




# Complicated Severe Acute Pancreatitis: Open and Laparoscopic Infracolic Approach

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Received: 18 January 2022 / Accepted: 30 April 2022 / Published online: 17 May 2022  
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## Abstract

**Introduction** The heterogeneous nature of severe acute pancreatitis (SAP) renders decisions related to complications challenging. Central solid collections at the root of the mesentery are difficult to access with traditional techniques. Here we describe a case series of laparoscopic infracolic necrosectomy (ICN) and open or laparoscopic infracolic necrosectomy with Roux-en Y cystjejunostomy (ICN-RY CJ) for the management of complicated SAP.

**Materials and Methods** A retrospective analysis of a prospectively maintained database identified all patients treated with infracolic necrosectomy or drainage of pancreatic collections for complicated SAP between 2012 and 2021 inclusive at a single institution.

**Results** Forty patients were identified (median age 53 years)—ICN group 9 patients (median time to intervention—22 days) and ICN-RY CJ group 31 patients (median time to intervention—99 days). Two patients in ICN group underwent interval fistula-tract jejunostomy. Thirty-one patients had laparoscopic surgery and 9 patients underwent an open approach. Four patients required intervention post-operatively. Nineteen patients were discharged from follow-up at two years.

**Conclusion** Infracolic approach with selective Roux-en Y cystjejunostomy, as a single or staged intervention, is an effective and safe operative option to add to the armamentarium of the pancreatic surgeon when dealing with complicated SAP not amenable to drainage/debridement by traditional techniques.

## Introduction

Acute pancreatitis is a common surgical condition that when severe (severe acute pancreatitis—SAP; 20%) presents with a wide range of complications [1, 2]. As described by the revised Atlanta classification, in the early

phase (<4 weeks) patients with SAP may develop acute pancreatic fluid collections (APFCs) or acute necrotic collections (ANCs) [3, 4]. When collections persist to between four and six weeks, the wall matures to form walled-off pancreatic necrosis (WON) or pseudocysts [4], which may become symptomatic (gastric outlet obstruction, biliary compression, pain and failure to thrive) or infected. Sepsis is more common following necrosis and tends to occur within two-to-four weeks following the initial presentation [5]. Thirty percent develop delayed infection [3] with mortality reported to be as high as 40% [6, 7].

There is significant variability in anatomical location of collections, where they can present along the root of the mesentery, either side of middle colic vessels, and below the transverse colon distant from the stomach and abdominal wall. Central, infracolic collections, that are dominantly solid, are particular configurations that are often not amenable to percutaneous drainage and even when adjacent to the stomach, due to a narrow window of access can be difficult to clear with endoscopic or surgical transgastric necrosectomy [8–10] (Fig. 1). In this particular configuration a laparoscopic drainage/debridement may be favourable via

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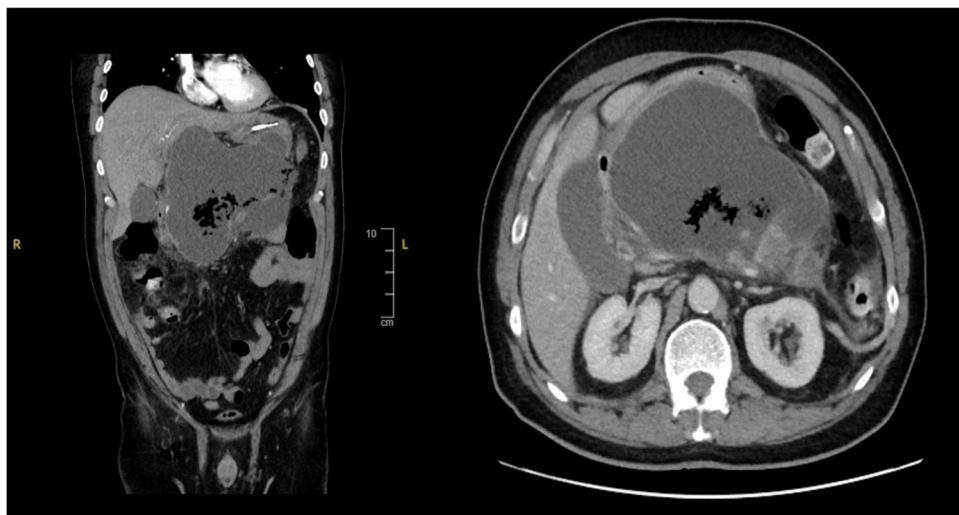
Association of Laparoscopic Surgeons of GB and Ireland (ALSGBI) ASM, Leeds, November 2019—Video Oral Presentation (Winner of Best Video).

