Abdominal Radiology (2019) 44:976–983
https://doi.org/10.1007/s00261-019-01904-9

REVIEW

The LACSEMS: what radiologists need to know

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Published online: 1 February 2019

Abstract
Endoscopic drainage is increasingly used in lieu of percutaneous or surgical drainage of pancreatitis-related fluid collections. The lumen-apposing, covered, self-expanding, metallic stent (LACSEMS) is a newly produced stent for the transmural drainage of such fluid collections. The use of LACSEMS devices requires close coordination between knowledgeable radiologic and gastrointestinal providers. We review pancreatitis-related fluid collections and show examples from our experience with LACSEMS and the appropriate case selection, planning, deployment, and follow-up for this novel device.

Keywords LACSEMS · AXIOS · Stent · Pancreatitis · Collection · Pseudocyst

Introduction to pancreatitis

Acute pancreatitis is diagnosed when at least two of the following are present: abdominal pain consistent with pancreatitis, serum lipase activity at least three times the normal upper limit, and characteristic findings on enhanced computed tomography (CT), magnetic resonance imaging (MRI), or ultrasound (US) [1]. Subtypes of acute pancreatitis include interstitial edematous pancreatitis (IEP) and necrotizing pancreatitis. In IEP, the pancreas is generally enlarged and homogeneously enhancing, often with surrounding fluid and/or inflammatory fat stranding; clinical symptoms of IEP usually resolve within 1 week [1]. In necrotizing pancreatitis, a necrotic area of the pancreas demonstrates nonenhancement. Necrotizing pancreatitis has a variable clinical course, with the increased morbidity and rates of intervention relative to IEP [1]. Notably, CT does not optimally assess for pancreatic necrosis until after 72 h from the onset of symptoms [2].

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Fluid collections in acute pancreatitis

The Revised Atlanta classification of fluid collections in acute pancreatitis defines four types of fluid collections: acute peripancreatic fluid collection (APFC) and pancreatic pseudocyst (PS) in the setting of IEP, as well as acute necrotic collection (ANC) and walled-off necrosis (WON) in the setting of necrotizing pancreatitis (Table 1) [1]. While approach to the management of these collections varies depending on severity, intervention is often pursued in the setting of refractory pain, complications such as bowel or biliary obstruction, or weight loss lasting more than 8 weeks [3]. Conventional interventions for pancreatitis-related fluid collections include cystogastrostomy, cystojejunostomy, and percutaneous drainage [4]. Endoscopic drainage is increasingly used for the treatment of pancreatitis-related fluid collections in order to avoid invasive surgery [4].

Management of fluid collections

Multiple approaches are available for management of fluid collections associated with pancreatitis. The three primary approaches are surgical, percutaneous, and endoscopic. Conventional surgical approaches include cystogastrostomy or cystojejunostomy. While surgical techniques enjoy low recurrence rates for pseudocyst management, complications can approach 30% [4]. Management of WON has historically involved open surgical debridement, but multiple minimally invasive approaches have been developed

Table 1 Fluid collections in acute pancreatitis according to the revised Atlanta classification [1]

Time frame (weeks)	Interstitial edematous pancreatitis	Necrotizing pancreatitis
< 4	Acute peripancreatic fluid collection (APFC)	Acute necrotic collection (ANC)
> 4	Pancreatic pseudocyst (PS)	Walled-off necrosis (WON)

