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Repetitive endoscopic drainage as initial intervention is safe and effective for early treatment of pancreatic necrotic collections

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Key words
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Abstract

Background: While endoscopic step-up approach with delayed drainage (more than 28 days from diagnosis) was shown to produce the best outcomes in the treatment of pancreatic walled-off necrosis (WON), we assessed our single centre experience of early versus delayed endoscopic drainage of pancreatic necrotic collections.
Methods: Patients who underwent endoscopic drainage of pancreatic necrotic collections between 2011 and 2022 under Monash Health were identified. They were excluded if below 18 years old or their follow up data were missing. The included patients' medical records, pathology results, and imaging findings were retrospectively reviewed.
Results: A total of 60 patients were included. 31.58% required percutaneous drainage and 15% received either endoscopic or surgical necrosectomy. The disease related mortality was 8.47% and the average length of stay (LOS) was 70.92 days. No significant difference was shown in disease-related mortality (10.5% *vs.* 7.5%, $P = 0.697$) or LOS (75.35 *vs.* 68.7, $P = 0.644$) between early and delayed drainage cohorts, but patients who received early drainage have higher qSOFA score on the day of drainage (2 *vs.* 0, $P = 0.004$).
Discussion: Repetitive endoscopic drainage with selective percutaneous drainage is effective in the management of pancreatic necrotic collections. Early drainage should be considered in patients who developed severe sepsis.

Introduction

Acute pancreatitis (AP) is a common gastrointestinal emergency. 80%–85% of presentations are due to interstitial pancreatitis (IP), and 15%–20% develop necrotising pancreatitis (NP).[1,2] Multi-organ failure and procedural intervention are more common in NP which has a 15% mortality rate.[3] Peripancreatic collections can develop in AP, and were categorized into two types in NP: acute necrotic collection (ANC) and walled-off necrosis (WON).[4] Both ANC and WON contains fluid and necrotic material, but WON has a well-defined encapsulated wall and usually requires 4 weeks to mature after onset of AP.[4]

The modality and timing of intervention in pancreatic necrotic collection (PNC) has remained debatable. Endoscopic, percutaneous, and laparoscopic are the main treatment approaches. A 2018 randomized controlled trial (RCT) compared endoscopic step-up approach (endoscopic drainage step up to endoscopic necrosectomy) with surgical step-up approach (percutaneous drainage step up to video-assisted retroperitoneal debridement [VARD]). Endoscopic step-up approach was associated with reduced inpatient length of stay (LOS) and pancreatic fistula formation but similar mortality.[5] This same reduction in LOS was further supported by a meta-analysis comparing endoscopic versus percutaneous drainage.[6] Endoscopic drainage was also found to have shorter LOS but required more re-intervention in comparison to laparoscopic drainage.[7,8] Based on endoscopic step-up approach, protocolised endoscopic necrosectomy after primary drainage has been reported.[9]

European guidelines recommended delaying the first intervention of PNC for 4 weeks, which was only supported by weak evidence.[3]

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Multiple cohort studies have investigated this issue but have conflicting results.[10–13] A recent meta-analysis demonstrated a trend favouring delayed drainage in regards to clinical success and adverse events but no difference in overall mortality.[14] Therefore, more evidence is required to decide the optimal timing for PNC drainage.

In this study, we retrospectively audited our experience with repetitive endoscopic drainage of PNC to decide if protocolised necrosectomy is indeed necessary. We also conducted a retrospective cohort study to assess if delayed drainage has better outcome than early drainage. Our results will contribute to the current understanding of PNC and assist with decision making in its treatment.

Methods

This study was reviewed and approved by Monash Health Human Research Ethics Committee (HREC) (RES-18-0000-454Q).

Participant recruitment and allocation

Patients who underwent endoscopic drainage of pancreatic collections between October, 2011 and January, 2022 under Monash Health were identified by medical record search using Medicare Benefit Schedule (MBS) code. The identified patient's computed tomography (CT) images were reviewed, and only patients who satisfied the diagnostic criteria for ANC or WON under 2012 revised Atlanta classification were included. Exclusion criteria were: age below 18 years old, loss of follow up after initial admission. Patients were then allocated into early (within 28 days) and delayed (more than 28 days) drainage cohorts based on duration between diagnosis of AP and first endoscopic drainage.

