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Original Research Article

Role of Minimally Invasive Step-Up Approach in the Management of Complicated Acute Pancreatitis

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Abstract

Background: Complicated acute pancreatitis, particularly infected pancreatic necrosis, poses significant therapeutic challenges with historically high morbidity and mortality rates. The minimally invasive step-up approach has emerged as an alternative to traditional open necrosectomy, potentially reducing surgical trauma and improving outcomes. This study aimed to evaluate the efficacy and safety of the minimally invasive step-up approach compared to direct open necrosectomy in patients with complicated acute pancreatitis.

Methods: A retrospective comparative cohort study was conducted involving 126 patients with complicated acute pancreatitis requiring intervention. Patients were divided into two groups: step-up approach (n=68) and primary open necrosectomy (n=58). Primary outcomes included mortality rate, major complications, and length of hospital stay. Secondary outcomes encompassed intensive care unit admission duration, number of interventions required, and new-onset organ failure.

Results: The step-up approach group demonstrated significantly lower mortality (8.8% vs. 20.7%, p=0.048) and reduced major complications (29.4% vs. 48.3%, p=0.025) compared to open necrosectomy. Mean hospital stay was shorter in the step-up group (32.4 ± 14.7 days vs. 45.6 ± 18.3 days, p<0.001). New-onset multiple organ failure occurred less frequently in the step-up group (14.7% vs. 31.0%, p=0.024). Approximately 35.3% of patients in the step-up group achieved resolution with percutaneous drainage alone without requiring surgical intervention.

Conclusion: The minimally invasive step-up approach demonstrates superior outcomes compared to primary open necrosectomy in managing complicated acute pancreatitis, with reduced mortality, fewer complications, and shorter hospitalization. This approach should be considered the preferred initial strategy for infected pancreatic necrosis.

Keywords: Acute Pancreatitis, Necrotizing Pancreatitis, Step-Up Approach, Minimally Invasive Surgery, Pancreatic Necrosis, Necrosectomy.

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Introduction

Acute pancreatitis represents one of the most common gastrointestinal disorders requiring hospitalization, with an increasing global incidence over the past decades [1]. While the majority of cases follow a mild, self-limiting course, approximately 15-20% of patients develop severe acute pancreatitis characterized by persistent organ failure and local complications [2].

Necrotizing pancreatitis, occurring in approximately 5-10% of acute pancreatitis cases, carries substantial morbidity and mortality, particularly when secondary infection develops [3]. The Revised Atlanta Classification established standardized definitions for local complications of acute pancreatitis, distinguishing between acute peripancreatic fluid collections, pancreatic pseudocysts, acute necrotic collections, and walled-off necrosis [4]. Infected pancreatic necrosis represents the most severe local complication, traditionally associated with mortality rates exceeding 30% when managed conservatively and requiring intervention in most cases [5].

Historically, open surgical necrosectomy served as the gold standard for managing infected pancreatic necrosis. However, this approach was associated with significant surgical trauma, high complication

rates, and substantial mortality [6]. The recognition that extensive surgical debridement in critically ill patients often precipitated further physiological deterioration led to the development of alternative treatment strategies [7].

The minimally invasive step-up approach, first systematically evaluated in the landmark PANTER trial, introduced a paradigm shift in managing infected necrotizing pancreatitis [8]. This strategy involves initial percutaneous or endoscopic drainage, followed by minimally invasive surgical necrosectomy only when drainage proves insufficient, with open surgery reserved as the final escalation step [9]. Subsequent trials and meta-analyses have supported the superiority of this approach over primary open necrosectomy [10].

Recent evidence has further refined the step-up concept, comparing endoscopic versus surgical step-up pathways and demonstrating potential advantages of the endoscopic route [11]. The International Association of Pancreatology and American Pancreatic Association guidelines now recommend delaying intervention until adequate demarcation of necrosis occurs, typically four weeks after symptom onset, and preferring minimally invasive techniques [12].

