Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

# Complications and prognosis of hepatic artery intervention for hemorrhage after pancreaticoduodenectomy: a multicenter retrospective study

**Bangjian Zhou**
the Fourth Affiliated Hospital of Anhui Medical University
**Wuhao Li**
the Fourth Affiliated Hospital of Anhui Medical University
**Gongneng Sun**
the Fourth Affiliated Hospital of Anhui Medical University
**Wei Qiu**
the Fourth Affiliated Hospital of Anhui Medical University
**Xiaoli Zhu**
First Affiliated Hospital of Soochow University
**Yu Yin**
First Affiliated Hospital of Soochow University
**Jun Yang**
First Affiliated Hospital of Soochow University
**Huanyu Chen**
the Fourth Affiliated Hospital of Anhui Medical University
**Caifang Ni**
First Affiliated Hospital of Soochow University
**Kewu He**
hekewu@ahmu.edu.cn

the Fourth Affiliated Hospital of Anhui Medical University

---

**Research Article**

**Keywords:** Post pancreaticoduodenectomy hemorrhage, interventional therapy, hepatic artery embolization, covered stent implantation, complications

**Posted Date:** June 3rd, 2026

**DOI:** https://doi.org/10.21203/rs.3.rs-9759345/v1

**License:** This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

**Additional Declarations:** No competing interests reported.

# Abstract

**Objective** To investigate the incidence of complications and their effect on prognosis in patients with post pancreaticoduodenectomy hemorrhage (PPH) after transcatheter arterial embolization (TAE) or covered stent implantation (CSI).

**Methods** The clinical data of patients who underwent common hepatic artery or proper hepatic artery intervention (TAE or CSI) due to PPH were retrospectively analyzed. The intervention method, hemostasis success rate, complications, and mortality were statistically analyzed.

**Results** A total of 113 patients were included (TAE:81, CSI:32). (1) Success rate of hemostasis: 110 patients (97.35%) had successful hemostasis in both groups. (2) Complications: The liver function indexes in the TAE group were worse than those in the CSI group: 88.89% (TAE: 72/81) vs. 53.13% (CSI: 17/32). (3) Mortality: The total mortality rate during hospitalization was 31.86% (36/113). The total mortality rate 1 year after surgery was 40.71% (46/113).

**Conclusion** The risk of liver injury (especially liver failure) and mortality in PPH patients after hepatic artery embolization are significantly higher than those in the CSI group. CSI can better protect liver function while effectively stopping bleeding, and may be a better choice for patients with relatively stable hemodynamics.


# Introduction

Post pancreaticoduodenectomy hemorrhage (PPH) is one of the most serious complications after Pancreaticoduodenectomy (PD), with an incidence of 3%-30% and a mortality rate of 11%-31% [1–3]. Once PPH occurs, the bleeding is rapid and fatal. The main responsible vessels for PPH are the celiac trunk and its branches [2]. Among them, the most common bleeding is from the gastroduodenal artery, common hepatic artery and its branches [4]. The stump of the gastroduodenal artery after PD is also a prone site for pseudoaneurysms [5].

For postoperative bleeding or pseudoaneurysms of the celiac trunk and its branches, interventional therapy has become a common emergency treatment for PPH [6]. Interventional therapy is minimally invasive and achieves rapid hemostasis; it can simultaneously diagnose and treat PPH, thereby controlling life-threatening bleeding. It mainly included transcatheter arterial embolization (TAE) and covered stent implantation (CSI) [7]. Interventional therapy is less invasive, stops bleeding quickly, and can diagnose and treat PPH at the same time.

Complete embolization can be achieved immediately during TAE, but this method increases the risk of serious liver complications such as liver abscess caused by liver ischemia/biliary ischemia [3, 8, 9]. Due to the change in the hepatic arterial supply, it may be difficult to achieve complete hemostasis of life-threatening bleeding and preserve hepatic arterial blood flow at the same time. In the past decade, CSI has become an effective treatment for PPH. Compared with TAE, CSI can preserve hepatic arterial blood

flow [9, 10]. A previous CSI-related study showed that CSI had a lower incidence of bleeding recurrence and liver function injury complications compared with TAE [11]. However, other studies have shown that the 30-day mortality and recurrent bleeding rates of CSI are not better than TAE [8, 12].

Will embolization of the hepatic artery cause serious complications leading to the patient's death? Is covered stent implantation the preferred choice for intervention of the hepatic artery? Whether TAE or CSI is given priority in the emergency treatment of such PPH patients remains to be further verified. Therefore, we conducted this multicenter retrospective study. We aimed to investigate the current status of diagnosis and treatment in patients with PPH. We also analyzed complications following hepatic artery intervention and their impact on prognosis. This study seeks to enhance the role of interventional diagnosis and treatment in the management and outcomes of PPH.

## Materials and methods

# General information

Patient selection: This study was a multicenter retrospective study, and the clinical data of all PPH patients from the Fourth Affiliated Hospital of Anui Medical University and the First Affiliated Hospital of Soochow University from January 2015 to December 2024 were statistically analyzed. The study was approved by the local ethics committee of each hospital (KYXM-202601-010, 2024 – 461). All patients underwent DSA examination. Inclusion criteria: (1) pancreaticoduodenectomy; (2) complete clinical data; (3) CT/DSA diagnosis of hepatic artery and gastroduodenal artery bleeding/pseudoaneurysm. Exclusion criteria: (1) non-pancreaticoduodenectomy postoperative bleeding; (2) simple gastroduodenal artery stump or branch embolization; (3) missing clinical data or lost to follow-up; (4) severe cardiopulmonary function or liver and kidney function abnormalities.