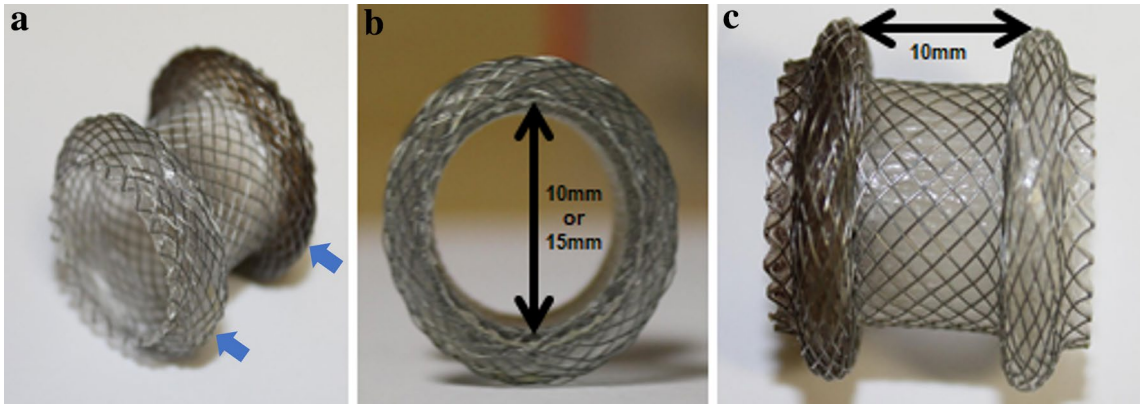

Fig. 1 The LACSEMS. **a** LACSEMS are made of nitinol wire and have flared flanges (blue arrows) designed to prevent stent migration. **b** LACSEMS are currently available with luminal diameters of 10 or 15 mm. **c** Available LACSEMS have a stent length of 10 mm

Table 2 LACSEMS checklist for the radiologist

Prerequisites	Contraindications	Postplacement evaluation
Accessible	Nearby vessels (within 1 cm)	Stent location and patency
Size > 6 cm	Nearby pseudoaneurysm	Collection size and contents
If WON, ≥ 70% fluid	Intervening gastric varices	Pseudoaneurysm and/or bleeding
	Non-inflammatory collection[a]	New fluid collections

[a]e.g., duplication cyst or cystic neoplasm

[5]. Percutaneous management frequently involves real-time CT or US guidance. Notably, infected PS (pancreatic pseudocyst) is more difficult to drain percutaneously and have higher complication rates [4]. For management of WON, percutaneous intervention is inferior to laparoscopy and is therefore more often used adjunctively (in a "step-up" approach to endoscopy or surgery) [5]. While percutaneous intervention for PS has similar efficacy and possible mortality benefit relative to surgical management, endoscopy has similar efficacy with reduced reintervention rate, hospital stay, and number of follow-up imaging studies [4]. Endoscopic management avoids surgical intervention and can utilize transenteric plastic stents, which have pigtails to prevent migration but have narrow lumens which can result in premature closure necessitating exchange or replacement [4]. Endoscopic necrosectomy for management of WON can also allow for avoidance of surgical intervention and has an 80–91% success rate with complication rates of 14–23%. While endoscopic necrosectomy has mortality rates of up to 8%, open necrosectomy is associated with mortality rates of 6–25% [4].

Introduction to LACSEMS

The LACSEMS is an endoscopically placed stent for use in drainage of pancreatitis-related fluid collections. Two of its salient features are its large lumen and flared ends. The large lumen is intended to allow drainage of thick, necrotic

