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Minimally invasive percutaneous interventions in the final stage of treatment of infected necrotizing pancreatitis. Review of recent studies

O. O. Dyrda

Shupyk National Healthcare University of Ukraine, Kyiv

✉ Oleksandr Dyrda: dirda.m.d@gmail.com

O. O. Dyrda, http://orcid.org/0000-0002-0736-5905

Infected necrotizing pancreatitis represents one of the most challenging conditions in abdominal surgery and requires multi-stage minimally invasive interventions as part of the widely accepted step-up approach. This strategy involves collaboration between interventional radiologists and interventional gastroenterologists. Navigation-assisted minimally invasive interventions are crucial during the initial 3–4 weeks of the disease, serving as the primary method for managing infected necrotic collections in the retroperitoneal tissue.

Objective – to analyze studies published between 2020 and 2025 and evaluate the effectiveness of percutaneous interventions as the definitive treatment for acute infected pancreatitis.

The analysis indicates that navigation-assisted minimally invasive interventions are effective in 35–55 % of cases involving infected pancreatic necrosis. The increasing effectiveness of these interventions facilitates rapid reduction of systemic intoxication and stabilization of the patient's condition. Effectiveness is evaluated by clinical and laboratory parameters, including reductions in body temperature, leukocytosis, and C-reactive protein or procalcitonin levels within 48–72 hours, as well as radiological assessment of the necrotic collection volume in retroperitoneal tissue. A reduction in the size of the necrotic focus by approximately 70–75 % within 10–14 days reliably predicts successful isolated drainage without the need for necrosectomy (M. Wroński et al., 2014). Clinical success rates were 67.6 % in the early drainage group (up to 2 weeks) and 77.0 % in the late drainage group (fourth week from disease onset). These findings support the integration of percutaneous and endoscopic methods as complementary components within a step-up strategy and underscore the necessity for further development of navigation-assisted minimally invasive percutaneous techniques for the treatment of complex infected retroperitoneal masses.

Keywords
infected necrotizing pancreatitis, percutaneous drainage, step-up-approach, navigation-assisted minimally invasive interventions, interventional radiology, interventional endoscopy.

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Current surgical strategies for acute necrotizing pancreatitis are guided by the step-up approach, which entails a progressive transition from navigation-assisted minimally invasive percutaneous interventions (MIPI) to more extensive surgical procedures, depending on patient clinical dynamics [2, 3, 10, 11, 30, 47, 55]. Initially, navigation-assisted MIPIs with drainage of fluid collections are performed. In some cases, this serves as the definitive method for managing infected formations, eliminating the need for further necrosectomy. The randomized PANTER trial [59] demonstrated that the step-up approach significantly reduced mortality and serious complications from 69 % to 40 % ($p = 0.006$), and decreased the incidence of multiple organ dysfunction from 40 % to 12 % ($p = 0.002$), with comparable overall mortality rates (19 % vs. 16 %) [59]. Long-term follow-up indicated that patients treated with the step-up approach had lower rates of postoperative hernias and exocrine insufficiency, along with a tendency toward reduced endocrine deficiency [28, 38, 60].

Subsequent meta-analyses have validated the effectiveness of navigation-assisted MIPIs as the

definitive treatment. For example, M. C. van Baal et al. [58] reported that navigation-assisted MIPIs and endoscopic methods prevented open necrosectomy in 55.7 % of patients.

K. Horvath et al. found that navigation-assisted MIPIs were effective in 23 % of patients. In 81 % of cases, a single surgical intervention after navigation-assisted MIPI was sufficient, with no need for additional debridement. The 30-day in-hospital mortality rate was 2.5 %. Bleeding occurred in 7.5 % of patients, while intestinal fistulas developed in 17.5 % [29].

Navigation-assisted MIPIs are typically indicated when infection of necrotic foci is suspected. Indications include the presence of gas bubbles within fluid collections on ultrasound or computed tomography (CT), as well as clinical and laboratory evidence of sepsis–such as fever, leukocytosis, elevated C-reactive protein, and increased procalcitonin levels–despite optimal conservative therapy [6, 18, 56]. On CT, a medium density (≥ 20–30 HU) suggests a higher proportion of solid necrotic infected tissue and is associated with an increased risk of failure for percutaneous isolated drainage [16, 27].

The optimal timing for intervention is during the «walled-off necrosis» phase, typically the fourth week after disease onset, when necrotic tissue is well-formed and demarcated, allowing safer access. However, in cases of escalating septic intoxication or persistent multiorgan failure, early drainage (within 2–3 weeks of disease onset) is permitted as part of the step-up approach [4, 5, 18, 39, 44, 64].