## Diagnosis

Hepatic artery, gastroduodenal artery bleeding or pseudoaneurysm: PPH patients experience abdominal pain, abdominal distension, hematemesis, melena, bloody fluid drainage and other clinical symptoms after surgery. Blood routine monitoring shows that the patient's hemoglobin is progressively decreasing or hemoglobin does not increase under blood transfusion. Once PPH is suspected, contrast-enhanced abdominal CT should be performed immediately, and a consultation with the interventional radiology and vascular surgery department may be requested for emergency interventional surgery. Abdominal enhanced CT may reveal mixed high-density shadows in the right upper and middle abdomen. DSA angiography may show contrast agent overflow or concentration in the hepatic and gastroduodenal arteries. If the patient's bleeding is relatively stable, a CBCT scan is performed to identify the bleeding vessel, which is conducive to rapid and accurate embolization/stent placement.

## Treatment

TAE/CSI is performed based on the bleeding situation:DSA examination shows obvious contrast agent spillage. For patients with heavy bleeding or even hemorrhagic shock, immediate embolization is performed. The gastroduodenal artery stump or common hepatic artery is embolized with a coil. This continues until contrast agent spillage stops and the patient's vital signs gradually stabilize.

Gastroduodenal artery stump/hepatic artery pseudoaneurysm formation: DSA examination shows contrast agent concentration. Hepatic artery embolization or hepatic artery covered stent implantation is then performed. The distal end of the stent should exceed the gastroduodenal artery stump. If bleeding from the gastroduodenal artery stump is also present, the decision to perform gastroduodenal artery stump embolization is based on the patient’s basic vital signs.

## Efficacy evaluation

Observation indicators: (1) Interventional treatment: interventional treatment method and hemostasis success rate; (2) Changes in laboratory indicators after interventional treatment; the occurrence of complications such as liver failure, liver infarction, liver abscess, and biloma.

Follow-up indicators: (1) Imaging indicators: abdominal enhanced CT within 1–7 days and the first month after interventional treatment; (2) Patients' mortality rate during hospitalization and 1-year mortality rate.

# Statistical analysis

Data analysis was performed from January 2026 to March 2026 using SPSS version 26.0. Measurement data that conformed to normal distribution were expressed as "mean () ± standard deviation (δ)", and those that did not conform to normal distribution were expressed as median (M) + interquartile range (P25, P75); count data were expressed as frequency (sample rate). Paired t-test and rank sum test were used for comparison between groups. $P < 0.05$ was considered statistically significant.

## Results

# Baseline data

A total of 276 PPH patients were included in this study. According to the hepatic artery embolization or stent implantation, 113 PPH patients were finally included, including 81 patients with hepatic artery embolization and 32 patients with stent implantation.

Among the 113 patients, 31 (27.43%) patients had pancreatic malignant tumors, 8 (7.08%) patients had pancreatic benign tumors, 25 (22.12%) patients had bile duct cancers, 7 (6.19%) patients had gallbladder cancers, 19 (16.81%) patients had ampullary borderline tumors, 13 (11.50%) patients had duodenal papillary cancer, and 10 (8.85%) patients had trauma. There was no statistical difference in the baseline data of the two groups of PPH patients (Table 1).

Table 1
Baseline characteristics of 113 patients

| Parameters | TAE (n = 81) | CSI (n = 32) | *p* value |
|---|---|---|---|
| Age, years (median, IQR) | 63.64 ± 11.83 | 62.25 ± 14.67 | 0.634 |
| ≥ 60 | 59 (72.84%) | 21 (65.62%) | |
| <60 | 22 (27.16%) | 11 (34.38%) | |
| Sex, n [%] | | | 0.379 |
| Female | 27 (33.33%) | 8 (25.00%) | |
| Male | 54 (66.67%) | 24 (75.00%) | |
| Nature of the disease [%] | | | 0.956 |
| Bengin | 13 (16.05%) | 5 (15.62%) | |
| Malignant | 68 (83.95%) | 27 (84.38%) | |
| Surgical duration (min) | 254.23 ± 64.63 | 256.97 ± 67.86 | 0.842 |
| ≥ 200 | 58 (71.60%) | 26 (81.25%) | |
| <200 | 23 (28.40%) | 6 (18.75%) | |
| Surgical methods | | | 0.206 |
| Radical pancreaticoduodenectomy | 61 (75.31%) | 21 (65.62%) | |
| Pancreatic body tail + splenectomy | 7 (8.64%) | 3 (9.38%) | |
| Pancreaticoduodenectomy with pylorus preservation | 10 (12.35%) | 5 (15.62%) | |
| Pancreatic head resection with preservation of the duodenum | 3 (3.70%) | 3 (9.38%) | |
| Pancreatic fistula | 23 (28.40%) | 7 (21.88%) | 0.470 |
| Haemorrhage time | | | 0.306 |
| Early bleeding | 4 (4.94%) | 2 (6.25%) | |
| late haemorrhage | 77 (95.06%) | 30 (93.75%) | |
| Degree of haemorrhage | | | 0.284 |
| Light bleeding | 19 (23.46%) | 12 (37.50%) | |
| Severe haemorrhage | 62 (76.54%) | 20 (62.50%) | |
| haemorrhage site | | | 0.442 |

| Parameters | TAE (n = 81) | CSI (n = 32) | *p* value |
|---|---|---|---|
| Gastrointestinal haemorrhage | 39 (48.15%) | 18 (56.25%) | |
| abdominal haemorrhage | 42 (51.85%) | 14 (43.75%) | |
| Clinical haemorrhage grade | | | 0.460 |
| A | 3 (3.70%) | 1 (3.12%) | |
| B | 35 (43.21%) | 17 (53.13%) | |
| C | 43 (53.09%) | 14 (43.75%) | |

## Interventional treatment

All 113 patients underwent interventional treatment successfully, of which 66 (58.41%) had positive gastroduodenal artery stump angiography, 47 (36.28%) had positive hepatic artery angiography. 17 patients had pseudoaneurysm angiography: 3 patients underwent hepatic artery stent implantation, and 14 underwent embolization. There was no statistical difference in the preoperative ECOG score, Child-Pugh score, ALBI score, hemoglobin reduction, and hemorrhagic shock between the embolization and stent groups (Table 2).