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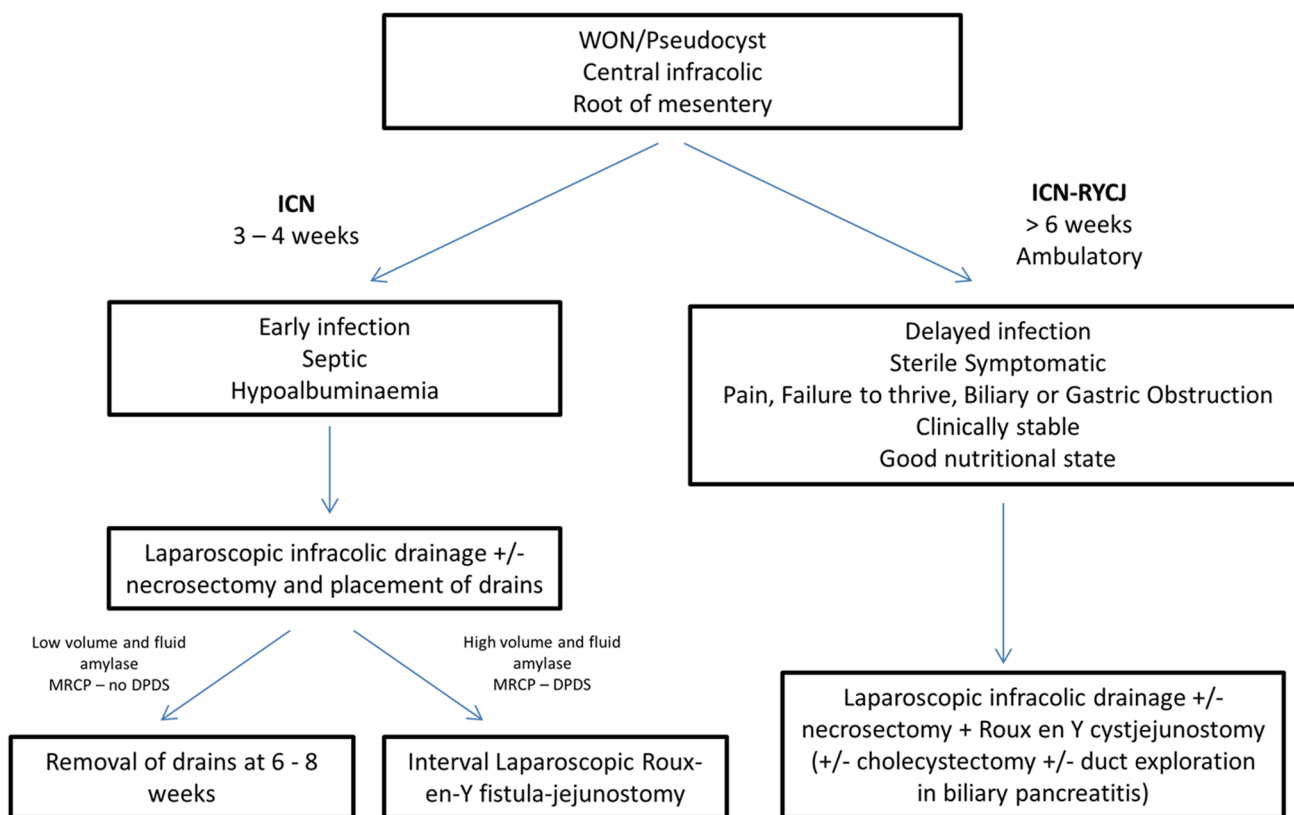
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**Fig. 1** Computerised tomography (CT) image showing WON with dominant protrusion into the infracolic compartment



the colonic mesentery with additional advantage of versatile laparoscopic instruments for adequate single-staged debridement of collections (Fig. 2) [11]. Symptomatic pseudocysts at the root of the mesentery with associated disconnected pancreatic duct syndrome (DPDS) may be managed with laparoscopic infracolic drainage with primary Roux-en-Y cystjejunostomy [12, 13].

Laparoscopic approaches for SAP were first described by Gagner in 1996, which included retrocolic, retroperitoneoscopic and transgastric drainage [14]. Subsequently, Cuschieri demonstrated laparoscopic infracolic necrosectomy and closed irrigation of the lesser sac [11]. Despite progress, there is a paucity of published literature surrounding laparoscopic infracolic drainage, especially when



**Fig. 2** Algorithm approach to management of central WON/Pseudocysts

utilising a concomitant Roux-en-Y cystjejunostomy [15–18], most likely due to a lack of both substantive studies regarding this approach and clear criterion for appropriate patient selection.

We describe outcomes of a case series of 40 patients that underwent either early laparoscopic infracolic necrosectomy (ICN) and selective delayed Roux-en-Y fistula-tract jejunostomy (for patients with pancreatic fistula) or interval laparoscopic/open drainage/debridement of WON/symptomatic pseudocysts with primary Roux-en-Y pancreatic cystjejunostomy (ICN-RYCJ) (Fig. 3).

## Methods

### Patient Population

This observational study included forty consecutive patients treated at a single, high-volume, tertiary benign pancreaticobiliary centre that underwent open or laparoscopic infracolic approach for early or established collections with selective Roux-en-Y cystjejunostomy for treatment of complicated SAP. This cohort represents 35% of the interventional approach our centre undertakes for SAP.

