

Interventional Radiology in the Management of Visceral Artery Pseudoaneurysms: A Review of Techniques and Embolic Materials

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Visceral artery pseudoaneurysms occur mostly as a result of inflammation and trauma. Owing to high risk of rupture, they require early treatment to prevent lethal complications. Knowledge of the various approaches of embolization of pseudoaneurysms and different embolic materials used in the management of visceral artery pseudoaneurysms is essential for successful and safe embolization. We review and illustrate the endovascular, percutaneous and endoscopic ultrasound techniques used in the treatment of visceral artery pseudoaneurysm and briefly discuss the embolic materials and their benefits and risks.

Index terms: *Interventional radiology; Pseudoaneurysm; Visceral artery; Endovascular embolization; Embolic agent*

INTRODUCTION

Abdominal visceral artery pseudoaneurysms are potentially lethal vascular lesions that arise from splanchnic circulation and the renal artery, as a result of various causes including inflammation, infection, trauma and neoplasm (1, 2). Unlike true aneurysms that have all three arterial wall layers, pseudoaneurysms develop due to disruption of intimal and medial layers of the arterial wall and do not contain any epithelized wall (Fig. 1) (3). They are outlined by thin fibrous tissue and usually surrounded by peri-arterial hematoma.

The incidence of rupture of pseudoaneurysms is varies

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from 2% to 80% depending on the location, with untreated mortality rates reaching up to 100% (3-5). Due to the high risk of rupture, treatment of these pseudoaneurysms is necessary (6). Surgery has been the initial treatment option for pseudoaneurysms, however, due to its high invasive nature and risk of complications, radiological intervention is currently the initial treatment of choice (7, 8). Radiological interventions are minimally invasive and are associated with high success rates and low rates of complications (9). In this article, we present various techniques of embolization of pseudoaneurysms, embolic materials available and review the performance of each technique and embolic agent.

Etiology and Pathogenesis

Pseudoaneurysms result from disruption of the elastic fibers and smooth muscles of the tunica media of the artery, often with interruption of the intima (3). It has various etiologies such as inflammation (pancreatitis and cholecystitis), infection (abscess), vasculitis, trauma (iatrogenic or penetrating injury), collagen vascular disease, segmental arterial mediolysis and malignancy (5, 10). Essentially all pseudoaneurysms, whether symptomatic

or not, need treatment (1). Occasionally, there may be spontaneous thrombosis of a pseudoaneurysm and very rarely, they may undergo spontaneous resolution (11, 12).

Clinical Presentation

Presentation of pseudoaneurysms may vary from absence of symptoms to life threatening hemorrhage and death (13). The most common symptom (50–63% cases) results from hemorrhage, presenting as gastrointestinal bleeding due to rupture of pseudoaneurysm arising from celiac, superior mesenteric arteries (SMA), and inferior mesenteric arteries (IMA), hematuria from renal artery pseudoaneurysm and intra-abdominal hematoma (3, 14, 15). Patients with severe hemorrhage may present with hypotension and shock. Pain is the next common presentation, seen in one third of patients (14). Uncommonly, hematoma can cause mass effect and present with symptoms like jaundice secondary to common bile duct compression (16). Pseudoaneurysms may be incidentally detected in up to one third of patients (14).

Relevant Anatomy

Abdominal visceral arteries consist of splanchnic circulation and renal artery. Splanchnic circulation includes celiac trunk, SMA and IMA. It is necessary to understand important collateral pathways for proper management of visceral artery pseudoaneurysms (17). Common collaterals are 1) between SMA and celiac axis through anterior and posterior pancreatico-duodenal arcades; 2) between branches of gastroepiploic, short gastric and splenic arteries (within the celiac arterial system); and 3) between right and left hepatic arteries. Variations of arterial anatomy are possible, such as replaced or accessory hepatic arteries that may have retroportal course (retroportal hepatic artery), celiacomesenteric trunk and middle colic artery arising from celiac trunk (18). Uncommon variations include arc of Buhler (persistence of direct embryological communication between celiac trunk and SMA) and arc of

Barkow (anastomosis of the right and left gastroepiploic arteries) (17, 19). Absence of collateral pathways in the renal arterial system is also an important deciding factor in selecting the embolization technique.

Imaging

Prior imaging is critical to interventional management of a pseudoaneurysm (13, 20). Ultrasonography, computed tomography (CT) and magnetic resonance imaging are non-invasive imaging techniques that are most commonly employed for the detection and evaluation of pseudoaneurysms. Invasive digital subtraction angiography (DSA) is reserved for specific situations.

Ultrasonography is often used as the initial screening tool and may detect large and superficially located pseudoaneurysms and those within the solid organs like liver and spleen (9, 13). A pseudoaneurysm typically appears as an anechoic lesion with thin walls on grey scale scan, which fills with color and shows the characteristic “yin-yang” flow with bidirectional waveform pattern on duplex color Doppler ultrasound (Fig. 2) (13). The peripheral part of a pseudoaneurysm may show variable extent of thrombosis, which appears hypoechoic or echogenic, often with stratification due to thrombosis of different ages (13). Obesity, bowel gas, operator dependency and deep location of visceral artery pseudoaneurysms result in lower sensitivity of detection (13).

Multidetector CT angiography (CTA) is the most commonly used and most sensitive non-invasive modality for detection of pseudoaneurysms (11, 13, 21). Routinely, CT should include both arterial and venous phases as some pseudoaneurysms with a narrow neck may not be seen on the arterial phase and opacify only in the venous phase. CTA demonstrates a well defined contrast filled sac with attenuation parallel to adjacent main artery in both the phases. Post-processing with maximum intensity projection and volume rendering better demonstrate the pseudoaneurysm and its origin and improve detection (Fig. 3) (13). Depending on the extent of thrombosis, the sac

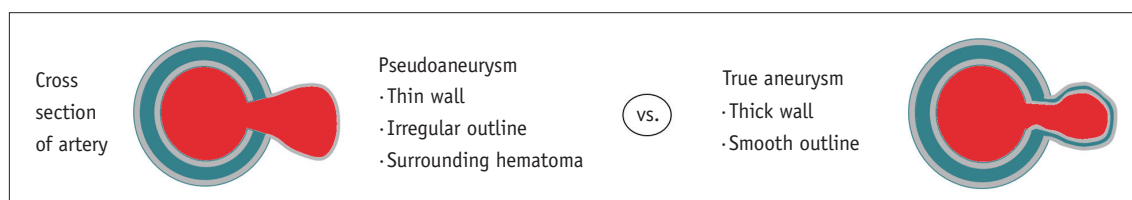


Fig. 1. Schematic diagram of differences between true aneurysm and pseudoaneurysm.

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may show low attenuation areas, usually in the periphery. In addition to the detection of a pseudoaneurysm, CTA provides a road map for intervention and depicts associated anatomical arterial variations.