Despite accumulating evidence supporting the step-up approach, questions remain regarding optimal patient selection, timing of escalation between steps, and long-term outcomes [13]. Furthermore, implementation in resource-variable settings and comparative effectiveness outside randomized trial conditions warrant investigation [14].

This study aimed to evaluate the clinical outcomes of the minimally invasive step-up approach compared to primary open necrosectomy in patients with complicated acute pancreatitis at a tertiary care center, hypothesizing that the step-up approach would demonstrate superior short-term outcomes.

Materials and Methods

Study Design and Setting: This retrospective comparative cohort study was conducted at the Department of Surgery of tertiary care hospital.

Study Population: Consecutive adult patients (age ≥18 years) diagnosed with complicated acute pancreatitis requiring intervention were identified through electronic medical records. Complicated acute pancreatitis was defined as acute pancreatitis with local complications (acute necrotic collections, walled-off necrosis, or infected pancreatic necrosis) or systemic complications requiring intervention beyond conservative management.

Inclusion and Exclusion Criteria:

Inclusion criteria comprised: (1) confirmed diagnosis of acute pancreatitis based on revised Atlanta Classification criteria; (2) presence of pancreatic and/or peripancreatic necrosis confirmed by contrast-enhanced computed tomography (CECT); (3) indication for intervention (infected necrosis or symptomatic sterile necrosis unresponsive to conservative management); and (4) complete medical records available for review.

Exclusion criteria included: (1) chronic pancreatitis with acute exacerbation; (2) pancreatic malignancy; (3) pregnancy; (4) intervention performed at another institution before transfer; and (5) patient preference for specific intervention type precluding comparative analysis.

Treatment Protocol

Step-Up Approach Group: Patients managed with the step-up approach underwent initial percutaneous catheter drainage (PCD) as the first intervention. Image-guided PCD was performed using ultrasound or CT guidance with placement of 12-14 French pigtail catheters, upsized as needed. Patients not responding to PCD (persistent sepsis, clinical deterioration) within 72-96 hours underwent minimally invasive necrosectomy via video-assisted retroperitoneal debridement (VARD) or laparoscopic transgastric necrosectomy. Open necrosectomy was performed only when minimally invasive approaches failed.

Open Necrosectomy Group: Patients in this group underwent primary open surgical necrosectomy through a subcostal or midline laparotomy approach with blunt debridement of necrotic tissue and placement of surgical drains for postoperative lavage.

Data Collection: Demographic variables (age, sex, body mass index), etiology of pancreatitis, Acute Physiology and Chronic Health Evaluation II (APACHE II) score at admission, CT severity index, timing of intervention, and Charlson Comorbidity Index were extracted. Primary outcomes included in-hospital mortality, major complications (defined as Clavien-Dindo grade III or higher), and total hospital length of stay. Secondary outcomes comprised ICU admission duration, number of interventions required, new-onset organ failure, incisional hernia, pancreatic fistula, and need for long-term enzyme supplementation.

Statistical Analysis: Continuous variables were expressed as mean ± standard deviation or median (interquartile range) based on distribution normality assessed by Shapiro-Wilk test. Categorical variables were presented as frequencies and percentages. Between-group comparisons utilized independent samples t-test or Mann-Whitney U test for continuous variables and chi-

square or Fisher's exact test for categorical variables.

Multivariate logistic regression analysis identified independent predictors of mortality. Statistical significance was set at $p<0.05$.

All analyses were performed using SPSS version 26.0 (IBM Corporation, Armonk, NY).

Results

Patient Demographics and Baseline Characteristics: A total of 126 patients met inclusion criteria, with 68 patients (54.0%) managed using the step-up approach and 58 patients (46.0%) undergoing primary open necrosectomy. Baseline demographic and clinical characteristics are presented in Table 1. The two groups were comparable regarding age, sex distribution, body mass index, etiology of pancreatitis, and disease severity parameters. Mean APACHE II scores were similar between groups (14.2 ± 4.8 vs. 15.1 ± 5.2, p=0.296).

