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HOW I DO IT

Minimally Invasive Debridement for Infected Pancreatic Necrosis

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Abstract
Necrotizing pancreatitis has historically been treated with open necrosectomy, which carries a high morbidity and mortality rate. More recently, there has been a shift towards endoscopic and percutaneous approaches employed as part of a minimally invasive step-up approach. Herein, we describe the technical approaches to video-assisted retroperitoneal debridement and sinus tract endoscopic debridement of pancreatic necrosis. Additionally, we review important patient selection considerations and the strengths and weaknesses of each of the approaches.

Keywords Video-assisted retroperitoneal debridement · Pancreatic necrosectomy · Infected necrotizing pancreatitis

Introduction

Acute pancreatitis is the third most common gastrointestinal disease resulting in hospital admission in the USA, with hospital admission rates of above 0.7 per 1000 population and hospital costs of more than $2 billion in hospitalizations cost annually.[1,2] Necrotizing pancreatitis occurs in about one in five patients with pancreatitis and is associated with increased rates of organ failure and mortality. For decades, the standard approach to infected necrosis was surgical management with open necrosectomy, which is associated with mortality rates of 8.8–11.4%.[3,4] More recently, minimally invasive techniques of necrosectomy via percutaneous and endoscopic approaches have been developed.[5,6] Randomized trials, reviews, and current guidelines now recommend minimally invasive necrosectomy within the framework of a "step-up" approach for treatment of infected necrosis. We present here our approach to pancreatic necrosectomy with specific discussion of the techniques of video-assisted retroperitoneal debridement (VARD) and sinus tract endoscopy (STE).

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Patient Selection

The International Association of Pancreatology/American Pancreatic Association (IAP/APA) has released evidence-based multidisciplinary consensus guidelines on the management of necrotizing pancreatitis.[7,8] As detailed in these guidelines, the primary indication for intervention in necrotizing pancreatitis is known or suspected infection of the necrosis with clinical deterioration. In acute pancreatitis patients with a lack of clinical improvement (i.e., persistent fevers, increasing inflammatory markers, etc.) despite optimal medical management, imaging is indicated. Infected necrosis can be diagnosed by imaging demonstrating gas within the areas of pancreatic necrosis. While this finding is highly specific, it is not sensitive. Until recently, percutaneous sampling of the necrotic collection for culture was routinely advocated to assess for infected necrosis, when there was clinical suspicion for infection but no definitive evidence on imaging. However, this practice has fallen out of favor because of its unacceptably high false-negative rate of ~ 20%.[4] While percutaneous sampling may be used selectively, currently, the decision to proceed with intervention via a step-up approach should be based on a clinical diagnosis of infection and the patient's overall clinical status. This can be one of the more difficult clinical judgments to make when treating these patients.

When intervention is indicated, endoscopic or percutaneous drainage should be initially pursued to alleviate the sepsis burden, and necrosectomy should be delayed for a minimum of 4 weeks to allow for encapsulation and demarcation of necrosis. In certain cases, the initial drainage may obviate

the need for necrosectomy. This initial treatment with drainage followed by necrosectomy only in the absence of clinical improvement is what is termed the step-up approach. In patients with infected necrosis who do not respond adequately to minimally invasive drainage, or with persistently symptomatic sterile necrosis (i.e., failure to thrive, abdominal pain, gastric outlet obstruction), necrosectomy should be considered. Figure 1 is an algorithm for choosing the optimal method of intervention and Table 1 illustrates their relative strengths and weaknesses, which are further detailed in the "Discussion" section. While we do not discuss the technical aspects of open surgical necrosectomy, surgical transgastric necrosectomy, or endoscopic transgastric necrosectomy in this paper, they are considered in Table 1 and the discussion as a thorough understanding of all techniques is important for properly employing the VARD and STE techniques we describe here. A variety of variations in the VARD and STE techniques have been developed,[5,6,9] but herein, we will describe how we perform VARD and STE.