MR angiography (MRA) is rarely used for the detection of pseudoaneurysms because of non-feasibility in hemodynamically unstable patient, long scan times and

high cost (13, 20). In addition, the spatial resolution of MRA is lower than CTA. However, absence of ionising radiation and availability of non-contrast techniques have advantages over CT (11, 22). Ghost or pulsatile artefact in the phase encoding direction is an important clue for detection of pseudoaneurysm on MRA.

Digital subtraction angiography remains the gold standard

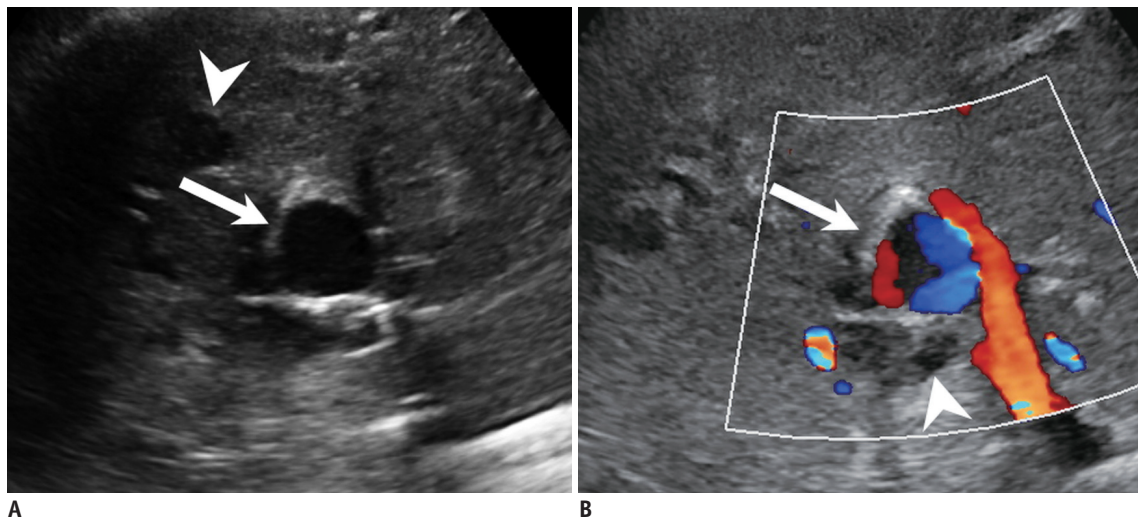


Fig. 2. 33-year-old male with confirmed chronic pancreatitis, presenting with high grade fever and hematemesis. Transabdominal ultrasonographic images of right hepatic artery pseudoaneurysm (arrows) showing well defined anechoic lesion on grey scale image (A) with characteristic “yin-yang” sign on color Doppler (B). Cholangitic abscesses are seen adjacent to pseudoaneurysm (arrowheads).

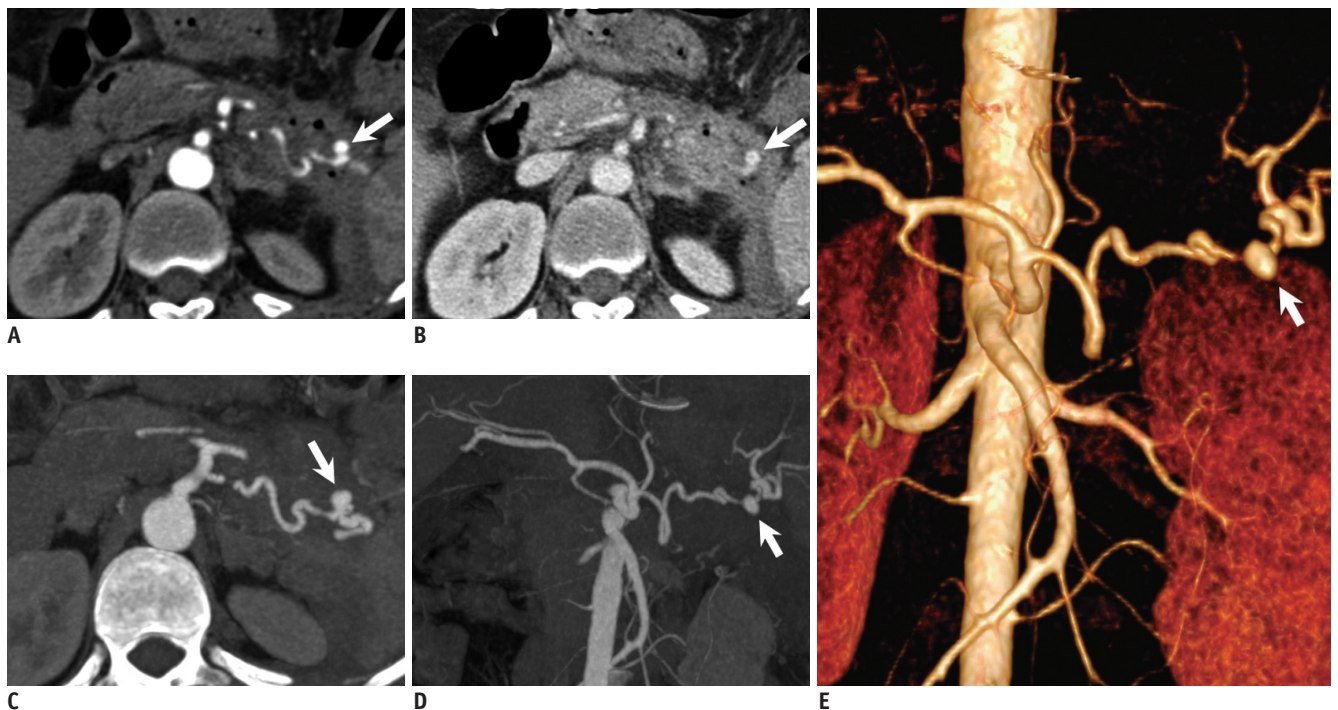


Fig. 3. CT angiography in 38-year-old male with acute pancreatitis and melena. Axial images in arterial (A) and venous (B) phases show small pseudoaneurysm arising from splenic artery (arrows) with pancreatic inflammation. Maximum intensity projections in axial (C) and coronal (D) planes and three-dimensional volume rendered image (E) better demonstrate characteristics of pseudoaneurysm (arrows).

for diagnosis (13). Two main indications of DSA in the setting of pseudoaneurysms are 1) possible embolization of a pseudoaneurysm detected on imaging, and 2) detection of a pseudoaneurysm under high clinical suspicion and normal findings on imaging. DSA has the advantage of real time assessment of hemodynamics of the source vessel, identification of collateral supply and expendability of donor inflow artery (13). DSA can be used to identify pseudoaneurysms that are not seen in ultrasonography, CTA and MRA, with the advantage of ability to perform concurrent therapeutic intervention (13). Cone beam CT, also known as rotational angiography, involves the acquisition of angiographic images in different planes by rotating the tube-detector assembly rapidly around the patient (23). The images can be viewed in all the three standard planes, facilitating the determination of size and exact origin of the pseudoaneurysm and the course of the inflow artery (24). Few studies have reported the superiority of cone beam CT over routine DSA images in management of pseudoaneurysms (25, 26).

