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Tracking Wall Characteristics of Necrotic Pancreatic Fluid Collections in Acute Pancreatitis on Serial Contrast-Enhanced Computed Tomography

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Abstract

Background Encapsulated pancreatic fluid collection (PFC) is a requisite for endoscopic drainage procedures. The 4-week threshold for defining walled-off necrosis does not capture the dynamic process of encapsulation. We aim to investigate the changes in the wall characteristics of PFC in acute necrotizing pancreatitis (ANP) by comparing baseline contrast-enhanced computed tomography (CECT) with follow-up CT scans.

Methods This retrospective study comprised consecutive patients with ANP who underwent a baseline CECT within first 2 weeks and follow-up CECT in the third to fifth weeks of illness. Presence, extent, and encapsulation thickness (defined as enhancing wall around the collection) on baseline CECT were compared with follow-up CT (done in the third–fifth weeks of illness).

Results Thirty patients (19 males and 11 females; mean age 41.5 ± 13.5 years) were included in the study. The mean time to first CECT was 10 ± 3.6 days. There were 58 collections. The most common site was the lesser sac ($n = 29$), followed by the left pararenal space ($n = 15$). At baseline CT, 52 (89.7%) collections had varying degree of encapsulation (15.3%, complete encapsulation). Complete encapsulation was seen in 52 and 82.6% collections in third and fourth week, respectively. All collections in fifth week and beyond were encapsulated. The wall was thicker on follow-up CECT scans ($p < 0.01$). The mean wall thickness was not significantly associated with the degree of encapsulation ($p = 0.417$). There was no significant association between the site and degree of encapsulation ($p = 0.546$).

Conclusion Encapsulation is dynamic and collections may get "walled off" before 4 weeks. Walled-off collections should be defined based on imaging rather than a fixed 4-week revised Atlanta classification threshold.

Keywords
- acute necrotizing pancreatitis
- computed tomography
- endoscopic
- necrosis

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Introduction

Acute pancreatitis (AP) is one of the most common emergencies and is a significant medical and surgical problem. The mortality rate associated with AP ranges from less than 1% in mild AP to up to 30% in severe AP.[1–3] Contrast-enhanced computed tomography (CECT) plays an important role in the evaluation of patients with AP. It helps detect and characterize fluid collections and plan their management. As per the revised Atlanta Classification (RAC), the pancreatic and peripancreatic fluid collections are divided into four categories.[4] Within the first 4 weeks after the onset of AP, either acute pancreatic fluid collections (APFCs), which represent a collection of fluid without associated necrosis, or acute necrotic collections involving pancreatic and/or peripancreatic necrosis may be seen. After 4 weeks of disease onset, encapsulated fluid collections (collection with a definable wall in imaging) are referred to as a "pancreatic pseudocyst" if these contains only fluid with no associated solid necrotic component, or as a "walled off necrosis" (WON) if there are necrotic debris.[4]

Conventionally, 4 weeks threshold is used for defining encapsulation. Thus, endoscopic drainage is recommended after 4 weeks of disease onset to ensure encapsulation and safe and successful drainage.[5,6] However, it has been observed that collections may encapsulate in the second or third week of illness too.[7] Despite this, there is a paucity of literature regarding the changes in necrotic fluid collections over time.[8–10] Specifically, there is no literature concerning influence of time (from onset of pain to imaging) on the encapsulation (appearance, completeness, and thickness) of pancreatic fluid collections in AP.

Thus, we aim to investigate the changes in encapsulation of necrotic fluid collection by evaluating serial CECT scans in patients with AP.

Materials and Methods

This retrospective study was approved by the institutional ethics committee and waiver of informed written consent was obtained. Consecutive patients with necrotizing AP between September 2020 and May 2023 were included. RAC criteria were used to diagnose AP.[4] All patients who underwent a baseline CECT scan within first 2 weeks of illness and subsequent follow-up CECT scans in the third to fifth weeks of illness were considered for inclusion. No drainage procedure (endoscopic/percutaneous/surgical drainage) was performed in the interval between the two CT scans. Patients with incomplete clinical details, acute on chronic pancreatitis, recurrent AP, and those with any form of drainage procedure between the two CECT scans were excluded to avoid the influence of these factors on the natural history of fluid collections.