Operative Technique

Sinus Tract Endoscopy

It is ideal to delay intervention until at least 4 weeks after the onset of pancreatitis to allow any necrosis to wall off and demarcate from viable surrounding tissue. Even if the patient's condition demands earlier percutaneous drainage, necrosectomy should be delayed until at least the 4-week mark in the majority of cases. The technique of STE is depicted in the video at the following link: https://youtu.be/e05-SVI-7rA.10 Our preferred technique is similar to that described by Carter et al.[5] Procedure planning begins with placement of the percutaneous drain and an exact path should be agreed upon with the interventional radiologist placing the drain. A point of entry that allows access to the entire cavity should be chosen. Usually, the optimal access is at one end of the cavity, allowing debridement to proceed from one end to the other (Fig. 2). The patient should be placed on the operating table in a position that best facilitates the exposure of the drain being accessed for necrosectomy. This is most commonly a partial decubitus position given the retroperitoneal position of the pancreas, but given that we often employ STE when transperitoneal access is required, patients may be supine. The drainage catheter is cut at the skin level, and the drain site prepped and draped into the surgical field in the usual sterile fashion. We prep the entire abdomen to allow for emergency laparotomy if necessary. The fluoroscopy X-ray machine should be positioned across from the primary surgeon.

Under fluoroscopic guidance, an Amplatz wire (Cook Medical, IN) is inserted through the cut end of the drain and passed out through the end into the necrosis cavity. The drain is then removed over the wire. Following removal, a 30-Fr Bard X-Force (Bard Medical, GA) nephrostomy balloon dilator catheter is inserted over the wire until the tip of the balloon is within the cavity of the necrotic tissue. The balloon dilator is then inflated with contrast to a pressure of 20 psi and kept inflated for approximately 1 min to allow for dilation of the tract. Then, a 30-Fr working sheath (length can be varied depending on cavity location) is inserted over this balloon. Following this, a rigid nephroscope is then inserted to examine the cavity via the sheath, and continuous irrigation of the cavity with normal saline facilitates the visualization. Immediately after sheath placement, the sheath is typically buried in necrotic tissue and it is impossible to recognize a cavity. Utilizing a grasper passed through the nephroscope, careful debridement is begun. Gradually, as the necrosis is excavated, a working space is developed within the cavity and the debridement is then carried out in a systematic fashion. Debridement should be performed until a healthy circumference of granulation tissue is observed. It is unnecessary and dangerous to debride necrosis that is tightly adherent to the walls of the cavity. If necrosis does not debride easily at the time of initial STE, it is safer to end the procedure, irrigate the cavity, and return in 48–72 h to repeat the debridement. Usually, the necrosis is significantly less adherent after an initial debridement, which loosens the cavity, followed by a period of irrigation.

Over-aggressive debridement may lead to bleeding. During sinus tract endoscopy, even minor bleeding can be problematic since it impairs visualization in the relatively small working space, especially when swirling in the irrigant. In this circumstance, the bleeding areas can be managed by packing the cavity with a half-inch gauze packing strip though the sheath for a few minutes. This is often enough to allow the procedure to proceed. Advancing the sheath past the point of bleeding to "jail" and tamponade the bleeding tissue can also be effective and allow debridement to continue at a different point in the cavity. An alternative is to stop the continuous irrigation and continue the debridement in a dry fashion, so that the blood can pool on the floor of the cavity instead of swirling in the irrigant (portrayed in the video).[10] These are all appropriate techniques to manage minor oozing. Happily, we have yet to encounter major intraprocedural bleeding during sinus tract endoscopy. Depending on the scenario (venous versus arterial bleeding, patient hemodynamics), options include cavity packing either through the sheath or after conversion to VARD, balloon tamponade of the cavity, urgent angioembolization, conversion to laparotomy, or a combination. Our bleeding complications occurring during VARD (discussed below) have been manageable by packing. Given the difficulty of accessing the cavity quickly during sinus tract endoscopy, it cannot be overemphasized that bleeding is better avoided than treated.