Interventions

Endoscopic drainage was achieved by cyst-gastrostomy of PNC mainly under endoscopic ultrasound (EUS) (EG-3870UTK, Pentax Medical or GF-UCT180, Olympus, Tokyo) guidance with occasional use of direct endoscopic visualization. Generally, a 19G needle was used to access the collection through which a 450 cm JAG wire was passed. A cystatome was used over this wire to enlarge the tract. Double pigtail stent (Zimmon biliary stent, Cook Medical, Bloomington) were used to maintain the tract. In the setting of a narrow cyst-gastrostomy tract, the tract was dilated using CRETM wire-guided balloon (Boston Scientific, Massachusetts) to facilitate drainage. Occasionally, a cyst gastrostomy was created using a fully covered lumen-opposing metal stent (Hot AXIOSTM, Boston Scientific, Massachusetts). The choice of technique and stent was subjected to operator judgement and preference.

For patients who had ongoing or recurrent sepsis after initial drainage, repetitive endoscopic drainage was attempted. Further insertion or replacement of stent was guided by the adequacy of drainage. For collections that were not amendable to endoscopic drainage due to location, percutaneous drainage was performed under CT guidance by interventional radiologists. Endoscopic necrosectomy was performed via the cyst-gastrostomy tract if sepsis failed to resolve with repetitive drainage. Surgical necrosectomy was conducted if inadequate percutaneous drainage or as part of another procedure (e.g., laparotomy for bowel perforation).

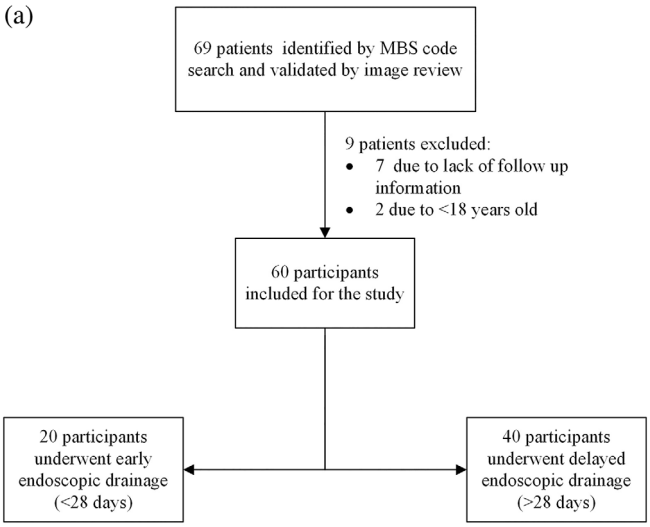
Clinical information collection

Participants' admission details, inpatient progress and outpatient follow-up results were reviewed on Monash Health Scanned Medical Records (SMR) and Electronic Medical Records (EMR). Imaging findings were assessed through Carestream Vue Motion system (Carestream Health, New York). Pathology results were reviewed through Monash Health Pathology Service and EMR.

Study variables

Patient demographic, pancreatitis aetiology, severity, collection size, endoscopic drainage and necrosectomy details, number and modality of other interventions were collected. Pancreatitis severity was assessed by CT severity index (CTSI), bedside Index of severity in acute pancreatitis (BISAP), C-reactive protein (CRP) level, presence of systemic inflammatory response syndrome (SIRS) and quick Sequential Organ Failure Assessment (qSOFA) score.[15]

(a)



(b)

Variable	Mean/ Median/ Number	SD/ IQR (25 - 75%)/ Percentage (%)
Age (n=60)	59.4	15.86
Sex (n=60)		
- Male	41	68
- Female	19	32
Aetiology (n=60)		
- Gall stone	31	51.7
- ETOH	12	20
- Hypertriglyceridaemia	1	1.7
- Post ERCP	4	6.7
- Steroids	1	1.7
- Idiopathic	11	18.3
CTSI at diagnosis (n=55)	5	4 - 7
BISAP at diagnosis (n=55)	2	1 - 2
SIRS at diagnosis (n=56)		
- Yes	38	67.86
- No	18	32.14
CRP at diagnosis (n=55)	159.80	157.62
Duration of follow-up (months) (n=60)	12.05	11.15

Number of participants (n) included for each variable was shown. Abbreviations: SD: Standard Deviation. IQR: Inter-Quantile Range. ETOH: ethanol or alcohol. ERCP: Endoscopic Retrograde Cholangiopancreatography. CTSI: CT severity index. BISAP: Bedside Index for Severity in Acute Pancreatitis. SIRS: Systemic Inflammatory Response Syndrome. CRP: C-reactive protein.