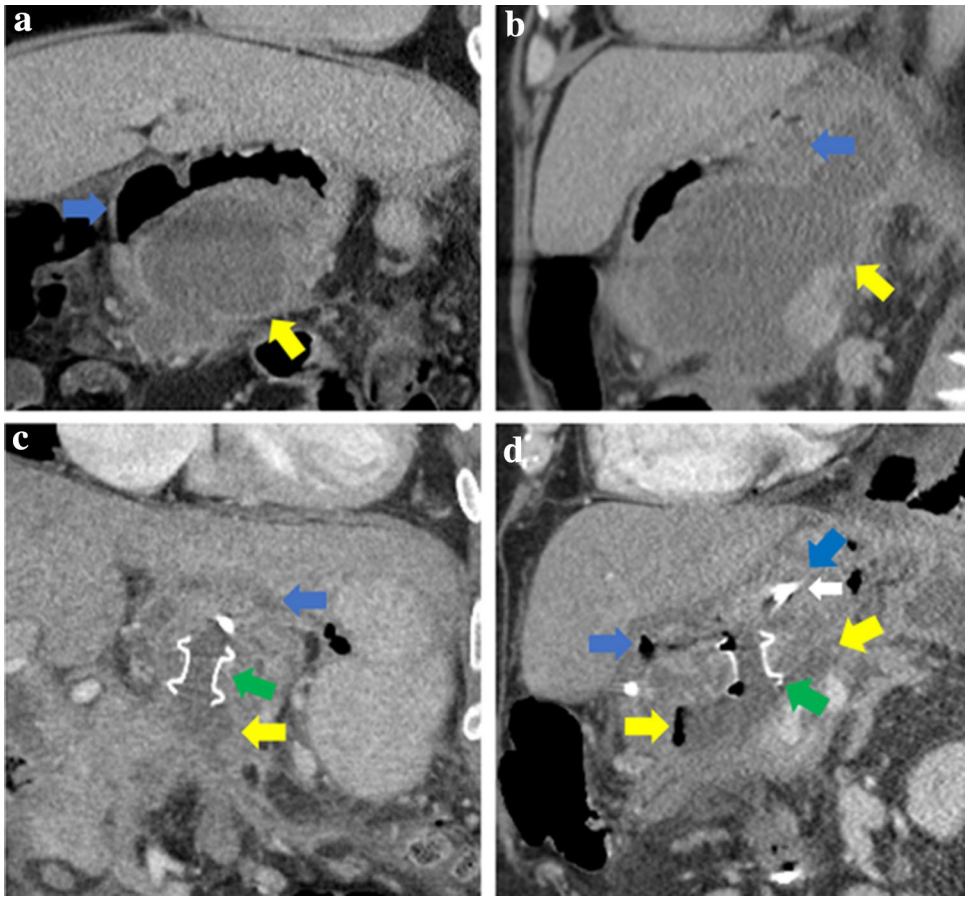

Fig. 2 ANC drainage by LACSEMS. **a** Coronal and **b** sagittal CT demonstrate an ANC (yellow arrows) inferior to the stomach (blue arrows) meeting requirements for LACSEMS placement. It measures > 6 cm in diameter and is directly accessible via the stomach, which is immediately superior to the collection. No intervening varices, nearby vessels, or pseudoaneurysm are identified. **c** Coronal and **d** sagittal follow-up CT after placement of LACSEMS (green arrow). The flared ends of the stent are closely apposed to the walls of the stomach (blue arrows) and the collection (yellow arrows). An enteric tube (white arrow) is seen in the stomach