Table 2
Preoperative bleeding severity and DSA results

| Parameters | TAE (n = 81) | CSI (n = 32) | *p* value |
|---|---|---|---|
| Severity of haemorrhage | | | |
| Reduced haemoglobin | 42.94 ± 18.79 | 36.72 ± 20.64 | 0.126 |
| haemorrhagic shock | 35 (43.21%) | 12 (37.50%) | 0.582 |
| ECOG score | | | 0.171 |
| 2 | 10 (12.35%) | 6 (18.75%) | |
| 3 | 56 (69.14%) | 23 (71.88%) | |
| 4 | 15 (18.52%) | 3 (9.38%) | |
| Child-Pugh score | 8.01 ± 1.15 | 7.84 ± 1.30 | 0.499 |
| ALBI score | -1.71 ± 0.47 | -1.84 ± 0.55 | 0.215 |
| haemorrhage site | | | 0.998 |
| Gastroduodenal artery stump | 45 (55.56%) | 21 (65.63%) | |
| common hepatic artery | 7 (8.64%) | 5 (15.63%) | |
| Proper hepatic artery | 29 (35.80%) | 6 (18.75%) | |

DSA:Digital subtraction angiography; ECOG:Eastern Cooperative Oncology Group; ALBI:Albumin-bilirubin.

**Changes in liver function, inflammatory indexes, blood coagulation and creatinine after intervention in patients with PPH**

All 113 patients were followed up for changes in liver function after intervention. With the exception of preoperative total bilirubin (P = 0.041), alanine aminotransferase (P = 0.010), alkaline phosphatase (P = 0.021), and prothrombin time (P = 0.037), which were statistically significant, the remaining preoperative factors were not statistically significant in all patients. On the first day after intervention, there were statistical differences in the levels of total bilirubin (P < 0.001), alanine aminotransferase (P < 0.001), aspartate aminotransferase (P < 0.001), and alkaline phosphatase (P = 0.011), prothrombin time (P = 0.010), Serum creatinine (P = 0.031) between the embolization group and the stent group. On the 7th day after intervention, there were statistical differences in the levels of total bilirubin (P < 0.001), alanine aminotransferase (P < 0.001), aspartate aminotransferase (P < 0.001) between the embolization group and the stent group. The levels of total bilirubin, alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase in the postoperative embolization group were higher than those in the stent group, and the level of prealbumin was lower than that in the stent group (Table 3). Before and after intervention, the liver function of the embolization group was worse than that of the stent group.

During hospitalization, the inflammatory indicators (white blood cells, neutrophils/lymphocytes) of the patients after surgery were compared. There was no statistical difference in the relevant indicators between the embolization group and the stent group before and after surgery (Table 3). However, the postoperative inflammatory markers in the embolization group were worse than those in the stent group.

Table 3
Changes in liver function and other related indicators

| Parameters | Time | TAE (n = 81) | CSI (n = 32) | *p* value |
|---|---|---|---|---|
| TBil(umol/L) | Before surgery | 21.40 (13.40,31.20) | 16.75 (12.83,21.70) | 0.041 |
| | Day 1 after surgery | 62.10 (49.25,88.50) | 31.30 (25.45,46.63) | <0.001 |
| | Day 7 after surgery | 60.10 (40.50,117.40) | 27.35 (16.00,40.43) | <0.001 |
| ALT(U/L) | Before surgery | 40.50 (23.00,56.65) | 34.20 (20.85,37.78) | 0.010 |
| | Day 1 after surgery | 830.20 (274.65,1898.50) | 75.50 (35.13,206.48) | <0.001 |
| | Day 7 after surgery | 958.00 (196.40,2516.05) | 69.15 (25.88,212.10) | <0.001 |
| AST(U/L) | Before surgery | 38.10 (27.70,56.05) | 34.90 (27.78,54.80) | 0.088 |
| | Day 1 after surgery | 968.40 (377.60,1889.80) | 83.70 (42.20,151.98) | <0.001 |
| | Day 7 after surgery | 1249.00 (335.60,3199.90) | 61.80 (21.25,211.35) | <0.001 |
| PA(mg/L) | Before surgery | 123.00 (91.15,145.00) | 166.40 (67.65,159.38) | 0.531 |
| | Day 1 after surgery | 101.00 (78.70,142.10) | 98.55 (58.03,157.13) | 0.713 |
| | Day 7 after surgery | 104.20 (73.60,134.50) | 110.20 (71.10,158.65) | 0.179 |
| ALP(U/L) | Before surgery | 102.40 (63.90,179.40) | 84.00 (62.80,127.10) | 0.021 |
| | Day 1 after surgery | 102.30 (74.30,160.50) | 87.70 (72.45,121.43) | 0.011 |
| | Day 7 after surgery | 102.70 (80.30,152.40) | 96.10 (78.63,162.68) | 0.992 |
| WBC($10^9$/L) | Before surgery | 8.76 (6.34,14.05) | 10.35 (5.24,16.47) | 0.512 |
| | Day 1 after surgery | 12.36 (8.11,16.27) | 11.31 (7.63,17.90) | 0.104 |
| | Day 7 after surgery | 11.63 (8.36,17.40) | 10.74 (6.96,16.73) | 0.618 |
| NLR | Before surgery | 6.25 (3.43,12.18) | 6.37 (3.80,13.86) | 0.953 |
| | Day 1 after surgery | 9.28 (6.74,12.42) | 8.63 (5.12,18.70) | 0.384 |
| | Day 7 after surgery | 9.25 (5.27,18.63) | 8.09 (4.86,14.57) | 0.193 |
| PT(S) | Before surgery | 15.20 (13.90,16.60) | 13.60 (13.13,15.48) | 0.037 |
| | Day 1 after surgery | 15.30 (13.90,16.80) | 14.55 (13.38,15.85) | 0.010 |
| | Day 7 after surgery | 15.60 (13.75,17.60) | 14.95 (13.05,16.53) | 0.029 |
| Scr(umol/L) | Before surgery | 62.50 (49.25,91.50) | 64.25 (50.25,76.40) | 0.292 |
| | Day 1 after surgery | 73.00 (54.65,108.50) | 69.00 (55.48,77.73) | 0.031 |
| | Day 7 after surgery | 64.50 (47.15,94.95) | 68.55 (53.83,86.65) | 0.319 |