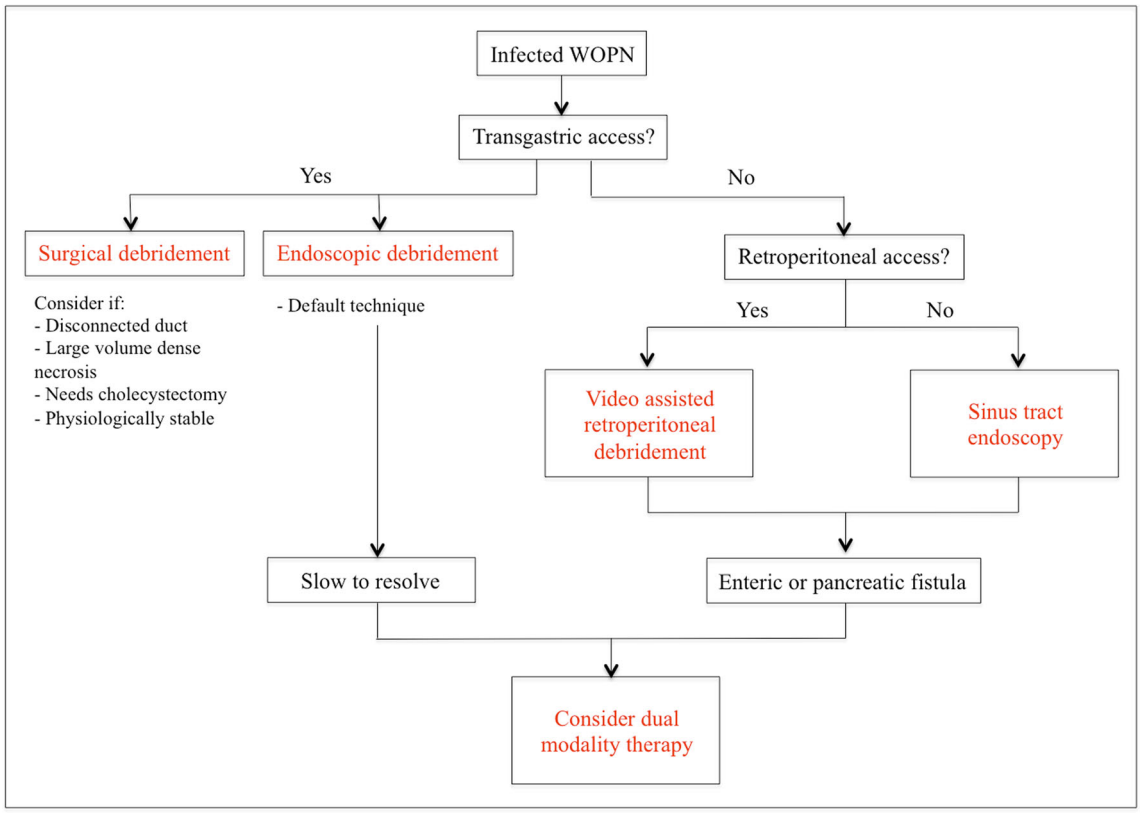

Fig. 1 Decision algorithm for selecting the optimal intervention approach in patients with infected walled off pancreatic necrosis. In this figure, "surgical debridement" refers to transgastric debridement which can be performed open or laparoscopically. Dual modality therapy refers to a combination of endoscopic transgastric drainage and external necrosectomy via video-assisted retroperitoneal debridement or sinus tract endoscopy and is depicted in Supplemental Video 2. WOPN walled off pancreatic necrosis

Following completion of the debridement, a drainage catheter is replaced over the Amplatz wire. We usually use a 24–28-Fr Thal catheter with additional side holes cut as needed so that the entire length of the cavity is drained. If a repeat procedure is planned, we place a 7-Fr catheter adjacent to the Thal catheter through the same skin incision through which to instill irrigation. We typically perform continuous irrigation with 0.9% saline at 200 mL/h for 48–72 h between procedures. Once the drains are in place, the guidewire is removed, and the drainage catheter may be flushed with contrast under fluoroscopy to visualize the debrided cavity and interrogate for enteric fistulae. If present, the irrigation catheter is attached to an infusion pump and the drainage catheter connected to a drainage bag. The skin is then closed with interrupted sutures around the catheter.

Table 1 Advantages and disadvantages of different pancreatic necrosectomy approaches

	Open transperitoneal necrosectomy	Transgastric necrosectomy	Video-assisted retroperitoneal debridement	Sinus tract endoscopic debridement
Advantages	Flexibility in access.	Lacks external drainage system. Endoscopic approach has decreased morbidity when compared to open necrosectomy. Surgical approach allows rapid debridement and simultaneous cholecystectomy.	Does not require a transgastric window. Decreased morbidity when compared to open transperitoneal necrosectomy. Uses equipment familiar to surgeons.	Flexibility in access (transperitoneal, retroperitoneal, intercostal). Decreased wound morbidity when compared to open necrosectomy or VARD.
Disadvantages	High rates of morbidity and mortality.	Requires a clear anatomical window with posterior stomach. Endoscopic approach usually requires multiple reinterventions.	Increased wound complications when compared to sinus tract endoscopic debridement. Requires a retroperitoneal drainage route.	Requires familiarization with equipment (rigid nephroscope, intraoperative fluoroscopy). Often requires multiple interventions.

