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Original Article

DPDS Demystified: Imaging Insights and Minimally Invasive Management

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Abstract

Aim This article retrospectively evaluates the radiological imaging features in establishing the diagnosis of pancreatic duct disconnection along with outlining the effective management protocols.

Materials and Methods Sixty-three patients with radiological or clinical suspicion of pancreatic duct disconnection were identified. Their computed tomography (CT) and magnetic resonance cholangiopancreatography (MRCP) images, clinical data, and laboratory parameters from medical records were retrieved and analyzed. Endoscopic retrograde cholangiopancreatography (ERCP) findings or raised amylase values in the necrotic collection higher than three times the reference range were considered as proven cases of disconnected pancreatic duct syndrome (DPDS) for the study. Multiple parameters were assessed on imaging to establish the diagnosis of DPDS. SPSS software was used for statistical analysis and radiological imaging features of pancreatic duct disconnection were evaluated. Laboratory parameters of serum amylase/lipase and amylase/lipase values from the collection were also studied along with the mode of clinical management and outcome on follow-up.

Results The radiological imaging features of pancreatic duct disconnection were assessed in 63 patients in which it was seen that magnetic resonance imaging had a significantly higher accuracy rate in diagnosing DPDS as opposed to CT. Minimally invasive procedures such as endoscopic cystogastrostomy was the preferred management in most cases with ERCP stenting being the next favored management of choice. Resolution or reduction of symptoms was mostly seen on follow-up with 12.69% of patients developing complications.

Conclusion This study highlighted the imaging features of DPDS apart from ascertaining the parameters that could be assessed to aid in early diagnosis of DPDS. MRCP has a higher accuracy rate compared with CT in diagnosing DPDS. A combination of two or more parameters on MRCP was more accurate in the identification of DPDS rather than a single parameter. Minimally invasive treatment options such as endoscopic transluminal drainage with or without stenting are currently preferred in the treatment of DPDS over surgical management. Early diagnosis and prompt management of DPDS is essential to reduce the onset of serious complications apart from improving the quality of life of these patients posttreatment.

Keywords

- disconnected pancreatic duct syndrome
- acute necrotizing pancreatitis
- magnetic resonance cholangiopancreatography
- pancreatic fistula
- pancreatic pseudocyst

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Introduction

Disconnected pancreatic duct syndrome (DPDS) is most frequently seen in cases of acute necrotizing pancreatitis and usually goes unrecognized and untreated because of its varied clinical presentation, absence of clearly defined diagnostic criteria, and low degree of recognition by clinicians.[1–4]

Early detection of DPDS in acute pancreatitis is essential since a delayed diagnosis could result in increased morbidity, longer hospital stays, and higher medical costs. Cross-sectional imaging is primarily used for diagnosis because it is noninvasive and permits pancreatic imaging distal to the disconnection, as opposed to the invasive traditional gold standard technique of endoscopic retrograde cholangiopancreatography (ERCP), which only shows termination of the duct's proximal portion and carries a higher risk of complications. Studies have explored computed tomography (CT), magnetic resonance cholangiopancreatography (MRCP), and ERCP to identify the best option for diagnosis. They have concluded that although the invasive traditional gold standard ERCP is both a diagnostic and therapeutic procedure,[5] MRCP is preferred due to its noninvasive nature and lesser risk of complications.[6]

DPDS occurs in roughly 50% of walled-off pancreatic necrosis patients who receive percutaneous drainage[7,8] and a majority of DPDS cases do not respond to conservative therapies which calls for hybrid approaches. Surgical methods of management of DPDS are no longer favored due to their invasive nature.[9,10] Endoscopic transluminal drainage is currently the standard preferred procedure for managing these patients.[1,11,12]

Although it may become a significant long-term issue in instances of necrotizing pancreatitis, only a few studies have discussed the imaging characteristics of DPDS. However, neither the standardized diagnostic criteria nor the management strategy for DPDS is currently recognized worldwide.[13] With improved understanding and the application of various imaging aspects, DPDS can be detected early via imaging, leading to a rapid diagnosis and early treatment.

We thus aim to evaluate the radiological imaging features in establishing the diagnosis of pancreatic duct disconnection along with outlining the effective management protocols.

