INTERVENTIONAL RADIOLOGY

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Strategy and management of severe hemorrhage complicating pancreatitis and post-pancreatectomy

Chao Zhang*
Ang Li* (iD)
Tao Luo* (iD)
Jia Li (iD)
Diangang Liu (iD)
Feng Cao (iD)
Jianxin Li (iD)
Fei Li (iD)

PURPOSE
Transcatheter arterial embolization (TAE) is increasingly used as the first-line treatment for hemorrhage complicating pancreatitis and post-pancreatectomy. However, the optimal therapeutic strategy remains unclear.

METHODS
Among 1924 consecutive patients, 40 patients with severe pancreatic hemorrhage in Xuanwu Hospital were enrolled between 2005 and 2017. Patients underwent angiography and direct TAE for primary diagnosis and treatment of bleeding. Repeat TAE, watch and wait, and laparotomy were used as the other therapeutic options. Patient data, technical success, and 90-day survival were identified.

RESULTS
Pancreatic diseases underlying hemorrhage included acute pancreatitis (n=19, 47.5%), chronic pancreatitis (n=12, 30%), and pancreatic cancer (n=9, 22.5%). A history of percutaneous catheter drainage or pancreatic surgery was seen in 29 patients (72.5%). There were 48 angiographies, 31 embolizations, and 5 laparotomies performed. Rebleeding occurred in 8 patients (20%); 4 of whom underwent re-embolization, 3 had laparotomy, and 1 had conservative treatment. Successful clinical hemostasis was achieved in 37 patients. Complications were observed in only 2 patients with renal failure and 1 patient with hepatic insufficiency. In total, 25 patients (62.5%) were alive at the 90-day follow-up.

CONCLUSION
Endovascular management is effective for achieving hemostasis in severe pancreatic hemorrhage with a high success rate and low recurrence, and laparotomy is not suitable for rebleeding cases.

From the Departments of General Surgery (C.Z., A.L., J.L., D.L., F.C., F.L. ✉ *feili35@126.com*) and Vascular Surgery (T.L., Jianxin.L.) Xuanwu Hospital, Capital Medical University, Beijing, China.

*These authors have contributed equally to this work.

P ancreas-associated hemorrhage is an uncommon but severe complication of pancreatic diseases. It includes acute pancreatitis (AP), chronic pancreatitis (CP), and iatrogenic bleeding, such as post-pancreatectomy hemorrhage (PPH) and pancreatic necrosectomy. Since pancreatic enzymes are released during pancreatitis or post-pancreatectomy, vascular structures, particularly the visceral arteries, are corroded by the proteolytic activity of these enzymes. The resulting acute hemorrhage has been recognized as a rapidly lethal condition, and the reported mortality rates range from 40% to 50% in patients with pancreatitis (1, 2) and from 30% to 50% in patients with PPH (3, 4). Recently, owing to rapid diagnoses using angiography and prompt retrieval using endovascular intervention, the mortality rate has been reduced considerably. However, the initial step and overall therapeutic strategy for pancreatic intra-abdominal hemorrhage or bleeding pseudoaneurysm remain controversial, particularly because of the failure to detect the bleeding site and to control the bleeding. Moreover, studies regarding massive hemorrhage are limited to review articles and short case series with the hemostasis methods, which still have no best therapeutic strategy.

The aim of the present study was to report a center-specific experience with angiography and transcatheter arterial embolization (TAE) as the first-step choice for the treatment of massive pancreatic hemorrhage, including severe bleeding pseudoaneurysm with AP, CP

and late PPH, to illustrate the effectiveness of this strategy and to compare the outcomes between the TAE procedures and surgical intervention in the management of pancreatic hemorrhage. Moreover, in the present study, the pre-hemorrhage clinical characteristics and other recent 10-year studies investigating pancreatic hemorrhage were reviewed.

Methods

This retrospective, observational study was conducted at the Department of General Surgery, Xuanwu Hospital, Capital Medical University. The local ethics committee approved the study according to the Declaration of Helsinki. Informed consent was obtained from each participant.

Patient selection

A retrospective review of the administrative diagnostic database was performed to identify patients with pancreatitis (International Classification of Disease (ICD)-10 codes K85 and K86) and pancreatic cancer (ICD-10 code C25) who were treated at Xuanwu Hospital of the Capital Medical University between January 2005 and December 2017. The medical records of the patients who underwent an endovascular procedure for acute hemorrhage, including gastrointestinal bleeding (intraluminal) and intraperitoneal bleeding/bleeding in the drainage (extraluminal), were obtained. Patients were enrolled in the study if they met the following criteria: 1) severe extra- or intraluminal hemorrhage in AP and CP associated with clinical shock and a rapid decrease in hemoglobin concentration >30 g/L requiring blood transfusion and 2) late PPH, defined as any hemorrhagic event that occurred >24 h after the end of pancreatic surgery and

graded B or C according to the International Study Group of Pancreatic Surgery (ISGPS) definition (5). Exclusion criteria were as follows: 1) early PPH (<24 h after the end of surgery) caused by insufficient hemostasis; 2) mucosal hemorrhage caused by peptic ulcer, anastomotic ulcer, or anastomotic dehiscence after pancreatic surgery; 3) stress gastrointestinal bleeding, hemorrhage in the abdominal wall vessel or muscle from the sinus tract after surgery or drainage intervention; and 4) direct surgical treatment as the primary treatment for hemorrhage without angiography diagnosis. Medical data regarding the patients' prehemorrhage clinical characteristics, management, and outcomes were retrospectively analyzed.