Differentiation of pseudoaneurysm from a true aneurysm is important, as indications for treatment are different in both cases (1). Presence of irregular outline, eccentric location, saccular shape, eccentric thrombosis and demonstration of etiology on imaging (like inflammation, trauma) may suggest a pseudoaneurysm (11, 13). However, in the absence of an etiology, it may be difficult to differentiate a pseudoaneurysm from a saccular true aneurysm.

Interventional Management

Indications for Interventions

Patients presenting with hemorrhage, unstable hemodynamic status and symptoms of mass effect due to a pseudoaneurysm need embolization (13). However, due to high mortality of rupture, all pseudoaneurysms require treatment as soon as detected (1, 27). Since pseudoaneurysms have thin walls, their size has no correlation with the risk of rupture (1, 11, 28). Small pseudoaneurysms may cause life threatening hemorrhage, while a large pseudoaneurysm may be detected incidentally. However, this is not the case with true aneurysms that need treatment when sized > 2 cm or with mass effect (5, 11, 28). Embolization for incidentally detected pseudoaneurysms in asymptomatic patients is still controversial. Due to high risk and mortality of rupture, we embolize all pseudoaneurysms irrespective of whether the

patient is symptomatic or not.

Principles of Intervention

Exclusion of the pseudoaneurysm from systemic circulation is the main aim of radiological intervention (11). This can be achieved by slowing the flow within the pseudoaneurysm (coils, stent grafts), inducing thrombosis (coils and liquid embolics) and stimulating inflammation (coils and liquid agents) (29). An interventional radiologist should consider some important principles while choosing the interventional technique and embolizing agent for managing the pseudoaneurysm, as shown in Table 1.

Embolic Materials

Various embolic materials used in treatment of visceral artery pseudoaneurysms are coils, liquid embolics (glue, thrombin), gelfoam slurry and vascular plugs (29, 30). The choice of embolics depends on various factors.

Coils are permanent embolic agents made of stainless steel that is stiffer or the softer platinum (29, 30). They are available in various sizes (both length and diameter) and shapes. Fibered coils with multiple soft fibers increase thrombogenicity. Based on method of administration, they can be pushable, injectable or detachable. Pushable coils are most commonly used. Detachable coils provide better control of deployment and are mostly used in the treatment of intracranial aneurysms (29). In visceral pseudoaneurysms, they may be used with sac packing or stent assisted coiling techniques (9, 13). Size (diameter) of the selected coil should be 20–30% larger than the size of the artery to allow adequate coiling and packing (30). Drawbacks of

Table 1. Points to Consider Prior to Embolization of Pseudoaneurysm

Size of pseudoaneurysm & its neck
Large size–option of percutaneous approach
Wide neck–risk of non target embolization (liquid agents)
Parent artery
End artery vs. artery with rich collaterals– proximal occlusion vs. sandwich embolization
Expendable vs. inexpendable artery– parent artery occlusion vs. preservation approaches
Tortuous artery–difficult catheterization; consider other approaches
Location
Proximal–short landing zone poses difficulty
Patient's coagulation parameters
Deranged–may prolong thrombosis with coils; glue is beneficial

coils are non-target embolization, pseudoaneurysm rupture, infection and requirement of normal coagulation factors for successful embolization (11, 29, 30).

N-butyl cyanoacrylate (glue) is a liquid permanent embolic agent that polymerises to form a cast when it comes in contact with anions (present in blood) (29, 30). Lipiodol® (Geurbet, Hong Kong, China), an iodised oil emulsion, is used as a carrier for glue; when mixed with glue, it acts as a diluting agent that slows the rate of solidification and provides radio-opacification for the solution. Concentration of glue in the glue-lipiodol mixture determines the rate of polymerisation (30, 31). Dextrose (5%), which is non-ionic, is used to flush the catheter before and after the administration of glue to prevent its polymerization within the catheter. Use of glue as an embolic agent requires expertise due to serious potential complications such as non-target embolization and catheter trapping or fragmentation (29).

Lyophilised thrombin derived from human plasma is available in powder form (2500–10000 IU) and mixed with calcium chloride solution prior to use (32). Thrombin injection at a 100–1000 IU/mL concentration, causes activation of coagulation cascade, resulting in polymerization of fibrinogen to form fibrin clot (13, 33). This is usually used for direct percutaneous embolization. To prevent reflux of thrombin into systemic circulation, the neck of the pseudoaneurysm may be occluded with a balloon catheter placed endovascularly (13, 32). Contraindications to thrombin include history of allergy and local infection (13). In addition to non-target embolization, allergic reaction, infection and recurrence due to collateral supply or high flow are frequent problems (13, 32).

Gelatin sponge, available as sheets or in powder form, is mixed with iodinated contrast medium to make pledgets or gelfoam slurry (29, 30). It is a low cost, temporary embolizing agent that acts by causing mechanical obstruction. It is mainly used in emergency situations to control bleeding (29). The main disadvantages are non-

target embolization and infection (29).

Amplatzer vascular plug (St. Jude Medical, MN, USA) is an expandable three dimensional nitinol mesh occlusive device attached to the delivery system by screw (29, 30). Once in the desired position, the plug is deployed by unscrewing after unsheathing. The plugs are required to be oversized by a factor of 30–50% with respect to the size of the vessel to be embolized (29); and may be used to occlude pseudoaneurysms arising from medium sized vessels (30, 34). The advantages are control in deployment and high success rates. Despite the limitation of high cost of a single plug device, as compared to a coil, it could be cost effective in cases that require multiple coils (29).

Patient Preparation

Patient preparation is important prior to all radiological interventions (35, 36). The blood pressure is required to be within normal limits. The morning dose of anti-hypertensive medication is mandatory in hypertensive patients. Furthermore, if the blood pressure is high, sublingual nifedipine can be given. Evaluation of the patient's coagulation parameters is necessary. Routine checking of prothrombin time, international normalized ratio and platelet count are sufficient. If deranged, fresh frozen plasma and single donor platelets can be transfused accordingly. Normal blood urea and serum creatinine are necessary; as well as obtaining any history of allergy to iodinated contrast agents. The puncture site requires preparation. In addition, informed consent should be obtained from all patients prior to performing the intervention. Most of the procedures can be performed under local anesthesia.

Interventional Techniques or Approach

Various approaches are available for the management of visceral artery pseudoaneurysms including 1) endovascular, 2) percutaneous, and 3) endoscopic (Table 2). Endovascular approach is the most widely used and preferred method (11).

