Open necrosectomy with duodenostomy and local drainage was performed in this patient. Another patient was operated on for biliohemorrhagic content via PCD, and underwent tube duodenostomy and an under-running of bleeder at the duodenal fistula site. Communication of PCD with jejunal loop was noted in 3 patients (Fig. 3b). In all these patients, irrigation through PCD was stopped and graded

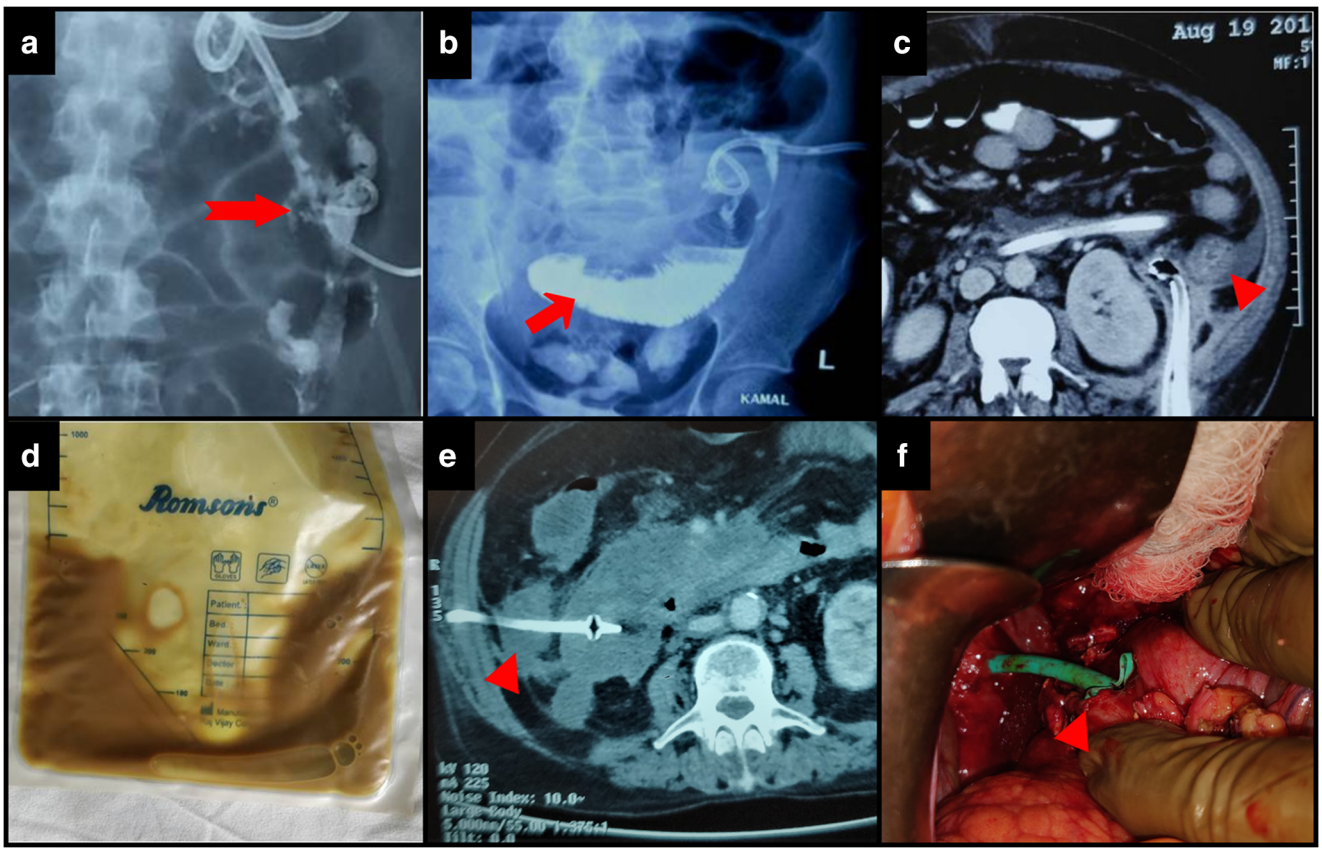

Fig. 3 Case capsules illustrating conservative and operative management of PCD-enteric fistula. **a** A 32-year-old man with severe acute necrotizing pancreatitis underwent percutaneous drainage for necrotic collection in peripancreatic and left paracolic regions 22 days after the onset of AP. Approximately 11 days after insertion of the drain, he complained of feculent drainage per PCD and watery diarrhea after saline irrigation of PCD. A contrast tubogram showed opacification of the descending colon (arrow). Fistula healed on conservative management with gradual pigtail withdrawal. **b** A 28-year-old man with moderately severe necrotizing pancreatitis treated with PCD 18 days after onset of illness. The patient presented with enteric content via PCD, 19 days following insertion. Contrast tubogram revealed PCD communicating with the jejunum (arrow). Conservative management with gradual PCD withdrawal was successful. **c** and **d** A 56-year-old male with alcohol-related necrotizing pancreatitis. PCD was inserted in the left anterior pararenal space on the 25th day of illness. It was later upgraded to 24 Fr and another PCD inserted alongside. Twelve days later, he presented with feculent discharge from PCD (**d**). A repeat CT scan image (**c**) showed collection almost resolved with the descending colon (arrowhead) in close proximity to the drain tip. This complication was managed conservatively with PCD withdrawal. **e** and **f** A 52-year-old male with alcohol-induced necrotizing pancreatitis underwent PCD of peripancreatic collection with a 16-Fr Malecot catheter. CECT scan was done in view of nonresponse to drainage with persistent sepsis. CT showed the PCD traversing through and through the ascending colon near the hepatic flexure (arrow). Exploratory laparotomy was done in view of persistent sepsis with organ failure and foul-smelling feculent discharge from PCD. The PCD was found to have pierced through the wall of the hepatic flexure of the colon (**e**) (arrow). Necrosectomy with right hemicolectomy and end ileostomy was performed

withdrawal with serial tubograms resulted in closure of the fistula in all 3 (100%).