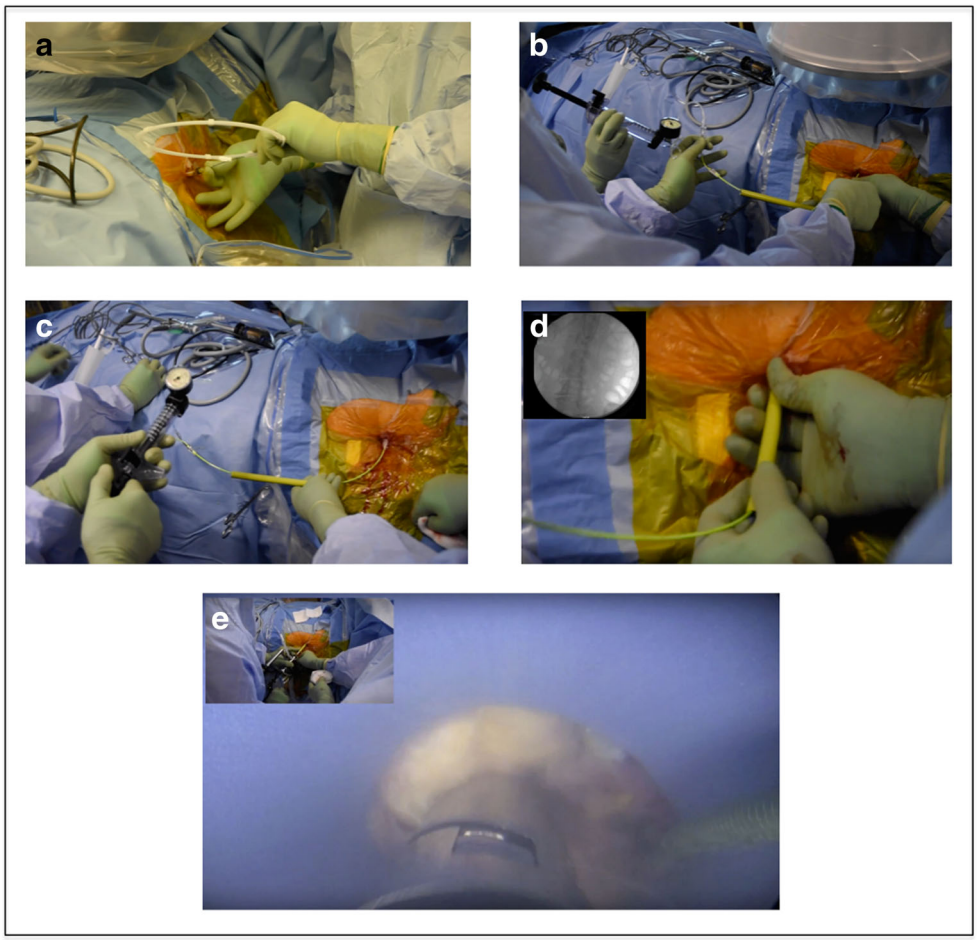

Fig. 2 Operative steps for sinus tract endoscopic debridement of pancreatic necrosis. **a** An Amplatz wire is inserted through the cut end of the drain into the necrosis cavity. **b** A 30-Fr nephrostomy balloon dilator catheter is inserted over the wire until the tip of the balloon is within the cavity of the necrotic tissue. **c** A balloon dilator is inflated with contrast for dilation of the tract. **d** A 30-Fr working sheath is inserted over this balloon into the cavity. **e** A rigid nephroscope is advanced into the cavity through the sheath, and a grasper is passed through the nephroscope for debridement of the necrosis cavity

To date, we have successfully performed STE on 17 patients for pancreatitis, with one post-operative death in an elderly patient who was fully debrided but was eventually transitioned to comfort measures due to a prolonged lack of clinical improvement. The median number of procedures for complete debridement was one (range 1–4, mean 1.8). Two patients suffered late bleeds related to pseudoaneurysms and required angioembolization. One patient developed a small incisional hernia at the site of a transperitoneal drain. All surviving patients have resolved their necrosis and recovered fully.