Clinical Evaluation

The etiology and severity of AP was recorded. RAC was used to define the severity of AP.[4]

CECT Scan Protocol

All the CECT scans were performed on a multidetector row scanner and acquired in the portal venous phase (70–90 seconds) after administration of 80 to 100 mL of nonionic iodinated intravenous contrast at 2.5 mL/second using a pressure injector. Noncontrast and arterial phase scans were acquired in cases of suspected hemorrhage with contrast injection at the rate of 4 mL/second.

CECT Parameters Recording

The baseline and follow-up CECT findings were recorded on the portal venous phase CT in all patients. Both the CECT scans were read by two radiologists with 3 and 10 years'

Table 1 Demographical details and baseline characteristics of fluid collections in 30 patients with acute pancreatitis

Parameter	Number
Number of patients	30
Males	19 (63.3%)
Females	11 (36.7%)
Moderately severe disease	7 (23.3%)
Severe disease	23 (76.7%)
Etiology	
Gallstone disease	11 (36.6%)
Alcohol	8 (26.7%)
Gallstone disease +alcohol	3 (10%)
Others[a]	8 (26.7%)
Median MCTSI	8
Median pain to CT interval	11 days
Total number of collections	58
Location of collection	
Lesser sac	29 (50%)
Left pararenal space	15 (25.9%)
Right pararenal space	5 (8.6%)
Left paracolic space	1 (1.7%)
Right paracolic space	1 (1.7%)
Mesentery	5 (8.6%)
Pelvis	2 (3.4%)
Size (mean ± SD)	7.6 ± 3.8 cm
Wall thickness (mean ± SD)	1.4 ± 0.7 mm
Mean attenuation	14.2 ± 8.2 HU
Encapsulation of collections	
Unencapsulated	6 (10.3%)
< 30% encapsulation	12 (20.6%)
30–50% encapsulation	18 (31%)
50–80% encapsulation	14 (24.1%)
>80% (complete) encapsulation	8 (13.7%)

Abbreviations: HU, Hounsfield unit; MCTSI, modified computed tomography severity index; SD, standard deviation.
[a]Include idiopathic, traumatic, hypercalcemia, and hypertriglyceridemia.

experience in abdominal imaging in consensus. The modified CT severity index was recorded at the baseline CECT. The number, size, and location of collections were recorded. Largest dimension of the collection in the sagittal or coronal reformatted planes was recorded. Encapsulation was defined as a smooth enhancing rim around the fluid collection. Encapsulation was assessed on multiplanar images and extent of encapsulation was recorded as less than 30%, 30 to 50%, 50 to 80%, and more than 80%. More than 80% encapsulation was defined as complete encapsulation. Thickness of the capsule was measured at the thickest portion of the enhancing wall on multiplanar images.

Statistical Analysis

The continuous data were recorded as mean (with standard deviation) or median. The categorical data were recorded as percentages. The baseline and follow-up CT characteristics were compared using Student's *t*-test or Mann–Whitney U test (quantitative data) and chi-squared or Fisher's exact test (categorical variables). A *p*-Value of less than 0.05 was considered statistically significant. The statistics were done using IBM SPSS statistics Version 29.

Results

Baseline Demographic Data

Thirty patients were included in the study. There were 19 (63.3%) males and 11 (36.7%) females. Mean age was 41.5 ± 13.5 years. The mean time to first CECT was 10 ± 3.6 days (range, 5–14 days). The etiologies of AP were gallstone disease ($n = 11$), alcohol ($n = 8$), gallstone disease and alcohol ($n = 3$), idiopathic ($n = 3$), hypercalcemia ($n = 2$), trauma related ($n = 2$), and hypertriglyceridemia ($n = 1$). Twenty-three patients (76.7%) had severe AP and seven (23.3%) patients had moderately severe AP.

Baseline CT

There were 58 collections in 30 patients. There were one to four collections in each patient (median number =2). The mean collection size was 7.6 ± 3.8 cm. The most common site was lesser sac ($n = 29$), followed by left pararenal ($n = 15$), right pararenal ($n = 6$), mesentery ($n = 5$), pelvis ($n = 2$), left paracolic space ($n = 1$), and right paracolic space ($n = 1$). The other parameters are summarized in ►**Table 1**.