On comparing the disease characteristic of patients who had enteric communication of PCD with those who did not (Table 1), no significant difference was noted in disease severity or timing of first PCD insertion. PCD characteristics like number of PCDs and number of interventional procedures were also similar in 2 groups. Duration of catheter drainage was significantly longer in patients who had enteric fistula (83.6 vs. 46 days, $p = 0.003$). The enteric fistula group also had a higher median drain size (14 Fr vs. 12 Fr) than those who did not have enteric communication. Length of hospital stay, length of ICU stay, need for mechanical ventilation, days on ventilator, need for surgery, and mortality were similar between the two groups.

Bleeding Complications

PCD-related bleeding complications occurred in 23 patients (7.3%). Bleeding complications were identified at a median of 13 days (IQR 4.5–18.5 days) after PCD insertion. The details and outcome of these patients are given in Fig. 4. Of these, 2 patients were referred from the Gastroenterology Department with massive bleed following PCD insertion and both succumbed before shifting to the operation theater. The source of bleed in these patients could not be identified.

Of the 21 patients who presented with bleeding after PCD insertion, 15 were hemodynamically stable and underwent urgent contrast-enhanced CT scan (CECT) with CT angiography. CECT demonstrated arterial pseudoaneurysm in 7 patients, and these patients underwent conventional angiography with embolization. Three patients had pseudoaneurysms arising from the splenic artery or branches, 2 patients had pseudoaneurysm arising from the gastroduodenal artery or branches, and another 2 patients had left colic artery pseudoaneurysm (Fig. 5a–f). Angioembolization was successful in stopping bleeding in 5 patients. We could not localize the site of bleeding in one patient, and another patient had recurrent bleed after angioembolization and both were successfully managed surgically.

CT angiography did not show any source of bleeding in 8 patients. All of these patients were stable after resuscitation and did not have further bleeding once coagulation parameters were optimized. We stopped saline irrigation through PCD in these patients, and PCD was withdrawn slightly to avoid impingement of the drain tip causing bleeding from granulation tissue lining the wall of the cavity. The bleeding episode was managed conservatively in all 8 of these patients. Three of these patients later needed necrosectomy for persistent sepsis with residual necrotic collections.

Six patients required surgery for hemodynamic instability while two patients required surgery due to failure of angioembolization. Open necrosectomy was performed in all 8 patients. Ligation of the bleeder was done in 4 patients. In the other 4 patients, diffuse oozing was encountered and packing of the cavity with sponges was done as a damage-control measure (Fig. 5g, h). Multiple re-explorations were required for recurrent bleeding in two patients (6 times and 5 times respectively). Both patients survived but later developed large incisional herniae.