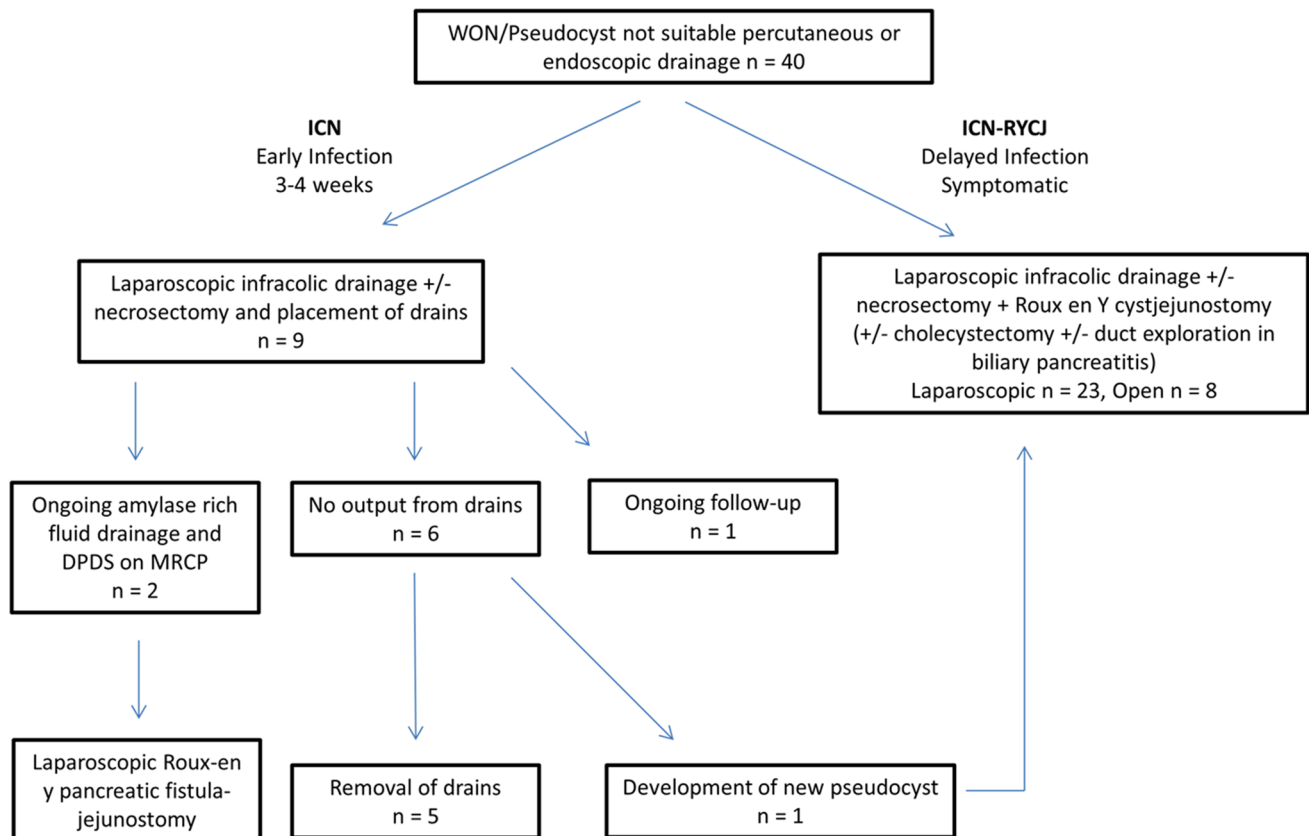
All cases were discussed at a specialist benign multidisciplinary team (MDT) meeting that included pancreatic surgeons, gastroenterologists, specialist pancreatic radiologists, and pancreatic nurse specialists.

A retrospective analysis of a prospectively maintained database, from 2012 to 2021 inclusive, was undertaken to ascertain patient, clinical and surgical outcomes. Our practice involves a follow-up period of 2 years, with those with a minimum of 6 months follow-up included in this study.

After consultation with our local Research and Development department, formal ethical approval was not required. Local National Health Service (NHS) approval from the audit department was obtained in order to evaluate quality of service.

### Parameters

Patients were allocated to ICN or ICN-RYCJ groups depending on timing of intervention following presentation with SAP. The following parameters were collated: demographic data (age, gender, ethnicity, BMI, and ASA grade), clinical characteristics of pancreatitis (aetiology, indication for intervention, nature of collection, presence of DPDS, biochemical characteristics and pre-operative organ failure),



**Fig. 3** Author's approach to cohort of patients with WON/pseudocyst not suitable for percutaneous or endoscopic drainage

and outcomes following intervention (operative time, morbidity, reintervention, and length of stay).

## Definitions

Acute pancreatitis was defined as per the revised Atlanta classification—this included two or more of the following: classical abdominal pain, serum amylase > 3 times the upper limit of normal, and findings of acute pancreatitis on cross-sectional imaging [19]. Severe acute pancreatitis was defined as the presence of APFCs or ANCs with subsequent development of pseudocyst or WON, confirmed by cross-sectional imaging [7].

Organ failure was defined using the modified Marshall scoring system [19]. Infected APFCs or ANCs was diagnosed either by clinical assessment by a pancreatico-biliary surgeon in patients with systemic inflammatory response syndrome with concomitant collections on imaging and biochemical (raised white cell count (WCC) and C-reactive protein (CRP) signs of infection, or the presence of gas within the collection on cross-sectional imaging.

DPDS was defined by complete disconnection of the main pancreatic duct secondary to WON or pseudocyst [20–22]. DPDS was diagnosed either by pre-operative magnetic resonance cholangiopancreatography (MRCP) showing absence of the main PD in any portion or assumed when on CT there was evidence of at least 2 cm of non-viable pancreatic tissue leaving a viable upstream (left-sided) pancreatic tail [23] (Fig. 1). All imaging was independently reviewed by a second specialist Hepatopancreaticobiliary radiologist.

A raised fluid amylase was defined as level > 300 U/L measured from an intraoperative sample and/or postoperative day 3 drain samples [24, 25].

Pancreatic fistula was defined according to the International Study Group (ISGPS) definition and grading for post-operative pancreatic fistula [26].

Resolution of disease was defined as clinical or radiographical resolution of pancreatic collections without further need for intervention. Follow-up was defined as a face-to-face or telephone consultation with a pancreatico-biliary surgeon.

## Inclusion and Exclusion Criteria

Inclusion criteria for this study were all patients > 18 years of age that developed SAP requiring early or delayed intervention. All patients in the ICN group had signs of an infected collection. In ICN-RY CJ group, indications for surgery included delayed infection, sterile symptomatic collections, new onset abdominal pain, early satiety, failure to thrive, biliary or gastric outlet obstruction.

Exclusion criteria included patients on intensive care with multiorgan failure not suitable for general anaesthetic

and/or pneumoperitoneum, and presence of intra-abdominal catastrophe. Those with previous intervention for SAP were excluded from this study.