Angiography and TAE procedure

Endovascular treatment was performed if the hemodynamic stability of the patients was successfully maintained by fluids, blood transfusion (packed red blood cells and fresh frozen plasma), vasoconstrictor pumping, and ice saline stomach washing for intraluminal bleeding or uterine cavity gauze abdominal packing for extraluminal bleeding. All patients underwent angiography performed by four board-certified radiologists with 10 to 20 years of clinical experience in endovascular therapy. Digital subtraction angiography (DSA) was performed in all patients by accessing the femoral artery using a 5 F Simmons 1 catheter (Cook Medical). Superselective catheterization was achieved using a coaxially introduced 2.8 F microcatheter (Transcend; Boston Scientific). The TAE procedure was performed using pushable steel coils/microcoils (MWCE-35 3-3/5-8 or MWCE-18S 3-2; Cook Medical) and N-butyl cyanoacrylate (NBCA) (Glubran 2; GEM Srl) mixed with contrast at ratios ranging from 1:1 to 1:3 and/or gelfoam. The coaxial technique was used in all patients to prevent back bleeding, and the standard "two-point" technique was used to treat embolism and to control the bleeding artery both proximal and distal to the vascular lesion employing coils and/or NBCA; the sac was also packed with materials to treat embolism. After embolization, angiography was immediately repeated to confirm that the bleeding had ceased. The vascular sheath was removed after 24 h in case of recurrent bleeding.

Surgical intervention

The indication for urgent laparotomy was based on the following findings: 1) obvious bleeding that drained percutaneously via the abdominal drainage or nasogastric tube that was considered inaccessible to endovascular treatment; 2) serious ischemic complications caused by the TAE procedure, including ischemia of the intestinal artery and distal colic artery; and (3) failure of the TAE or repeat TAE procedures.

Outcomes

Patients were retrospectively followed up for 90 days after the treatments. The primary end point was technical success, which was defined as the absence of presentation for further hemorrhage. The secondary end points were as follows: 1) rebleeding, which was defined as the requirement for an additional procedure (angiography, repeat TAE, or laparotomy) due to hemorrhage; 2) 90-day survival, which was defined as patients who lived for 90 days after the hemorrhage and interventional treatment during follow-up; and 3) major complications (renal failure, hepatic insufficiency, and bowel ischemia), which was defined according to international reporting standards (6).

Statistical analysis

Patient characteristics, clinical presentations, and outcomes are expressed as median, interquartile range (IQR), or number (%), unless otherwise specified. The SPSS version 17.0 software (SPSS Inc.) was used for statistical analysis. Chi-square and Fisher's exact test were used to determine the advantage of the technique of hemostasis and the association between hemorrhage and patient clinical characteristics. A P value <0.05 was considered statistically significant.
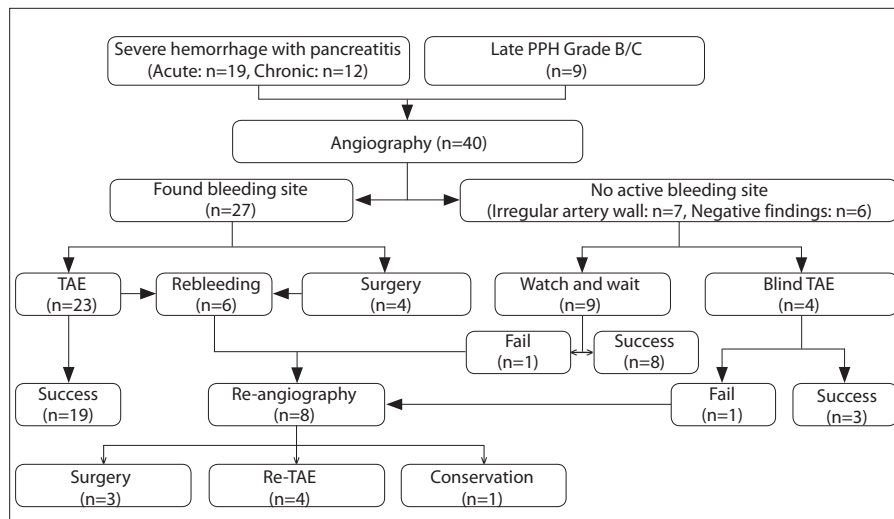
Results

A total of 1924 patients were identified between January 2005 and December 2017, with 306 patients with pancreatic tumor and 1618 patients with AP or CP. Of the patients, 658 (34.2%) underwent surgical or interventional treatment. Of the 1924 patients, 40 (2.1%) who experienced severe hemorrhage were included in the study. Nine patients experienced PPH, while severe hemorrhage was attributed to AP in 19 patients and CP in 12 patients. Patient data included the endovascular and surgical management of hemorrhage (Fig. 1).