On comparing characteristics of patients who had PCD-related bleeding with those who did not (Table 2), no significant difference was noted in parameters of the severity of disease or PCD characteristics. Patients who bled had a significantly higher need for surgery ($p = 0.02$) and need for mechanical ventilator support ($p = 0.005$). However, hospital stay, ICU stay, and number of days on ventilator were similar among the two groups. Mortality in patients who bled was slightly higher (34.8% vs. 23.7%), but was not statistically significant ($p = 0.23$).

Table 1 Comparison of clinical and PCD characteristics between patients who had enteric communication of PCD and those who did not have enteric communication

	PCD communication with bowel ($n = 28$)	No communication with bowel ($n = 286$)	p value
APACHE II score at presentation, median (IQR)	11 (5–12)	9 (6–12)	0.42
Interval between onset of ANP to first PCD in days, mean (SD)	24.2 (13.1)	24.1 (18.6)	0.95
Number of drains, median (IQR)	2 (2–3)	2 (1–3)	0.19
Number of interventional procedures, median (IQR)	4 (3–6)	3 (2–5)	0.12
Upsizing of drain, *n* (%)	15 (53.6%)	108 (37.8%)	0.09
Maximum diameter of drain (French), median (IQR)	14 (12–16)	12 (10–14)	*0.01*
Drainage duration (days), mean (SD)	83.6 (77.4)	46 (40.5)	*0.003*
Infected necrosis, *n* (%)	24 (85.7%)	254 (88.8%)	0.95
Total hospital stay, days, mean (SD)	47.1 (25.5)	43.7 (25.7)	0.25
Total ICU stay, days, mean (SD)	12 (8–27)	16 (7–27)	0.49
Need for ventilation, *n* (%)	8 (28.6%)	101 (35.3%)	0.53
Days on ventilator, mean (SD)	16.3 (12.6)	19.2 (15.4)	0.89
Need for surgery, *n* (%)	9 (32.1)	84 (29.4)	0.10
Mortality, *n* (%)	8 (28.6%)	72 (25.2%)	0.29

The emphasized font denotes *p*-value that is statistically significant

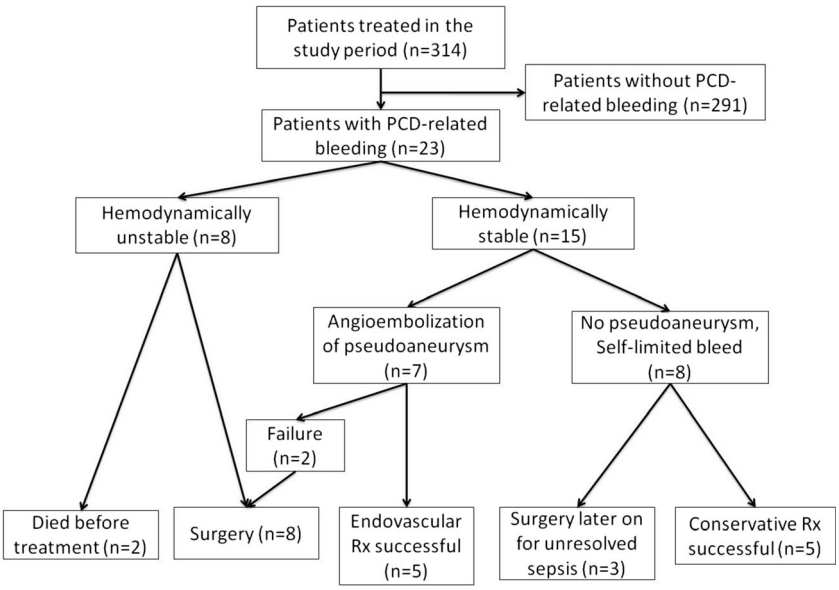

Fig. 4 Details of management and outcome of patients with PCD-related bleeding

Other Complications

We also observed breakage of the PCD tip in 3 patients. In one patient, the pigtail tip was removed during subsequent necrosectomy done for worsening sepsis, while in 2 other patients, it was left in situ, as there were no symptoms related to it (Fig. 6a, b). We also noted necrotizing fasciitis of the abdominal wall around the site of PCD in 2 patients, due to tracking of infected fluid into subcutaneous and muscle planes around the PCD. Surgical debridement was carried out in both patients along with pancreatic necrosectomy. Both patients succumbed in the postoperative period due to severe sepsis with multiorgan failure.