## Selection Criteria

Initial treatment for patients with SAP was consistent with evidence based guidelines [7, 23, 27]. Indications for necrosectomy was infection resistant to antibiotic therapy or symptoms > 6 weeks after onset (Fig. 2). Following case-review of patients with WON/Pseudocyst at a specialist benign MDT meeting, those cases with central collections dominantly in the infracolic compartment were selected for ICN. These collections were not confined to the lesser sac and had limited adherence to the posterior wall of the stomach. Cross-sectional imaging demonstrated protrusion of the collection through the transverse mesocolon (Fig. 1), most commonly to the left of the middle colic vessels immediately superior to the duodeno-jejunal (DJ) flexure.

ICN alone was performed in patients with early infection (3–4 weeks) and signs of sepsis (Fig. 2). These patients were malnourished and ICN-RY CJ was avoided due to concerns of developing anastomotic complications. Following necrosectomy, drains were placed to allow for postoperative irrigation of the WON/Pseudocyst cavity.

ICN-RY CJ was performed in patients presenting with symptoms (pain and failure to thrive) or delayed infection more than 6 weeks after the initial attack of SAP (Fig. 2). This cohort included clinically stable and well-nourished patients.

## Intervention Strategy

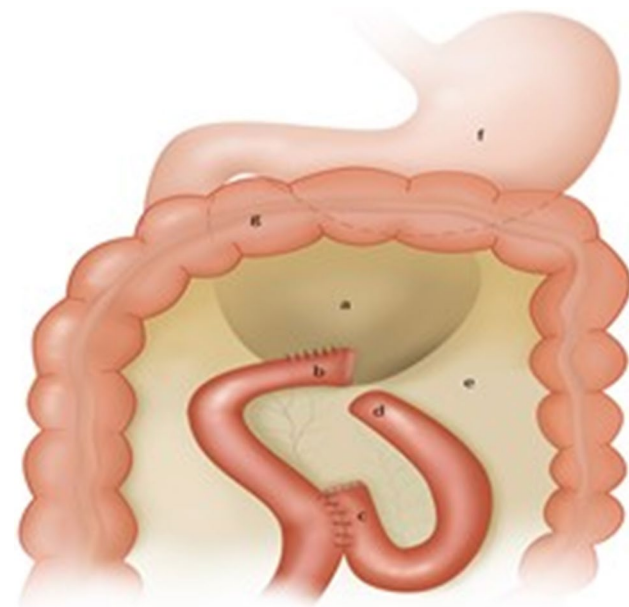
Patients that had an emergent operation were critically ill and underwent a necrosectomy/drainage and placement of 18F Robinson drains in the cavity (closed drainage) without cystjejunostomy (ICN). A proportion of these patients with DPDS went on to form pancreatic fistula and therefore required an interval (6 months from infracolic necrosectomy) laparoscopic pancreatic fistula tract-jejunostomy. Those that had an interval urgent intervention for development of either symptoms or delayed infection, a Roux-en Y cystjejunostomy was performed for internal drainage (ICN-RY CJ). The cystjejunostomy/fistula-tract jejunostomy is described below.

The operative intervention, whether open or laparoscopic, involved initial identification of the pancreatic collection (pseudocyst/WON) as a tense bulge through the transverse mesocolon. During the laparoscopic approach, the collection was confirmed by laparoscopic ultrasound (Hitachi Arietta 70 Surgery with L51K probe) and a long Angiocath (Becton Dickinson Infusion Therapy Systems; 14 gauge; 5.25 IN) aspiration needle, used to puncture the cavity wall

and aspirate the collection for confirmation. A window was made via the infracolic compartment, through the transverse mesocolon into the cavity and the fluid/necrotic material were removed with careful blunt dissection. Samples of fluid and tissue were sent for fluid amylase, microbiology, and histology.

For patients that underwent a laparoscopic infracolic necrosectomy and closed drainage (ICN) and subsequently developed a postoperative pancreatic fistula due to DPDS; a laparoscopic fistula-tract jejunostomy was performed. Following a careful laparoscopic adhesiolysis, the tract with abdominal drain in-situ was identified. The drain was removed, and the fistula tract was isolated by debriding adjacent tissue in preparation to perform a fistula-tract jejunostomy. The redundant tract was excised.

The Roux limb was formed by dividing jejunum approximately 60 cm from DJ flexure with EndoGIA 60 mm Gold cartridge (Medtronic, UK). A Roux limb (20 cm in length) was sutured to the cyst wall (WON or Pseudocyst) or fistula tract using 3/0 polydioxanone (PDS) suture in a continuous, single layer. A side-to-side stapled jejunum-jejunal distal anastomosis was formed (EndoGIA 45 mm, Medtronic, UK) to restore intestinal continuity. The mesenteric defects were closed using 0 Ethibond suture. Two 18 French Robinson drains were placed adjacent to the cyst/fistula-tract jejunostomy anastomosis. (Fig. 4).



**Fig. 4** The Roux-en-Y reconstruction illustrating the anastomosis of jejunum to the pancreatic cyst wall through the transverse mesocolon. (a) pseudocyst/area of walled off necrosis; (b) roux limb; (c) jejunum-jejunal anastomosis; (d) DJ flexure; (e) mesocolon; (f) stomach; (g) transverse colon

Patients underwent a number of concurrent interventions including cholecystectomy, common bile duct exploration and insertion of feeding nasogastric/nasojejunal (NG/NJ) tube for post-operative enteral nutrition. With increasing experience and a move from open to laparoscopic surgery, early post-operative oral feeding superseded NG/NJ enteral nutrition and feeding lines were no longer inserted routinely in ICN-RYJ patients. In ICN patients drains remained for a variable length of time and only removed when sepsis had resolved and no biochemical evidence of pancreatic fistula. In ICN-RYJ group, drains were removed on post-operative day three provided that drain fluid amylase was not elevated.