Table 2. Approaches for Treatment of Visceral Artery Pseudoaneurysm

Endovascular	Percutaneous	EUS
Most widely used	Failed endovascular	Failed endovascular
Preferred approach	Large, superficial pseudoaneurysm	For pseudoaneurysm seen on EUS
High success rates	Pseudoaneurysm with narrow neck	Gastroduodenal A
	Pseudoaneurysm in solid organs	Splenic A
	Ultrasonography/CT guidance	

A = artery, EUS = endoscopic ultrasonography

Percutaneous or endoscopic techniques are usually reserved for failed endovascular approach.

Endovascular Approach

Endovascular method is the common initial choice for embolization of a pseudoaneurysm. It better defines the vascular anatomy and hemodynamics of blood flow through the pseudoaneurysm prior to embolization and thus, helps in avoiding non target embolization (8, 27, 37). Problems of endovascular embolization include difficulty in catheterization due to tortuous artery and difficult anatomy, short landing zone with risk of non-target embolization and inability to approach through previously blocked artery in cases of recurrent pseudoaneurysms (27).

Coils or microcoils are the preferred and most widely used agents for embolization of a pseudoaneurysm (11, 13, 37, 38). Coils act by slowing the flow by causing mechanical obstruction, inducing thrombosis via their thrombogenic fibres and by inciting inflammatory reaction. The main aim of coil embolization is occlusion of the pseudoaneurysm and its neck or its exclusion from circulation (11). Various techniques are described for embolization of a pseudoaneurysm using coils (11, 13, 27, 39). These include sack packing, sandwich technique and proximal delivery (13). Sack packing involves filling the pseudoaneurysm with coils or microcoils, typically using a coaxial technique (14). Sack packing is done for saccular pseudoaneurysms with narrow neck, which allows retention of coils within the sac maintaining the patency of parent vessel (Fig. 4) (11, 14). The success of this technique depends on the coil

packing density, although 80–90% packing is sufficient for pseudoaneurysms (14, 40). There is however, a rare risk of secondary rupture of the pseudoaneurysm (14). Sandwich technique is performed for pseudoaneurysms that are likely to have collateral inflow vessels (11). Here occlusion is done distal, across and proximal to the neck of the pseudoaneurysm blocking the efferent (back door) and afferent artery (front door) (Fig. 5). Embolization of only the parent or afferent artery will lead to incomplete embolization and recurrence due to retrograde filling from the efferent collateral. The efferent artery or back door is closed first, followed by afferent artery or front door (41). Splenic, hepatic and gastroduodenal artery pseudoaneurysms require embolization through the sandwich technique (8). This technique has clinical success rates of > 90% (39, 41). Proximal occlusion of parent or inflow artery is done for end arteries like renal arteries (Fig. 6) (38, 39).

Embolization with glue is not performed routinely due to higher risk of complications (42). However, it is useful when reaching the target site is not possible due to the presence of a tortuous artery, in cases of recurrent pseudoaneurysm after previous coil embolization, and in patients with deranged coagulation parameters, as coils need normal coagulation profile for thrombosis of the pseudoaneurysm (42, 43). Interventional radiologist should understand the hemodynamics of blood flow in the source artery and pseudoaneurysm, in order to decide the glue-lipiodol mixture concentration, and amount and rate of injection, to avoid non target embolization (Fig. 7) (30).

Pseudoaneurysms with wide neck have an increased

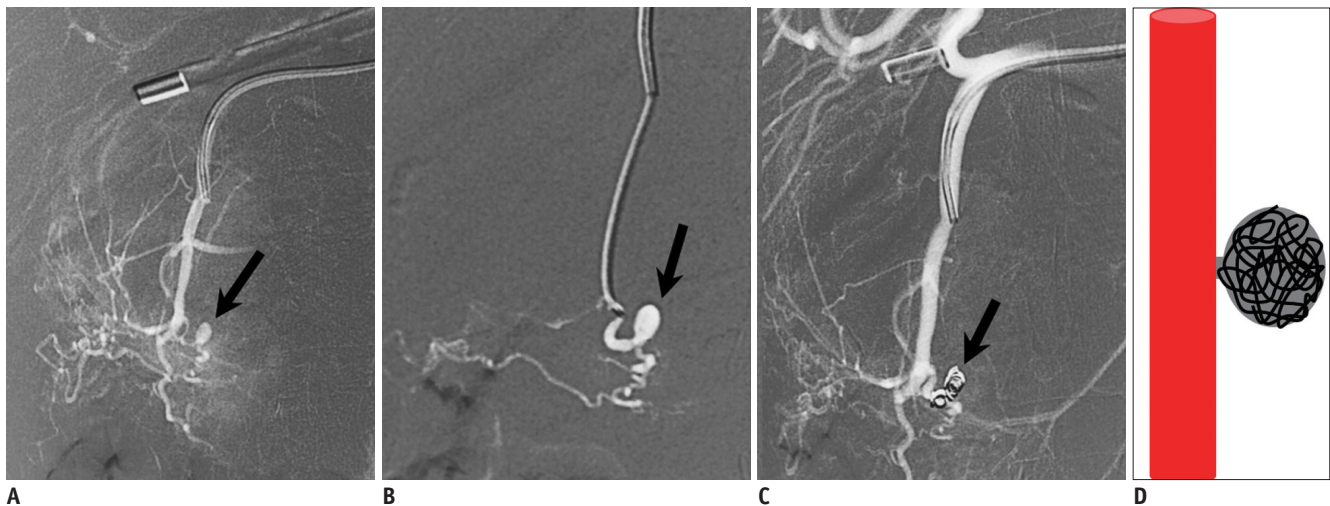


Fig. 4. Sac packing. 42-year-old male patient with acute pancreatitis, presenting with hematemesis and hemodynamic instability. DSA image showing short necked pseudoaneurysm (arrows) arising from gastroduodenal artery (A, B), which was subsequently packed with microcoils and embolized (C). Sac packing was made possible due to origin from branch of gastroduodenal artery, narrow neck, and ability to enter pseudoaneurysm with microcatheter. Schematic diagram of sac packing (D). DSA = digital subtraction angiography

tendency of migration of embolic material (11, 13). To overcome this, stent graft (covered stent) placement, stent assisted coiling and balloon remodelling techniques are useful (Fig. 8). These techniques also help in preserving the patency of parent artery. Stent graft is reserved for larger proximal arterial segments like main hepatic artery, main splenic artery and SMA as the stent deployment system cannot pass through small tortuous arteries (44, 45). This technique has long term patency rates of about 82% (44). Recently, flow diverting multi-layered bare stents is available, which facilitate slowing the blood flow within the visceral artery aneurysms and maintaining patency of the parent artery as well as any branches arising from or proximal to the aneurysm (46). Thrombosis of the aneurysm is seen in a high percentage (over 90%) of treated cases; and furthermore, in stent thrombosis and stenosis are complications seen in < 10% cases. Although it is used in the treatment of true aneurysms, its use in pseudoaneurysms is limited, as thrombosis occurs slowly and there is a possibility of rupture in the interim (47, 48). Stent assisted coiling and balloon remodelling (Fig. 8) are used in cases where the parent artery is in expandable, in order to prevent the coils from projecting into the lumen (11,

13). In both these techniques, the bare stent or balloon catheter is placed across the neck of the pseudoaneurysm. They act as scaffold for coil embolization through the gaps in the stent or by the side of balloon (11).