Time Trends

We also compared our outcomes over two time periods. In the first 5 years of our experience, 120 patients were managed in our division, which increased to 194 patients in the second 5 years. The total number of interventions in the first 5 years was 546, compared to 648 in the second 5 years. In the second 5 years, patients needed significantly fewer interventions (median 4 vs. 3, $p = 0.002$) and had significantly higher median drain size (10 Fr vs. 12 Fr., $p < 0.001$). There was no difference in incidence of all complications (14.2% vs. 15.5%, $p = 0.754$), GI fistulae (7.5% vs. 9.8%, $p = 0.488$), or bleeding complications (7.5% vs. 9.4%, $p = 0.925$).

Imaging Modality

Out of 314 patients, ultrasound was used for image-guided intervention in 117 patients (37.3%) and CT in 79 (25.2%), and a combination of ultrasound and CT guidance was used in 118 (37.6%). The use of combined image guidance was significantly more common during the second 5 years of our experience (29.2% vs. 42.8%, $p = 0.019$). However, there was no difference in rates of complications with different modalities used for guidance (16.2%, 11.4%, and 16.1%, respectively, $p = 0.58$).

Nutrition

Data on nutrition was available for 242 patients (77.1%). Of these, 112 patients (46.2%) received nasoenteric nutrition using a nasojejunal tube. Median duration of nasojejunal tube feeding was 24 (IQR 14–35) days. Ninety patients (37.1%) required parenteral nutrition for a median duration of 12 (IQR 5–18) days. Patients with PCD-related enteric fistulae had a significantly higher requirement for parenteral nutrition than those who did not (60.7% vs. 39.28%, $p = 0.013$).

Discussion

The technique and outcomes of image-guided PCD in the setting of ANP with acute necrotic collections and walled-off necrosis have been well described.[13–16] Nevertheless, there are few systematic studies specifically addressing complications in patients with PCD in situ. In the present study, we assessed frequency, etiology, treatment, and outcome of visceral and vascular complications occurring in ANP patients with PCD.

The reported incidence of GI fistula in ANP varies from 4 to 41%.[17–21] Incidence reported in patients undergoing open necrosectomy is much higher varying from 41 to 47%.[17, 20] In contrast, reported incidence in patients undergoing the step-up approach is around 12.8–14%.[9,18] In the present study, it is 8.9% (28/314). Intestinal fistulas in the setting of ANP may