Patients were followed up 6 weeks after discharge, at 3 months, 6 months and annually for at least 2 years. Following discharge from follow-up, patient's general practitioners/family physicians were advised to monitor for signs of pancreatic endocrine and exocrine dysfunction and provide on-going care. Further investigation was only performed in those with clinical indication of pain or sepsis.

## Statistical Analysis

Data was recorded using Microsoft Excel 2007–2019 (Microsoft, Inc., Redmond, WA) and analysed with STATA 16. Descriptive statistics for continuous data included median (with interquartile range, IQR); median was chosen due to non-parametric distribution of dataset. Categorical data was expressed as numbers and percentages.

## Results

### Study Population Demographics

Forty patients were identified, 27 males, with a median age (IQR) of 53 (45–60) years. Thirty-seven (93%) patients were of Caucasian ethnicity. Median (IQR) Body Mass Index (BMI) was 27.7 (23.1–31.2) kg/m<sup>2</sup>. Majority of patients ( $n = 25$ ; 68%) were ASA grade 2 (Table 1).

**Table 1** Patient demographics for ICN & ICN-RYJ groups

Parameter	ICN ( $n = 9$ )	ICN-RYJ ( $n = 31$ )
Median Age in Years (IQR)	63 (49–73)	53 (44–60)
Gender Ratio (M:F)	7:2	19:12
Ethnicity, n, (%)		
Caucasian	7 (78)	30 (97)
South Asian	2 (22)	1 (3)
Median BMI (IQR)	29.0 (26.8–33.5)	27.5 (23.8–30.5)
Median ASA Grade	3	2

The aetiology of pancreatitis was gallstones in 24, alcohol in 8, idiopathic in 6 and hypertriglyceridaemia in 2 (both patients with a family history of hypertriglyceridaemia induced pancreatitis) (Table 1).

The distribution of patients that either had an urgent infracolic drainage/necrosectomy with closed drains placed into the cavity (ICN) and interval infracolic drainage/necrosectomy with Roux-en-Y cystjejunostomy  $\pm$  cholecystectomy (ICN-RYCJ) are shown in Table 1 and Fig. 2.

### Pre-operative Imaging

All patients had pre-operative abdominal ultrasound, documenting the presence or absence of gallstones. All patients also had at least one pre-operative computerised tomography (CT) and 25 (68%) patients had MRCP. Two (5%) patients underwent pre-operative endoscopic investigation. One patient underwent endoscopic ultrasound (EUS) to assess the peri-pancreatic collection and its suitability for endoscopic drainage; however, drainage was not performed due to the dominant presence of solid contents. A second patient had successful drainage through endoscopic cystgastrostomy with AXIOS stent, but the pseudocyst re-occurred following removal of the stent.

### Microbiology

Positive microbiology from intra-operative samples was seen in 14 (37%) patients (5 = ICN; 9 = ICN-RYCJ) and identified a mix of organisms within the necrotic tissue which included candida, streptococcus salivarius, E. Coli and enterococcus. However, there was no common organism identified.

ICN—Infracolic drainage/necrosectomy with closed drainage.

Median (IQR) time from index admission with SAP to intervention was 26 (21–31) days. Median (IQR) operative time was 154 (107–212) minutes. The most common location of WON/pseudocyst was tail of the pancreas. Median (IQR) maximal size of WON/pseudocyst was 9.1 (8.0–16.4) cm (Table 2).

Median (IQR) white cell count ( $\times 10^9/L$ ) was 14.5 (range 13.3–18.8), median (IQR) CRP (mg/L) was 296 (range 232–327), and median (IQR) serum albumin (g/l) was 18 (16–21) (Table 2).

Transient Renal failure was demonstrated in 2 (5%) patients, which completely resolved at least 48 h prior to intervention. (Table 2).

Indication for intervention included sepsis from infected collections (8 patients; 20% entire cohort) and small bowel obstruction (1 patient; 3% entire cohort) (Table 3).

Nine patients underwent laparoscopic infracolic necrosectomy and closed drainage. Of these nine patients, two patients that had DPDS went on to develop grade B pancreatic fistula and underwent interval planned Roux-en-Y fistula-tract jejunostomy. Six patients that had minimal drain output and/or normal fluid amylase had drains removed. From these, one patient had further symptoms (pain) and was found to have a recurrent pseudocyst (subsequently treated surgically with drainage and Roux-en Y cystjejunostomy). Three patients had a cholecystectomy during the initial necrosectomy when the aetiology of pancreatitis was gallstones. One patient went on to have an interval cholecystectomy.

Three (8% entire cohort) patients had readmissions. One patient required EUS after displacement of drains. Two patients required readmission for irrigation with warm saline of abdominal drains and treatment of infected inflammatory bed with intravenous antibiotics, with CT imaging demonstrating no drainable collection.

Median (IQR) post-operative length of stay was 27 (16–55) days.

ICN-RYCJ – Infracolic drainage and Roux-en-Y cystjejunostomy.

Median (IQR) time from index admission with SAP to intervention was 99 (45–291) days. Median (IQR) operative time was 265 (208–298) minutes. Incidence of WON (26 patients) was higher than pseudocyst (5 patients). The most common location of WON/pseudocyst was body and tail of pancreas. Median (IQR) maximal size of WON/pseudocyst was 12.1 (7.5–16.1) cm (Table 2).

Median (IQR) white cell count ( $\times 10^9/L$ ) was 13.5 (9.0–19.3), median (IQR) CRP (mg/L) was 115 (range 75–134), and median (IQR) serum albumin (g/l) was 28 (25–30) (Table 2).

Transient renal failure was evident in 5 (13%) patients, which completely resolved during the index acute admission with SAP (Table 2).

Twenty-three patients (58% entire cohort) underwent surgery for symptomatic collections, and 8 (20% entire cohort) patients for infected collections (Table 3).