Six (10.3%) collections were unencapsulated, while 52 (89.7%) collections had varying degree of encapsulation. Of these, 8 (15.3%) collections showed complete encapsulation and 44 (84.6%) showed incomplete or partial encapsulation. Twelve (23%) collections showed less than 30% encapsulation, 18 (34.6%) showed 30 to 50% encapsulation, and 14 (26.9%) showed 50 to 80% encapsulation.

Follow-up CECT

Group 1: Third Week (13 Patients)

This group had 23 collections. Most common site was lesser sac ($n = 12$; ►**Figs. 1**–**4**). Largest collection was located in the lesser sac. Left anterior pararenal collections had maximum wall thickness. Gas was present in five (21.7%) collections. More than 50% of the collections showed complete encapsulation (►**Table 2**).

Group 2: Fourth Week (12 Patients)

This group had 23 collections. Most common site was lesser sac ($n = 12$). Largest collections were seen in lesser sac. Lesser sac collections had the maximum wall thickness. Most collections ($n = 19$, 82.6%) showed complete encapsulation (►**Table 3**).

Group 3: Fifth Week and beyond (5 Patients)

There were 12 collections in this group. Lesser sac was the most common site ($n = 5$). Lesser sac had the largest

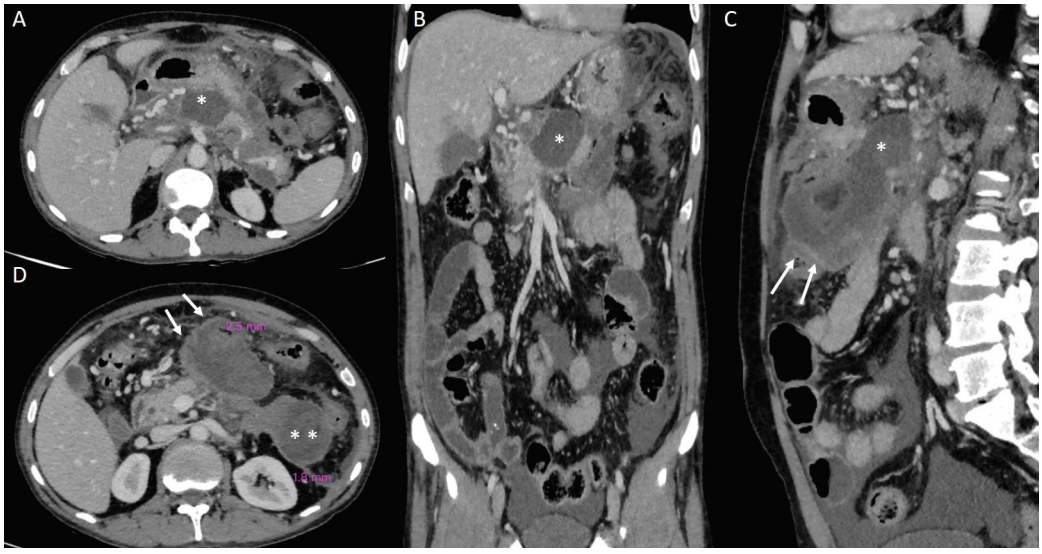

Fig. 1 Baseline contrast-enhanced computed tomography (**A**, **B**: axial sections; **C**: coronal and **D**: sagittal reformatted images) in a 43-year-old male with alcohol-induced pancreatitis on day 11 of illness shows a large lesser sac collection with an unencapsulated superior aspect (*) and a well-defined enhancing rim around the inferior aspect of the collection (white arrows). The left pararenal collection also showed partial encapsulation (**).