Fig. 1. Allocation and demographic of study participants. (a) Flow chart summarizing patient recruitment, exclusion, and allocation. (b) Table summarizing patient demographics.

Table 1 Characteristics and outcomes of interventions

Variable	Mean/Median/ Number	SD/IQR (25%–75%)/ Percentage (%)
Endoscopic drainage		
Days between diagnosis and initial drainage ($n = 60$)	32.5	22.5–49
Timing of drainage ($n = 60$)		
Early	20	33.33
Delay	40	66.67
Drainage method ($n = 60$)		
EUS	58	96.67
Gastroscopy	2	3.33
Type of stent ($n = 60$)		
Pigtail stent	50	83.33
Hot AXIOS	9	15
Both	1	1.67
Number of stent ($n = 60$)	2	2–2
Complications of drainage ($n = 60$)	13	21.67
Bowel perforation	2	3.33
UGIB	6	10
Recollection related		
Gastric outlet obstruction	3	5
Biliary obstruction	1	1.67
Both	1	1.67
Number of drainage ($n = 60$)	2	1–3
Endoscopic necrosectomy		
Endoscopic necrosectomy ($n = 60$)	4	6.67
Number of endoscopic necrosectomy ($n = 4$)	1	1–1
Complication of endoscopic necrosectomy ($n = 4$)	1	25
Colonic fistula	1	25
Percutaneous drainage		
Percutaneous drainage ($n = 60$)	19	36.67
Number of percutaneous drainage ($n = 19$)	2	1–2
Indication of percutaneous drainage ($n = 19$)		
Distant collection	18	94.74
No access to endoscopic drainage	1	5.26
Complication of percutaneous drainage ($n = 19$)	11	57.89
Re-collection	11	57.89
Surgical necrosectomy		
Surgical necrosectomy ($n = 60$)	5	8.33
Number of surgical necrosectomy ($n = 5$)	1	1–2
Surgical necrosectomy technique ($n = 5$)		
Retroperitoneal	3	60
Open	1	20
Both	1	20
Surgical necrosectomy indications ($n = 5$)		
Retroperitoneal collection	3	60
Persisting collection	1	20
Sigmoid perforation	1	20
Other interventions		
ERCP ($n = 60$)	7	11.67
Number of ERCP ($n = 7$)	1	1–2
Indication of ERCP ($n = 7$)		
CBD stone	1	14.29
Biliary stricture	4	57.14
Pancreatic duct leak	1	14.29
Sphincter of Oddi dysfunction	1	14.29
PTC ($n = 60$)	3	5
Number of PTC ($n = 3$)	1	1–1
Indication of PTC ($n = 3$)		
Biliary stricture	3	100
Outcomes		
Initial admission LOS ($n = 58$)	50.31	46.24
Number of admission ($n = 60$)	3	2–3
Total LOS ($n = 60$)	70.92	55.6
Clinical outcome ($n = 59$)		
Resolution	51	86.44
Death	8	13.56
Cause of death ($n = 8$)		
Sepsis	5	62.5
Enterotomy bleed	1	12.5
Pneumonia	1	12.5
Pancreatic cancer	1	12.5
Death rate ($n = 59$)		
Disease related	5	8.47
Non disease related	3	5.08

Number of participants (*n*) included for each variable was shown.

Pancreatitis severity was assessed retrospectively on initial diagnosis of pancreatitis by CTSI, BISAP, CRP and SIRS, and again on the day of first drainage by qSOFA, CRP and SIRS. The primary outcome was disease-related mortality, and secondary outcomes were total inpatient LOS, percentage of residual collection and complications of endoscopic drainage.