TBil:Total bilirubin; ALT:Alanine amiotrans; AST:Aspartate aminotrans ferase; PA:Prealbumin; ALP:Alkaline phosphatase; WBC:White blood cell; NLR:Neutrophil-to-lymphocyte ratio; PT:Prothrombin time; Scr:Serum creatinine.

# Occurrence of liver-related complications

Among the 113 patients with PPH, all had positive angiography and underwent successful hepatic artery embolization or stent implantation (Figs. 1 and 2 are patients who underwent interventional treatment), with a technical success rate of 97.35% (110/113). Three patients with hepatic artery pseudoaneurysm died of rupture and bleeding after embolization. In the TAE group, 7 patients underwent embolization again due to recurrent bleeding from the branches of the superior mesenteric artery. Both groups of patients had varying degrees of liver damage, including acute liver failure, hepatic infarction, liver abscess, biliary tract infection, perihepatic effusion, and hypoproteinemia, requiring prolonged hospitalization for intervention. The most common complication in the TAE group was acute liver failure (71.60%: 58/81); hypoproteinemia (53.13%: 17/32) was in the CSI group (Table 4).

# Follow-up and prognosis

During hospitalization, 8 patients (9.88%) in the TAE group died of worsening liver failure, and the remaining 22 patients (27.16%) died of liver failure combined with other organ failure and infection; 6 patient (18.75%) in the CSI group died of pulmonary infection and multiple organ failure despite a patent hepatic artery. During the 1-year follow-up, the median survival time of patients in the TAE group and the CSI group was 53.00 (18.50, 170.00) days and 212.00 (73.00, 365.00) days, and the difference in survival time between the two groups was statistically significant ($P < 0.001$). 34 patients (41.98%) in the TAE group and 12 patients (37.50%) in the CSI group died of tumor recurrence, infection, or multiple organ failure. There was no early occlusion in the CSI group. Three patients (9.38%) developed hepatic artery stent occlusion within 1 year of follow-up and underwent interventional treatment to open the occluded stent (Table 4).

Table 4
Outcomes in patients with TAE and CSI

| Parameters | TAE (n = 81) | CSI (n = 32) | P |
|---|---|---|---|
| Technical success | 78 (96.30%) | 32 (100%) | 0.159 |
| Re-intervention | 7 (8.64%) | 3 (9.38%) | 0.903 |
| Hospital mortality rate | 30 (37.04%) | 6 (18.75%) | 0.043 |
| 1-year mortality rate | 34 (41.98%) | 12 (37.50%) | 0.665 |
| Survival time (days) | 53 (18.50, 170.00) | 212 (73.00, 365.00) | <0.001 |
| Liver complications | | | |
| Acute liver failure | 58 (71.60%) | 7 (21.88%) | <0.01 |
| Hepatic infarction | 27 (33.33%) | 2 (6.25%) | 0.002 |
| Liver abscess | 9 (11.11%) | 0 | 0.002 |
| Biloma | 7 (8.64%) | 0 | 0.007 |
| Perihepatic effusion | 41 (50.62%) | 11 34.38(%) | 0.117 |
| Hypoproteinemia | 46 (56.79%) | 17 (53.13%) | 0.518 |
| Early stent occlusion(≤ 30 days) | 0 | 0 | |
| Long-term stent occlusion(> 30 days) | 0 | 3 (9.38%) | |

TAE:Transarterial embolization; CSI:Covered stent implantation.

# Discussion

In this study, there were 276 patients with PPH. Among them, 113 had positive DSA findings in the hepatic artery and underwent interventional treatment. The main manifestations included contrast agent extravasation, pseudoaneurysm, and local stenosis of the proper hepatic artery. 113 PPH patients successfully underwent TAE/CSI treatment, and 3 patients with hepatic artery pseudoaneurysm died due to rupture and bleeding after embolization. The technical success rate was 97.35%.

Pancreatic fistula is one of the most common complications after PD [13, 14]. It can cause continuous damage to the arterial wall, leading to arterial wall rupture and bleeding or the formation of pseudoaneurysms [15, 16]. Arterial bleeding can easily lead to unstable hemodynamics, sepsis, and liver ischemia [15, 17, 18]. Prolonged bleeding can lead to shock and coagulopathy, which can further lead to disseminated intravascular coagulation [3, 8, 19]. The gastroduodenal artery often originates from the common hepatic artery. When bleeding occurs around the hepatic artery and gastroduodenal artery in PPH patients, some patients may experience bleeding from both the hepatic artery and the gastroduodenal artery, which is often more complicated to treat. Retaining a gastroduodenal artery

stump of about 1 cm, unfolding the omental flap, and wrapping the hepatic artery with the round ligament of the liver can minimize direct contact between pancreatic fluid and adjacent blood vessels [20, 21].