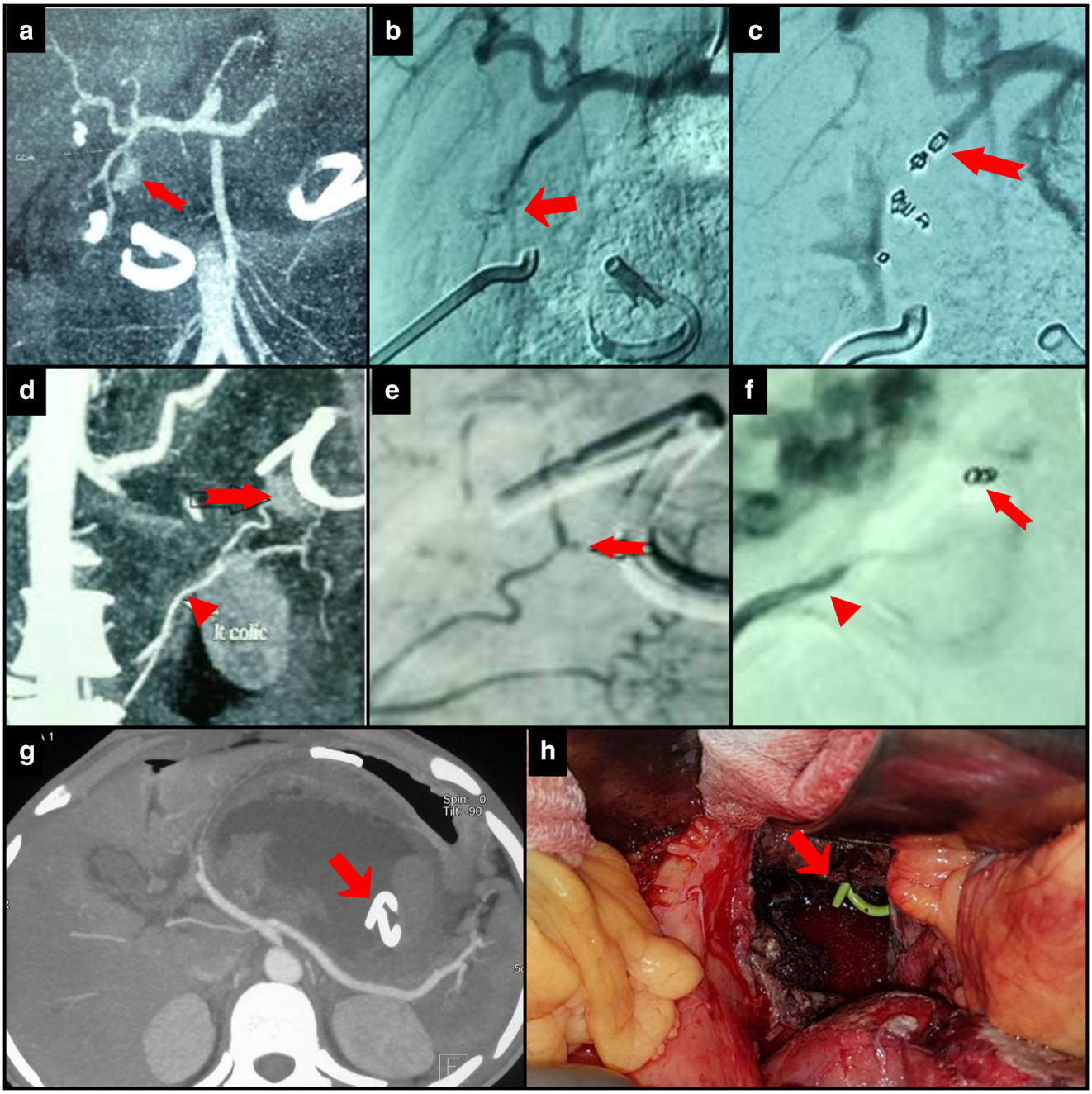

Fig. 5 Case capsules illustrating endovascular and operative management of PCD-related bleeding complications. **a**, **b**, and **c** A 40-year-old man with severe acute necrotizing pancreatitis underwent percutaneous drainage for necrotic collection in the peripancreatic and right pararenal region 19 days after the onset of AP. Five days after insertion of the drain, bright red bleeding was observed from the PCD. Urgent CT angiography showed pseudoaneurysm (arrow) of the gastroduodenal artery (**a**). Digital subtraction angiography (DSA) showed active contrast extravasation (arrow) suggestive of ruptured pseudoaneurysm (**b**). Coil embolization (arrow) was performed which was successful in stopping the bleeding (**c**). **d**, **e**, and **f** A 52-year-old man with alcohol-related severe necrotizing pancreatitis treated with PCD 18 days after onset of illness. He presented with hypovolemic shock and bleed via PCD. Urgent CT angiography showed pseudoaneurysm (arrow) of the left colic artery (arrowhead) (**d**). Digital subtraction angiography (DSA) showed active contrast extravasation (arrow) suggestive of ruptured left colic artery pseudoaneurysm (**e**). Coil embolization (arrow) was performed which was successful in stopping bleeding (**f**). **g** and **h** A 33-year-old male with alcohol-induced necrotizing pancreatitis underwent PCD of lesser sac collection. He presented with altered blood via PCD which increased suddenly in output. CT angiography (**g**) showed hyperdense contents within the cavity suggestive of bleed with PCD in situ (arrow), but no pseudoaneurysm was found. Exploratory laparotomy was performed in view of hemodynamic instability. Intraoperatively, the entire cavity was found to be full of clots mixed with necrosum (**h**). The source of bleed was found to be due to the PCD (arrow) impinging on the wall of the cavity with generalized ooze from the granulation tissue. Necrosectomy, PCD removal, and packing of the cavity with sponges were performed. The packs were removed 48 h later. The patient made a good recovery

Table 2 Comparison of clinical and PCD characteristics between patients who had bleeding complication of PCD and those who did not have bleeding complication