Measurement of collection size

Contrast enhanced abdominal CT was performed when clinical deterioration occurred or local complication was suspected. The identified collection was measured in three dimensions with maximum values recorded in centimetre (cm): anterior–posterior (AP), lateral (Lt) and cranio-caudal (CC). The collection size (cm^3) was estimated using simplified ellipsoid model as below[16]:

$$\text{Collection Size} = \text{AP} \times \text{Lt} \times \text{CC} \times 0.523$$

Collection size was measured pre-drainage, post initial drainage and on latest follow-up. Percentage of residual collection was then calculated after initial drainage and on final follow-up as below:

$$\text{Residual Collection}\,(\%) = \frac{\text{Pre} - \text{drainage Collection Size}}{\text{Post} - \text{drainage Collection Size}} \times 100\%$$

Statistical analysis

Continuous variables were summarized as mean with standard deviation (SD) for parametric data and median with inter-quantile range (IQR) for non-parametric data. Binomial and categorical data were reported as number of cases and percentage. For hypothesis testing,

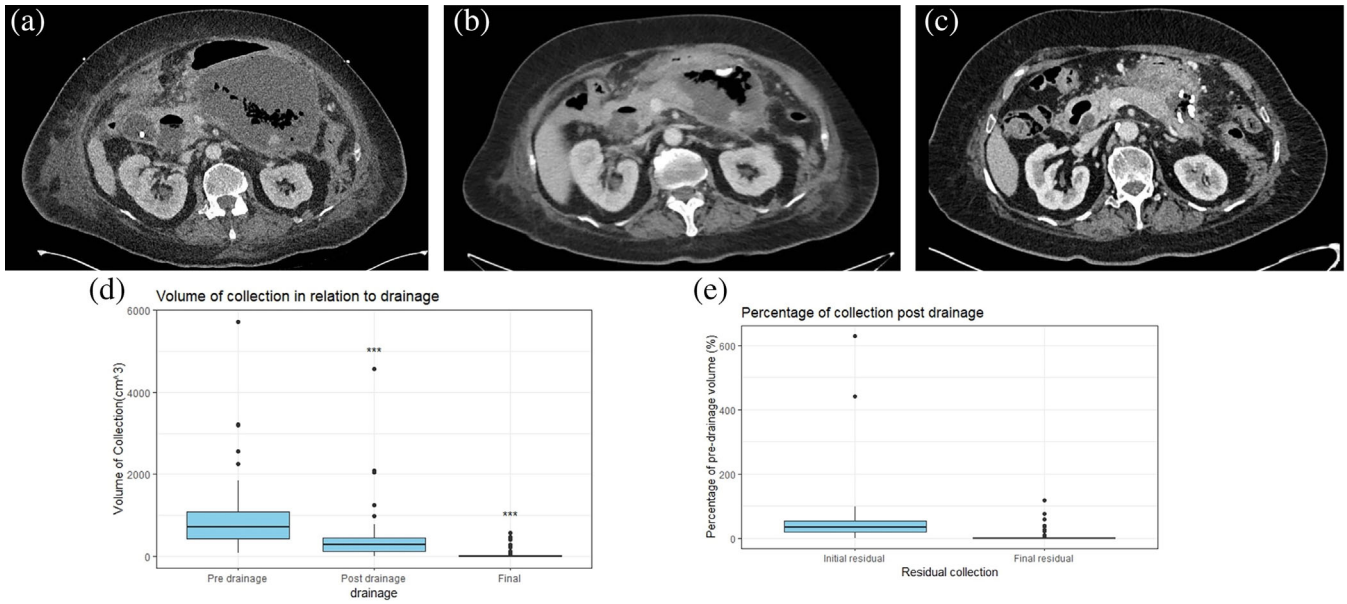


Fig. 2. Endoscopic drainage significantly reduced size of collection. An example of endoscopic drainage was demonstrated. (a) Gas containing necrotic collection was shown on CT before EUS guided drainage. Initial drainage was performed on Day 38 after diagnosis of pancreatitis. (b) CT post first drainage showed reduction in collection size with pigtail stent *in situ*. Patient had one repetitive endoscopic drainage due to re-collection. (c) CT on final follow up before stent removal showed resolution of collection. (d) Box plot demonstrating volume of pancreatic necrotic collection on CT before drainage, post initial drainage and upon final follow up. (e) Percentage of residual collection on CT post initial drainage and upon final follow up was shown on box plot. Statistical significance: $*P < 0.05$; $**P < 0.01$; $***P < 0.001$.

parametric data was analysed with Student's t-tests (t) and non-parametric data was analysed with Mann–Whitney's test (W). Binomial and categorical data were assessed by Pearson's chi-square (χ^2) test. Univariate and multivariate analysis was performed using regression models: linear regression for continuous variables, logistic regression for binomial variables and Poisson regression for count variables.