The most common severe hemorrhage symptoms were bleeding from the abdominal drainage (n=28, 70%) and gastrointestinal tract (n=15, 37.5%). Other symptoms

Figure 1. Algorithm for the management of severe hemorrhage complicating pancreatitis and post-pancreatectomy. PPH, post-pancreatectomy hemorrhage; TAE, transarterial embolization.

included severe abdominal pain and high fever (>39°C). In total, 22 patients (55%) presented with hemorrhagic shock with a heart rate >100 beats/min and systolic blood pressure <100 mm Hg. The amylase levels before the endovascular procedure, particularly those in the drainage, were extremely high as shown in Table 1 (median, 600 U/L; IQR, 310–15 609 U/L), and these data were available for 23 patients. Table 1 shows the demographic and medical history of the study patients.

Concurrently, 29 patients (72.5%) had a history of interventional therapy or surgery, and the hemorrhage rate was 4.4% in 658 patients who underwent iatrogenic procedure. However, the hemorrhage rate with no surgical intervention was only 0.87% (χ^2=21.812, P = 0.000). Of the 29 patients who underwent surgical interventions, 16 (55.2%) underwent pancreatic necrosectomy debridement, including laparotomy and laparoscopy assisted, 4 (13.8%) underwent percutaneous catheter drainage (PCD), and 9 (34.5%) underwent pancreatoduodenectomy (Whipple procedure). The median bleeding time after surgical intervention was 9 days (IQR, 5.8–17.5 days).

Forty patients underwent a total of 48 DSA procedures (8 repeat DSAs for rebleeding). Active bleeding was observed in 27 patients with contrast extravasation, and bleeding pseudoaneurysm was observed in 10 patients at the first DSA diagnosis. Seventeen patients had an irregular arterial wall, including 10 patients with active bleeding. Six patients had a negative DSA presentation, while 34 arteries had a positive DSA presentation, which mainly included the splenic artery (SpA), gastroduodenal artery (GDA), pancreaticoduodenal artery (PDA) arcade, and branches of the superior mesenteric artery (SMA) (Fig. 2). Table 2 summarizes the details.

There were 31 procedures performed at the first DSA diagnosis; 27 cases were treated with TAE or blind (empirical) TAE (Fig. 3), while 4 cases underwent surgery for laparotomy. Nine cases followed the watch and wait (WAW) policy for observation due to suspected variceal hemorrhage of left-sided portal hypertension. With regard to the TAE materials, coils were used in 18 arteries (mean, 3.8 coils per artery) with the "two-point" technique, mainly for the SpA and GDA; NBCA was used in 9 arteries (1:1 to 1:3 dilution with lipiodol), mainly for the GDA and PDA arcade; and gelfoam was used in 4 arteries with coils using the "sandwich" technique. In 8 arteries, two different embolic materials were used in a single procedure, including coils and NBCA in 4 arteries and coils and gelfoam in 4 arteries. No misplaced coils were observed in the nontarget arteries on the final angiography. In 4 laparotomies and one repeat laparotomy, the choice was made according to the blood supply of the small intestine and colon, in case of ischemic complications. The branches of the SMA and inferior mesenteric artery (IMA) were suspected by DSA presentation, and during the operation, the bleeding sites were confirmed with one SMA, one right colic artery, one internal carotid artery (ICA), and two bleeding jejunal arteries.

Eight patients experienced rebleeding and underwent second DSA. Of the eight patients, one patient had no positive DSA presentation at the time of initial angiography and underwent conservative treatment, five patients suffered from rebleeding following TAE, and two patients suffered from rebleeding of the SMA branches following laparotomy. Among these patients, the rebleeding site was found in six patients as follows: two patients exhibited in situ rebleeding in the SpA, one patient exhibited rebleeding in the artery of the Drummond arcade (ICA–left colic artery), and three patients exhibited rebleeding in other arteries. The rebleeding site was not identified in one patient during repeat DSA. The repeat TAE procedure was performed in four patients with a positive DSA presentation, three patients underwent laparotomy for suspected rebleeding in the SMA, jejunal artery, and distal ICA, and one patient was followed using the WAW policy due to the lack of positive findings (Table 3).