Materials and Methods

Patients and Control Subjects

Our study is a retrospective observational study having a study population of 63 patients in the age group of 18 to 70 years with radiological or clinical suspicion or diagnosis of pancreatic duct disconnection. The study was conducted after Institutional Review Board and Ethics Committee approval of the study protocol. Data collection was undertaken after obtaining consent from the Institutional Ethics Committee and Medical Superintendent in December 2022. A sample size of 63 patients was identified after applying inclusion and exclusion criteria.

Inclusion criteria comprised patients with radiological or clinical suspicion/diagnosis of pancreatic duct disconnection who undergo imaging.

Exclusion criteria comprised patients with imaging of suboptimal quality for visualization of ductal anatomy or with early resolution of symptoms of pancreatitis.

ERCP findings confirming the diagnosis and raised amylase values in the necrotic collection higher than three times the reference range were considered as proven cases of DPDS.[13,14]

Image Acquisition and Postprocessing

Upon clinical diagnosis, patients underwent contrast-enhanced CT abdomen and pelvis using Philips Incisive 128-slice or Philips Brilliance Big Bore 64- slice CT machines and/or magnetic resonance imaging (MRI) abdomen with MRCP using 1.5-T MR imager (Philips Signa) with a phased-array torso coil.

CT images were acquired in axial sections in arterial and portal venous phase; parenchymal phase and delayed portal venous phase were acquired if indicated. Raw data was generated in axial planes with 3-mm thickness and later reconstructed in coronal and sagittal planes with a section thickness of 3 mm. T2-weighted SSFP (axial and coronal), axial and coronal three-dimensional (3D) MRCP, axial T2 FS, axial diffusion-weighted imaging, and axial two-dimensional FIESTA sequences were acquired on MRI. MRCP was obtained in the coronal plane using T2-weighted acquisitions, and the individual slices and reconstructed maximum intensity projections were used to display the 3D MRCP. Images were transferred to picture archiving and communication system for review.

Image Analysis

The following definitions were used to retrospectively analyze and diagnose DPDS.

CT parameters included length of parenchymal necrosis involving the entire width of the pancreas with a cutoff value of >2 cm; presence of disconnection of main pancreatic duct (MPD) with the presence of a variable portion of viable parenchyma upstream to the disconnection; site of duct disconnection; collection replacing the parenchyma along the course of MPD; communication of MPD with the collection; angle of MPD with the collection; and presence of viable pancreatic tissue upstream to disconnection (►**Fig. 1**).

MRCP/MRI parameters assessed were length of parenchymal necrosis involving the entire width of the pancreas with a cutoff value of >2 cm; presence of disconnection of MPD with the presence of a variable portion of viable parenchyma upstream to the disconnection; site of duct disconnection; collection replacing the parenchyma along the course of MPD; presence of upstream dilated MPD; and angle of MPD with the collection (►**Fig. 2**).

Apart from this, the laboratory parameters such as serum amylase/lipase and amylase/lipase values from the collection were assessed and the clinical management and outcome on follow-up was studied.

The collected data was tabulated and analyzed to identify the various imaging features of pancreatic duct disconnection syndrome on CT and MRI. The single most accurate parameter and a combination of parameters to aid in the