Drainage is conducted under ultrasound or CT guidance using pigtail catheters, typically beginning with sizes of 8–12 Fr. The tract may be gradually expanded to 14–20 Fr, and multiple drains may be placed for multi-chamber collections [16, 17, 41, 54]. When indicated, active irrigation through the drains with isotonic NaCl 0.9 % solution, with or without antiseptic additives, is performed according to local protocols to enhance infection control and support organ function [12, 17].

Effectiveness is evaluated by clinical and laboratory parameters, including reductions in temperature, leukocytosis, C-reactive protein, and procalcitonin levels within 48–72 hours. Radiological assessment involves measuring the decrease in collection volume on follow-up CT scans performed 7–14 days after the initial CT. Several studies indicate that a reduction in lesion size by approximately 70–75 % within 10–14 days reliably predicts successful isolated drainage without the need for necrosectomy [5, 21, 63].

Notably, in some instances, navigation-assisted MIPI serves as both the initial and final stage of treatment [4, 8, 20, 30, 41, 49]. This approach gradually reduces bacterial load, eliminates the source of endotoxemia, and stabilizes systemic hemodynamics without additional surgical trauma [12]. Continuous drainage of liquid necrotic material and the reabsorption process facilitate granulation capsule formation and progressive cavity reduction. The adjunctive use of vacuum-assisted systems further stimulates microcirculation, promotes angiogenesis, and accelerates healing by applying negative pressure to the necrotic area [13, 17, 19, 48]. Table 1 presents the results of key studies demonstrating the effectiveness of navigation-assisted MIPIs in patients with infected pancreatitis.

A representative meta-analysis by P. Keshavarz et al., which included 32 clinical trials and a total of 1,398 patients, reported a clinical success rate of navigation-assisted MIPIs of 63 % (95 % CI 55–71 %), defined as infection and symptom control without further necrosectomy. Approximately 33 % of patients required a step-up approach. The overall mortality rate was 13 %, underscoring navigation-assisted MIPI's effectiveness in mixed patient cohorts with varying disease severity [36].

In contrast, A. K. Singh et al. analyzed a more homogeneous and severely ill cohort of patients with persistent organ failure due to acute necrotizing pancreatitis (n = 83). Despite the severity, navigation-assisted MIPI achieved clinical success in 56.6 % of patients, with 100 % of patients recovering without surgical necrosectomy. Only 13.3 % required surgical intervention, indicating that navigation-assisted MIPI can stabilize critically ill patients. The high mortality rate (37.3 %) in this group reflects the initial severity and systemic involvement, rather than a lack of technique efficacy [51].

In a prospective study by H. Bhatia et al. involving 148 patients with acute necrotic collections, the effectiveness of early (≤ 2 weeks) versus late (after 3–4 weeks) navigation-assisted MIPI was compared. Clinical success was 67.6 % in the early drainage group and 77.0 % in the late drainage group. The need for repeated necrosectomy was significantly lower with delayed intervention (6.8 % vs. 17.6 %), and complication rates were also reduced with late navigation-assisted MIPI (5.4 % vs. 16 %). These findings highlight the importance of allowing a walled-off cavity to form, which improves navigation-assisted MIPI outcomes and reduces the need for surgical intervention [15].

Collectively, these studies indicate that navigation-assisted MIPI achieves clinical success in 55–77 % of cases, enabling the avoidance of open necrosectomy for most patients. The effectiveness of navigation-assisted MIPIs is notably higher when

Table 1. **Effectiveness of navigation-assisted minimally invasive percutaneous interventions**

Research	Design	Clinical success parameters	Clinical success after navigation-assisted MIPI without surgery	Surgery required after navigation-assisted MIPI	Mortality
P. Keshavarz et al. [36] Systematic review and meta-analysis	32 studies, 1398 patients with pancreatic necrosis/ pseudocysts	Infection/ symptom control without the need for further intervention	63 % (95 % CI 55–71 %)	33 % (95 % CI 25–40 %) still required surgery after navigation-assisted MIPI	13 % (95 % CI 9–17 %) overall mortality
A. K. Singh et al. [51] Outcome of percutaneous drainage in patients with pancreatic necrosis having organ failure	83 patients with persistent organ failure, percutaneous catheter drainage on day 25	Complete recovery after PCD + survival without necrosectomy	56.6 % (47/83) successful with PCD only	13.3 % (11/83) proceeded to surgery	37.3 % (31/83) overall mortality (very severe OF cohort)
H. Bhatia et al. [15] Early vs. late PCD of acute necrotic collections (ANC) in necrotizing pancreatitis	148 patients, PCD ≤ 2 weeks (n = 74) vs. 3–4 weeks (n = 74)	Infection/ symptom control without further necrosectomy	67.6 % with early PCD vs. 77.0 % with late PCD	Surgery required by 17.6 % (13/74) vs. 6.8 % (5/74)	Mortality is mentioned in the article, but not detailed in the abstract. The authors did not find a significant difference between the groups.