Thirty-one patients underwent ICN-RYCJ (WON: 26, Pseudocyst: 5), of which 23 (WON: 20, Pseudocyst: 3) were completed laparoscopically. No conversions occurred from laparoscopic to open approach. The open approach was planned and utilised early in the series. Additional interventions included 24 cholecystectomies (3 with on-table cholangiogram) – 17 concomitant, 2 preceding pancreatic intervention, 5 interval following pancreatic intervention, 1 concomitant CBD exploration, and insertion of feeding jejunostomy in 3 patients.

**Table 2** Clinical characteristics of pancreatitis for ICN & ICN-RYCYJ groups

Parameter	ICN ( <i>n</i> =9)	ICN-RYCYJ ( <i>n</i> =31)
Aetiology of Pancreatitis, <i>n</i> , (%)		
Gallstones	4 (44)	20 (65)
Alcohol	1 (12)	7 (23)
Idiopathic	4 (44)	2 (6)
Triglycerides	0 (00)	2 (6)
Indication for Intervention, <i>n</i> , (%)		
Sepsis	8 (88)	8 (26)
Symptomatic collection	0 (0)	23 (74)
Small bowel obstruction	1 (12)	0 (0)
Approach to Drainage, <i>n</i> , (%)		
Laparoscopic	9 (100)	23 (74)
Open	0 (0)	8 (26)
Type of Collection, <i>n</i> , (%)		
WON	6 (67)	26 (84)
Pseudocyst	3 (33)	5 (16)
Location of WON/Pseudocyst, <i>n</i> , (%)		
Head	0 (0)	14 (13)
Neck	2 (22)	3 (10)
Body	1 (12)	9 (29)
Tail	3 (32)	3 (10)
Body + Tail	1 (12)	7 (23)
Pancreatic ascites/DPDS	0 (0)	1 (2)
Median Size of WON/Pseudocyst (cm)		
(IQR)	9.1 (8.0–16.4)	12.1 (7.5–16.1)
Evidence of DPDS on preoperative imaging, <i>n</i> , (%)		
Median Time from Index Admission to Intervention (Days)	3 (32)	22 (71)
(IQR)	26 (21–31)	99 (45–291)
Median Serum White Cell Count ( $\times 10^9/l$ )		
(IQR)	14.5 (13.3–18.8)	13.5 (9.0–19.3)
Median Serum CRP (mg/L)		
(IQR)	296 (232–327)	115 (75–134)
Median Serum Albumin (g/l)		
(IQR)	18 (16–21)	28 (25–30)
Median Fluid Amylase (U/L)		
(IQR)	22,660 (16,004–29,230)	12,812 (1138–31,679)
Pre-operative Organ Failure, <i>n</i> , (%)		
	2 (33)	5 (16)

**Table 3** Aetiology of symptomatic WON or pseudocysts in ICN-RYCYJ group

Nature of Symptoms	No. of patients
Pain	18
Nausea and vomiting	1
Anorexia with due to gastric compression	2
Gastric Outlet Obstruction	2

Two (5% entire cohort) patients required re-admission for intravenous antibiotics due to recurrent sepsis, but CT imaging demonstrated no drainable collections.

Median (IQR) post-operative length of stay was 5 (3–14).

### Fluid Amylase

Intra-operative fluid analysis for amylase (all available post-operatively) was taken in 35 (88%) patients that confirmed an elevated level of  $> 300$ U/L in 29 (73%) patients; median (IQR) value was 22,660 (16,004–29,230) in ICN group and 12,812 (1138–31,679) in ICN-RYCYJ group (Table 2). All intraoperative cyst aspirates in ICN group ( $n=9/9$ ) were rich in amylase ( $> 300$  U/L) irrespective of presence or absence of DPDS. Two patients with confirmed DPDS on

cross-sectional imaging went on to develop post-operative pancreatic fistula. One patient developed a pseudocyst after index laparoscopic infracolic necrosectomy with closed drainage and required an interval Roux-en-Y cystjejunostomy. In ICN-RYCJ group, an elevated fluid amylase (> 300 U/L) correlated with pre-operative cross-sectional imaging demonstrating DPDS (n = 23/31).

### Morbidity and Reintervention

Post-operative complications occurred in 8 (20%) patients. These included lower respiratory tract infection [1], acute kidney injury [2], post-operative ileus [1], transient ischaemic attack [1], port site bleed [1], drain dislodgement [2] and temporary grade A pancreatic fistula following ICN-RYCJ [1] (Table 7). Emergency re-intervention was needed in 4 (11%) patients, described below.

In ICN group, 3 patients underwent reintervention. One patient that had a infracolic necrosectomy returned to theatre for replacement of dislodged drain on day 19. One patient on therapeutic dose low molecular weight heparin for a lower limb deep vein thrombosis developed a port-site bleed, which required a return to theatre for laparoscopy and washout. One patient underwent endoscopic ultrasound drainage of pancreatic pseudocyst, with dominantly liquid component confirmed on MRI, by insertion of HOT AXIOS/LAMS (Lumen-Apposing Metal Stent), following drain dislodgement in the community after laparoscopic infracolic necrosectomy (Table 4).

Following ICN-RYCJ, one patient underwent post-operative ERCP for common bile duct stone (Table 4).

### Follow-up

Nineteen patients were discharged from follow-up at two years and twenty-one patients are still under routine follow up. Exocrine insufficiency was identified in 19 (48%) patients during follow up, endocrine insufficiency in 2 (5%) patients and both endocrine and exocrine insufficiency in 10 (25%) patients (Table 4).