Test statistic and P-values were reported for all analysis. For regression models, correlation coefficients (r) of independent variables were reported, together with their associated P-values. A two-sided P-value less than 0.05 indicated statistical significance. Complete case analysis was employed because inference of missing data was impossible. Statistical analysis was performed using R, version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Percutaneous drainage is the most common intervention to supplement repetitive endoscopic drainage

A total of 69 patients who had endoscopic drainage of PNC were identified for the study period. Nine patients were excluded: 7 due to loss to follow up, 2 were below 18 years old. A total of 60 participants were included: 20 had early endoscopic drainage, 40 had delayed endoscopic drainage (Fig. 1a). Demographics of study participants were summarized in Figure 1b.

Table 1 showed results of interventions performed. Majority of endoscopic drainage were performed under EUS guidance using pigtail stents, and the most common complication was upper gastrointestinal bleed (UGIB). Most patients required two endoscopic drainages to achieve resolution of collection. Only four patients required formal endoscopic necrosectomy, among whom one developed colonic fistula as a complication.

Percutaneous drainage was the most common associated intervention required for distant collections which were not effectively drained by endoscopic drainage (Table 1). Only five patients required surgical necrosectomies (Table 1). Retroperitoneal necrosectomies were more commonly performed (60%) as a step-up approach of percutaneous drainage for persistent retroperitoneal collections. Open necrosectomies were rarely indicated: one due to failure of both endoscopic and retroperitoneal necrosetomies, and the other one in the setting of colonic resection for sigmoid perforation. Endoscopic retrograde cholangioprancreatography (ERCP) and percutaneous transhepatic cholangiogram (PTC) were also occasionally required to relieve biliary obstruction. In summary, majority of PNC can be treated with repetitive endoscopic drainage and occasional percutaneous drainage without need for formal necrosectomy.

Repetitive endoscopic drainage is safe and effective for treatment of pancreatic necrotic collection

Clinical outcomes of study participants were summarized in Table 1. 86.44% of patients achieved symptom resolution at the end of follow-up. Eight deaths were reported and three were not disease related (surgical complication, aspirational pneumonia, and underlying pancreatic cancer respectively). The mean LOS

Table 2 Comparison between early and delayed drainage cohorts

Variable	Early ($n = 20$)	Delay ($n = 40$)	$t/\chi^2/W$	P value
Age	59.30	59.45	0.034	0.973
Gender			0.616	0.433
Male	15 (75%)	26 (65%)		
Female	5 (25%)	14 (35%)		
Aetiology			6.985	0.222
Gall stone	9 (45%)	22 (55%)		
ETOH	4 (20%)	8 (20%)		
Hypertriglyceridaemia	1 (5%)	0 (0%)		
Post ERCP	0 (0%)	4 (10%)		
Steroids	0 (0%)	1 (2.5%)		
Idiopathic	6 (30%)	5 (12.5%)		
CTSI at diagnosis	4.5	5	360.5	0.859
BISAP at diagnosis	2	2	291	0.286
SIRS at diagnosis			0.728	0.394
Yes	15 (75%)	23 (63.9%)		
No	5 (25%)	13 (36.1%)		
CRP at diagnosis	168.48	154.83	336	0.813
Year of drainage	2019	2018	326.5	0.248
Volume of collection before drainage	1168.59	846.06	333	0.545
qSOFA at drainage	2	0	13.468	0.004**
SIRS at drainage			10.144	0.001**
Yes	16 (84.2%)	16 (40%)		
No	3 (15.8%)	24 (60%)		
CRP at drainage	242.69	133.23	105	0.008**
Endoscopic drainage method			0.259	0.611
EUS	19 (95%)	39 (97.5%)		
Gastroscopy	1 (5%)	1 (2.5%)		
Type of stent			2.75	0.253
Pigtail	15 (75%)	35 (87.5%)		
HOT AXIOS	4 (20%)	5 (12.5%)		
Both	1 (5%)	0 (0%)		
Duration of follow-up (months)	11.55	12.3	455.5	0.388
Endoscopic drainage complications	3 (15%)	10 (25%)	0.786	0.375
Bowel perforation	0 (0%)	2 (5%)		
Gastric outlet obstruction	1 (5%)	2 (5%)		
Biliary obstruction	0 (0%)	1 (2.5%)		
Gastric outlet and Biliary obstruction	1 (5%)	0 (0%)		
UGIB	1 (5%)	5 (12.5%)		
Number of endoscopic drainages	2	2	334	0.288
% residual collection after initial drainage	81.66	38.44	349	0.88
% residual collection final	13.42	4.66	263	0.104
Percutaneous drainage	9 (45%)	10 (25%)	2.465	0.116
Endoscopic Necrosectomy	2 (10%)	2 (5%)	0.536	0.464
Surgical Necrosectomy	3 (15%)	2 (5%)	1.745	0.186
ERCP	3 (15%)	4 (10%)	0.323	0.570
PTC	2 (10%)	1 (2.5%)	1.579	0.209
Initial admission LOS	61.95	44.64	278.5	0.129
Number of admissions	2	3	447.5	0.446
Total LOS	75.35	68.7	370	0.644
Total Death	4 (21.1%)	4 (10%)	1.343	0.247
Disease related death	2 (10.5%)	3 (7.5%)	0.152	0.697