drainage is performed during the walled-off necrosis (WON) phase. Therefore, navigation-assisted MIPI often serves as both the initial and final stage of treatment within modern step-up-approach protocols [15, 36, 51]. Data presented in Table 1 suggest that navigation-assisted MIPI for acute infected pancreatic necrosis, particularly when integrated with a multidisciplinary approach and advanced control technologies, may become a standard of definitive treatment for selected patients with infected necrotizing pancreatitis.

Comparison of these results reveals a consistent trend toward reduced surgical aggressiveness in the management of acute infected necrotizing pancreatitis. In the 1990s, mortality after open necrosectomy reached 40 %, as documented in early surgical series [42, 70]. However, studies from 2014 to 2024 utilizing navigation-assisted MIPIs report a reduced mortality rate of 15–20 % [3, 34, 46, 61, 68, 69].

Furthermore, navigation-assisted MIPI serves as the final stage of treatment for acute post-necrotic collections and WON in 40–60 % of patients. It demonstrates the method's capacity to effectively control infection sources and stabilize systemic conditions without further surgical intervention [3, 8, 24, 61].

A systematic review by M. C. van Baal et al. involving 384 patients found that navigation-assisted MIPI was a definitive treatment in 55.7 % of cases, thereby eliminating the need for further necrosectomy and resulting in an overall mortality rate of 17.4 % [58]. Subsequent cohort studies support these findings. For example, X. Cao et al. reported that 41.8 % of 74 patients with infected necrosis were cured with navigation-assisted MIPI monotherapy, with a mortality rate of 3.1 % [16]. Similarly, C. Garret et al. observed successful outcomes with isolated percutaneous drainage in 44.4 % of patients [25].

Table 2 presents a comparison of the primary advantages and disadvantages of minimally invasive approaches for treating infected necrotizing pancreatitis.

A meta-analysis by M. Gjeorgjievski et al. (16 studies, 282 patients) reported that percutaneous endoscopic necrosectomy (PEN) achieved clinical success in 82 % of patients, with a procedural mortality of 0 % and an overall mortality of approximately 16 % during follow-up [26]. Similarly, a review by M. Jagielski et al. demonstrated that PEN via a percutaneously placed esophageal stent achieved technical success in 100 % of cases and clinical success in 81 % [31]. Smaller series by L. Ke et al. and M. Saumoy et al. reported clinical success rates for minimally invasive interventions ranging from 70 % to 89 % [35, 43, 50].

Current studies indicate that the endoscopic transluminal approach to necrosequestrectomy in infected pancreatitis, primarily via transgastric

Table 2. **Comparative characteristics of the advantages and disadvantages of minimally invasive techniques in the treatment of infected necrotizing pancreatitis**

Method	Basic technique	Average clinical success	Clinical benefits	Limitations/ Disadvantages
Navigation-assisted percutaneous drainage	Ultrasound/ CT-guided catheter placement	Up to 77 %	Minimally invasive, can be performed in critically ill patients, effective with fluid collections	Risk of repeated punctures, obturation, need for irrigation, high risk of external fistulas
Percutaneous drainage + endoscopic necrosectomy (PEN)	Tract dilation, nephroscopy, mechanical debridement	80 %	Visual control, effective evacuation of detritus, lower trauma compared to traditional surgery, possibility of irrigation	Requires equipment, skills, lengthy procedure, risk of fistula development, requires canal dilation
Transgastric necrosectomy	Transmural access, negative pressure	Up to 90 %	Minimally invasive access without the development of external fistulas, better infection control in centrally located WON, possibility of multiple revisions	High cost, requires highly qualified interventional gastroenterologist, multiple endoscopy sessions required

access, achieves a clinical success rate of 80–90 %, a procedural complication rate of 20–35 %, and a mortality rate of 5–10 %, which is significantly lower than that observed with open necrosectomy [9, 33, 37, 47, 67, 71].