Once hepatic artery bleeding is diagnosed, active and effective treatment should be given as soon as possible. TAE is still the main treatment for hepatic artery bleeding, especially for patients with massive bleeding caused by ruptured pseudoaneurysms [3, 22]. Liver failure, liver infarction, and liver abscess are classified as major complications after TAE [8]. Abnormal liver function can be seen after TAE of the common hepatic artery, and the incidence of liver abscess is 10%-13% [23, 24]. Although TAE is technically easier than CSI, liver infarction secondary to liver ischemia often occurs [25, 26]. In this study, 81 patients underwent embolization treatment due to contrast agent overflow or pseudoaneurysm formation in the hepatic artery and gastroduodenal artery. All PPH patients had varying degrees of liver damage. The incidence of acute liver failure after surgery (71.60%) was the highest. More serious patients may also have liver abscesses, which can lead to liver infarction. After TAE, approximately 30% to 80% of patients experience liver ischemia, and approximately 20% to 40% of patients progress to hepatic infarction [3]. The reported mortality rate ranges from 30% to 50% [26]. After embolization, 8 patients (9.88%) died due to worsening of irreparable liver failure, and the remaining 22 patients (27.16%) died due to varying degrees of liver failure combined with other organ failure or infection. The total mortality rate during hospitalization was 37.04%.

Covered stent implantation can stop bleeding while preserving the patient's hepatic artery blood flow [10, 27, 28]. CSI has high requirements for vascular anatomy, and a series of problems may occur after the operation, such as stent thrombosis, stent distortion, occlusion, and infection. Although stent occlusion may block the blood flow of the hepatic artery and cause ischemic changes in the liver. Fortunately, the portal vein and collateral vessels can jointly provide dual blood supply to compensate for the reduction in hepatic artery blood flow. This compensatory mechanism allows the liver to gradually adapt to changes in blood flow, thereby maintaining its normal function.

When analyzing patients who experienced hepatic artery bleeding or bleeding from the stump of the gastroduodenal artery (causing blood inflow to the liver), CSI was associated with fewer liver complications and zero in-hospital mortality [27]. This may mean that CSI is more effective than TAE in the treatment of PPH. This may be because CSI allows more time for intensive treatment of complications such as pancreatic fistula or abdominal abscess, thereby improving short-term prognosis.

In some studies, stent grafts were placed in the proper hepatic artery with a diameter less than 4 mm [18, 29]. In this study, all 32 hepatic artery stent grafts were placed in the common hepatic artery, with the distal end covering the stump of the gastroduodenal artery. The diameter of the stent implanted in the common hepatic artery was 6–8 mm, which exceeded the normal diameter of the hepatic artery. We considered that the vessel diameter measured during bleeding was smaller than the actual vessel diameter due to vascular spasm. Selecting a stent based on the measured value may cause fistula after the spasm disappears. Placing a suitable stent can effectively reduce the occurrence of fistula[30].

Usually, after stent implantation, at least 6 months of anticoagulant and antiplatelet therapy is required to avoid stent thrombosis. However, PPH patients have poor coagulation function after surgery. Bleeding may recur after the use of anticoagulant and antiplatelet drugs. In our study, none of the 32 patients had short-term stent occlusion. Three patients had stent occlusion on the 108th, 154th and 167th days after the intervention, and the stent was successfully opened after re-intervention. Therefore, anticoagulation and antiplatelet therapy should be appropriately selected according to the patient's preoperative hemodynamic stability and coagulation status. None of the 32 stent implantation patients experienced severe liver-related adverse reactions, nor did they die from late stent occlusion. Whether patients with hepatic artery covered stent implantation need anticoagulation and antiplatelet therapy after surgery needs to be considered based on the patient's basic vital signs and the occurrence of postoperative complications.

This study is a retrospective study, and the reliance on the characteristics of the existing database may lead to missing data or information bias. The number of patients undergoing hepatic artery covered stent implantation is still small, and its technical specifications (such as stent positioning) and postoperative anticoagulation strategies need to be prospectively verified. In addition, the evolution of technical standards and multidisciplinary collaboration models over a span of ten years may affect the homogeneity of results. Although this study has explored related issues, the sample size is currently small and it is a retrospective study. In the future, it is necessary to establish evidence of the efficacy of CSI through multicenter prospective studies and build a standardized MDT emergency system for PPH to improve the efficiency of treatment.

## Conclusion

Bleeding from the gastroduodenal artery stump or hepatic artery is a fatal complication after pancreaticoduodenectomy. This study confirmed that transcatheter arterial embolization (TAE) significantly increases the risk of liver failure, while covered stent implantation (CSI) can effectively stop bleeding and maintain liver blood perfusion. For hemodynamically stable patients, CSI is a better strategy to achieve a balance between hemostasis and organ function protection. This may provide a preferred option for the timely and effective treatment of PPH.

## Abbreviations

PD Pancreaticoduodenectomy

PPH Post pancreaticoduodenectomy hemorrhage

TAE transcatheter arterial embolization

CSI covered stent implantation

DSA Digital Subtraction Angiography

CT Computed Tomography

CBCT Cone Beam Computed Tomography

ECOG Eastern Cooperative Oncology Group

ALBI Albumin-bilirubin

# Declarations

### Ethics approval and consent to participate

This study was approved by the Fourth Affiliated Hospital of Anui Medical University and the First Affiliated Hospital of Soochow University. Participant informed consent was exempted because of the retrospective study design in accordance with the Declaration of Helsinki of the World Medical Association (Ethics approval and consent to participate: KYXM-202601-010, 2024-461). The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

### Consent for publication

Not applicable.

### Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

### Competing interests

The authors declare no competing interests.


### Funding

This work was suppreted by the Innovative Research Group Project of the National Natural Science Fundation of China, P.R.C (82272094), the Key Research and Development Program of Anhui Provincial Department of Science and Technology (2023s07020023).


### Author contributions

Bangjian Zhou and Wuhao Li designed the study and wrote the initial draft of this manuscript. Gongneng Sun and Wei Qiu performed the statistical analysis and participated in its design. Xiaoli Zhu and Yu Yin participated in the acquisition, analysis, and interpretation of the data. Jun Yang and Huanyu Chen put forward valuable opinions on the subject design. Caifang Ni and Kewu He critically reviewed and approved the final manuscript.

**Clinical trial number**

Not applicable.

**Acknowledgements**

Not applicable.