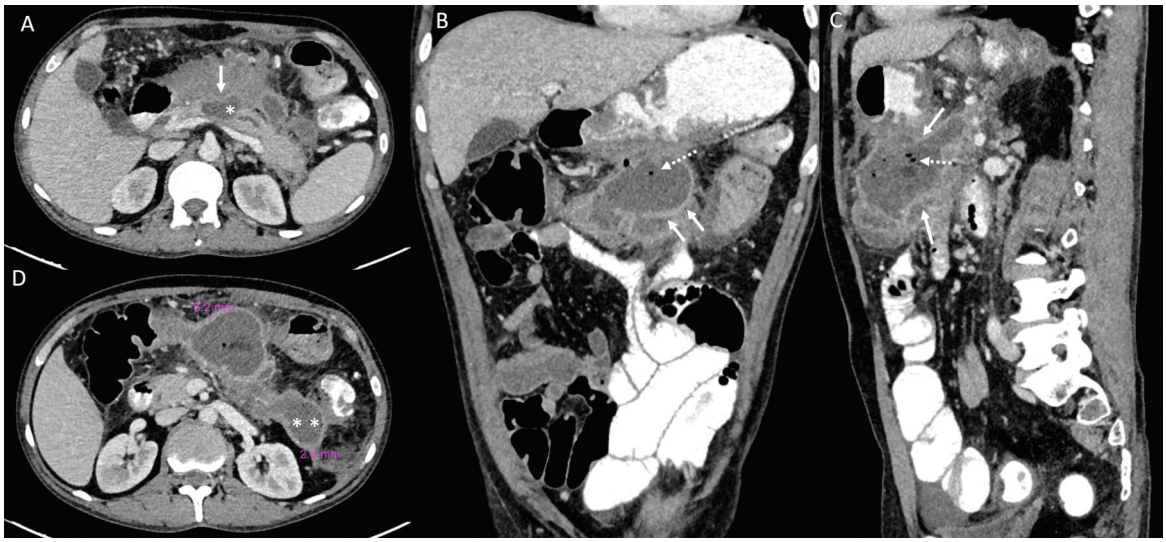

Fig. 2 Follow-up contrast-enhanced computed tomography (CECT) (same patient as Fig. 1) in the fourth week of illness shows completely encapsulated lesser sac (white arrows in **A–C**) and left pararenal (** in **D**) collections with thicker walls in comparison to the baseline CT. Dashed white arrows in C and D denote presence of gas.