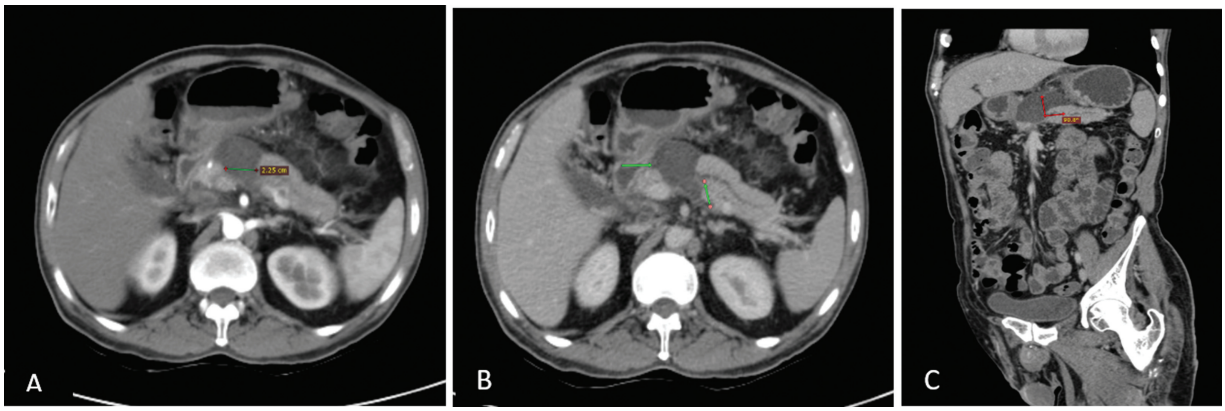

Fig. 1 Postcontrast axial computed tomography (CT) section of the abdomen (**A**) and (**B**) showing acute necrotizing pancreatitis with necrotic collection in the body of pancreas and upstream dilated duct communicating with it. (**C**) Postcontrast oblique coronal CT section of the abdomen showing upstream duct communicating with the collection at an angle of 90 degrees.

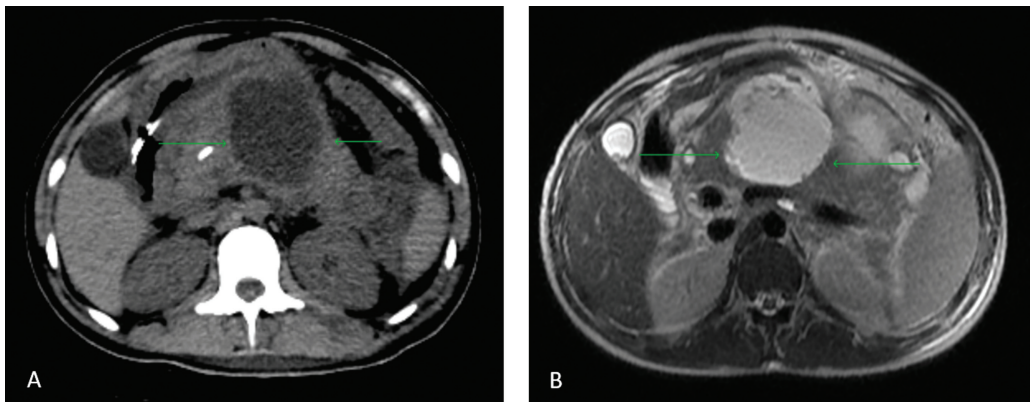

Fig. 2 Site of disconnection of main pancreatic duct (MPD) as seen on postcontrast axial computed tomography (CT) section (**A**) and axial section on magnetic resonance cholangiopancreatography (MRCP) (**B**).

diagnosis of DPDS were also evaluated. The comparison of overall accuracy of CT and MRI in diagnosing DPDS along with the clinical management and respective outcome on follow-up was studied.

Statistical Analysis

The presentation of categorical variables was done in the form of number and percentage (%). The quantitative data were presented as the means ± standard deviation and as median with 25th and 75th percentiles (interquartile range) while comparison of the accuracy rate was analyzed using Fisher's exact test. A *p*-value of less than 0.05 was considered statistically significant. The data entry was done in a Microsoft Excel spreadsheet and the final analysis was done with the use of Statistical Package for Social Sciences (SPSS) software (IBM, Chicago, United States, ver 25.0.) and Microsoft Word and Excel were used to generate graphs and tables.

Results

A total of 63 patients were included among which majority of the subjects were in the age group of 31 to 40 years (31.75%) and ethanol consumption was the most common etiologic factor (60.31% cases). Clinical diagnosis in 29 cases was acute necrotizing pancreatitis and 14 cases were of acute on chronic pancreatitis. Nine cases of recurrent acute pancreatitis, six cases of chronic pancreatitis, and five cases of traumatic pancreatic transection were also included. The most common complaint at the time of presentation was epigastric pain abdomen in 59 cases.

We considered either ERCP findings or raised amylase values in the necrotic collection higher than three times the reference range as proven cases of DPDS,[13,14] since all cases included in our study were not proven using the conventional gold standard technique of ERCP. This resulted in 36 proven cases out of which 31 had undergone CT and 30 had undergone MRI.