### Discussion

The current standards of care for SAP are variable, dependent on an institution's skills and experience. Recent evidence has moved practice away from early (< 4 weeks) open surgery which was associated with both significant morbidity and mortality and shifted towards supporting minimally invasive techniques. These include 'Step up' from percutaneous drainage to video assisted retroperitoneal debridement (VARD) and endoscopic placement of lumen apposing stents (LAMS) followed by transluminal necrosectomy

**Table 4** Outcomes following intervention for both ICN & ICN-RYCJ groups

Parameter	All Patients (n = 40)
Median (IQR) Operative Time (minutes)	
ICN	154 (107–212)
ICN-RYCJ	265 (208–298)
Microbiology from Pancreatic Tissue, n, (%)	
Positive	14 (35)
Sterile	25 (63)
No sample	1 (2)
Postoperative Morbidity, n, (%)	
Lower Respiratory Tract Infection	1 (2)
Acute Kidney Injury	2 (5)
Post-operative ileus	1 (2)
Transient Ischaemic Attack	1 (2)
Port-site haematoma	1 (2)
Grade A pancreatic fistula	1 (2)
Readmission, n, (%)	
ICN	3 (8)
ICN-RYCJ	2 (5)
Reintervention, n, (%)	
Laparoscopy	2 (5)
Postoperative ERCP for CBDS	1 (2)
EUS for recurrent Pseudocyst	1 (2)
Late Complications, n, %	
Exocrine insufficiency	1 (2)
Endocrine insufficiency	2 (5)
Exocrine/Endocrine insufficiency	10 (25)
Median (IQR) Post-operative Length of Stay (Days)	
ICN	27 (16–55)
ICN-RYCJ	5 (3–14)

[18]. Nevertheless, management decisions for SAP are complex due to variability in disease presentation. Factors that contribute to complexity include volume of fluid versus necrosis, anatomical location and presence or absence of infection, DPDS, pseudo-aneurysm, timing of presentation, critical and nutritional state and patient co-morbidity [2, 5, 8, 28]. Management in a select group of stable patients without persistent organ failure should be supported by minimally invasive/laparoscopic techniques that are able to achieve complete drainage in a single stage and therefore ideally should be guided by a specialist multidisciplinary meeting led by a team of relevant interventionists [8, 9, 29].

Advancements in critical care and other therapies (antibiotics and percutaneous drains) have reduced the need for emergent surgery (3–4 weeks), leaving a proportion of patients with non-life-threatening sepsis, symptoms, or failure to thrive [17]. This group of patients are reflected in our study by a cohort that were fit to undergo laparoscopic

or open ICN-RY CJ ( $n=31$ ) with or without biliary surgery (cholecystectomy  $\pm$  common bile duct exploration). While another group of patients were critically unwell, developed early infection from week 3 onwards and were suitable for ICN ( $n=9$ ) alone. A common theme in the patients from ICN-RY CJ group was that they were stable, well-nourished with minimal co-morbidity and localized pockets of unresolved fluid collections or necrosis without major abdominal catastrophe (Ischaemic colon leading to perforation and peritonitis or compartment syndrome) or persistent organ failure requiring support. Seven patients in the study had renal failure, with all resolving before intervention. The stability in the patients' critical state made it possible to perform major intervention with the laparoscopic approach.

The laparoscopic infracolic necrosectomy and closed irrigation of the lesser sac was first described in 1998 [11]. Cuschieri et al. entire series was limited to 11 patients with confirmed infected necrosis. The clinical course of 9 patients was satisfactory, not requiring repeat intervention and had a median hospital stay of 21 days. There was a patient that succumbed to sepsis and multi-organ failure, another survived a prolonged illness characterised by renal failure, septic complications requiring a laparotomy, pancreatic ascites and an episode of bleeding from the pancreatic bed. These were critically ill patients that would correlate with ICN group in our cohort. Interestingly, Cuschieri et al. did not discuss whether or not the patients developed pancreatic fistula (amylase rich fluid  $> 50$  ml/24 h) which occurred in 2 of 9 patients in our cohort requiring an interval fistula-tract jejunostomy. There is limited evidence of long-term outcomes for fistula-tract jejunostomy in the context of severe acute pancreatitis [22]. However, those that underwent interval fistula-tract jejunostomy ( $n=2$ ) were followed up for 2 years, without evidence of recurrence of collection confirmed by MRCP. Therefore, more evidence is needed before we can make conclusions regarding the long-term outcomes of this approach.

The laparoscopic infracolic approach has been previously reported in small case series whereas we believe this is the largest reported series for treatment of WON with selective Roux-en-Y cyst-jejunostomy (Infracolic necrosectomy and Roux-en-Y cystjejunostomy; Laparoscopic: 20, Open: 6) [8, 12, 30]. Fluid amylase samples obtained intra-operatively from the cyst cavity were analysed and available postoperatively. In retrospect, even in cases where there was a low amylase ( $< 300$ ), the authors believe that providing a RY CJ allows for dependent internal drainage of remnant pancreatic necrosis and inflammatory/potentially infected fluid preventing re-accumulation, and concomitantly provides a drainage route for possible side branch disruption, which would not have been diagnosed from preoperative cross-sectional imaging. Thus, the Roux limb helps prevent recurrent infections in the short-term and a

risk of re-accumulation of the cyst in the long-term. The insertion of drains alone could potentially lead to subsequent pancreatic fistula from side branch disruption, which may heal over time with or without pancreatic duct intervention from ERCP. This would cause unnecessary morbidity to patients that are already physically depleted from long hospital stays and recurrent visits. Furthermore, in our experience the RY CJ anastomosis in a group of well-nourished patients has shown good results rarely posing problems from re-accumulation of fluid collections or fistula formation due to failure of healing. Only one patient that had an ICN-RY CJ had a temporary low volume leak from the Roux anastomosis to the cavity which dried up (drain removed at day 15) with conservative management (subcutaneous somatostatin analogue – initially Octreotide followed by a single dose Lanreotide).