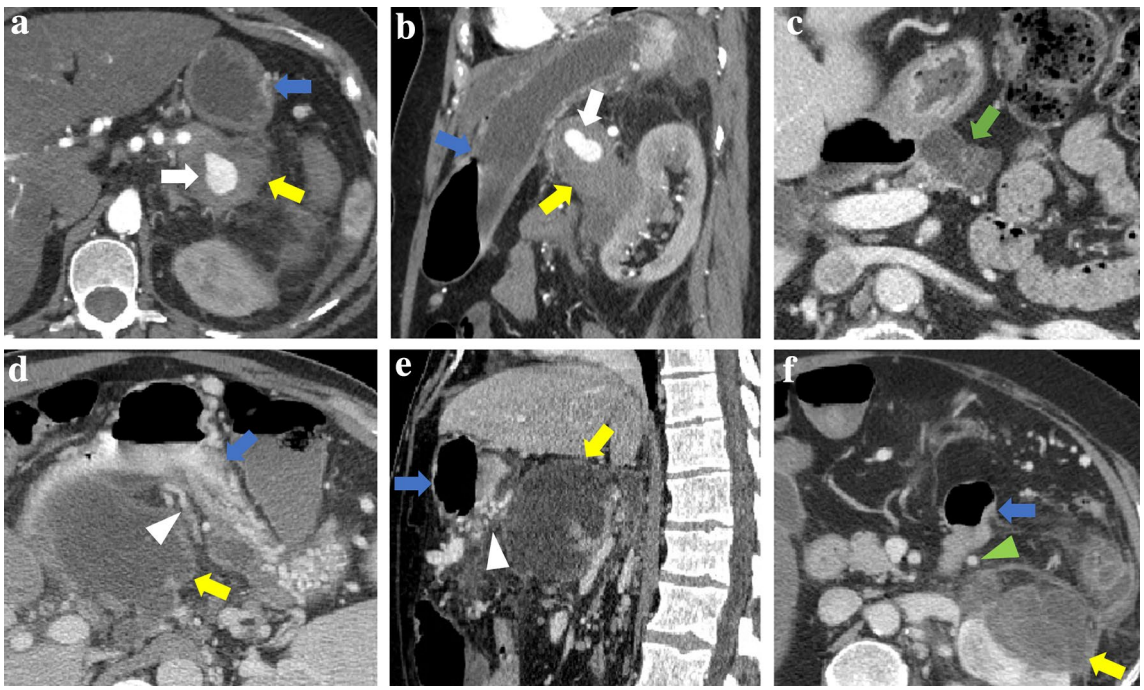

Fig. 3 Contraindications to LACSEMS placement. **a** Axial and **b** sagittal CT demonstrate a pseudoaneurysm (white arrows) between the stomach (blue arrows) and a peripancreatic fluid collection (yellow arrows); the collection was also evident on precontrast images. **c** CT of a noninflammatory lesion (clinically presumed cystic neoplasm, green arrow). **d** Axial and **e** sagittal CT demonstrate gastric varices (white arrowheads) between the stomach (blue arrows) and a peripancreatic fluid collection (yellow arrows). **f** Axial CT shows a vessel (green arrowhead) within 1 cm of a potential access site between the stomach (blue arrows) and a peripancreatic fluid collection (yellow arrows)