CT Evaluation

CT was available for 54 out of 63 patients at the time of study (►**Table 1**). DPDS was diagnosed on CT in 55.55% cases overall. Presence of viable parenchyma upstream to the disconnection, length of necrotic component in the pancreas > 2 cm, and ductal discontinuity were the most frequently identified parameters. The accuracy rate of CT parameters in 31 proven cases of pancreatic duct disconnection was highest for the length of necrotic component in the pancreas > 2.0 cm and collection along the course of MPD and ductal

Table 1 Distribution of CT parameters ($n = 54$)

CT parameters	Frequency	Percentage
Length of necrotic component in pancreas (cm) {> 2 cm}	46	85.18
Collection along the course of MPD	46	85.18
Presence of dilated MPD with disconnected segment	28	51.85
Presence of viable parenchyma upstream to the disconnection	50	92.6
Ductal discontinuity		
No	6	11.11
Suspicious	1	1.85
Yes	47	87.03
Communication of MPD with collection		
No	8	14.81
Suspicious	7	12.96
Yes	32	59.25
N/A	7	12.96
Angle between WON and duct (90°)		
< 90°	1	1.85
90°	28	51.85
N/A	25	46.29

Abbreviations: CT, computed tomography; MPD, main pancreatic duct; N/A, not available; WON, walled-off necrosis.

discontinuity (83.87% each). The overall accuracy rate of DPDS diagnosed on CT in proven cases was 61.29%.

MRI Evaluation

MRI was available for 50 out of 63 patients at the time of study (►**Table 2**). DPDS was diagnosed on MRI in 84% cases. Ductal discontinuity, communication of MPD with collection, and dilated MPD with disconnected segment were the most frequently identified parameters. In 30 proven cases of pancreatic duct disconnection, ductal discontinuity and communication of MPD with collection were the most accurate parameters in diagnosing DPDS (86.67% each). Angle of 90 degrees between the MPD and presence of collection were the next most accurate parameters (83.3% each). The overall accuracy rate of MRI in diagnosing DPDS in proven cases was 90.00%.

On assessing imaging features of pancreatic duct disconnection in 30 proven cases, the diagnostic accuracy rate of CT (61.29%) was significantly lower as compared with MRI (90%) (p-value = 0.03). Majority of the cases of DPDS underwent cystogastrostomy (44.44%), ERCP stenting was performed in 19.05% cases, 15.87% cases received conservative management, 11.11% cases underwent pigtail drainage, and 6.35% cases underwent surgical procedures such as pancreaticojejunostomy or open necrosectomy.

On follow-up of 63 patients, 29 had resolution of symptoms, clinical reduction of symptoms was seen in 12 cases while 9 cases developed recurrence; 5 cases succumbed to

Table 2 Distribution of MRI parameters ($n = 50$)

MRI parameters	Frequency	Percentage
Length of necrotic component in pancreas (cm) {> 2 cm}	39	78.00
Ductal discontinuity	46	92.00
Collection along the course of MPD	39	78.00
Communication of MPD with collection	41	82.00
Presence of dilated MPD with disconnected segment	40	80.0
Angle between WON and duct (90°)		
< 90°	1	2.0
90°	39	78.00
N/A	10	20.0

Abbreviations: MPD, main pancreatic duct; MRI, magnetic resonance imaging; WON, walled-off necrosis.

other causes and 8 cases developed complications such as postoperative jejunal fistula, gastric outlet obstruction, pancreatic diabetes, splenic artery pseudoaneurysm, and pancreatic ascites (1 case each) while 3 patients developed pancreaticopleural fistula.

Discussion

We undertook this study to identify and establish the imaging features of DPDS, identify the most important radiological imaging criterion for diagnosis and evaluate the management protocols of pancreatic duct disconnection. The management of subjects with the outcome on clinical or radiological follow-up was also assessed.

Based on existing literature, multiple parameters were identified and studied on CT and MRI of selected patients to formulate an approach on imaging to aid in early diagnosis of DPDS. Out of 63 identified cases included in our study, 36 of them were confirmed to have DPDS on ERCP or raised amylase levels in the necrotic collection (more than three times the reference range) and were treated clinically as DPDS.[13,14]

The accuracy rate of CT parameters in our 36 proven cases of pancreatic duct disconnection was highest for the length of necrotic component in the pancreas ($>$ 2.0 cm), collection along the course of MPD, and ductal discontinuity (83.87% each). It was therefore seen that a combination of these parameters was accurate for diagnosis on CT. However, communication of MPD with collection and presence of an angle of 90 degrees between the collection and MPD had a lower accuracy rate, thus proving the poor sensitivity of CT in depicting ductal anatomy.

MRI/MRCP is now considered the first-line diagnostic modality for evaluation of ductal pathologies considering its noninvasive nature and excellent depiction of pancreaticobiliary pathologies.[6,15,16] Secretin-enhanced MRCP was not a part of the routine MRCP protocol in our institution due to its higher cost, increased scanning time, and lesser availability.