Table 1 shows the procedure outcomes. Successful hemostasis without rebleeding was achieved in 32 patients (80%) during the initial decision for treatment or WAW, and overall technical success was obtained in 37 patients (92.5%). Only three patients died as a consequence of intra-abdominal bleeding, with one repeat TAE failure and two surgical failures (Table 3). Complications were observed in only three patients with AP, including two patients with renal failure and one patient with hepatic insufficiency after the TAE procedure due to NBCA reflux into the common hepatic artery. There were no occurrences of bowel ischemia. Splenic infarction was excluded in the present study. In total, 25 patients (62.5%) were alive for 90 days after hemorrhage, and 15 patients (37.5%) died within the 90-day follow-up with rebound of serious abdominal infection and sepsis (n=7, 17.5%), multiple organ dysfunction syndrome (n=4, 10.0%), hemostasis failure (n=3, 7.5%), and lung infection (n=1, 2.5%). There was no rebleeding within the 90-day follow-up period.

We compared the outcomes between the TAE procedure and surgery for laparotomy following DSA diagnosis (Table 4). Although there was no significant difference in the first technical success (24/27 vs. 2/5; P = 0.085) between the patients who underwent the TAE procedure and

Table 1. Patient baseline characteristics and medical history

Patient characteristics (n=40)	
Gender (male/female)	29/11
Age (years), median (IQR)	51 (41.0–62.0)
BMI (kg/m^2), median (IQR)	26.8 (24.9–28.2)
Disease cause, n (%)	
Acute pancreatitis	19 (47.5)
Chronic pancreatitis	12 (30)
Pancreatic tumor	9 (22.5)
Signal bleeding symptom, n (%)	
Bleeding in drainage	28 (70)
GI bleeding	15 (37.5)
Both bleeding GI and drainage	3 (7.5)
Hemorrhagic shock, n (%)	22 (55)
Severe abdominal pain	10 (25)
High fever (>39 °C)	4 (10)
Laboratory index, median (IQR)	
Amylase of blood before DSA (U/L)	359 (69–1103)
Lipase of blood before DSA (U/L)	233 (65–811)
Amylase of drainage before DSA (U/L)	600 (310–15 609)
Hemoglobin before DSA (g/L)	65 (36–80)
Platelet before DSA (×10^{10}/L)	8.6 (21–215)
APTT before DSA (s)	75 (52–135)
Blood transfusion, units of packed RBCs , median (IQR)	30 (15–45)
Duration in ICU (days), median (IQR)	22 (12–52)
Intervention or surgery before bleeding, n (%)	29 (72.5)
Debridement	16 (55.2)
PCD	4 (13.8)
Whipple	9 (34.5)
Bleeding time after surgery (days), median (IQR)	9 (5.8–17.5)

IQR, interquartile range; BMI, body mass index; GI, gastrointestinal tract; DSA, digital subtraction angiography; APTT, activated partial thromboplastin time; RBC, red blood cells; ICU, intensive care unit; PCD, percutaneous catheter drainage.

those who underwent laparotomy, the TAE group clearly achieved a significantly higher overall technical success rate than the surgery group (26/27 vs. 2/5; *P* = 0.008). Indeed, the TAE group exhibited significantly higher survival rate than the surgery group during the 90-day follow-up (20/27 vs. 1/5; *P* = 0.037).

Discussion

In the present study, the characteristics of pancreatitis-related hemorrhage and PPH were described, and the endovascular management of these patients was evaluated as the first rescue procedure. To date, most published studies have focused on evaluating hemorrhage associated with a single disease, such as bleeding pseudoaneurysm of AP and CP or PPH. Only a few series have reported the outcomes of TAE in both diseases, but these studies did not show the standard for severe abdominal hemorrhage or the clinical characteristics of the hemorrhage cases (7, 8). In our study, the standard mainly depended on the PPH of the ISGPS definition with Grade B/C, as well as the pancreatitis-related hemorrhage. The signs of severe hemorrhage in patients suffering from pancreatitis and post-pancreatectomy include bleeding from the gastrointestinal tract or abdominal drainage, hemorrhagic shock, and rapid decrease in hemoglobin.

Remarkably, most patients had a pancreatic fistula before the bleeding occurred, with evidence of elevated amylase in the drainage. Pancreatic fistula and severe inflammation result in the local spread of exocrine proteolytic and lipolytic enzyme-rich fluids that weaken tissue and lead to elastolytic erosions of the vessel wall (9). Thus, it is firmly believed that the most important factor associated with the risk of bleeding is pancreatic fistula after pancreaticoduodenectomy (10) and pancreatic necrosectomy (11). Furthermore, vessel injury may occur due to iatrogenic causes after pancreatic surgery and percutaneous drains (8, 12). Surgical and draining procedures that are applied for long-term lavage and treatment of pancreatic fluid collections also increase the risk of injuring the visceral artery. Even a slight injury around the pancreas could damage the weakened arterial wall or form pseudoaneurysms. In our study, 29 patients (72.5%) had PCD or surgical history. Indeed, the most important factors associated with the risk of pancreatic bleeding are pancreatic fistula and iatrogenic injury.