**Authors' information**

[1]Department of Interventional Radiology, the Fourth Affiliated Hospital of Anhui Medical University, Hefei, Anhui 238000, China; [2]Department of Interventional Radiology, the First Affiliated Hospital of Soochow University, Suzhou, Jiangsu 215006, China.

# References

1. Hassold N, Wolfschmidt F, Dierks A, et al. Effectiveness and outcome of endovascular therapy for late-onset postpancreatectomy hemorrhage using covered stents and embolization. J Vasc Surg. 2016;64(5):1373-1383. https://doi.org/10.1016/j.jvs.2016.05.071.
2. Fang Y, Han X, Liu L, et al. Diagnosis and treatment efficacy of digital subtraction angiography and transcatheter arterial embolization in post-pancreatectomy hemorrhage: A single center retrospective cohort study. Int J Surg. 2018;51:223-228. https://doi.org/10.1016/j.ijsu.2018.01.045..
3. Mine T, Murata S, Ueda T, et al. Contribution of extrahepatic collaterals to liver parenchymal circulation after proper hepatic artery embolization. J Gastroenterol Hepatol. 2014;29(7):1515-1521. https://doi.org/10.1111/jgh.12571.
4. Wolk S, Radosa CG, Distler M, et al. Risk Factors for In-hospital Mortality After Transarterial Intervention After Postpancreatectomy Hemorrhage. Cardiovasc Intervent Radiol. 2020;43(9):1342-1352. https://doi.org/10.1007/s00270-020-02509-2.
5. Floortje van Oosten A, Smits FJ, van den Heuvel DAF, et al. Diagnosis and management of postpancreatectomy hemorrhage: a systematic review and meta-analysis. HPB (Oxford). 2019;21(8):953-961. https://doi.org/10.1016/j.hpb.2019.02.011.
6. Bassi C, Marchegiani G, Dervenis C, et al. International Study Group on Pancreatic Surgery (ISGPS). The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 Years After. Surgery. 2017;161(3):584-591. https://doi.org/10.1016/j.surg.2016.11.014
7. Farvacque G, Guilbaud T, Loundou AD, et al. Delayed post-pancreatectomy hemorrhage and bleeding recurrence after percutaneous endovascular treatment: risk factors from a bi-centric study of 307 consecutive patients. Langenbecks Arch Surg. 2021;406(6):1893-1902. https://doi.org/10.1007/s00423-021-02146-4.

8. Hasegawa T, Ota H, Matsuura T, et al. Endovascular Treatment of Hepatic Artery Pseudoaneurysm after Pancreaticoduodenectomy: Risk Factors Associated with Mortality and Complications. J Vasc Interv Radiol. 2017;28(1):50-59. https://doi.org/10.1016/j.jvir.2016.04.004.
9. Lin YM, Lin EY, Tseng HS, et al. Preventive covered stent placement at the gastroduodenal artery stump in angiogram-negative sentinel hemorrhage after pancreaticoduodenectomy. Abdom Radiol (NY). 2021;46(10):4995-5006. https://doi.org/10.1007/s00261-021-03123-7.
10. Izumi H, Yoshii H, Fujino R, et al. Endovascular treatment of postoperative hemorrhage after pancreatectomy: a retrospective study. BMC Gastroenterol. 2023;23(1):379. https://doi.org/10.1186/s12876-023-03022-9.
11. Gaudon C, Soussan J, Louis G, et al. Late postpancreatectomy hemorrhage: Predictive factors of morbidity and mortality after percutaneous endovascular treatment. Diagn Interv Imaging. 2016;97(11):1071-1077. https://doi.org/10.1016/j.diii.2016.08.003.
12. Ching KC, Santos E, McCluskey KM, et al. Covered Stents and Coil Embolization for Treatment of Postpancreatectomy Arterial Hemorrhage. J Vasc Interv Radiol. 2016;27(1):73-79. https://doi.org/10.1016/j.jvir.2015.09.024.
13. Russell TB, Labib PL, Denson J, et al. Postoperative complications after pancreatoduodenectomy for malignancy: results from the Recurrence After Whipple's (RAW) study. BJS Open. 2023;7(6):zrad106. https://doi.org/10.1093/bjsopen/zrad106.
14. Mirza W, Khan ME, Iqbal H, et al. Omental wrapping of the pancreaticojejunostomy during pancreatoduodenectomy to prevent clinically relevant POPF: a GRADE-assessed systematic review and meta-analysis featuring geographic subgroup analysis. World J Surg Oncol. 2026;24(1):54. https://doi.org/10.1186/s12957-026-04218-5.
15. Hori T, Yamamoto H, Harada H, et al. Inferior Pancreaticoduodenal Artery Aneurysm Related with Groove Pancreatitis Persistently Repeated Hemosuccus Pancreaticus Even After Coil Embolization. Am J Case Rep. 2019;20:567-574. https://doi.org/10.12659/AJCR.914832.
16. Chatani S, Inoue A, Ohta S, et al. Transcatheter Arterial Embolization for Postoperative Bleeding Following Abdominal Surgery. Cardiovasc Intervent Radiol. 2018;41(9):1346-1355. https://doi.org/10.1007/s00270-018-2019-8.
17. Lin YJ, Ho TW, Wu CH, et al. Specific Bile Microorganisms Caused by Intra-Abdominal Abscess on Pancreaticoduodenectomy Patients: A Retrospective Cohort Study. Curr Oncol. 2021;29(1):111-121. https://doi.org/10.3390/curroncol29010009.
18. Miyazawa R, Kamo M, Nishiyama T, et al. Covered Stent Placement Using "Pull-Through" Technique for a Gastroduodenal Artery Stump Pseudoaneurysm after Pancreaticoduodenectomy. J Vasc Interv Radiol. 2016;27(11):1743-1745. https://doi.org/10.1016/j.jvir.2016.06.033.
19. Guan Y, Zhang JL, Li XH, et al. Postpancreatectomy hemorrhage with negative angiographic findings: outcomes of empiric embolization compared to conservative management. Clin Imaging. 2021;73:119-123. https://doi.org/10.1016/j.clinimag.2020.12.009.