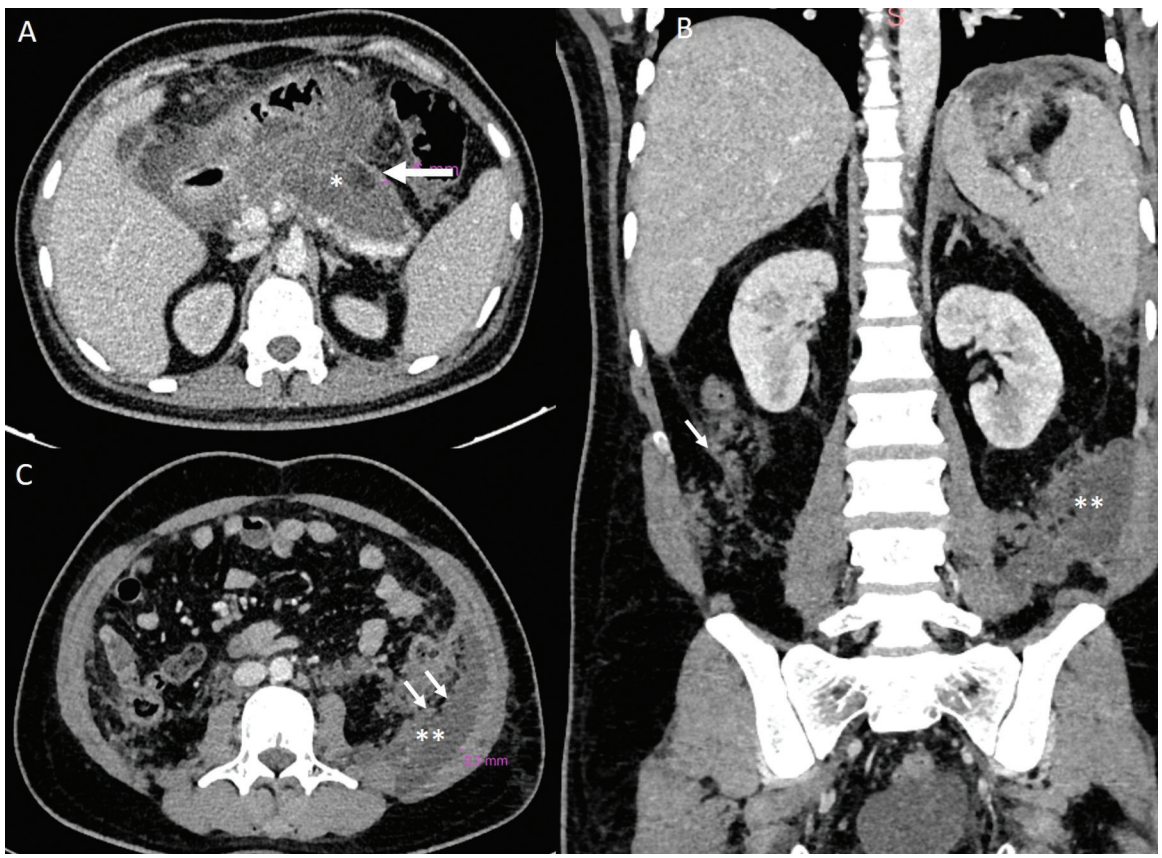

Fig. 3 Baseline contrast-enhanced computed tomography (**A**, **B**: axial sections; **C**: coronal reformatted images) in a 62-year-old male with alcohol-induced pancreatitis on day 12 of illness shows partially encapsulated lesser sac (*) collection (~40–50%) and partially encapsulated left pararenal collection (**) with unencapsulated anterior aspect (white arrows).

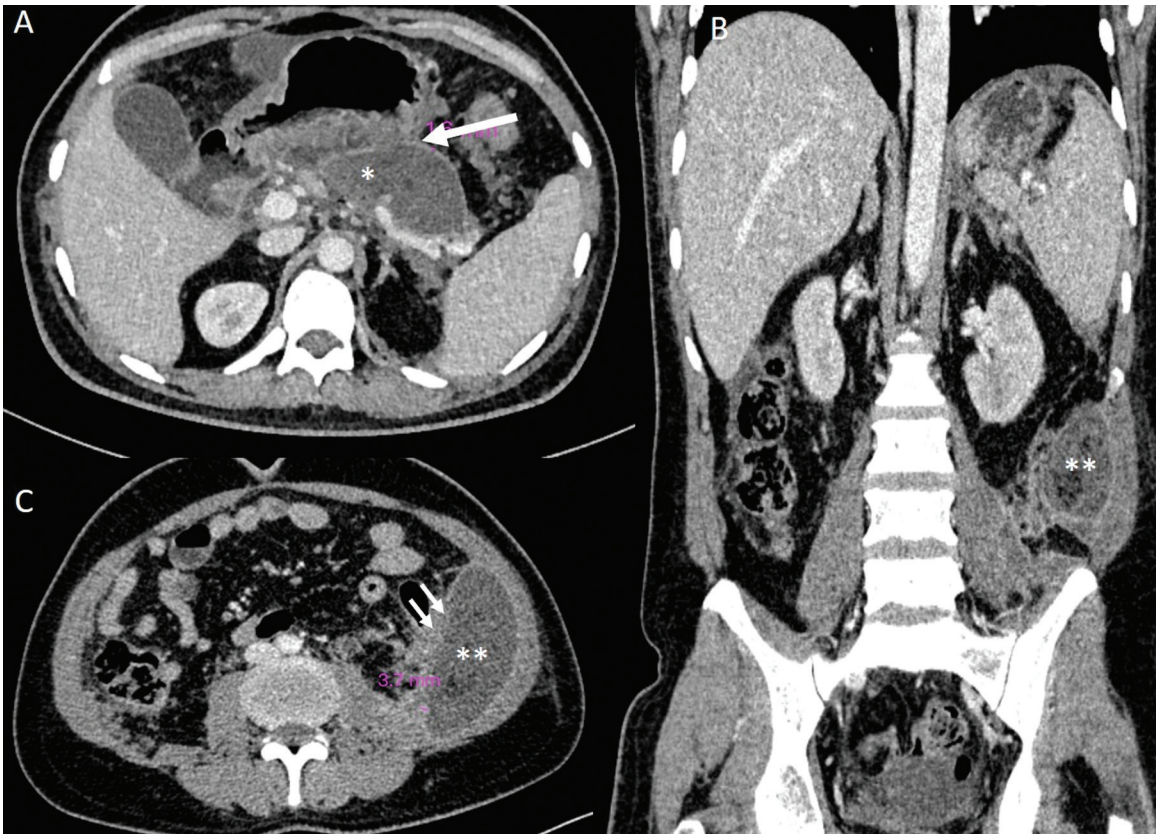

Fig. 4 Follow-up contrast-enhanced computed tomography (CECT) (same patient as Fig. 3) in the fourth week of illness shows completely encapsulated lesser sac (* in **A**) and left pararenal collection (** in **B** and **C**) with thicker walls. White arrows in **A** and **C** denote thick enhancing wall that was not seen on baseline CT.