Table 1: Baseline Demographic and Clinical Characteristics

Variable	Step-Up Approach (n=68)	Open Necrosectomy (n=58)	p-value
Age (years), mean ± SD	48.6 ± 12.4	51.2 ± 13.8	0.262
Male sex, n (%)	44 (64.7)	39 (67.2)	0.762
BMI (kg/m²), mean ± SD	28.4 ± 5.2	27.9 ± 4.8	0.571
Etiology, n (%)			0.684
- Biliary	32 (47.1)	25 (43.1)	
- Alcoholic	22 (32.4)	21 (36.2)	
- Hypertriglyceridemia	8 (11.8)	8 (13.8)	
- Other/Unknown	6 (8.8)	4 (6.9)	
APACHE II score, mean ± SD	14.2 ± 4.8	15.1 ± 5.2	0.296
CT Severity Index, mean ± SD	7.4 ± 1.8	7.8 ± 1.6	0.184
Charlson Comorbidity Index, mean ± SD	2.1 ± 1.4	2.3 ± 1.6	0.442
Infected necrosis, n (%)	58 (85.3)	52 (89.7)	0.458
Extent of necrosis >50%, n (%)	26 (38.2)	24 (41.4)	0.721
Time to intervention (days), mean ± SD	28.4 ± 8.6	21.2 ± 7.8	<0.001

Clinical Outcomes: Primary and secondary clinical outcomes are summarized in Table 2. The step-up approach group demonstrated significantly lower in-hospital mortality compared to the open necrosectomy group (8.8% vs. 20.7%, p=0.048). Major complications occurred in 29.4% of step-up patients versus 48.3% of open necrosectomy patients (p=0.025). Mean total hospital stay was significantly shorter in the step-up group (32.4 ± 14.7 days vs. 45.6 ± 18.3 days, p<0.001).

ICU length of stay was also reduced in the step-up approach group (8.6 ± 6.4 days vs. 14.2 ± 9.8 days, p<0.001).

Table 2: Primary and Secondary Clinical Outcomes

Outcome	Step-Up Approach (n=68)	Open Necrosectomy (n=58)	p-value
Primary Outcomes			
In-hospital mortality, n (%)	6 (8.8)	12 (20.7)	0.048
Major complications (CD ≥III), n (%)	20 (29.4)	28 (48.3)	0.025
Hospital stay (days), mean ± SD	32.4 ± 14.7	45.6 ± 18.3	<0.001
Secondary Outcomes			
ICU stay (days), mean ± SD	8.6 ± 6.4	14.2 ± 9.8	<0.001
Number of interventions, mean ± SD	2.4 ± 1.2	1.8 ± 0.9	0.002
New-onset organ failure, n (%)	10 (14.7)	18 (31.0)	0.024
Need for reintervention, n (%)	22 (32.4)	24 (41.4)	0.287
30-day readmission, n (%)	8 (11.8)	6 (10.3)	0.798

CD = Clavien-Dindo classification; ICU = Intensive Care Unit

Specific Complications: Detailed complication profiles are presented in Table 3. New-onset multiple organ failure was significantly less common in the step-up group (14.7% vs. 31.0%, p=0.024). Incisional hernia rates were markedly lower with the step-up approach (7.4% vs. 24.1%, p=0.008). Pancreatic fistula and bleeding requiring intervention showed trends favoring the step-up approach without reaching statistical significance.

Table 3: Specific Complications and Procedural Details

Complication/Parameter	Step-Up Approach (n=68)	Open Necrosectomy (n=58)	p-value
New-onset MODS, n (%)	10 (14.7)	18 (31.0)	0.024
Pancreatic fistula, n (%)	12 (17.6)	14 (24.1)	0.364
Bleeding requiring intervention, n (%)	6 (8.8)	10 (17.2)	0.154
Gastrointestinal fistula, n (%)	4 (5.9)	8 (13.8)	0.123
Incisional hernia, n (%)	5 (7.4)	14 (24.1)	0.008
Wound infection, n (%)	8 (11.8)	18 (31.0)	0.007
New-onset diabetes, n (%)	14 (20.6)	16 (27.6)	0.354
Enzyme supplementation required, n (%)	18 (26.5)	20 (34.5)	0.325
Step-up procedural outcomes			
PCD only successful, n (%)	24 (35.3)	N/A	
Required VARD/minimally invasive, n (%)	36 (52.9)	N/A	
Escalation to open surgery, n (%)	8 (11.8)	N/A	