20. Desai GS, Pande PM. Gastroduodenal artery: single key for many locks. J Hepatobiliary Pancreat Sci. 2019;26(7):281-291. https://doi.org/10.1002/jhbp.636.
21. Senthilkumar MP, Battula N, Perera M, et al. Management of a pseudo-aneurysm in the hepatic artery after a laparoscopic cholecystectomy. Ann R Coll Surg Engl. 2016;98(7):456-460. https://doi.org/10.1002/jhbp.636.
22. Gwon DI, Ko GY, Sung KB, et al. Endovascular management of extrahepatic artery hemorrhage after pancreatobiliary surgery: clinical features and outcomes of transcatheter arterial embolization and stent-graft placement. AJR Am J Roentgenol. 2011;196(5):627-634. https://doi.org/10.2214/AJR.10.5148.
23. Lim SJ, Park KB, Hyun DH, et al. Stent graft placement for postsurgical hemorrhage from the hepatic artery: clinical outcome and CT findings. J Vasc Interv Radiol. 2014;25(10):1539-1548. https://doi.org/10.1016/j.jvir.2014.06.023.
24. Hur S, Yoon CJ, Kang SG, et al. Transcatheter arterial embolization of gastroduodenal artery stump pseudoaneurysms after pancreaticoduodenectomy: safety and efficacy of two embolization techniques. J Vasc Interv Radiol. 2011;22(3):294-301. https://doi.org/10.1016/j.jvir.2010.11.020.
25. Pedersoli F, Isfort P, Keil S, et al. Stentgraft Implantation for the Treatment of Postoperative Hepatic Artery Pseudoaneurysm. Cardiovasc Intervent Radiol. 2016;39(4):575-581. https://doi.org/10.1007/s00270-015-1274-1.
26. Ding X, Zhu J, Zhu M, et al. Therapeutic management of hemorrhage from visceral artery pseudoaneurysms after pancreatic surgery. J Gastrointest Surg. 2011;15(8):1417-1425. https://doi.org/10.1007/s11605-011-1561-3.
27. Aoun C, El Rassi Z. Stent graft placement for an incidental finding of hepatic artery pseudoaneurysm post hepatectomy, a case report and literature review. Int J Surg Case Rep. 2018;49:191-193. https://doi.org/10.1016/j.ijscr.2018.06.038.
28. Zhou TY, Sun JH, Zhang YL, et al. Post-pancreaticoduodenectomy hemorrhage: DSA diagnosis and endovascular treatment. Oncotarget. 2017;8(43):73684-73692. https://doi.org/10.18632/oncotarget.17450.
29. Koukoutsis I, Bellagamba R, Morris-Stiff G, et al. Haemorrhage following pancreaticoduodenectomy: risk factors and the importance of sentinel bleed. Dig Surg. 2006;23(4):224-228. https://doi.org/10.1159/000094754.
30. Li X, Fu Z, Cao K, et al. Vascular stent graft for the treatment of post-pancreaticoduodenectomy hemorrhage and risk factors for rebleeding. Pancreatology. 2025;25(3):396-404. https://doi.org/10.1016/j.pan.2025.02.009.