Percutaneous Approach

Percutaneous embolization of pseudoaneurysms is conducted under either ultrasonography or CT guidance (9, 13). It is usually used for cases of failed endovascular approach or pseudoaneurysms not accessible endovascularly (15, 32). This technique is usually performed for a pseudoaneurysm that is surrounded by solid organ, or a large pseudoaneurysm with adjacent scaffolding structures (11, 13). The pseudoaneurysm is punctured using a 22 G Chiba needle under ultrasonography or CT guidance. Care should be taken to keep the tip of the needle away from the neck, to avoid non-target embolization. Once within the pseudoaneurysm, embolizing agent is slowly injected preferably under guidance, until thrombosis of the pseudoaneurysm occurs (Fig. 9). Thrombin, glue and occasionally coils are used as embolic materials (13, 15). Complications include rupture of the pseudoaneurysm, non-

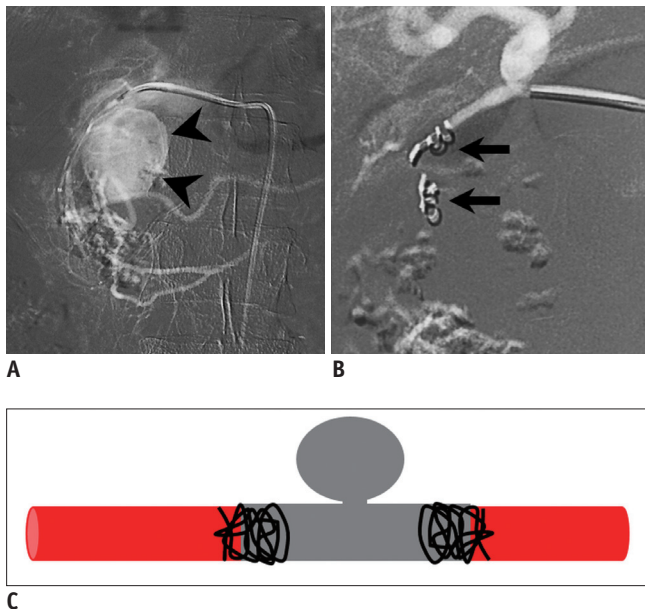


Fig. 5. Sandwich technique. 36-year-old male patient with chronic pancreatitis, presenting with upper gastrointestinal bleed.

A, B. DSA images showing pseudoaneurysm arising from gastroduodenal artery (arrowheads in **A**), which was embolized with coils occluding back door and front door (arrows in **B**). Sandwich technique was used, since pseudoaneurysm arose from main trunk of gastroduodenal artery, which has collateral supply. **C.** Schematic diagram of same. DSA = digital subtraction angiography

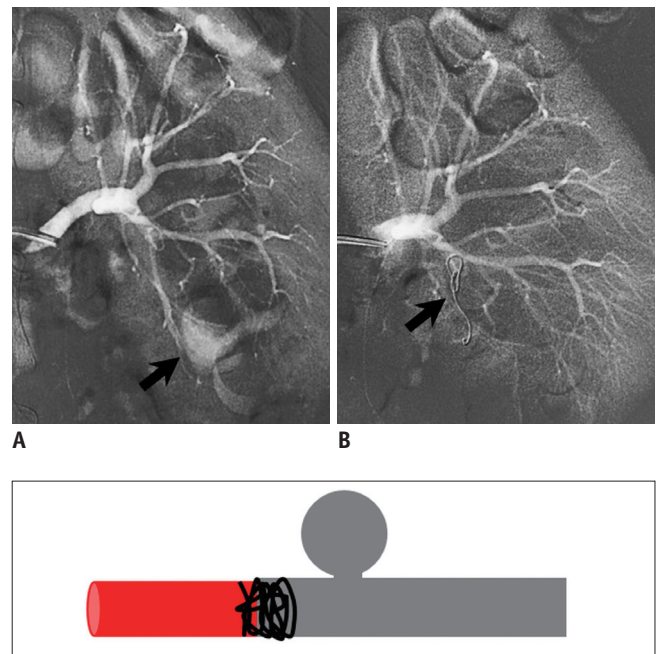


Fig. 6. Proximal occlusion. 30-year-old male presenting with hematuria and hypotension after percutaneous nephrolithotomy.

A. DSA image showing pseudoaneurysm (arrow) arising from lower pole branch of renal artery. **B.** DSA image after embolization with proximal coil placement (arrow). As renal arteries are end arteries, proximal occlusion is sufficient to treat pseudoaneurysm. **C.** Schematic diagram of proximal delivery. DSA = digital subtraction angiography

target embolization, and recurrence.

Endoscopic Ultrasonography

Endoscopic ultrasonography (EUS) is used when endovascular approach fails and is reserved for pseudoaneurysms detected on EUS, like those arising from splenic and gastroduodenal arteries (49, 50). Here, the pseudoaneurysm is directly punctured under EUS guidance and the embolic agent is injected within (Fig. 10). Thrombin or glue is used as embolic materials, although thrombin is preferred for its safety (50). Complications are the same as those of percutaneous approach.

Complications

Complications can be grouped into puncture site,

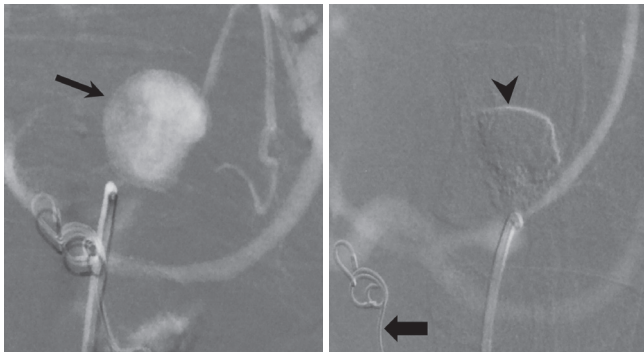


Fig. 7. 26-year-old male patient with chronic pancreatitis, presenting with recurrent melena. **A.** DSA image showing left gastric artery pseudoaneurysm (arrow). Glue-lipiodol mixture was used to embolize pseudoaneurysm and post embolization DSA image (**B**) shows glue cast (arrowhead). Coil placed in previous gastroduodenal artery pseudoaneurysm is also seen (block arrow). As pseudoaneurysm arose from close to celiac artery division, coil would have protruded proximally. Glue was used to fill pseudoaneurysm successfully. DSA = digital subtraction angiography

intervention site and post-embolization complications (35, 51).