Table 2 CT parameters for group with follow-up CT in third week of illness (number of patients = 13, number of collections = 23)

Location	LS ($n = 12$)	LPR ($n = 5$)	RPR ($n = 3$)	Mesentery ($n = 2$)	Pelvis ($n = 1$)
Size					
Mean ± SD	10.1 ± 3.5	4.8 ± 1.9	5.1 ± 1.0	8 ± 1.06	8.9 ± 1.2
Wall thickness					
Mean ± SD	1.7 ± 0.4	2.1 ± 0.7	1.8 ± 0.28	1.7 ± 0.28	1.8 ± 1.1
Encapsulation					
Absent	0	0	0	0	0
Present[a]	12 (9)	5 (1)	3 (1)	2 (1)	(0)
Degree of encapsulation					
<30%	0	0	0	0	0
30–50%	0	1	2	0	0
50–80%	3	3	0	1	1
>80%	9	1	1	1	0

Abbreviations: CT, computed tomography; LPR, left pararenal; LS, lesser sac; RPR, right pararenal; SD, standard deviation.
[a]Numbers in parenthesis represent complete encapsulation.

Table 3 CT parameters for group with follow-up CT in fourth week of illness (number of patients = 12, number of collections = 23)

Location	LS ($n = 12$)	LPR ($n = 8$)	RPR ($n = 1$)	Mesentery ($n = 1$)	Pelvis ($n = 1$)
Size (in cm)					
Mean ± SD	10.5 ± 4.8	5.9 ± 2.8	6.1 ± 1.8	7.9 ± 1.1	8.8 ± 1.1
Wall thickness (in mm)					
Mean ± SD	2.9 ± 0.8	2.2 ± 0.4	1.4 ± 0.6	1.8 ± 0.9	2.5 ± 0.9
Encapsulation					
Absent	0	0	0	0	0
Present[a]	12 (10)	6 (4)	1 (1)	1 (1)	1 (1)
<30%	0	0	0	0	0
30–50%	0	2	0	0	0
50–80%	2	0	0	0	0
>80%	10	6	1	1	1

Abbreviations: CT, computed tomography; LS, lesser sac; LPR, left pararenal; RPR, right pararenal; SD, standard deviation.
[a]Numbers in parenthesis represent complete encapsulation.

dimensions of collections. Left pararenal space collections had the thickest walls. All collections were completely encapsulated (►**Table 4**).

Group Comparisons

Baseline versus Follow-up CECT (Overall)

There was a significant increase in size and wall thickness on follow-up CECT scans ($p < 0.01$). The presence of capsule and degree of encapsulation were also significantly more in the follow-up CECT ($p < 0.001$).

The Week Wise Comparisons (►Table 5)

The mean wall thickness was greater (1.75 ± 0.61 mm) in patients with complete encapsulation versus those with incomplete encapsulation (1.59 ± 0.55 mm). However, the difference was not statistically significant ($p = 0.417$). There was no significant association between the site and degree of encapsulation ($p = 0.546$).

Discussion

This retrospective study analyzed the encapsulation of pancreatic fluid collections in patients with necrotizing AP on CECT. All patients had a baseline CECT scan within first 2 weeks of illness. The characteristics of collections on follow-up CECT in the third, fourth, and fifth week (and beyond) of illness were compared with baseline CECT. We found that encapsulation started as early as the second week of illness. In fact, 52 of the 58 collections showed

Table 4 CT parameters for group with follow-up CT in fifth week of illness (number of patients = 5, number of collections = 12)