	PCD-related bleeding complication (n = 23)	No PCD-related bleeding complication (n = 291)	p
APACHE II score at presentation, median (IQR)	10.5 (5–13.25)	9 (6–12)	0.44
Interval between onset of ANP to first PCD in days, mean (SD)	23.1 (11.5)	24.1 (18.5)	0.68
Number of drains, median (IQR)	2 (1–2)	2 (1–3)	0.62
Number of interventional procedures, median (IQR)	4 (3–5)	3 (2–5)	0.22
Upsizing of drain, *n* (%)	8 (36.4%)	115 (40.8%)	0.68
Maximum diameter of drain, median (IQR)	12 (10–14)	12 (10–14)	0.39
Drainage duration (days), mean (SD)	53.8 (39.1)	48.5 (45.8)	0.62
Infected necrosis, *n* (%)	20 (90.9%)	249 (88.3%)	0.71
Total hospital stay, days, mean (SD)	35.2 (19.7)	44.65 (25.9)	0.09
Total ICU stay, days, mean (SD)	15.2 (13.1)	19.3 (15.4)	0.19
Need for ventilation, n (%)	*13 (59.1%)*	*96 (34%)*	*< 0.01*
Days on ventilator, mean (SD)	9.2 (7.6)	10.3 (9.3)	0.82
Need for surgery, n (%)	*11 (47.8%)*	*82 (28.2%)*	*0.02*
Mortality, *n* (%)	8 (34.8%)	69 (23.7%)	0.23

The emphasized font denotes p-value that is statistically significant

occur as a complication of pancreatitis or as a result of interventional, endoscopic, or operative management. The inflammatory process of acute pancreatitis results in local complications like acute necrotic collections and walled-off necrosis. Infected fluid under high pressure may lead to compression and erosion of the adherent, inflamed surrounding bowel resulting in perforation and fistula formation. The inflammatory process can also result in thrombosis of the middle colic artery and lead to ischemia and necrosis of the affected bowel wall with resultant fistula formation.[20,22]

On the other hand, patients managed with the step-up approach can have bowel fistulae due to direct puncture of the adherent bowel or due to erosion by constant pressure of indwelling drains.[23] This is more likely to occur in patients with large necrotic cavities where drains need to stay for a longer duration. These drains also tend to become stiffer over a period of time. Therefore, a weakened bowel wall due to inflammation which is densely adherent to the cavity and a stiffened indwelling drain may be a possible reason for bowel fistulization over and above the direct inadvertent puncture. This is exemplified by the present study in which the mean duration of PCD in patients with PCD-bowel communication was significantly longer than in those without PCD-bowel communication (83.6 vs. 46 days, p = 0.003). Baudin et al.[13] also reported a longer duration of drainage (61 vs. 41 days) among patients who developed fistulae.

Colonic fistulae were the most common site of PCD-enteric fistulae occurring in 20/28 (71.4%) patients in the present study. These findings were similar to the study by Doberneck[17] and Jiang et al.,[18] where colonic fistula constituted 45.4% and 60.5%, respectively, of all enteric fistulae. Higher incidence of coloni fistulae may be because of the anatomical proximity of the transverse colon to the lesser sac collections which tend to spread in paracolic space involving the ascending and descending colon as well. Similarly

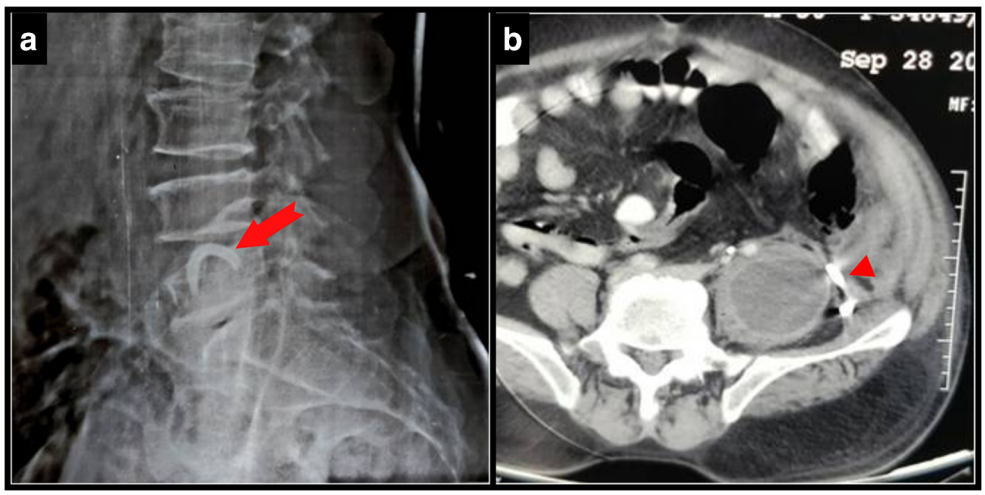

Fig. 6 Case capsule illustrating breakage of PCD within the necrotic cavity. A 60-year-old male with moderately severe pancreatitis was treated with PCD for collection in the left paracolic space. He recovered on PCD alone and it was removed. A routine follow-up scan revealed a portion of the PCD tip retained within the paracolic space. Plain X-ray (**a**) and CT scan (**b**) images are displayed below. As the patient was asymptomatic and was not willing to undergo surgical removal, the PCD fragment was left in situ. The patient is on regular follow-up

necrotic collections involving necrosis of the pancreatic head can involve the duodenum, while direct puncture is more likely in the jejunum.