Puncture site complications include bleeding, hematoma, pseudoaneurysm formation, arterial thrombosis, arteriovenous fistula and nerve damage (35, 52). Most of these complications are rare if proper puncture and compression after the procedure is done. Closure devices may also be used for hemostasis with good results (53). Bleeding, which is more common with supra-inguinal punctures, should be managed by local compression, resuscitation and if necessary, balloon placement from contralateral side. Pseudoaneurysm formation is most often due to inadequate compression and use of anticoagulants, and is managed by ultrasound guided manual compression or percutaneous thrombin injection (52). Arterial thrombosis may require thrombolysis or thrombectomy.

Intervention site complications include rupture of the pseudoaneurysm, arterial dissection, non-target embolization, distal migration of coil and straight deployment of coil (Fig. 11) (5, 9, 13, 54). Rupture of a pseudoaneurysm during embolization is life threatening and immediate steps should be taken to control the bleeding. In these cases, immediate patient resuscitation with fluids is required; and an attempt must be made to occlude the site of rupture with glue or gelfoam. Mostly this is sufficient, especially if rupture occurs during endovascular embolization. Rupture during percutaneous or EUS approach requires immediate endovascular or surgical treatment in hemodynamically unstable patients. Arterial dissection is often resolved by infusion of heparinised saline; however, stenting may be necessary if it involves a major artery (35). Non-target embolization may result in end organ damage causing tissue infarction. Often, expectant management is sufficient. Splenic infarction may cause persistent pain or abscess, which may need splenectomy. Bowel ischemia may

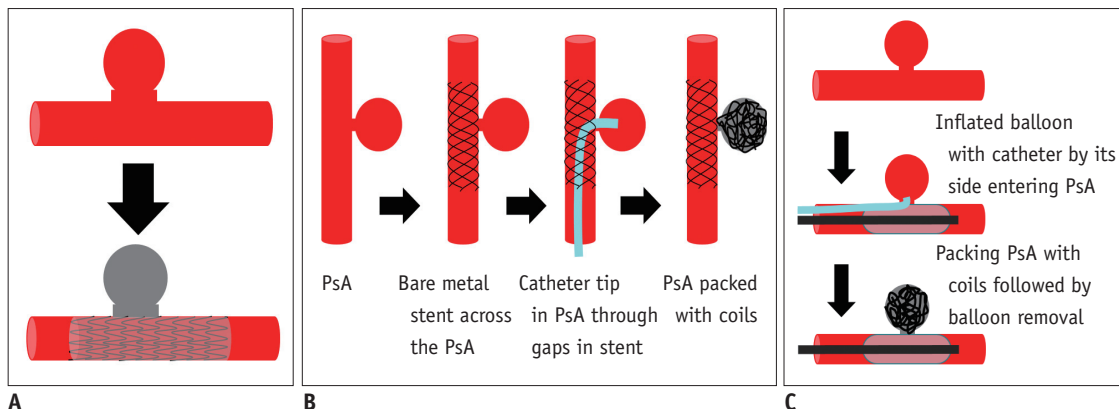


Fig. 8. Other techniques: schematic diagram illustrating stent graft placement (A), stent assisted coiling (B), and balloon remodeling (C) techniques. PsA = pseudoaneurysm

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require surgical intervention. Distal migration of coil occurs due to smaller size of coil and straight deployment occurs due to oversized coil.

Post-embolization complications include secondary infection (commonly in gelfoam slurry due to trapped

air bubbles) and embolization syndrome (pain, fever and vomiting) (35). Recurrence of the pseudoaneurysm may occur secondary to its incomplete exclusion or collateral supply, and rarely migration of coils, and needs repeat embolization.

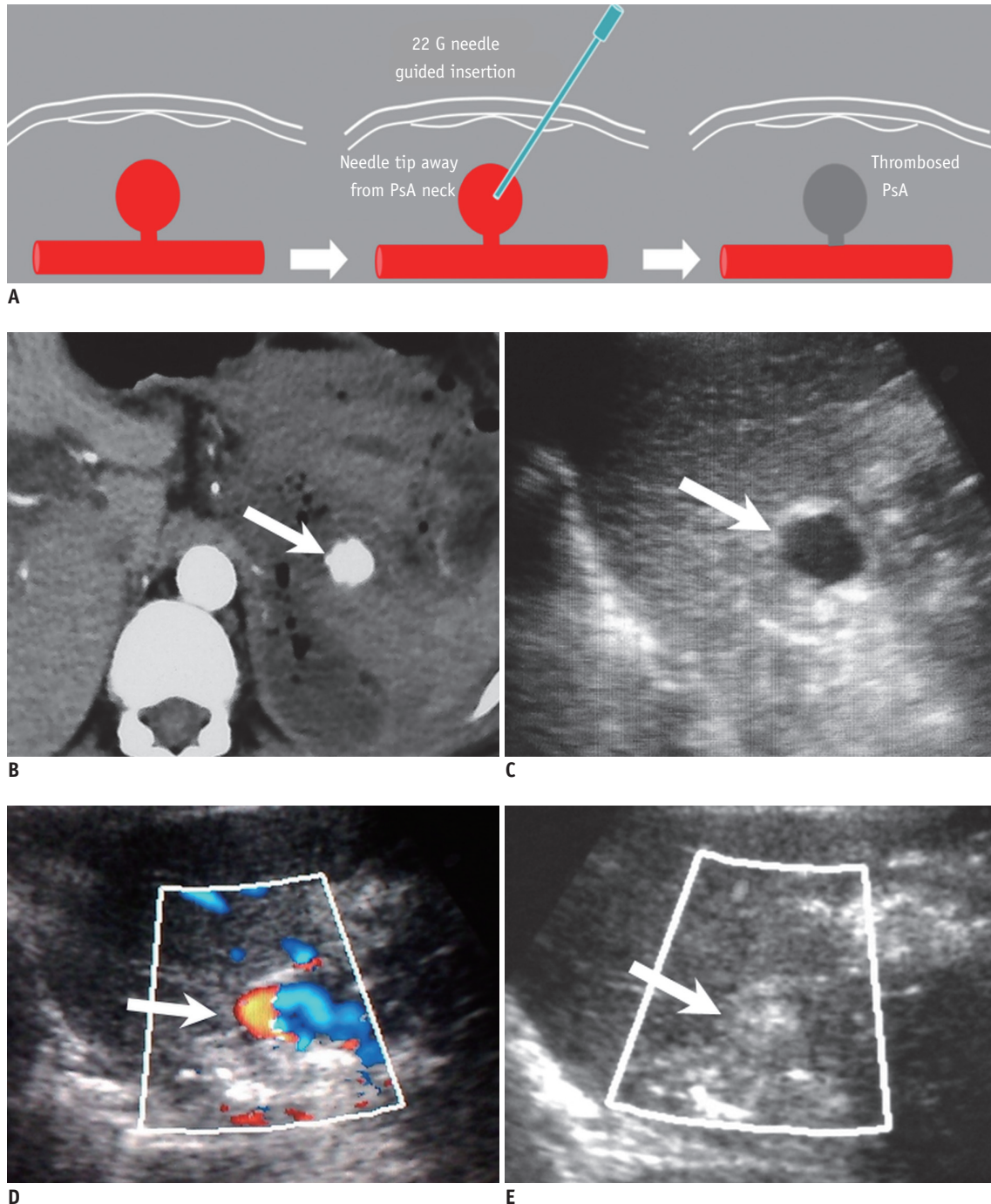


Fig. 9. Percutaneous approach for pseudoaneurysm embolization. 34-year-old female patient with pancreatitis, presenting with hemodynamic instability. DSA showed spastic splenic artery, which could not be catheterized.