During the previous decade, reviews have revealed that endovascular procedures, including angiography and TAE, were more frequently used to detect and to control bleeding because TAE can be applied in patients who cannot tolerate laparotomy or anesthesia (1, 13). However, surgical intervention was less frequently used without any comparison with the endovascular procedures. It is particularly important that our results revealed a significant advantage of the TAE procedure over laparotomy with respect to the technical success and 90-day survival rates. Moreover, most previous studies reported that the success rates of endovascular procedures are high with multiple embolizations and prolonged supportive treatment. Taina et al. (14) study,

Table 2. Details of angiographic findings, treatments, and outcomes

Treatment details	n (%)
Angiographic presentation (n=40)	
Contrast extravasation	27 (55.0)
Bleeding pseudoaneurysm	10 (20.0)
Irregular artery wall	17 (37.5)
Negative findings	6 (15.0)
Involved artery (n=34)	
SpA	8 (23.5)
GDA	7 (20.6)
SMA	1 (2.9)
PDA (superior/inferior)	4 (11.8)
RCA	3 (8.8)
LCA	1 (2.9)
ICA	1 (2.9)
Jejunal artery	2 (5.9)
IMA	2 (5.9)
Gastric artery (right/left)	2 (5.9)
Gastroepiploic artery (right/left)	2 (5.9)
Phrenic artery (left)	1 (2.9)
First technique (n=40)	
TAE	23 (57.5)
Blind (empirical) TAE	4 (10.0)
Surgery	4 (12.5)
Watch and wait	9 (22.5)
First TAE materials	
Coil trapping alone	18 (52.9)
NBCA alone	5 (23.5)
Combine coiling and NBCA	4 (11.8)
Combine coiling and gelfoam	4 (11.8)
Complications	3
Renal failure	2 (5.0)
Hepatic insufficiency	1 (2.5)
Outcome	
First technical success	32/40 (80.0)
Re-intervention	7/40 (17.5)
Overall technical success	37/40 (92.5)
90-day survival	25/40 (62.5)

SpA, splenic artery; GDA, gastroduodenal artery; SMA, superior mesenteric artery; PDA, pancreaticoduodenal artery; RCA, right colic artery; LCA, left colic artery; ICA, internal carotid artery; IMA, inferior mesenteric artery; TAE, transarterial embolization; NBCA, N-butyl cyanoacrylate.

involving 58 patients with bleeding pancreatic pseudoaneurysms, achieved a success rate of 96.6% and a mortality rate of 13.8% without hemorrhage classification. However, Nicole et al. (15) reported a 30-day survival rate of 70% in the embolization group, which included patients with Grade B/C PPH. Other studies also revealed a higher success rate, but more recent studies demonstrated varying mortality rates (16–18). According to our data, the first technical success rate was 80% in 32 patients who underwent interventional treatment or observation. The overall technical success rate was 92.5%, and the 90-day survival rate was 62.5%.