Management of PCD-bowel fistulae is based on the site and clinical presentation. At our center, we followed a protocol of conservative management with graded withdrawal of PCD if there was no peritonitis and nutrition was maintained. We performed repeated check tubograms to confirm the withdrawal of PCD from the bowel lumen. Previous studies have reported that most duodenal and small-bowel fistulae close with conservative management.[18–20,24] In the present study also, all of the jejunal fistulae and 3 out of 5 duodenal fistulae closed with conservative management. Among patients who had colonic fistulae, conservative management was successful in more than two thirds (70%); however, fistulae of the right colon mandated surgery. In a review of pancreatitis-associated colonic complications reported by Mohamed et al.,[25] the authors concluded that colonic fistulae arising in conjunction with percutaneous drainage usually closed spontaneously. In another study by Heeter et al.,[26] the authors also observed a high success rate of 85% with nonoperative treatment for pancreatico-colonic fistulae treated with drainage of collection and serial tubograms. However, bowel fistulae occurring in patients undergoing open necrosectomy have been associated with a much lower closure rate, i.e., around 35% respectively.[18,20] A higher closure rate of the fistula in patients with PCD is probably related to a smaller fistula and tract size, which is more likely to close spontaneously.

Previous studies[18,19] have reported that the occurrence of enteric fistula did not increase mortality in necrotizing pancreatitis. In the present study also, the mortality rate of patients with or without PCD-bowel communication did not differ significantly. In contrast, Jiang et al.[18] reported that mortality was significantly higher in the subgroup of patients with colonic fistula (34.7%) compared to patients with no fistula. In their study, fistulae were predominantly disease related and occurred in a sicker patient population. In contrast, enteric fistulae in our study were more likely to be related to PCD as disease severity was similar in patients with or without fistulae.

Bleeding Complications

In the present study, the incidence of PCD-related bleeding complications was 7.3% (23/314), which was comparable to 4–5% incidence reported previously,[13, 14] but much lower than 16% reported in the PANTER study.[9] Pseudoaneurysms are the dreaded cause of bleeding and may form at any time in the course of illness, either de novo or after percutaneous drainage. Mallick et al.[27] reported that around 30% of arterial pseudoaneurysms in acute pancreatitis developed after percutaneous drainage. The underlying mechanism might be iatrogenic vessel injury during PCD insertion or erosion of the surrounding vessel by a longstanding drain. Pseudoaneurysms may also form when there is sudden decompression of large fluid/necrotic collection after insertion of PCD and may rupture and bleed. In our study, direct injury to the vessel wall was the most likely cause of massive bleeding in two patients immediately following PCD insertion. Both these patients succumbed before treatment could be initiated. We observed that among patients with bleeding, pseudoaneurysms were detected in 30.4% of patients by CT angiography.

Bleeding may also occur without pseudoaneurysm formation. Acute necrotic collections mature over time to form "walled-off" necrosis.[28] The wall of the cavity is formed by hypervascular granulation tissue and may also contain major vessels. The cavity may reduce in size after successful drainage by PCD, resulting in the impingement of the PCD tip on the wall of the cavity and causing bleeding from granulation tissue. Such bleeding is usually self-limited and tends to stop when PCD is withdrawn a few centimeters. In our study, 34% (8/23) of patients had a self-limited bleed which settled after PCD withdrawal. However, cavity bleed may be significant enough to cause hemodynamic instability, especially in the setting of organ failure and coagulopathy. In our study, diffuse bleeding was encountered from the cavity wall in 4 patients who presented with hemodynamic instability and needed surgery. We observed that patients who sustained PCD-related bleeding complications had a higher requirement for surgery than those without bleeding (47.8% vs. 28.2%, $p = 0.02$). These patients also had a significantly higher requirement for mechanical ventilation. Mortality in these patients was higher (34.8% vs. 23.7%); however, it was not statistically significant. A similar mortality rate of 34.1% was reported by Flati et al.[29] Wei et al.[30] reported on predictors of intraabdominal bleeding following intervention and found that a higher Marshall Score, preintervention organ failure, and sepsis were predictors of bleeding complications.