Ductal discontinuity and communication of MPD with collection had an accuracy of 86.67% each on MRI. MRI was seen to be a better modality in depicting ductal anatomy compared with CT. The overall accuracy rate of CT in diagnosing DPDS was significantly lower as compared with MRI (63.33% vs. 90%, respectively) (p-value = 0.03; significant) (►**Fig. 3**).

Therefore, MRCP can be considered more precise in diagnosing DPDS before clinical symptoms develop. A single best parameter could not be established on both CT and MRI; however, a combination of parameters as described above can be used to diagnose DPDS.

A study performed in by Kamal et al[6] in 2014 in 28 patients demonstrated that the pancreatic duct communication with a collection could be included or excluded in 19 (68%) cases on CT and an uncertain diagnosis was given in 9 (32%) cases, while on MRI/MRCP a certain diagnosis was made in 26 (93%) cases and an uncertain diagnosis in 2 (7%) cases (►**Table 3**).

Trauma cases are exceptions as there is no well-defined collection or obvious ductal injury seen on the first presentation, hence, only a suspicion of duct disconnection can be raised in such cases. ERCP is feasible in these patients due to the nonfriability of MPD and can be accompanied by therapeutic stenting as seen in most of our cases (3 out of 5 cases of trauma to the pancreas). Thus, the criteria for diagnosis of DPDS defined in our study are not applicable to such patients (►**Fig. 4**).

The presence of DPDS could not be evaluated in cases of chronic pancreatitis[17] due to the absence of collections and preexisting presence of dilated ducts and strictures in these cases. However, these cases were treated as confirmed cases of DPDS on clinical suspicion and ductal discontinuity was eventually confirmed on ERCP (►**Fig. 5**).

One of the cases was that of pancreatic adenocarcinoma masquerading as acute necrotizing pancreatitis with duct disconnection. Histopathological examination of the tissue obtained during ERCP confirmed the diagnosis. It was thus noted that the remote possibility of underlying malignancy

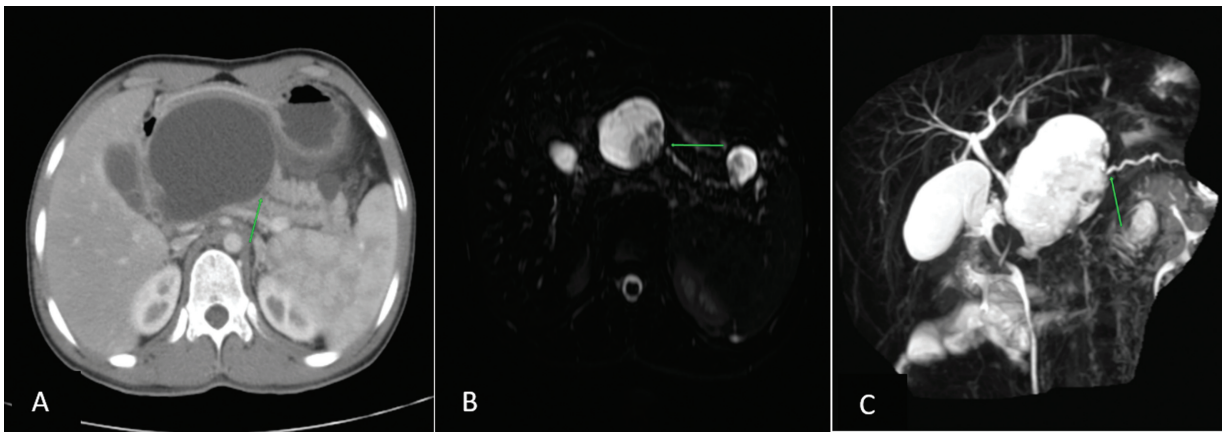

Fig. 3 Contrast-enhanced computed tomography (CT) section of the abdomen (**A**) in pancreatic parenchymal phase shows acute necrotizing pancreatitis with necrotic collection in the neck and proximal body of pancreas with upstream dilated duct communicating with it; axial magnetic resonance cholangiopancreatography (MRCP) section (**B**) and three-dimensional (3D) MRCP reconstructed image (**C**) confirming the same.