The materials used in the TAE procedures may vary (e.g., embolic agents such as coils, NBCA, gelfoam, and particles or stent grafts). First, coils are the most widely used embolic materials in recent studies. In our series, coils and microcoils were used in approximately 75% of the patients with the "two-point" or "sandwich" technique to occlude the efferent and afferent arteries, and minimize the potential for rebleeding. Importantly, the arcade, including the GDA-SMA (PDA arcade), SMA-IMA (Riolan arcade or Drummond arcade), and SPA-left gastroepiploic artery, should be carefully attended to during the procedure. Coiling feeders from both ends of the arcade are usually required; in one patient, the rebleeding, which was due to an embolism, occurred only at one end of the arcade. With regard to the pseudoaneurysm sac, we packed the entire sac when bleeding of the pseudoaneurysm occurred. One study indicated that packing the sac with coils increases the risk of rupture (19), but these ruptures did not occur in our study. In addition, NBCA has been increasingly reported in recent studies, the liquid nature of this embolic agent allows its delivery through the pathologic or tortuous vessels via the microcatheter and filling the bleeding sac without the risk of new vessel injury or ruptured sac (7, 20). In addition, NBCA can be used individually or in combination with other embolic materials, such as coils and gelfoam. However, NBCA is more difficult to control than coils because an assessment of the flow rate across the pseudoaneurysm or bleeding position is required to calculate the NBCA/contrast ratio, and this affects the viscosity and polymerization rates. An NBCA concentration of 20%–50% is recommended to allow filling and complete exclusion of the bleeding or pseudo-
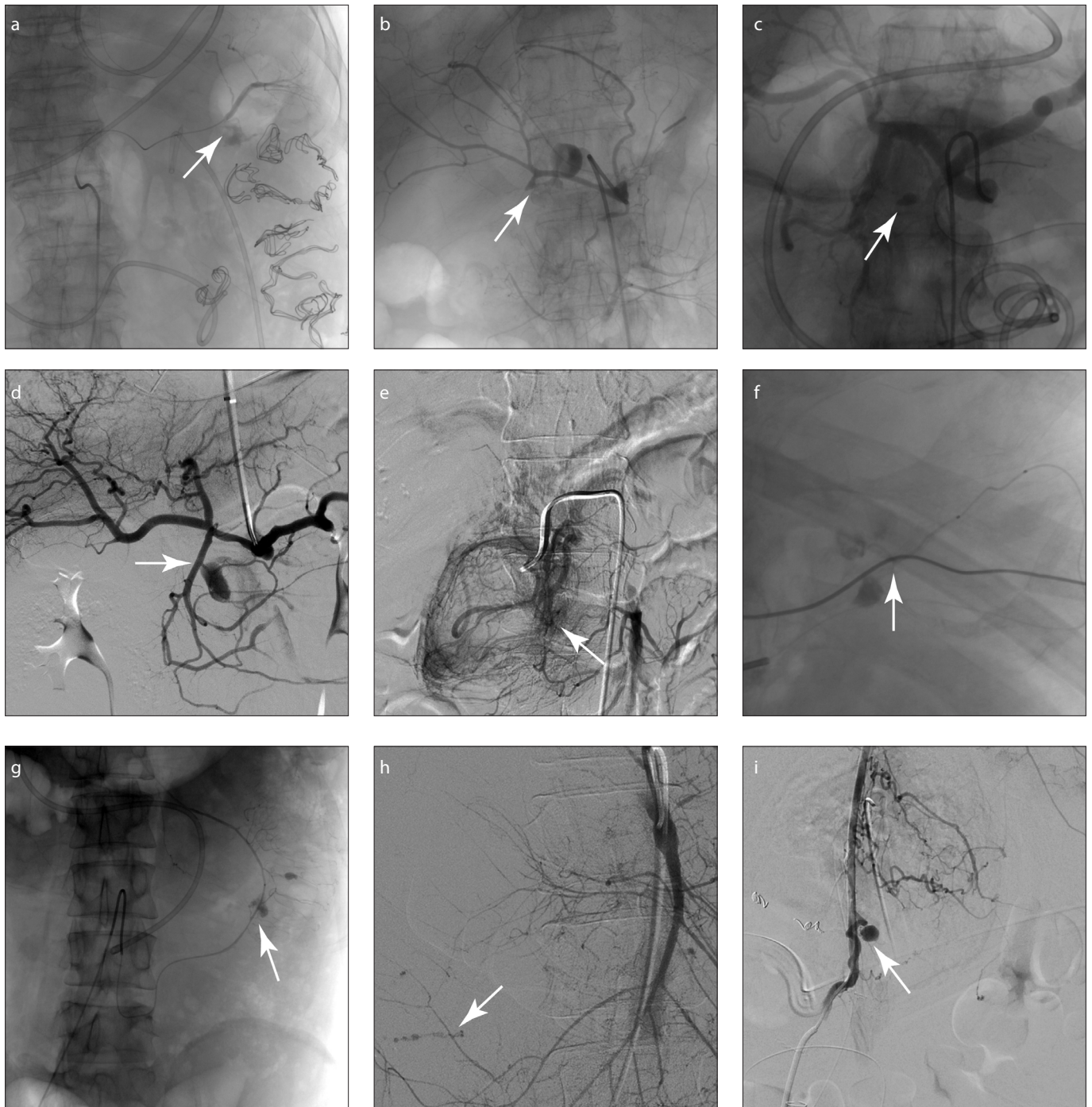
Figure 2. a–i. DSA images show the bleeding site and bleeding pseudoaneurysm *(arrow)*, in **(a)** splenic artery, **(b, c)** gastroduodenal artery, **(d, e)** pancreaticoduodenal artery, **(f)** right gastric artery, **(g)** inferior mesenteric artery, **(h)** jejunal artery, and **(i)** left phrenic artery.

aneurysm. We used NBCA in 10 cases at a 25%–50% concentration. However, in one case, hepatic insufficiency occurred during the process of GDA embolism due to occlusion of the hepatic artery; we believe that in this case NBCA overflowed into the GDA with reflux. Gelfoam is a temporary embolic material that may be rapidly resorbed by pancreatic proteolytic enzymes and has the

potential to migrate into the small arteries, potentiating tissue ischemia; thus, it is usually used between two coils in a "sandwich" technique (19).