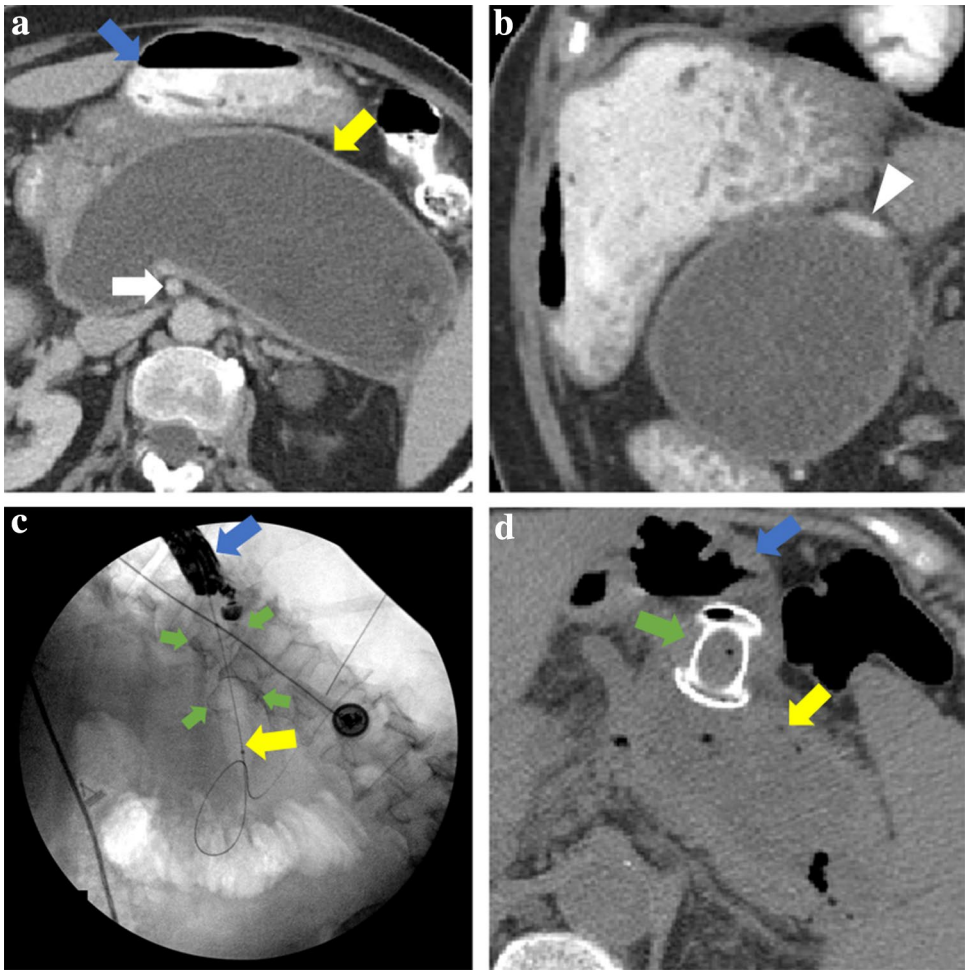

Fig. 4 LACSEMS placement planning. **a** Axial and **b** sagittal CT allow identification of important structures near the collection to be drained (yellow arrow), including the superior mesenteric artery (white arrow) and splenic artery (white arrowhead), as well as the collection's position in relation to the stomach (blue arrow). **c** Fluoroscopic imaging demonstrates endoscopic placement of LACSEMS (green arrows), with endoscope (blue arrow) and guidewire (yellow arrow) labeled for orientation. **d** Repeat CT confirms stent (green arrow) position bridging the stomach (blue arrow) and collection (yellow arrow), in addition to evaluating for efficacy of drainage