Table 3 Presence of ductal communication with pancreatic collection compared with a prior study conducted by Kamal et al[6]

	Kamal et al (39)		Our study	
	Ductal communication with a collection ($n = 28$)		Ductal communication with a collection	
	CT	MRI	CT ($n = 31$)	MRI ($n = 30$)
Present	13	20	18	26
Absent	6	6	5	4
Uncertain	9	2	8	0

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging.

should be ruled out in patients with persistent collections which do not resolve despite treatment.

The traditional modality of open surgical management has been demoted to the position of last resort as a therapeutic approach with minimally invasive treatment preferred currently.[7,9,14]

Management has switched from early debridement to delayed intervention, which has been found to have decreased morbidity and mortality. Radiological approaches are used to monitor treatment efficacy and provide direction for draining collections in treating problems due to acute pancreatitis.

Thiruvengadam et al[18] performed a study in 2022 where 171 patients with necrotizing pancreatitis undergoing conservative and/or surgical management (►**Table 2**) were identified and followed up. Forty-eight patients (28.1%) developed DPDS and the rate of DPDS incidence was 40% (42 patients) in 104 patients who had at least 36 months of the radiographic follow-up (►**Table 4**). Chen et al[5] in 2019 conducted a retrospective analysis on the effectiveness of endoscopic transpapillary drainage along with the beneficial long-term results in 31 patients of DPDS. A relatively small number of adverse outcomes and a failure rate

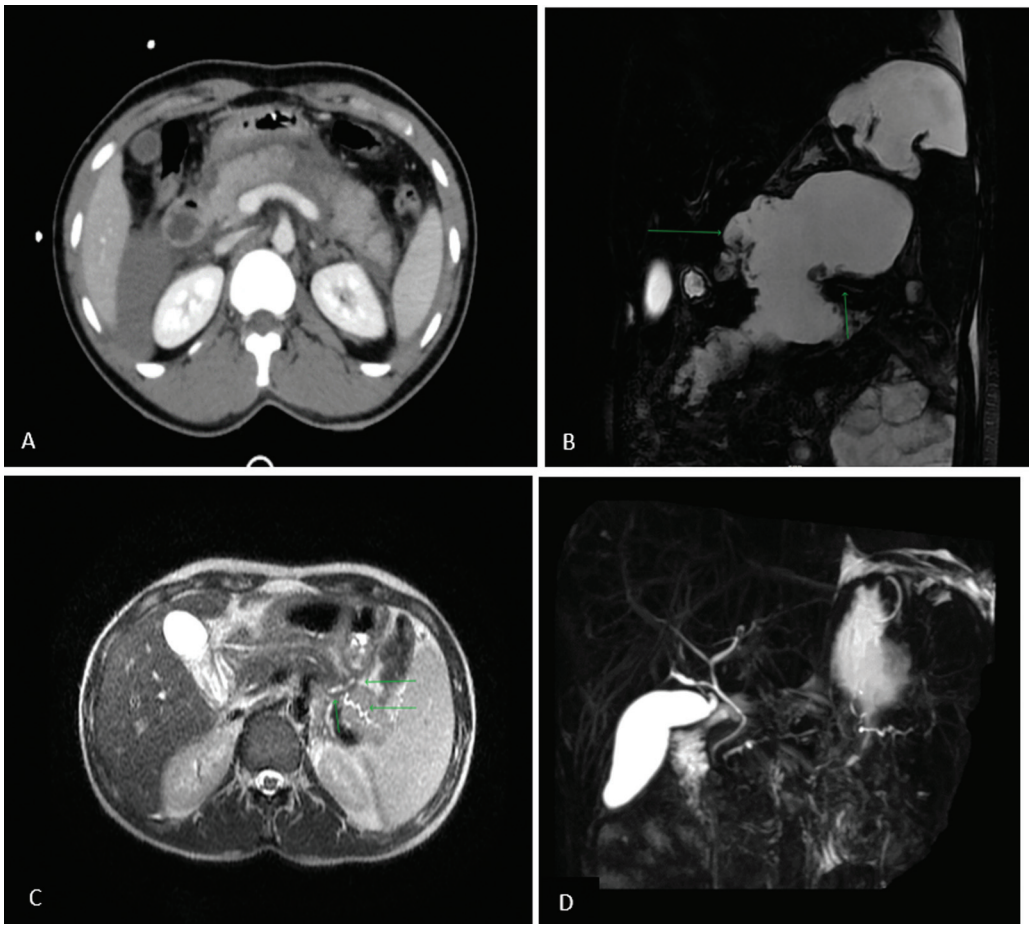

Fig. 4 Postcontrast axial (**A**) computed tomography (CT) section of the abdomen showing American Association for the surgery of Trauma (AAST) grade III pancreatic injury with possible ductal disconnection. Coronal (**B**) magnetic resonance cholangiopancreatography (MRCP) image of the same patient on follow-up showed significant pancreatic and peripancreatic collection with prominent upstream duct showing communication with the collection. Poststenting imaging (**C** and **D**) showed near total resolution of the collection with sustained prominence of the duct.