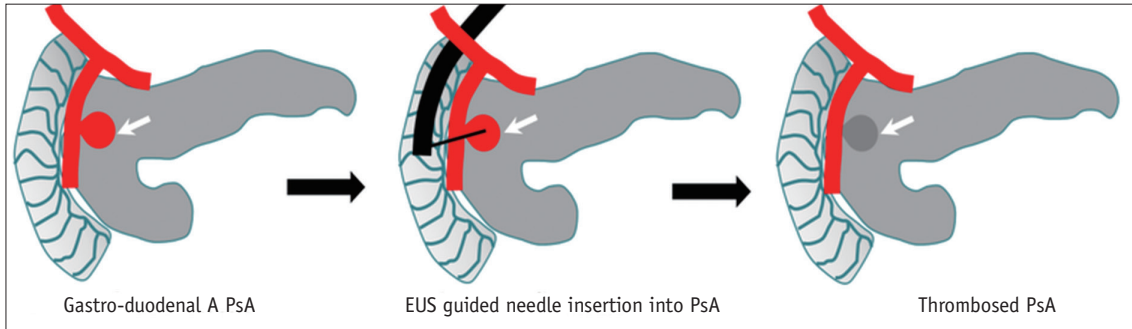
A. Schematic illustration. **B.** Axial CTA image showing PsA arising from tortuous splenic artery (arrow). **C, D.** Ultrasonographic images showing anechoic PsA with color filling on Doppler image (arrow). **E.** Ultrasonography image after percutaneous embolization with glue showing thrombosis of PsA (arrow). CTA = CT angiography, DSA = digital subtraction angiography, PsA = pseudoaneurysm

An algorithm for embolization of visceral artery pseudoaneurysms is shown in Figure 12.

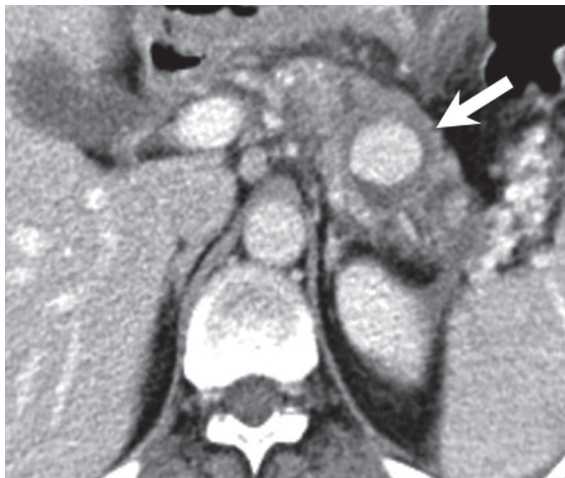
Follow-Up

Follow up is an important and integral part of

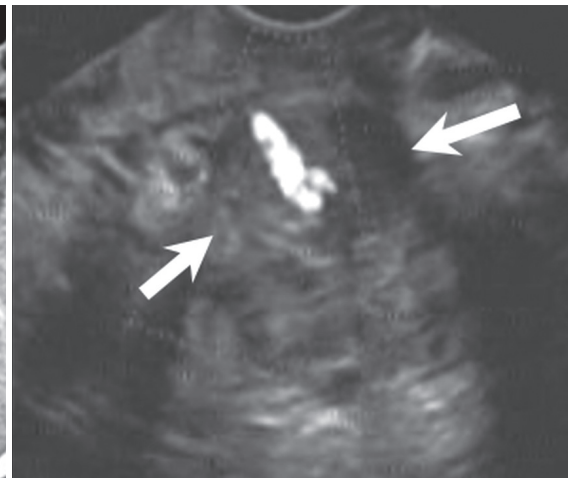
management of pseudoaneurysms. Established imaging protocol for follow up of pseudoaneurysms after embolization is currently not available in the literature (1, 11). Mostly, clinical assessment of symptoms of hemorrhage and vital parameters is sufficient to evaluate recurrence. Assessment by an imaging modality is also often necessary



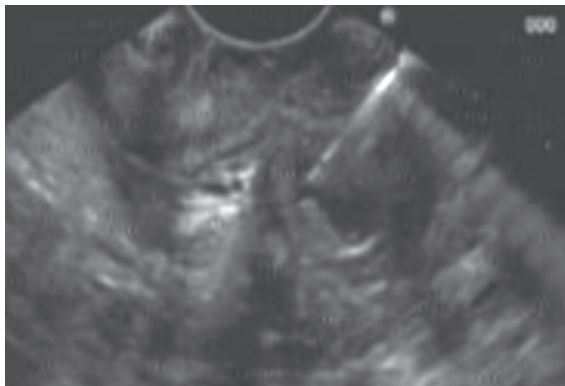
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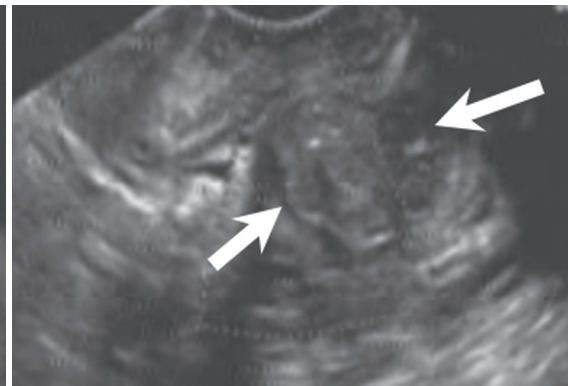
B



C



D



E

Fig. 10. EUS guided thrombin injection. 27-year-old male patient with pancreatitis, presenting with hematemesis. DSA and ultrasonography did not demonstrate pseudoaneurysm.

A. Schematic diagram. B. Axial CT image in venous phase showing pseudoaneurysm (arrow) within pancreas. C. EUS with color Doppler showing pseudoaneurysm with peripheral thrombus (arrows). D. Needle placed in pseudoaneurysm under EUS guidance prior to thrombin injection. E. EUS image showing thrombosed pseudoaneurysm after thrombin injection (arrows). A = artery, DSA = digital subtraction angiography, EUS = endoscopic ultrasonography, PsA = pseudoaneurysm

Embolization of Visceral Artery Pseudoaneurysms

after embolization (11). For pseudoaneurysms visible on ultrasonography, follow up with the same modality 24–48 hours after the procedure and possibly one month later is adequate. CTA is usually not required in asymptomatic patients, but becomes necessary when there is a strong clinical suspicion of recurrence and when pseudoaneurysm

is inaccessible by ultrasonography. Endovascular approach is the treatment of choice for recurrent pseudoaneurysms, and in failed cases, percutaneous or EUS approach may be attempted. Thus, follow up evaluation varies from case to case and initially includes clinical assessment, followed, if necessary, by ultrasonography or CTA.