material, decreasing the risk of occlusion and reducing the need for repeat procedures [4]. Further, the lumen size also allows for direct trans-stent endoscopic necrosectomy, making this stent a preferred approach in the setting of WON [4, 6]. When the stent is expanded, its flared ends are designed to limit stent migration (Fig. 1) [7]. These advantages make LACSEMS an appealing choice for the gastroenterologist to use in pancreatitis-related fluid collection drainage.

The radiologist who is aware of the key factors in LACSEMS planning, deployment, and follow-up is able to provide gastroenterologists with the most helpful collaboration and reports.

Requirements and contraindications

Careful consideration is necessary when reviewing potential candidates for LACSEMS use. The requirements and contraindications for employing these stents are summarized in Table 2. The targeted collection must be in a location accessible by endoscopic transmural access and must be larger than 6 cm (large enough for stent deployment) (Fig. 2). If the collection is WON, it must be at least 70% fluid. Contraindications include vessels within 1 cm of the planned access site, nearby pseudoaneurysm, and gastric varices between the collection and endoscopic access point. Non-inflammatory collections should also be

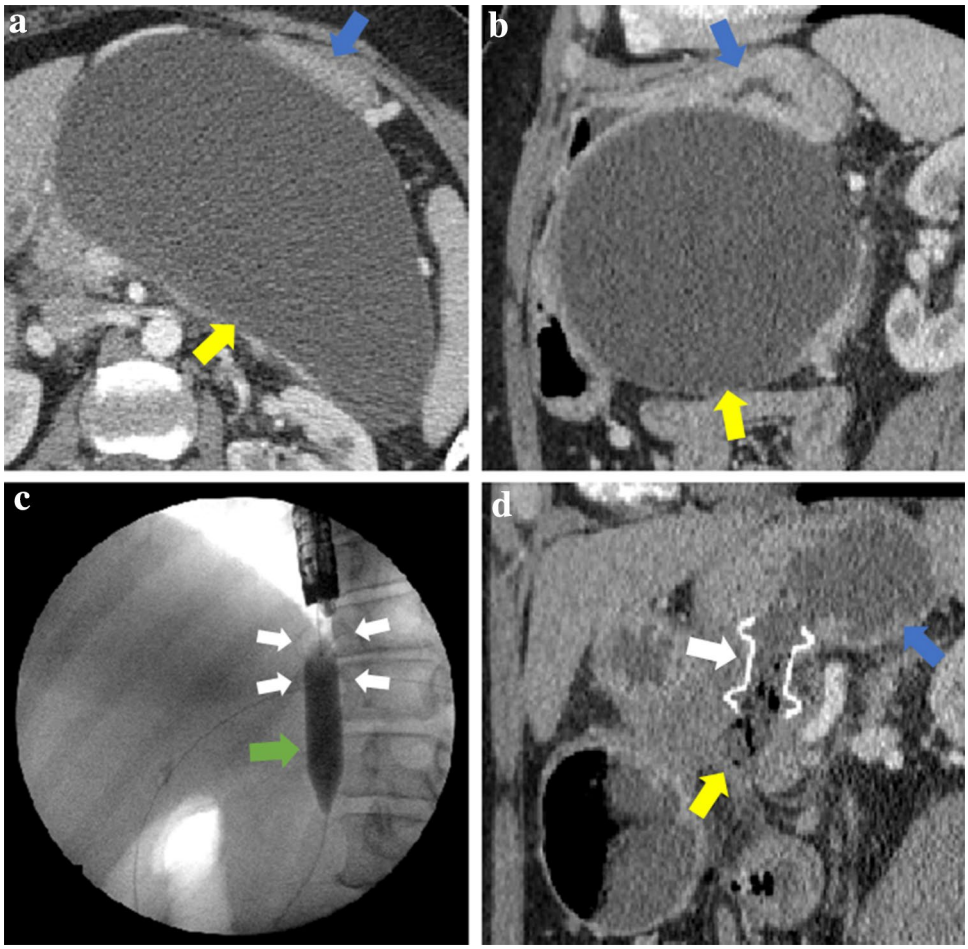

Fig. 5 LACSEMS placement in a large area of WON. **a** Axial and **b** sagittal CT demonstrate marked compression of the stomach (blue arrows) by an area of WON (yellow arrows), providing useful information for approach planning. **c** Fluoroscopy demonstrates placement of the LACSEMS (white arrows), with contrast-filled balloon (green arrow) to assist stent expansion; endoscopic necrosectomy was subsequently performed through the stent. **d** Follow-up CT 1 month after stent (white arrow) placement reveals substantially decreased size WON (yellow arrow) and decreased mass effect on the stomach (blue arrow)

excluded, including cystic neoplasms or duplication cysts (Fig. 3).

LACSEMS planning

Primary considerations in planning deployment of LACSEMS include the requirements and contraindications listed above, in addition to case-specific anatomic considerations. Accessibility must be determined by evaluation of surrounding structures and subsequent careful selection of endoscopic approach (Fig. 4). Frequent considerations include proximity of splenic vessels, limitation of endoscopic maneuvering due to luminal compression by the targeted collection (Fig. 5), and distance from lumen to collection. Use of maximum intensity projections (MIPs) can help identify vessels along possible stent trajectories. Both trans-gastric and trans-duodenal approaches are feasible. When multiple access sites are available, ease of endoscopic approach, safety of deployment, and ensuring longevity of patency are the leading concerns.

LACSEMS follow-up

After stent deployment (Fig. 6), monitoring of efficacy and stent position is frequently achieved by serial cross-sectional imaging. Efficacy is assessed by evaluating collections for evolution or resolution (Fig. 6). Stent position should be carefully evaluated for migration, particularly regarding the positions of the flared ends relative to the gastrointestinal lumen and collection (Fig. 2). Notably, while changing collection size can alter stent position, patency and lumen apposition are the primary positional considerations. Evaluation should include