# Figures

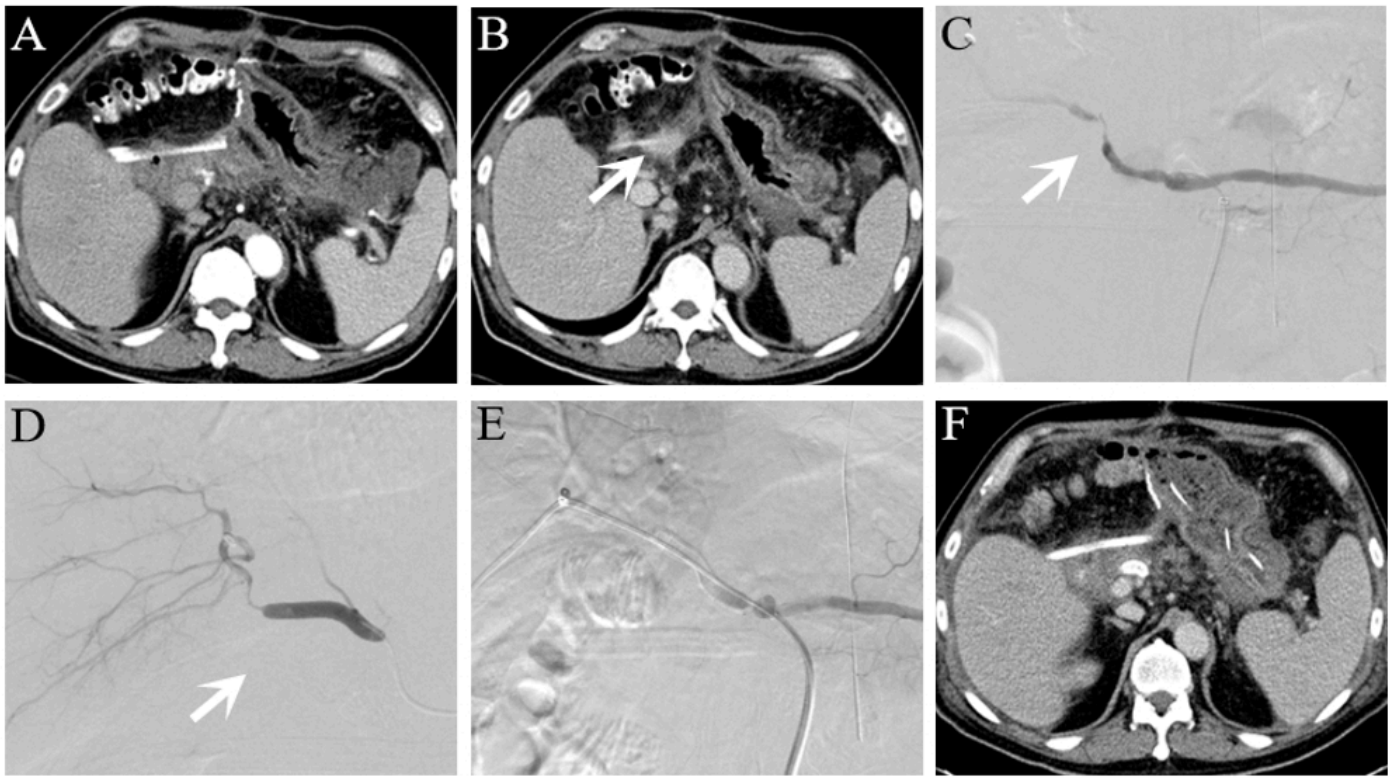



**Figure 1**

A patient with pancreatic malignancy who underwent pancreaticoduodenectomy and had bleeding after surgery. On the 28th day after surgery, he developed upper abdominal pain and bloody fluid was seen flowing out of the abdominal drainage tube. **A-B** Contrast-enhanced abdominal CT revealed an encapsulated fluid collection posterior to the body and tail of the pancreas. **C-D** DSA angiography demonstrated significant stenosis of the distal hepatic artery. **E** Immediate covered stent implantation in the hepatic artery was performed. **F** After the procedure, the patient had no further bleeding, and follow-up CT showed patent blood flow within the hepatic artery stent.

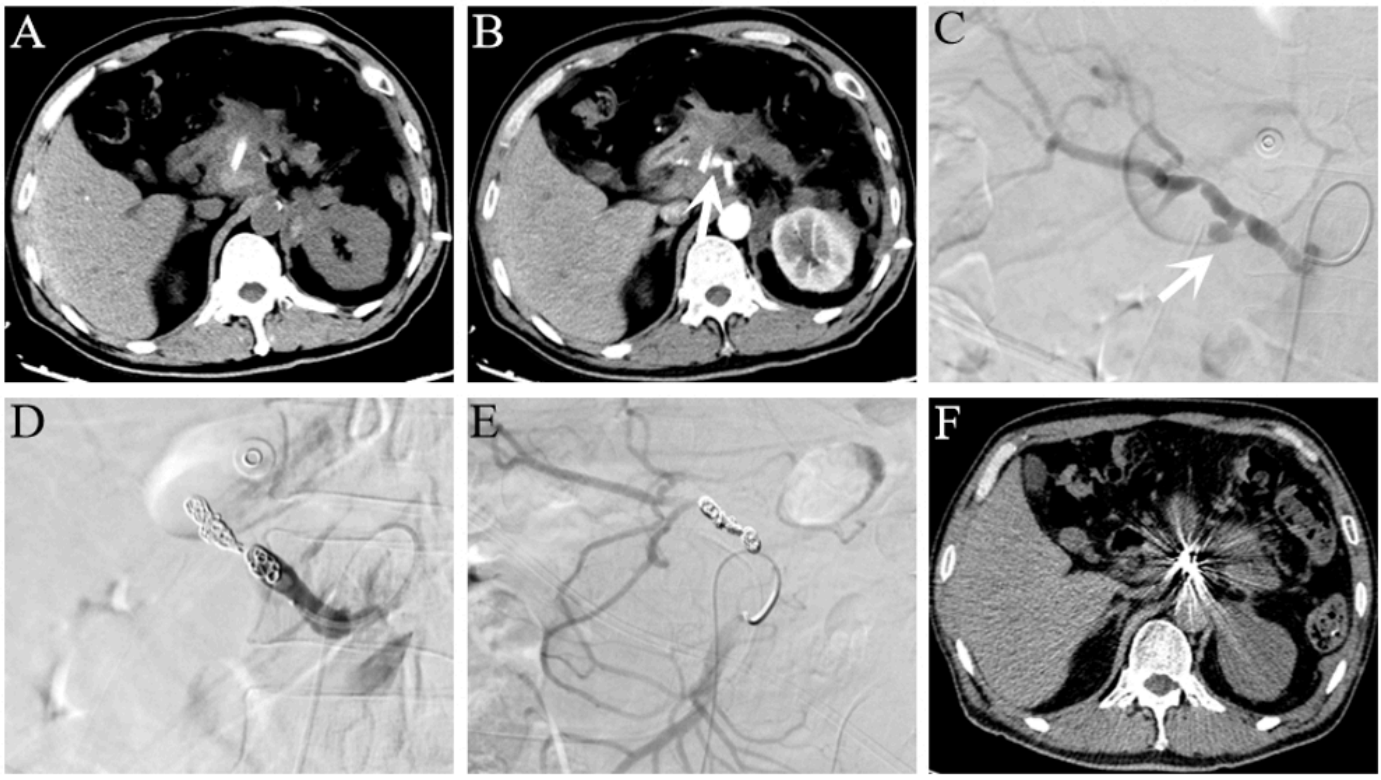



**Figure 2**

A patient with bleeding after pancreaticoduodenectomy for pancreatic malignancy had obvious abdominal pain and distension on the 25th day after surgery. **A-B** Contrast-enhanced abdominal CT revealed a mixed-density shadow around the distal end of the drainage tube, suggestive of a hematoma. **C** DSA angiography demonstrated a roundish contrast pooling near the origin of the common hepatic artery, suggestive of pseudoaneurysm formation. **D** Due to the patient's critical condition, immediate transcatheter hepatic artery embolization was performed. **E** Post-procedural angiography showed that distal branches of the superior mesenteric artery supplied the hepatic artery via the gastroduodenal artery as collaterals. **F** Follow-up CT indicated significant resolution of the previous surrounding hematoma.