Video-Assisted Retroperitoneal Debridement

The technique of VARD is depicted in the video at the following link: https://youtu.be/9ErPBAnrOAU.11 As for STE, 4 weeks should ideally be allowed to pass before any attempted operation to allow adequate demarcation of peripancreatic collections to optimize conditions for debridement. Initial preoperative drainage should be via a retroperitoneal route. This is most commonly from the left side in the window between the mesocolon and the left kidney (Fig. 3a). If the patient does not improve with percutaneous drainage and requires step-up to VARD, then the drain is used as a guide into the cavity. The percutaneous drain is prepped into the field, which typically requires a partial lateral decubitus position with a 30–40° angle. A 5-cm lateral flank incision is made overlying the drain and the drain is followed through the retroperitoneum into the necrotic collection using electrocautery. Meticulous attention should be paid to the preoperative CT scan and the relationship of the surrounding structures (colon, kidney, splenic vessels) to the course of the drain, so that surrounding structures can be avoided.

When the cavity is first entered, suction and irrigation are used to clear liquid debris. If the cavity extends laterally close to the skin, ring forceps can be used to excavate the necrotic material. As the debridement is carried out deeper into the cavity, longer rigid retractors and a laparoscope are introduced into the cavity and laparoscopic graspers are used for debridement. Typically, the necrosis cavity is rigid enough that with retraction, there is a fixed working space even in the absence of insufflation. In the event of bleeding within the necrotic cavity during debridement, the options are similar to STE, namely packing, angioembolization, laparotomy, or a combination thereof. It is possible to use laparoscopic clip appliers and even to suture during VARD, depending on the shape of