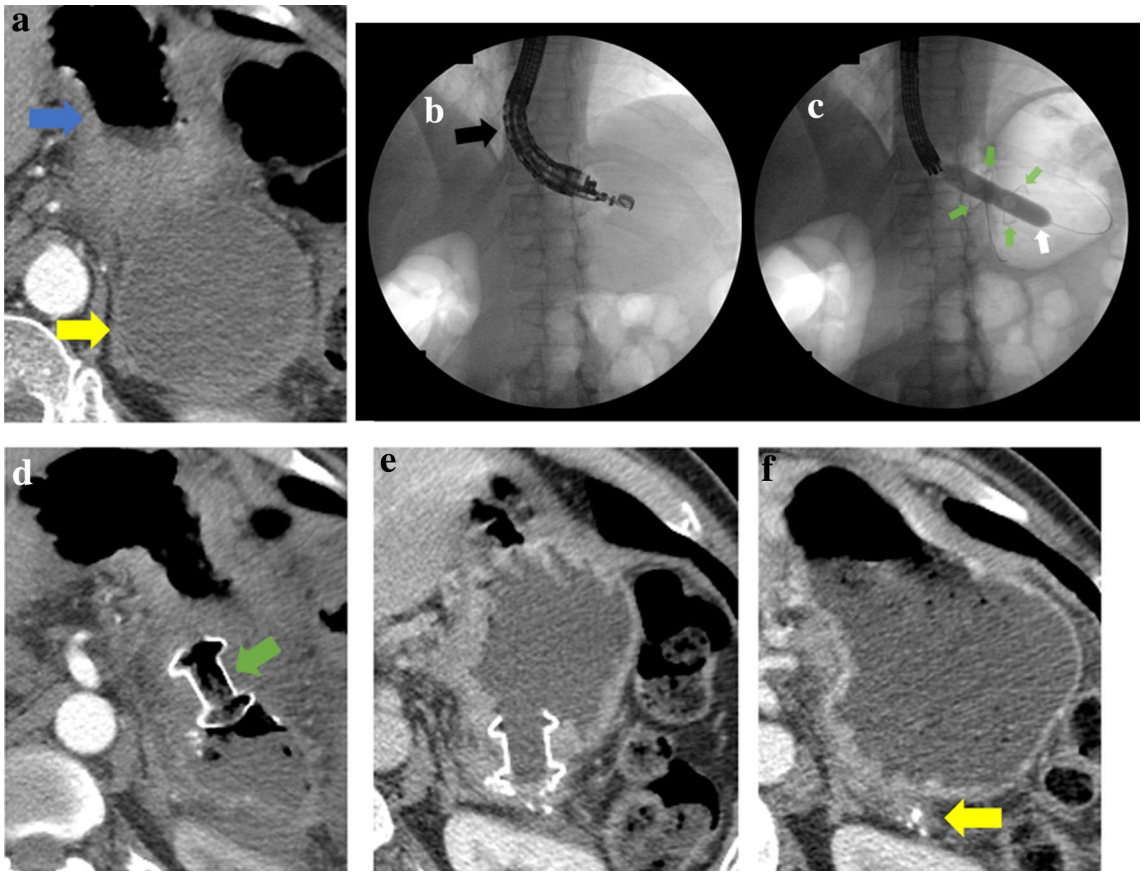

Fig. 6 Endoscopic LACSEMS placement and subsequent pseudocyst evolution. **a** Initial CT imaging demonstrates a pseudocyst (yellow arrow) posterior to the stomach (blue arrow). **b** Fluoroscopy shows the endoscope (black arrow) being advanced into the stomach. **c** Full expansion of the stent (green arrows) was achieved via balloon dilation (white arrow), after which the stent could be traversed with the endoscope. **d** Follow-up CT 1 day after deployment of LACSEMS (green arrow) reveals substantial decrease in pseudocyst size. **e** Follow-up CT 5 weeks after deployment shows complete pseudocyst resolution. **f** Postremoval CT demonstrates small calcifications at the site of the resolved pseudocyst

assessment for new fluid collections, as cases of complicated pancreatitis frequently involve more than one collection and additional collections can alter anatomy via mass effect. Potential LACSEMS complications include bleeding with or without pseudoaneurysm (Fig. 7), stent migration or dislodgement (Fig. 8), and stent occlusion.

Conclusion

The LACSEMS is a novel stent for transmural drainage of pancreatitis-related fluid collections. Close collaboration between gastroenterologists and radiologists is necessary in each case considered for LACSEMS placement. Radiologists' knowledge of key factors in appropriate case selection, deployment planning, and postdeployment monitoring is essential for contributing to clinical decision making and providing clinically relevant assessments.