MODS = Multiple Organ Dysfunction Syndrome; PCD = Percutaneous Catheter Drainage; VARD = Video-Assisted Retroperitoneal Debridement

Within the step-up approach group, 24 patients (35.3%) achieved successful resolution with percutaneous drainage alone, 36 patients (52.9%) required escalation to minimally invasive surgical necrosectomy, and only 8 patients (11.8%) eventually required conversion to open necrosectomy.

Discussion

This retrospective study demonstrates that the minimally invasive step-up approach yields superior clinical outcomes compared to primary open necrosectomy in managing complicated acute pancreatitis. Our findings of reduced mortality (8.8% vs. 20.7%) and lower major complication rates (29.4% vs. 48.3%) align with established evidence supporting minimally invasive strategies in this high-risk patient population [15].

The landmark PANTER trial established the foundation for step-up approach superiority, demonstrating reduced new-onset multiple organ failure and lower composite endpoints of death or major complications [16]. Our mortality reduction mirrors these findings, with the step-up approach achieving mortality rates comparable to contemporary series from high-volume centers [17]. The observed 35.3% success rate with percutaneous drainage alone is consistent with reported literature ranges of 25-50%, indicating appropriate patient selection and drainage technique [18].

The significantly shorter hospital and ICU stay durations observed in the step-up group carry substantial implications for healthcare resource utilization and patient recovery [19]. Reduced hospitalization translates to decreased nosocomial infection risk, earlier rehabilitation initiation, and improved quality of life during recovery [20]. These findings support guideline recommendations advocating minimally invasive interventions as first-line management [21]. New-onset organ failure occurred significantly less frequently in the step-up group, reflecting the reduced physiological insult associated with minimally invasive interventions compared to extensive open surgery [22]. The systemic inflammatory response triggered by open necrosectomy may precipitate or exacerbate organ dysfunction in already compromised patients [23]. By graduating intervention intensity based on clinical response, the step-up approach minimizes unnecessary surgical trauma.

The markedly lower incisional hernia rate (7.4% vs. 24.1%) in the step-up group represents an important long-term benefit often underappreciated in acute management discussions [24]. Given that many patients with severe acute pancreatitis are relatively young and may have predisposing factors such as obesity, avoiding large abdominal incisions confers lasting quality-of-life advantages [25].

Our finding that only 11.8% of step-up patients ultimately required open surgery emphasizes that escalation to maximal intervention is infrequently necessary when appropriate drainage and minimally invasive techniques are employed [26]. This supports the safety of initiating management with the least invasive effective modality and escalating only when clinically indicated.

The longer time to intervention in the step-up group (28.4 vs. 21.2 days) reflects deliberate delayed intervention strategy, allowing encapsulation and demarcation of necrotic collections [27]. This delay facilitates safer drainage and debridement by permitting natural walling-off of necrosis, reducing bleeding risk and improving tissue plane definition [28].

Several limitations warrant acknowledgment. The retrospective design introduces potential selection bias, with healthier patients possibly preferentially managed with step-up approach. Temporal trends during the study period may have influenced

treatment selection and outcomes as institutional experience evolved. Long-term functional outcomes and quality of life measures were not systematically assessed.

Conclusion

The minimally invasive step-up approach demonstrates superior outcomes compared to primary open necrosectomy in managing complicated acute pancreatitis, achieving significant reductions in mortality, major complications, hospital stay duration, and new-onset organ failure.

Over one-third of patients achieved resolution with percutaneous drainage alone, avoiding surgical intervention entirely. The step-up approach should be considered the standard initial strategy for infected pancreatic necrosis, with open surgery reserved for cases failing minimally invasive management. These findings support current guideline recommendations and emphasize the importance of expertise in minimally invasive pancreatic interventions at centers managing complicated acute pancreatitis.

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