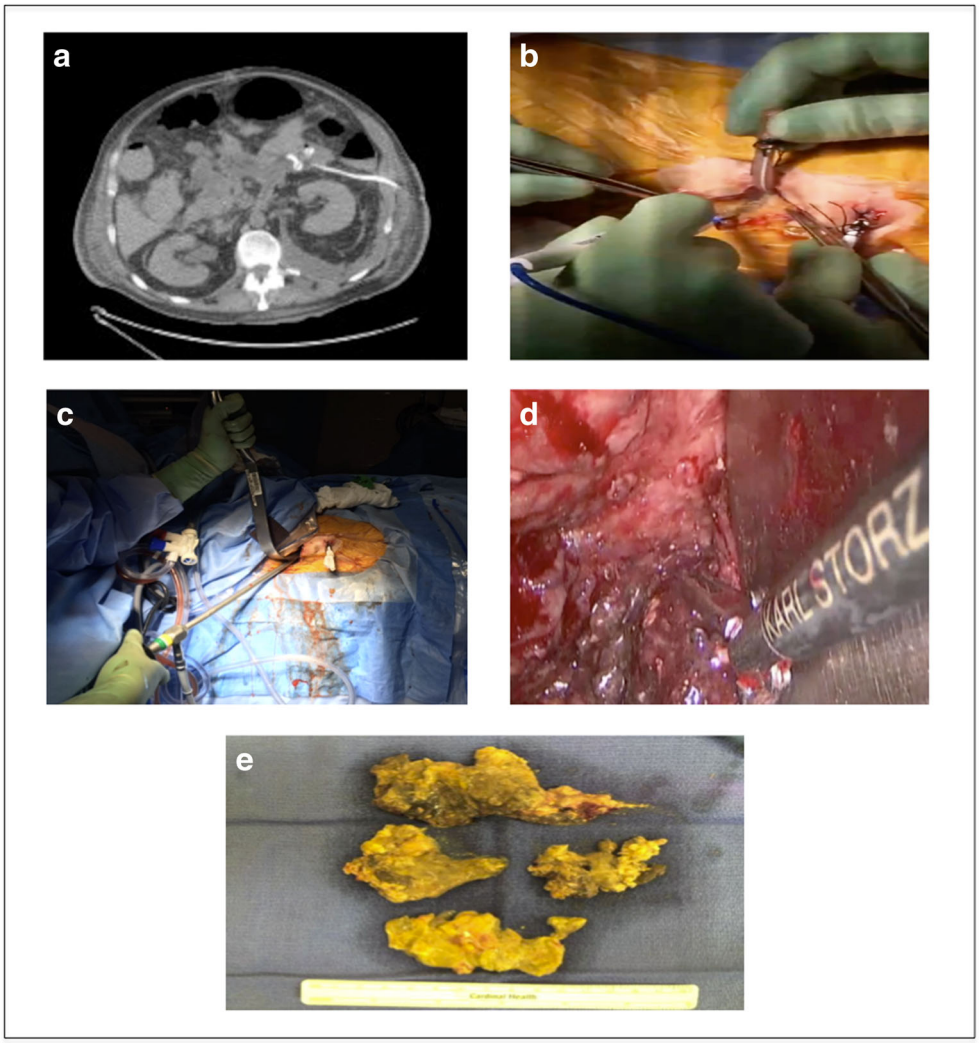

Fig. 3 Operative steps for video-assisted retroperitoneal debridement of pancreatic necrosis. **a** Axial view of the percutaneous catheter that is used as a guide as the dissection is carried out into the retroperitoneum. **b** The cut down on the percutaneous drain carried out through the fascia with electrocautery. **c** Retractors and a laparoscope are inserted through the incision into the necrosis cavity. **d** A laparoscope is used for better cavity visualization, and laparoscopic graspers are used to manually debride and remove necrotic material. **e** Necrotic specimen at the end of the procedure

the cavity, but the preferred method of hemorrhage control remains avoidance of hemorrhage. We have twice experienced bleeding that required packing to be left in situ at the end of the case. In both cases, we removed the packing on post-operative day 2 with angiographic embolization capacity available, but in both cases, the packing sufficed and no embolization or other intervention was required. When debridement is complete, drains are placed. We typically use Thal catheters as above, but any standard external drain is acceptable. If possible, we try not to bring the drains directly through the incision, but to make adjacent incisions and tunnel the drains into the cavity to reduce leakage around the drains through the incision. However, if that proves difficult, the drains can be brought in through the original incision. We close the wound in multiple layers to try to reduce the risk of leakage through the incision. In our opinion, the role of continuous irrigation is primarily to loosen residual necrosis when it is known that a repeat debridement will be required. None of our VARD patients have required a repeat VARD, and so we do not routinely use continuous irrigation, opting instead for intermittent drain flushes (50–250 mL 0.9% saline every 8 h). However, in the event a second debridement is planned, a 7-Fr drainage catheter or a larger multi-side-hole catheter can be placed adjacent to the Thal catheter and irrigated in a similar fashion to that described for STE above.

To date, we have performed VARD on 14 pancreatitis patients with no mortality. No patients required repeat VARD. In addition to the two cases of intraprocedural bleeding requiring packing described above, one patient developed a late bleed related to a splenic artery pseudoaneurysm which required angioembolization. One patient in whom we had hoped to navigate two narrow isthmuses within the necrosis cavity to complete the debridement was converted to a laparotomy to complete the debridement.

Discussion

Recent years have seen a shift from open surgery to a minimally invasive, step-up approach for the treatment of infected

pancreatic necrosis.[12,13] Herein, we describe two minimally invasive techniques of surgical necrosectomy. The step-up approach and utilization of these techniques, in conjunction with the adoption of endoscopic transgastric necrosectomy, has significantly decreased our institutional mortality rates for patients undergoing intervention for infected pancreatic necrosis. Regardless of the exact technique employed, the common management principles include early non-interventional management to allow necrosis to wall off, initial intervention with minimally invasive drainage, and minimally invasive necrosectomy addressing clearly demarcated necrosis only when clinically mandated.