Location	LS ($n = 5$)	LPR ($n = 2$)	RPR ($n = 1$)	Mesentery ($n = 2$)	LPCG ($n = 1$)	RPCG ($n = 1$)
Size (in cm)						
Mean ± SD	10.3 ± 6.1	8.4 ± 0.9	5.6 ± 0.8	5.4 ± 0.5	8.2 ± 1.1	7.9 ± 0.9
Wall thickness (in mm)						
Mean ± SD	2.9 ± 1.3	5.6 ± 1.2	2.1 ± 0.3	1.8 ± 0.8	3.7 ± 0.6	2.6 ± 0.8
Encapsulation						
Absent	0	0	0	0	0	0
Present[a]	5 (5)	2 (2)	1 (1)	1 (1)	1 (1)	1 (1)
<30%	0	0	0	0	0	0
30–50%	0	0	0	0	0	0
50–80%	0	0	0	0	0	0
>80%	5	2	1	1	1	1

Abbreviations: CT, computed tomography; LPCG, left paracolic space; LPR, left pararenal; LS, lesser sac; RPR, right pararenal; RPCG, right paracolic space; SD, standard deviation.
[a]Numbers in parenthesis represent complete encapsulation.

Table 5 Comparison of parameters between BL and FU CT scans

Interval	Size (cm) Mean ± SD		*p*-Value	Wall thickness (mm) Mean ± SD		*p*-Value	Encapsulation (complete)		
	BL	FU		BL	FU		BL	FU	*p*-Value
3rd week	8.9 ± 3.5	10.1 ± 3.5	<0.001	1.1 ± 0.7	1.8 ± 0.4	0.02	2	12	0.001
4th week	9.8 ± 4.4	10.5 ± 4.8	0.04	1.4 ± 0.7	2.1 ± 0.8	0.006	2	19	<0.001
≥5th week	9.3 ± 5.8	11.9 ± 6.1	0.03	1.7 ± 0.5	2.9 ± 1.3	0.10	5	11	0.009

Abbreviations: BL, baseline; CT, computed tomography; FU, follow-up; SD, standard deviation.

some degree of encapsulation at the baseline CT. In the third week, more than 50% of the collections and in the fourth week, more than 80% of the collections showed complete encapsulation. The thickness of the capsule also increased progressively. These results suggest that encapsulation is a dynamic process and collections may get "walled-off" before the 4 weeks threshold proposed by RAC. Our results also emphasize that imaging-based definition for walled-off necrosis should be used in clinical practice.

Few previous studies have reported that partial or complete wall encapsulation occurs before 4 weeks.[11–15] van Grinsven et al quantified the percentage of encapsulation of collection on CT.[14] They reported that the number of largely or fully encapsulated collections (i.e., clinically relevant walled-off necrosis) increased from 17% in second week to 61% in third week, 88% in fourth week to 100% in the fifth week. Trikudanathan et al reported that 36.5% of the collections undergoing endoscopic drainage prior to 4 weeks had extensive wall formation.[11] Oblizajek et al defined partial and complete encapsulation as 20 to 80% and more than 80%, respectively. More than 50% of patients undergoing early (<4 weeks) drainage had a partial wall and most (89%) of these had a thick wall (reported as a well-defined wall showing contrast enhancement). Choudhury et al evaluated the wall maturation of necrotic collections in 195 patients on CT and concluded that more than one-third of collections had a complete wall in third week and more than 50% showed a complete wall in the fourth week of illness.

To our knowledge, none of the published studies quantitatively analyzed and compared the encapsulation of fluid collection on follow-up CECT scans. This study focused on assessing the encapsulation of the fluid collections in the patients with AP by comparing the baseline CECT scans with follow-up CECT scans.

There were a few limitations to our study. First, the sample size was small. Second, the patients in all the groups were exclusive of each other. Ideally, the best insight about the encapsulation process would have been obtained by following the same patient group with CECT in various weeks of illness. However, this is not feasible as CT scans are performed based on the clinical indication and doing them electively every week exposes patients to cumulative ionizing radiation. A trial comprising serial T2-weighted magnetic resonance imaging scans (performed every fifth day starting at day 14 after pain onset) is being conducted to better elucidate the natural history of pancreatic fluid collections (identifier: NCT05716633).

In conclusion, encapsulation of pancreatic fluid collection in AP should thus be considered a dynamic process. An imaging-based definition should be used for defining "walled-off" collections.

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Conflict of Interest
None declared.

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