The risk of bleeding can be reduced by adhering to certain precautions. We preferred the Seldinger technique for PCD insertion. A small needle/stylet was used to enter the cavity. A smaller catheter (8 to 10 Fr) was placed initially and subsequently upsized once a track had formed. Use of Doppler ultrasound for image guidance was often helpful, sometimes as an adjunct to CT-guided drainage. This helps to avoid puncturing adjacent or surrounding vascular structures.[24] Placement of drains should be meticulous; soft drains should be placed and should not be positioned in proximity to big vessels.[30] If bleeding occurs, it is important to obtain imaging before removing the PCD, as premature removal of PCD can result in a catastrophic escalation in bleeding.[24] In the meantime, PCD may be temporarily capped to tamponade acute bleeding till resuscitation is initiated and imaging and intervention are planned. Patients who remain hemodynamically unstable after initial fluid challenge should be rushed immediately to the operation theater without further delay.

Other Complications

We also encountered breakage of the PCD tip within the cavity in 3 patients. In one patient who subsequently required surgical necrosectomy due to worsening sepsis, the broken catheter tip was found lying free within the cavity and was removed. The two other patients with broken catheter tip were discharged and kept on follow-up. There is disagreement as to whether retained fractured catheters need to be removed.[31] Fractured PCD may act as a nidus for infection or it may erode into surrounding structures. However, finding and removing a small fragment may not be easy in an inflamed area, and may cause more morbidity.

Necrotizing fasciitis of the abdominal wall around the PCD insertion site was seen in two patients with large collections filled with necrosum and pus under pressure. Due to the pressure within the cavity, there was tracking of pus along the PCD into the musculofascial planes. This complication is more likely to occur in patients with cavities containing predominantly liquid contents. In such patients, multiple catheters may be inserted at the same sitting or rapidly upsized to prevent the tracking of infected fluid. The technique of "dual-modality drainage"[32] may also be useful in this scenario.

Relation Between Complications and Timing of Intervention

The exact timing of initial intervention in necrotizing pancreatitis remains a matter of debate. Current guidelines advocate delaying any invasive intervention preferably until 4 weeks of the illness. PCD becomes technically easier in walled-off necrosis. Also, the resolution of the cavity with PCD becomes more likely as necrosis liquefies with time. In our study, the median time from disease onset to the first PCD placement was 19 days. PCD was performed for ANC (i.e., less than 4 weeks from onset) in 221 patients (70.3%) and WON (more than 4 weeks from onset) in 93 (29.7%) patients. We did not find any relationship between the timing of intervention and PCD-related complications. A study by the Dutch Pancreatitis Study Group reported significantly lower complication rates if the initial intervention was postponed till or beyond 29 days from onset of illness.[21]. However, van Grinsven et al.[33] and Mallick et al.[34] reported no relation of the bleeding complications with the timing of the first catheter placement.

The single-center, retrospective nature of this study forms one of the limitations. Another weakness is the inability to distinguish whether some of the complications occurred due to PCD insertion or due to the disease process or both. However, the management protocol would not change based on the mechanism of injury. This study also did not address the frequency and outcome of pancreatico-cutaneous fistula which occurs commonly with external drainage of pancreatic necrosis. We feel that external pancreatic fistula secondary to ductal disruption is purely disease related and not an iatrogenic complication of PCD, and hence, it was not included in the present study.

In conclusion, enteric fistulae and vascular injuries are infrequent yet important complications seen with PCD use in the "step-up" approach for necrotizing pancreatitis. PCD-enteric fistulae were seen in 8.9% of patients. Colonic fistulae were the most common, followed by duodenal fistulae. Majority (78.5%) of patients with enteric communication of PCD were managed conservatively, with no significant impact on mortality or requirement of surgery. The duration of drainage was significantly higher in patients with fistula. Bleeding complications related to PCD were seen in 7.3% of patients. Bleeding complications led to higher requirement for surgery and mechanical ventilatory support, but mortality was not significantly different compared to patients without bleeding.

Author Contributions All of the authors were involved in the formation of the study concept and design; acquisition of data; analysis and interpretation of data; drafting of the manuscript; critical revision of the manuscript for important intellectual content; statistical analysis; and administrative, technical, or material support.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

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