Notably, the rebleeding rate was as high as 20%, which required an additional endovascular procedure or laparotomy; this rate was as high as that reported in most published studies (ranging between 20%

and 30%) (21, 22). Current studies indicate that the mortality rates reach 40% to 50% following direct surgery for the treatment of initial pancreatic bleeding, and no related studies revealed the mortality rate in rebleeding cases (23, 24). In our study, three patients with rebleeding eventually died following repeat laparotomy, demonstrating that repeat TAE might be a better strat-
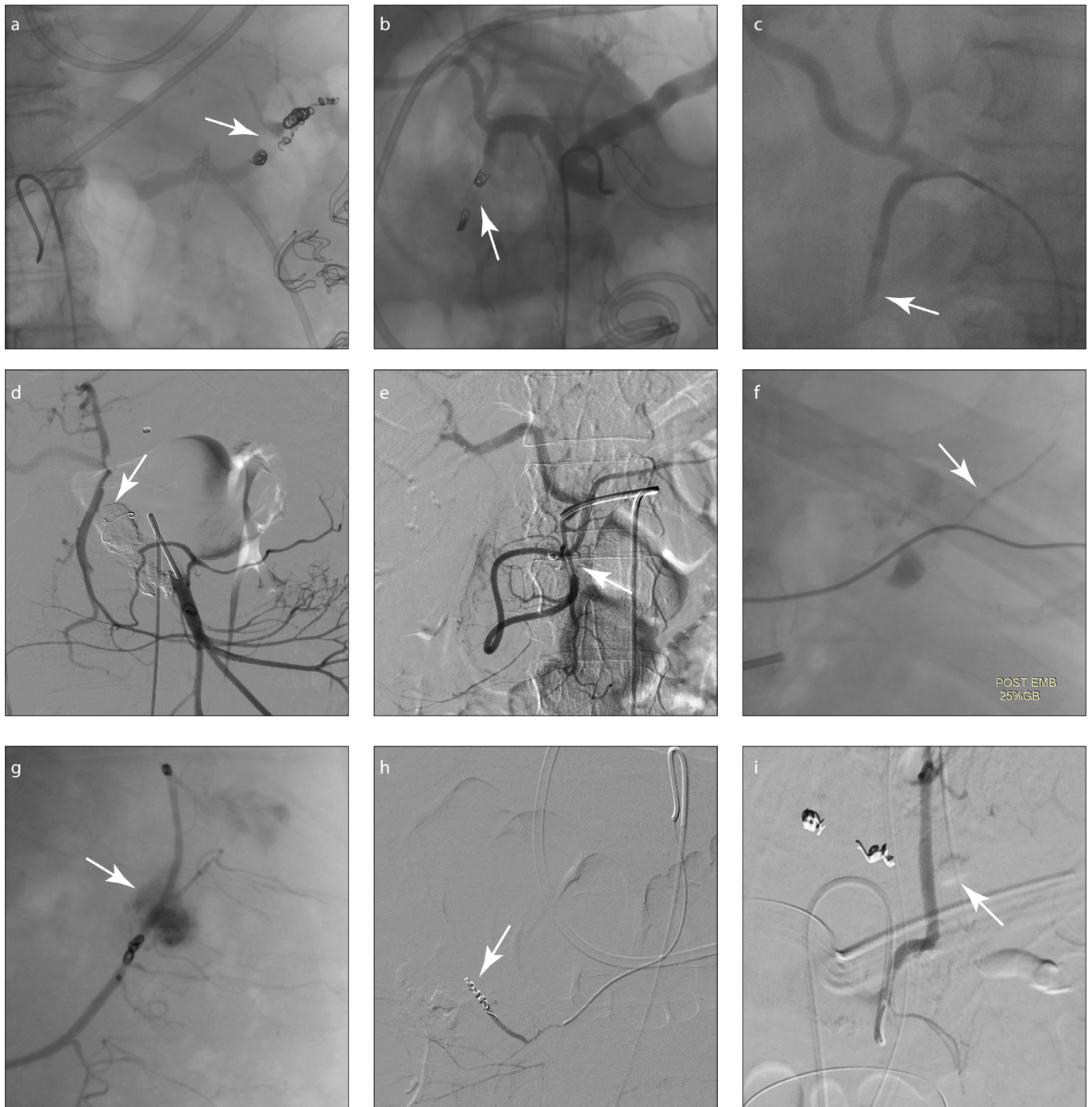
Figure 3. a–i. Post-embolization DSA demonstrated no contrast leak in the abdomen with embolization procedure ("sandwich" or "two-point" technique) of **(a)** splenic artery with coils and N-butyl cyanoacrylate (NBCA), **(b)** gastroduodenal artery with coils and gelfoam, **(c)** gastroduodenal artery with NBCA, **(d, e)** pancreaticoduodenal artery with coils and/or NBCA, **(f)** right gastric artery with NBCA, **(g)** inferior mesenteric artery with coils, **(h)** jejunal artery with coils, and **(i)** left phrenic artery with NBCA.

egy for the treatment of rebleeding than repeat laparotomy. Studies of negative angiography with no detectable bleeding site vary in the literature; the negative rate has increased in recent years from 15% to 44% in several large-scale studies (11, 14, 25–27). In our studies, no bleeding site was detected in 13 patients using angiography. A high success rate was achieved in patients who received empirical TAE in our study. Recently, interventional radiologists have become more active in performing empirical TAE of arteries such as GDA and SpA and this technique is increasingly important in treating hemorrhage in patients with negative angiographies.