Statistical significance: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. Number of participants (n) in each cohort was shown.

was 70.92 days and most patients required three inpatient admissions.

Endoscopic drainage also significantly reduced collection volume. Figure 2a–c demonstrated a case of endoscopic drainage of PNC in a 79 years old female. EUS guided drainage was performed at Day 38 post pancreatitis diagnosis. Pre-drainage (Fig. 2a), post drainage (Fig. 2b) and final follow-up (Fig. 2c) CT showed significant reduction in collection size. The patient did not require percutaneous drainage or formal necrosectomy. As shown in Figure 2d,e, a significant reduction in collection volume was noted after initial endoscopic drainage, which dropped further on final follow up. This correlated with 54.45% of residual collection volume after initial drainage and 7.84% on final follow up. Our results demonstrated repetitive endoscopic drainage is a safe and effective treatment strategy for PNC.

Early endoscopic drainages were performed in patients with more severe sepsis

To assess the optimal timing of endoscopic drainage for PNC, we compared patients who had early versus delayed endoscopic drainage. As shown in Table 2, the early and delayed cohorts have similar age, sex, aetiology, and severity of pancreatitis on diagnosis.

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Table 3 Regression analysis of outcome variables in relation to timing of drainage

Dependent variable	Univariate		Multivariate	
	Correlation coefficient (*r*)	*P* value	Correlation coefficient (*r*)	*P* value
Endoscopic drainage complications	0.636	0.380	0.610	0.500
Number of endoscopic drainages	−0.1823	0.29	−0.448	0.618
% residual collection after initial drainage	−43.22	0.125	8.261	0.836
% residual collection final	−8.760	0.144	−3.561	0.710
Percutaneous drainage	0.898	0.121	−0.084	0.926
Endoscopic necrosectomy	−0.747	0.473	−0.640	0.633
Surgical necrosectomy	−1.210	0.207	−0.521	0.759
ERCP	−0.463	0.572	1.446	0.309
PTC	−1.466	0.244	18.726	0.999
Initial admission LOS	−17.31	0.183	20.175	0.225
Number of admissions	0.129	0.444	−0.633	0.458
Total LOS	−6.65	0.666	22.685	0.235
Total Death	−0.876	0.256	1.703	0.291
Disease related death	−0.372	0.698	8.508	0.216

Statistical significance: $*P < 0.05$; $**P < 0.01$; $***P < 0.001$. Regression models were built with timing of drainage, volume of collection before drainage, qSOFA, SIRS and CRP on the day of drainage as independent variables. Correlation coefficients (*r*) of timing of drainage and correlated *P*-values were reported.

Both early and delayed endoscopic drainage were more commonly performed using EUS guidance and pigtail stent with no significant difference. Given participants were recruited over a 10 years period, we also examined if the two cohorts are different in their year of drainage, which was not significantly different. While the two cohorts have no difference in sepsis level on initial diagnosis, sepsis level was significantly different on the day of first endoscopic drainage, as indicated by higher qSOFA score, percentage of SIRS, and CRP level (Table 2). This suggested that the timing of endoscopic drainage was influenced by the development and severity of sepsis.