The selection of minimally invasive strategies in necrotizing pancreatitis follows a step-up approach: initial management involves drug therapy, followed by drainage (percutaneous or endoscopic) if infected necrosis or clinical deterioration occurs, and minimally invasive necrosequestrectomy if these measures are ineffective. Open surgical intervention is reserved for refractory cases [3, 39, 53, 59, 63, 65, 71]. Ideally, invasive procedures should be postponed until WON has developed, typically after approximately four weeks, as early necrosequestrectomy is associated with increased morbidity. Debridement within the first two weeks should be avoided [13, 22, 32, 40, 43, 59, 65]. Routine drainage is not recommended during the sterile phase; intervention is indicated for symptoms or complications such as obstruction, persistent pain, nutritional insufficiency, fistulas, persistent systemic inflammatory response syndrome (SIRS), or prolonged organ failure lasting several weeks [1, 3, 21, 22, 32, 62]. The choice of intervention is determined by the anatomical location and extent of the necrotic collection in the retroperitoneal tissue: endoscopic approaches are preferred for encapsulated WON adjacent to the stomach or duodenum, while percutaneous drainage is recommended as an adjunct or salvage method for collections extending into the paracolic gutters or pelvis [3, 7, 21, 43, 45, 53, 60, 62].

The described minimally invasive techniques should not be viewed as alternative or mutually exclusive, as each addresses specific clinical challenges and has distinct anatomical and technical indications. In the management of acute necrotizing pancreatitis, these methods should be applied within an integrated step-up approach, either sequentially or in combination, depending on the localization of the pathological process. For example, a single patient may present with centrally located collections in the lesser omentum, best managed by transgastric necrosectomy, alongside retroperitoneal paracolic accumulations, which are more suitable for percutaneous access. Therefore, effective removal of necrotic and purulent material often requires the complementary use of both endoscopic and percutaneous interventions to optimize therapeutic outcomes.

Conclusions

Minimally invasive percutaneous interventions play a crucial role in the current step-up approach to managing infected necrotizing pancreatitis, with clinical success rates of 55 % to 77 % without the need for necrosectomy. The effectiveness of these interventions depends on the location and structural characteristics of the necrosis, frequently requiring a combination of percutaneous and endoscopic techniques to achieve complete debridement of both central and retroperitoneal collections in the right and left paracolic gutters. Ongoing development of navigation-assisted percutaneous methods is essential, as these approaches remain the primary option for managing infected parietal and paracolic fluid collections.

Declaration of interests

The author declares no conflict of interest.

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Роль перкутанних малоінвазивних втручань на завершальному етапі лікування інфікованого некротичного панкреатиту. Огляд сучасних досліджень

О. О. Дирда

Національний університет охорони здоров'я України імені П. Л. Шупика, Київ

Інфікований некротичний панкреатит залишається однією із найскладніших патологій в абдомінальній хірургії та потребує застосування багатоетапних малоінвазивних втручань у межах загальновизнаної тактики поетапного підходу із залученням у лікувальний процес інтервенційного радіолога та інтервенційного ендоскопіста. Малоінвазивні навігаційні втручання відіграють провідну роль як стартовий етап лікування в перші 3—4 тиж захворювання. Їх застосовують як остаточний метод санації інфікованих некротичних скупчень у заочеревинній клітковині.

Мета — проаналізувати дослідження, проведені в 2020—2025 рр., та оцінити ефективність перкутанних втручань як остаточного методу лікування гострого інфікованого панкреатиту.

Аналіз продемонстрував, що навігаційні малоінвазивні втручання є ефективними в 35—55% випадків лікування інфікованого панкреонекрозу. Ефективність втручання зростає, що дає змогу швидко знизити системну інтоксикацію та стабілізувати стан. Ефективність оцінюють за клініко-лабораторною динамікою (зменшення температури тіла, лейкоцитозу, рівня С-реактивного білка/прокальцитоніну впродовж перших 48—72 год) та радіологічно — за ступенем зменшення об'єму скупчення. Зменшення розмірів вогнища приблизно на 70—75% протягом 10—14 днів вірогідно прогнозує успіх ізольованого дренування без потреби в некректомії (M. Wroński et al., 2014). Частота клінічного успіху становила 67,6% у групі ранньої інтервенції (до 2 тиж) та 77,0% у групі пізнього дренування (4-й тиждень від початку захворювання). Отримані дані свідчать про необхідність розгляду перкутанних та ендоскопічних методів як інструментів step-up стратегії, що доповнюють один одного, та наголошують на важливості подальшого розвитку навігаційних перкутанних технологій для лікування складних інфікованих ретроперитонеальних утворень.

Ключові слова: інфікований некротичний панкреатит, перкутанне дренування, поетапний підхід, малоінвазивні навігаційні втручання, інтервенційна радіологія, інтервенційна ендоскопія.

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