In our series' most patients from ICN group (7/9) required debridement by infracolic necrosectomy alone. In these select patients, preoperative imaging did not confirm DPDS although the median (IQR) fluid amylase samples taken during laparoscopic necrosectomy was 22,660 (16,004–29,230). Three patients from ICN group had DPDS confirmed by preoperative imaging from which two developed pancreatic fistulae, subsequently needing to undergo a fistula-tract jejunostomy. One patient had drains removed after reporting no discharge but then later developed a symptomatic pseudocyst needing to undergo a laparoscopic cyst drainage and Roux-en-Y cystjejunostomy. Therefore, although all intra-operative fluid aspirates from ICN group were rich in amylase, integrity of the main pancreatic duct confirmed from preoperative imaging was the most sensitive predictor of DPDS and therefore post-operative pancreatic fistula.

Persistence or re-accumulation of WON/Pseudocyst is usually associated with an underlying DPDS. Presentation of DPDS is variable; however, in our study, we specified cases in the early phase of acute necrotizing pancreatitis associated WON or pseudocyst [20, 22]. Currently treatment of this complication is not standardised, and evidence is lacking [21]. Treatment strategies include endoscopic drainage (transluminal or transpapillary), surgical drainage, distal pancreatectomy or a combination of interventions achieving a success rate of over 80% [31]. In circumstances where there is a DPDS, percutaneous drainage should be avoided due to the high risk of pancreatic fistula and transluminal endoscopic drainage may lead to recurrence of collections after removal of cystgastrostomy stents causing recurrent symptoms [21, 31]. Drainage surgery offers a more permanent solution by way of drainage of the cyst [32]. Distal pancreatectomy can offer success although is technically difficult and often requires the need for concomitant splenectomy [32]. This can be associated with increased blood loss and transfusion requirement with both long-term endocrine and exocrine insufficiency [32].

The infracolic approach is especially useful when the anatomical distribution of collections in the root of the mesentery and access by traditional endoscopic and percutaneous approaches are limited [28]. Solid collections as mentioned before are difficult to manage with endoscopic debridement techniques requiring multiple and lengthy interventions to achieve clearance [29]. Therefore, even when solid collections are accessible (EUS or surgical transgastric approach) with a narrow window from the stomach, dominantly in the infracolic space, we prefer laparoscopic infracolic debridement in order to achieve a single staged clearance. The laparoscopic view and instrumentation allow for safe debridement of majority of the necrosis within the cavity [28]. In our study there was one patient in ICN group that had displacement of drains and therefore required EUS guided placement LAMS to clear the accumulation of infected fluid (no solid component) in the inflammatory cavity. Two (22%) patients in ICN group were readmitted for further irrigation with warm saline of abdominal drains and treatment with intravenous antibiotics were required to treat infection in the bed of the inflammatory cavity. Although there were clinical signs of sepsis and inflammatory stranding in bed of previous WON, CT imaging during re-admission showed no significant collections. Two (6%) patients in ICN-RY CJ required re-admission for intravenous antibiotics due to recurrent sepsis but CT imaging again demonstrated no drainable collections.

Early comparisons between open pancreatic cystgastrostomy and infracolic pancreatic necrosectomy with Roux-en Y cystjejunostomy in small retrospective studies have identified increased haemorrhage rates with cystgastrostomy [33]. Despite this, cystgastrostomy is now being practiced with increasing frequency and has gained broader traction. Recently, Maatman, et al. reported a large series of 160 patients that underwent operative and endoscopic TCG (operative: 101, endoscopic: 59), demonstrating superior efficacy of the operative approach with reduced number of interventions, unplanned readmissions and length of stay [23]. Similar to operative TCG, ICN achieved a durable and complete debridement, with few needing repeat interventions. We concur with Maatman et al. statement that the importance of necrosis anatomy can't be underestimated in selecting patients for the transgastric approach. Necrosis extending into the root of the small bowel mesentery is less than ideal for transgastric approach, where dependent portions of the cavity are at high risk of reaccumulating, abscess and recurrent necrosis. In this specific anatomical morphology, the ICN ± RY CJ has been ideal in producing good results in patient with WON/Pseudocyst [34]. However, the two techniques should not be directly compared because their respective indications differ based on the anatomical configuration of the collection.

Nineteen patients in our cohort had surveillance with an MRI and CT scan at 2 years confirming absence of recurrence of cyst after Roux en Y cystjejunostomy. Two patients went on to develop chronic pancreatic pain which would be consistent with long-term sequelae of SAP. A limitation to our study was a maximum of 2 years follow-up; however, a significant proportion of patients following operative necrosectomy will develop pseudocysts or left sided pancreatitis [13] and therefore long term follow (> 2 years) would be prudent to identify and manage the sequela of pancreatitis.

In conclusion, laparoscopic or open infracolic pancreatic necrosectomy alone or with Roux-en-Y cystjejunostomy are effective alternative treatments for a select group of patients described with solid/liquid collections at the route of the mesentery, confirming satisfactory results. The technique requires advanced laparoscopic skills and experience in making use of the approach in appropriate patients. More work needs to be undertaken and a multicentre study to ascertain both short- and long-term outcomes is warranted given the relatively small proportion of patients that require intervention of this type.

**Author Contribution** Javed Latif, Lee Creedon, Pritesh Mistry, Imran Bhatti, and Altaf Awan were involved in conception, collection, and analysis of data, drafting and revising paper critically, final approval and agree to be accountable for all aspects of work. Peter Thurley was involved in conception, collection, drafting and revising paper critically, final approval and agrees to be accountable for all aspects of work.

## Declarations

**Conflict of Interest** The authors declare no competing interests.

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