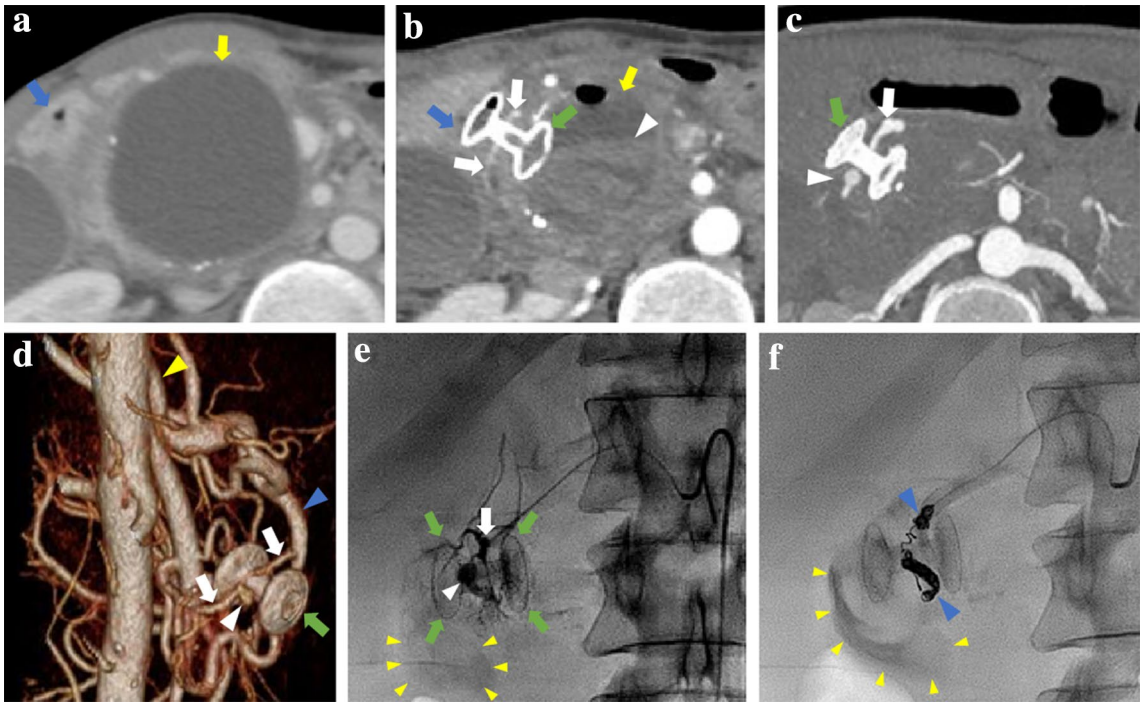

Fig. 7 Pseudoaneurysm and bleeding related to LACSEMS. **a** Initial CT demonstrates a pseudocyst (yellow arrow) adjacent to the duodenum (blue arrow). **b** CT one day after LACSEMS placement shows the stent (green arrow) bridging the duodenum (blue arrow) and pseudocyst (yellow arrow), with an artery (white arrows) immediately adjacent to the stent. A fluid-blood level (white arrowhead) can be seen in the pseudocyst; self-limited bleeding was noted during stent placement. **c** MIP from follow-up CT three weeks later demonstrates a pseudoaneurysm (white arrowhead) arising from the artery (white arrow) adjacent to the stent (green arrow). **d** Volume rendered CT better shows the pseudoaneurysm (white arrowhead) adjacent to the LACSEMS (green arrow), arising from the superior pancreaticoduodenal artery (white arrows); the celiac artery (yellow arrowhead) and gastroduodenal artery (blue arrowhead) are labeled for orientation. **e** Arteriography two days later demonstrates the LACSEMS (green arrows), with adjacent pseudoaneurysm (white arrowhead) arising from the superior pancreaticoduodenal artery (white arrow), as well as active bleeding (yellow arrowheads). **f** Fluoroscopy after coil (blue arrowheads) embolization better shows the extravasated contrast (yellow arrowheads)

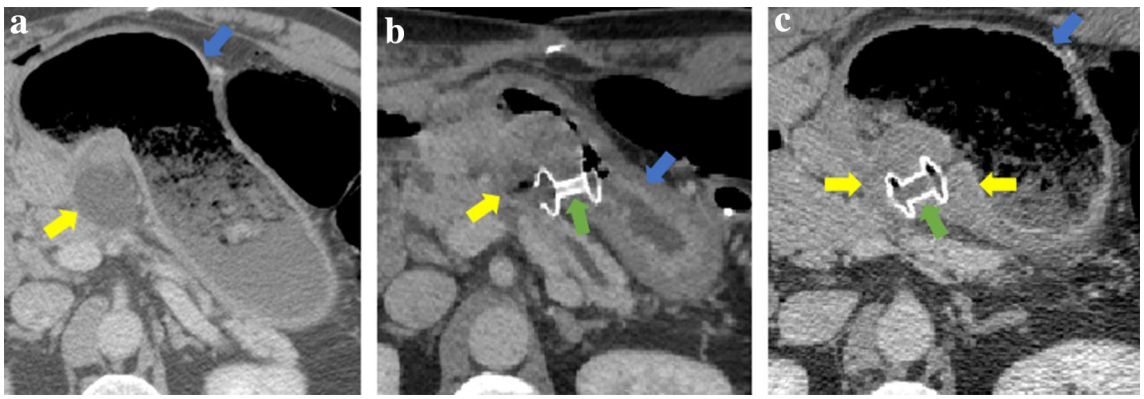

Fig. 8 Migration of LACSEMS. **a** Initial CT reveals a pseudocyst (yellow arrow) adjacent to the stomach (blue arrow). **b** CT 1 day after stent placement demonstrates appropriate LACSEMS (green arrow) location between the stomach (blue arrow) and the pseudocyst (yellow arrow), which has decreased in size. **c** Follow-up CT one month later reveals interval stent migration, with the LACSEMS (green arrow) now outside the stomach (blue arrow) and in the region of the previously identified pseudocyst (yellow arrows)

Compliance with ethical standards

Conflict of interest Pat Whitworth, Brenda Holbert, Rishi Pawa, Neeraj Lalwani, and Rafel Tappouni declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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