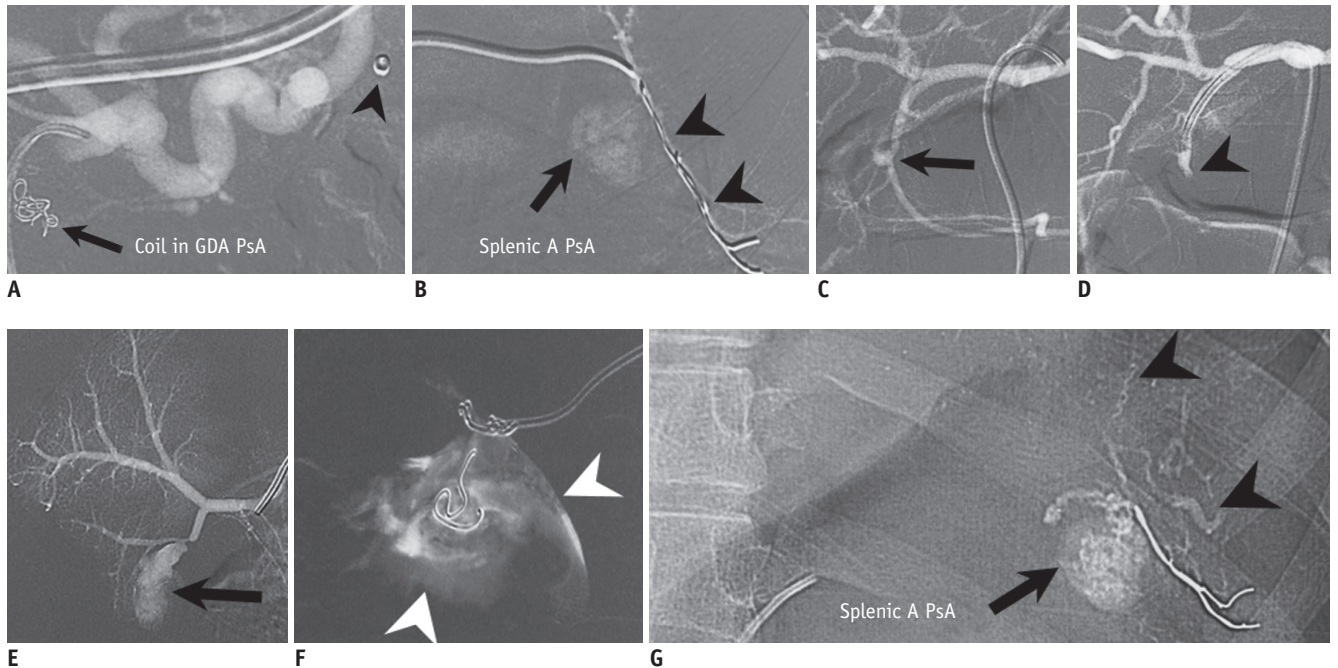


Fig. 11. Complications of embolization.

A. Coil embolization of pseudoaneurysm (arrow) with distal migration (arrowhead) into gastroepiploic artery due to undersize of coil. **B.** Oversized coil resulting in its straight deployment in inflow artery (arrowheads). Arrow shows splenic artery pseudoaneurysm. **C, D.** Gastroduodenal artery pseudoaneurysm (arrow) with dissection (arrowhead). **E, F.** Rupture of renal artery pseudoaneurysm (arrow) with extravascular perinephric leakage of contrast (arrowheads). **G.** Non-target embolization due to reflux of glue (arrowheads) into splenic artery branches. Arrow points to splenic artery pseudoaneurysm. A = artery, GDA = gastroduodenal artery, PsA = pseudoaneurysm

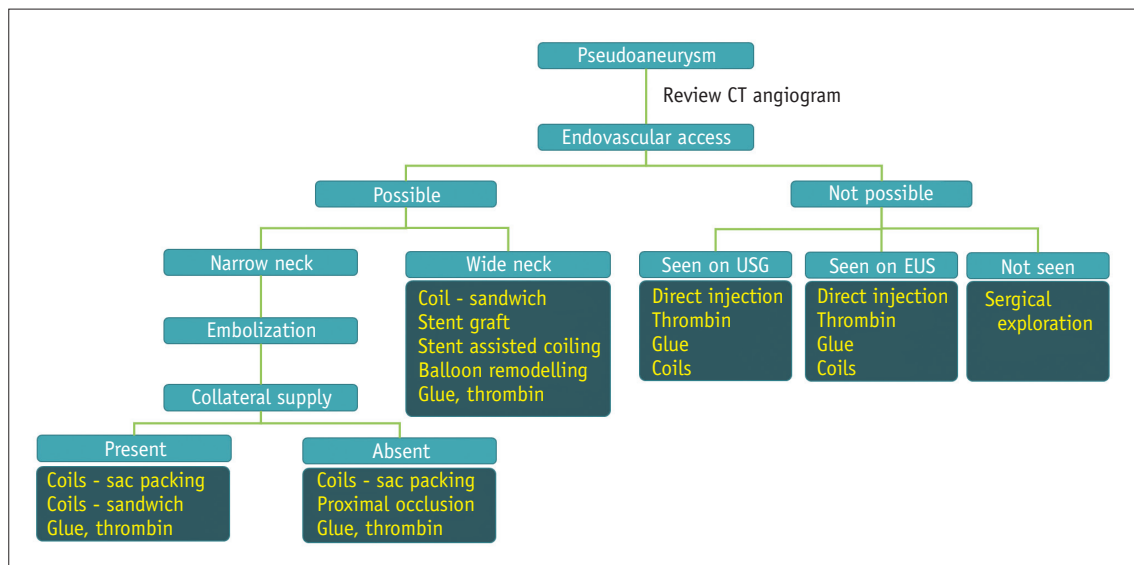


Fig. 12. Algorithm for management of visceral artery pseudoaneurysms. EUS = endoscopic ultrasonography, USG = ultrasonography

CONCLUSION

All visceral artery pseudoaneurysms should be treated due to high mortality of rupture cases. Radiological intervention is the treatment of choice. The approach, technique and agents chosen vary with size of the pseudoaneurysm and its neck, location of the pseudoaneurysm, type of the source vessel, presence of collateral supply and individual preference and expertise of the interventionist. Endovascular approach is the preferred technique in most cases. Percutaneous and EUS guided techniques are reserved for specific situations.

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