While we do not discuss endoscopic transgastric necrosectomy in this technique paper, it is critical to understand how and when it is best employed when selecting the optimal necrosectomy technique. Transgastric necrosectomy is a preferred route when there is a clear transgastric window into the necrosis cavity with the majority of the necrosis burden in continuity with the posterior stomach, or if the patient has enteric fistulas or appears to be particularly high risk for external pancreatic fistula. Endoscopic transluminal drainage and debridement and VARD have been favorably compared to open necrosectomy in two recent randomized trials.[14,15] Both were shown to reduce the incidence of new-onset organ failure after debridement, which is the strongest determinant of mortality in patients with necrotizing pancreatitis.[16] Endoscopic debridement also resulted in a reduction in mortality and external fistula formation compared to surgical necrosectomy. Its main disadvantages are the anatomic requirements for transgastric access and the frequent need for multiple reinterventions (median 3, interquartile range 2–6 in the PENGUIN trial).[14] Surgical transgastric necrosectomy can be done open or laparoscopically, obviates the need for multiple procedures, and allows for simultaneous cholecystectomy when needed in cases of biliary pancreatitis. However, it is still subject to the same anatomic constraints as endoscopic transgastric necrosectomy. VARD performed as part of a step-up protocol resulted in lower costs and lower rates of diabetes mellitus compared to necrosectomy performed via laparotomy, but did not produce a mortality benefit nor reduce the rate of fistula formation.[14] These two techniques are now being compared directly to each other in a head-to-head randomized trial.[17]

Combining endoscopic transgastric drainage with percutaneous drainage, termed "dual modality drainage" (DMD), accrues the chief benefit of endoscopic drainage—the low rate of external fistula—but also allows access to portions of the collections that may be difficult to reach endoscopically. In the original description of DMD, no necrosectomy was performed by either route. We recently described a case of combined VARD and transgastric drainage for pancreatic necrosis with multiple enteric fistulae and a large volume of necrosis tracking into the left paracolic gutter, which would have been difficult to reach endoscopically.[18] We have now employed this technique in 12 of the 31 patients reported here (Supplemental Video 1) and have found that it combines the main advantages of surgical necrosectomy (rapid debridement and the ability to more easily access necrosis not adjacent to the stomach) and endoscopic transgastric necrosectomy (control of external fistulae).

When considering VARD versus STE, some of the relative strengths and weaknesses are included in Table 1. VARD utilizes equipment familiar to surgeons, such as a laparoscope for visualization and ring or laparoscopic forceps for debridement, and the actual act of debridement once the cavity is entered is very similar to open surgical necrosectomy. For these reasons, many surgeons may find it to be an easier technique to adopt. VARD, like open necrosectomy, also allows rapid debridement of large chunks of necrosis, and in our experience, has not yet required repeated procedures. There are two main disadvantages to VARD. One is that wound complications, while generally minor, are common. The other is the requirement for a retroperitoneal pathway into the necrosis that is wide enough to allow a safe cut down along the drain tract and also enters the cavity in a location that allows complete debridement.

Compared to VARD or endoscopic transgastric drainage, STE is relatively free of anatomic requirements. Virtually, any necrotic collection that can be accessed percutaneously can be accessed by STE. This is an advantage when the only or best route into the necrosis is transperitoneal and intercostal, or when the window into the necrosis is so narrow that the cut down required for VARD risks damage to vital structures. This flexibility is perhaps the biggest benefit of STE as it greatly expands patient eligibility and obviates the need for either a more morbid open necrosectomy or very prolonged percutaneous drainage for the treatment of collections inaccessible via transgastric or retroperitoneal approaches. Additionally, STE is essentially free of wound complications since the only incision is the actual drain site. However, STE requires familiarization with equipment used less frequently by surgeons, such as a rigid nephroscope and intraoperative fluoroscopy. The relatively small instrumentation required also means that for large necrotic collections, multiple procedures are frequently required.

In summary, VARD and STE are minimally invasive approaches to the treatment of infected pancreatic necrosis. VARD utilizes tools familiar to most surgeons and allows rapid debridement of large volumes of necrosis, whereas STE provides access to both intraperitoneal and retroperitoneal pancreatic collections with minimal wound complications, but often requires multiple reinterventions. Both should be employed within the context of a step-up approach and decisions about the best mode of intervention should be made in a multidisciplinary fashion with interventional radiologists experienced with percutaneous drainage and interventional

endoscopists capable of endoscopic transgastric drainage. In our opinion, while randomized trials will continue to elucidate the pros and cons of each technique, an individualized approach based on patient anatomy, physiology, and preference should be employed to choose the best technique in each case to obtain optimal results.

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Drafting the work or revising it critically for important intellectual content: ZVF and PJF

Final approval of the version to be published: ZVF and PJF

Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: ZVF and PJF

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