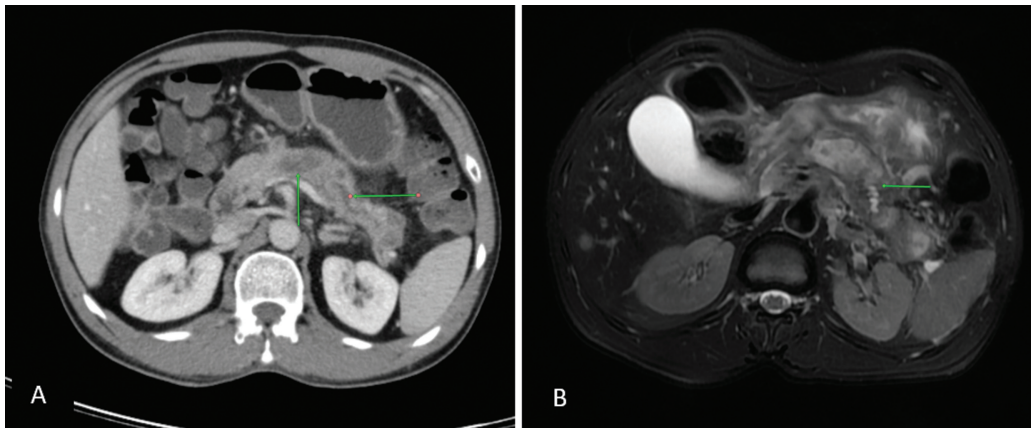

Fig. 5 Axial computed tomography (CT) (**A**) and magnetic resonance cholangiopancreatography (MRCP) (**B**) images of a 40-year-old female patient with pancreatic adenocarcinoma masquerading as acute necrotizing pancreatitis and pancreatic duct disconnection syndrome. Features of necrotizing pancreatitis are seen with dilated duct communicating with necrotic collection in the body of the pancreas.

Table 4 Comparison of treatment strategies with a prior study conducted by Thiruvengadam et al[18]

Treatment strategy	Thiruvengadam et al[15]	Our study
Conservative management	29 (17.0%)	10 (15.87%)
Percutaneous drainage	67 (39.2%)	7 (11.11%)
Therapeutic endoscopic procedures	48 (28.1%)	40 (63.50%)
Minimally invasive surgery alone	7 (4.1%)	1 (1.59%)
Open surgery	20 (11.7%)	5 (7.93%)

of 13.3% (2/15) were observed, which highlighted that initial surgery is not mandatory for all DPDS patients.

Among the cases included in our study, it was found that endoscopic procedures such as cystogastrostomy were performed in most of the patients of DPDS with the next preferred modality being ERCP stenting, both of which led to significant resolution or reduction of collection along with clinical improvement on follow-up, thus highlighting the fact that early diagnosis on imaging could improve the overall outcome of DPDS.

Out of 28 patients who underwent cystogastrostomy, 25 showed reduction or resolution of collection. Only one patient underwent open necrosectomy and four underwent pancreaticojejunostomy in our study. One patient who underwent video-assisted retroperitoneal drainage developed postoperative jejunal fistula. Patients who underwent percutaneous drainage (10 out of 63) of the collections also developed complications or recurrence.

Limitations to this study include its retrospective nature and selection bias which may have influenced the final overall result. Moreover, the subject of this study pertains to a niche and sparsely researched aspect of acute necrotizing pancreatitis.

Conclusion

Both CT and MRI features along with assessment of amylase and lipase in the collection instead of invasive diagnostic procedures like ERCP can aid in the early and accurate diagnosis of DPDS. Minimally invasive endoscopic procedures such as cystogastrostomy and stenting are the currently preferred modalities for treatment of DPDS as these cause lesser complications compared with surgical management.

Conflict of Interest
None declared.

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