Early and delayed endoscopic drainage have equivalent clinical outcome

As shown in Table 2, early and delayed cohorts demonstrated no significant difference in clinical outcomes. While the early drainage group showed a trend towards higher percentage of residual collection, this did not translate to increased LOS or disease related mortality. However, the early drainage group did have a trend towards higher number of associated interventions (especially percutaneous drainage and necrosectomy), while delayed drainage group had a slightly higher risk of UGIB.

Due to the differences in qSOFA, SIRS, and CRP levels, as well as the trend towards higher percentage of residual collection in early drainage group, multivariate regression analysis involving timing of drainage, pre-drainage volume of collection, qSOFA, SIRS, and CRP level on the day of drainage was conducted and compared with univariate analysis (Table 3). No significant difference was detected between early and delayed cohorts with regards to number of drainages, collection size change, associated interventions, LOS, and disease related mortality. This again confirmed that early and delayed endoscopic drainage had equivalent outcome in treatment of PNC.

Discussion

PNC is one of the most common complications of NP, but significant debate surrounding best treatment still exists in the literature. In this study, we found that repetitive endoscopic drainage as primary intervention with percutaneous drainage for distant collections was effective in the management of PNC. Formal necrosectomy either by endoscopic or surgical measures was rarely needed. Furthermore, we found that early endoscopic drainage in patients with severe sepsis did not lead to worse outcome. Therefore, repetitive endoscopic drainage is safe and effective in early treatment of PNC with severe sepsis.

Endoscopic step-up approach was shown to be superior to surgical step-up approach in terms of LOS and pancreatic fistula formation.[5] However, 43% of patients in the endoscopic step-up group did not require necrosectomy, and the remaining ones require an average of two procedures to control sepsis.[5] In comparison, our results showed a similar overall mortality rate (13.56% *vs.* 18%) with a median of two endoscopic drainages required per patient. Only 6.67% and 8.33% of patients required endoscopic and surgical necrosectomies respectively, which contrasts with the reported 57% and 49% in step-up approach.[5] A slightly longer LOS was reported in our study (71 days *vs.* 53 days), and this can be related to a higher proportion of percutaneous drainage performed.[5] A recent study recommended protocolised use of endoscopic necrosectomy, but it did not consider potential complications.[9] In fact, the only colonic fistula in our study was a complication of endoscopic necrosectomy and its invasiveness may also limit its use in ANC due to lack of mature capsule.

While 2018 European Society of Gastrointestinal Endoscopy (ESGE) guideline recommended delaying intervention to more than 28 days after diagnosis, this is based on weak evidence.[3] Recently, a meta-analysis showed no difference between early and delayed drainage with regards to overall mortality.[14] Consistent with recent retrospective studies, our results failed to demonstrate significant difference between early and delayed drainage in regards to overcall complication, total LOS, and disease-related mortality.[10,11] This was in the setting of higher level of sepsis in the early drainage group. Therefore, in PNC with severe sepsis, endoscopic drainage should not be delayed and can be safely performed for sepsis control.

Our results are limited by the small sample size and retrospective design of study. Although this study has similar sample size to

previous studies, it remained relatively small and can be underpowered to detect small differences in outcome. Secondly, the retrospective design is vulnerable to selection bias. Although multivariate analysis was conducted to correct for confounding effects, unrecognized selection bias remains a possibility. To confirm findings of the current study, well designed multi-centre RCT will be the gold-standard.

In conclusion, our results suggest that repetitive endoscopic drainage with *ad-hoc* percutaneous drainage is safe and effective in treating PNC. Formal necrosectomy, either by endoscopic or surgical measures, is rarely required. Early drainage does not result in worse outcome in comparison to delayed drainage, and should be considered in patients with severe sepsis.

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Author contributions

Yi Ma: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; validation; visualization; writing – original draft; writing – review and editing. **Felicia Ong:** Data curation; investigation; methodology; validation; writing – review and editing. **Simon Hew:** Data curation; investigation; methodology; resources; visualization; writing – review and editing. **Michael Swan:** Investigation; methodology; resources; supervision; validation; writing – review and editing. **David Devonshire:** Investigation; methodology; resources; validation; writing – review and editing. **Daniel Croagh:** Conceptualization; investigation; methodology; project administration; resources; supervision; validation; visualization; writing – review and editing.

Conflicts of interest

Dr. Yi Ma, Dr. Felicia Ong, Dr. Simon Hew, Dr. Michael Swan, Dr. David Devonshire and Mr. Daniel Croagh have no conflict of interest or financial ties to disclose.

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