Our policy was to perform angiography in all patients with suspected severe pancreatic hemorrhage after maintaining basic hemodynamic stability. Angiography can clearly identify the rupture position in an artery, whereas computed tomography scan can only locate hematoma. Moreover, hemostasis with TAE could be continued

Table 3. Case details and outcomes in patients with rebleeding after initial management

No.	Disease	Previous surgery	Pancreatic fistula	Hg	Bleeding day after surgery	Location	First treatment	First TAE material	Rebleeding day after first treatment	Location	Second treatment	Second TAE material	Outcome
1	AP	Debridement (lap-assisted)	Yes	62	17	SpA	TAE	Coils+NBCA	7	In situ	Re-TAE	Coils	Died
2	CP	PCD	No	62	12	GDA	TAE	NBCA	12	SpA	Re-TAE	Coils	Died
3	CP	Whipple	Yes	50	26	GDA	TAE	Coils+gelfoam	7	–	WAW	–	Alive
4	AP	Debridement	Yes	60	7	ICA	TAE	Coils	9	In situ (LCA)	Re-TAE	Coils	Alive
5	CP	Debridement (lap-assisted)	No	44	15	LGA	TAE	Coils (blind)	8	Phrenic A.	Re-TAE	NBCA	Alive
6	AP	Debridement	Yes	72	22	SMA	Laparotomy	–	6	Jejunal A.	Laparotomy	–	Died
7	AP	Debridement (lap-assisted)	Yes	40	5	RCA	Laparotomy	–	0	–	Laparotomy	–	Died
8	AP	PCD	Yes	80	6	–	WAW	–	15	ICA	Laparotomy	–	Died

Hg, hemoglobin; TAE, transarterial embolization; AP, acute pancreatitis; lap-assisted, laparoscopy-assisted; SpA, splenic artery; NBCA, N-butyl cyanoacrylate; Re-TAE, repeat TAE; CP, chronic pancreatitis; PCD, percutaneous catheter drainage; GDA, gastroduodenal artery; WAW, watch and wait; ICA, internal carotid artery; LCA, left colic artery; LGA, left gastroepiploic artery; SMA, superior mesenteric artery; RCA, right colic artery; A., artery.

Table 4. Comparison of technical success and outcomes between the TAE and surgery groups

Group	n	First technical success	Overall technical success	90-day survival
TAE	27	24	26	20
Surgery	5	2	2	1
Fisher's P value		0.085	0.008*	0.037*

TAE, transarterial embolization.
*P < 0.05.

after angiography without delay due to transferring the patient, which is superior to any other examination. Based on these advantages and our results, we propose an algorithm for managing severe hemorrhage occurring in the setting of pancreatitis or PPH as shown in Fig. 1. First, TAE should be performed in patients with explicitly active bleeding with contrast extravasation. Blind empirical TAE also should be attempted if the patient has a negative DSA presentation for active bleeding, particularly in patients with an abnormal vascular wall, such as a pseudoaneurysm-related irregular vascular wall. Laparotomy should be reserved for patients with active bleeding that is not suitable for TAE according to the blood supply to the organ, such as the SMA or celiac trunk, common hepatic artery, and patients with unstable hemodynamics, or rebleeding cases. The WAW policy could be adopted only in hemodynamically stable negative DSA patients who are suspected to have massive variceal hemorrhage due to left-sided portal hypertension. In the present study, 9 cases were suspected with massive variceal hemorrhage, and 8 cases achieved hemostasis with conservative treatment. Rebleeding cases require angiography to be performed again; repeat TAE should be performed for in situ rebleeding or a new rupture; a conservative treatment may be an alternative for stable patients with rebleeding, but surgery appears to be of no benefit in rebleeding cases.

The limitations of the current study are its retrospective nature in a single center and the length of the retrospective time, which was >10 years in some cases. Although the inclusion criteria were limited to Grade B to C according to the ISGPS definition, heterogeneity existed, and the study included patients undergoing pancreatic surgery and those suffering from AP or CP because severe hemorrhage is a rare but potentially lethal complication of pancreatic diseases. Additionally, the patients' characteristics could have been biased because only patients who underwent angiography first were selected; patients who were treated directly via surgical intervention or endoscopy without angiography were excluded from the study.

In conclusion, endovascular techniques could be the optimal choice for diagnosis and management of pancreatic bleeding. TAE is the main component in the proposed algorithm with other measures, such as observation or surgery, used in cases where TAE is not suitable. Laparotomy is not suitable for rebleeding cases, as it results in low technical success rate and survival rate. Further investigation is required to identify the factors predictive of rebleeding risk and develop methods to keep the mortality rate in an acceptable range.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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