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HOW TO DO IT

Endovascular micro-arterial stenting for arterial pseudoaneurysm after pancreatic surgery

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Abstract

Although arterial pseudoaneurysm is one of the most serious complications after pancreatic surgery, the best practice with maximum efficacy and minimum adverse effects to overcome such a serious situation has not yet been elucidated. We performed endovascular micro-arterial stenting (EMAS) to manage this serious situation while preserving a sufficient hepatic arterial flow, and herein report the technical details and challenges of the procedure. Dilation of the stent using a balloon catheter to adhere to the parent artery, and embolization of the surrounding artery to prevent type I and type II endo-leaks are the most important points for ensuring a successful procedure. We applied this technique to 6 cases of hepatic arterial pseudoaneurysm, with a mean size of 6.5 ± 1.3 mm. The mean time of the procedure was 81 ± 22 min, without adverse events, including hepatic necrosis or arterial bleeding. EMAS may be the ideal procedure for treating pseudoaneurysm after pancreatic surgery while preserving the hepatic arterial inflow.

Keywords Pseudoaneurysm · Stent · Hepatic artery

Abbreviations

EMAS	Endovascular micro-arterial stenting
CHA	Common hepatic artery
PHA	Proper hepatic artery
GDA	Gastroduodenal artery
CT	Computed tomography
LHA	Left hepatic artery

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Introduction

Ruptured arterial pseudoaneurysm is one of the most serious and life-threatening complications after pancreatic surgery, including pancreaticoduodenectomy and distal pancreatectomy. The most common cause of arterial pseudoaneurysm is the erosion of the arterial wall by amylase-rich pancreas juice due to a pancreatic fistula [1, 2]. The incidence of catastrophic hemorrhaging from a ruptured pseudoaneurysm in such situations has been reported to be between 2 and 11% [3–5], and the mortality rate for massive arterial hemorrhaging was shown to be almost 50% [6]. It has been recognized that surgical hemostasis for ruptured pseudoaneurysm is not appropriate, as difficulties locating the bleeding point in an eroded surgical field in such cases were associated with increased mortality [7]. Interventional radiologic procedures to embolize or coil hepatic arteries have been the treatment of choice despite the risk of liver necrosis, biliary necrosis or liver failure.

With recent advancements in endovascular devices [8, 9], we have been inserting endovascular micro-arterial stents (EMASs) using original technical refinements to prevent endo-leak in the treatment of arterial pseudoaneurysm after pancreatic surgery.

Methods (video file 1: case #3)

Between December 2016 and April 2020, we performed 183 pancreatectomies. EMASs were placed for all patients with pseudoaneurysms of the common hepatic artery (CHA), proper hepatic artery (PHA) and gastroduodenal artery (GDA) after pancreatic surgery (pancreaticoduodenectomy [PD, $n = 5$] and distal pancreatectomy [DP, $n = 1$]) for pancreatobiliary tumors (pancreatic ductal adenocarcinoma [n = 2], intraductal papillary mucinous adenoma [$n = 1$], ampulla of Vater adenocarcinoma [$n = 2$] and bile duct adenocarcinoma [$n = 1$]). This research was approved by the Ethics Committee of The Jikei University School of Medicine (27–177 [8062]).

The patient characteristics are summarized in Table 1. Pseudoaneurysm was diagnosed by the discovery of extravasation from CHA, GDA or PHA using dynamic contrast-enhanced computed tomography (eCT). When active hemorrhaging or hypovolemic shock was identified, the patients received adequate fluid infusion therapy or blood transfusion, including red blood cells, fresh-frozen plasma and platelets, before the endovascular intervention. The important point was that patients' vital signs were maintained during endovascular treatments. Type I and type II endo-leaks were defined as the leaks from attachment sites and branches without attachment site connection, respectively [10].

The blood access of the EMAS was via the right femoral artery, using the Micropucture® introducer set (Cook Medical, Bloomington, IN, USA) and subsequently inserted 6-Fr Destination® (TERUMO Co., Ltd., Tokyo, Japan) or 7-Fr Flexor® guiding sheath (Cook Medical). The celiac artery was selectively catheterized using a 4-Fr Shepherd's hook or cobra catheter, and digital subtraction angiography was performed to detect the pseudoaneurysm (Fig. 1a: Case #4). The diameters of the pseudoaneurysm and the parent artery were measured to decide the size and length of the stent (Fig. 1b: Case #4). When the pseudoaneurysm was located distal of the PHA (Fig. 1e: Case #3) or proximal of the celiac artery (Fig. 1g: Case #1), reflux flow from these arteries due to their distance from the left hepatic artery (LHA) or dorsal pancreatic artery caused type II endo-leak. According to the measurement results, if the stent occluded these arteries, the LHA (Fig. 1f: Case #3) and dorsal pancreatic artery (Fig. 1h: Case #1) should be embolized to prevent endo-leak prior to stent insertion using mechanical detachable fibered coils (Interlock; Boston Scientific Co., Ltd., Marlborough, MA, USA) or electrical detachable bare platinum coils (Target helical ultra; Stryker Neurovascular, Fremont, CA, USA). Stents with diameters of 4–6 mm (GORE® VIABAHN® Endoprosthesis with Heparin Bioactive Surface; W. L. Gore

Table 1 Patients' characteristics and the post-interventional course

#	Age (y)	Sex	Surgery	POPF	Arterial pseudoaneurysm				Endovascular micro-arterial stent				Follow-up		
					Location	Timing (days)	Size (mm)	Rupture	Location	Length (mm)	Coiling	AST* (IU/L)	Periods (m)	Patency	Complications
1	76	M	DP	Yes	CHA	122	9	No	CHA	25	DPA	19	0.5	Patent	No
2	54	M	PD	No**	GDA	35	5.4	No	CHA-RHA	25	LHA	32	6.6	Patent	No
3	72	M	PD	Yes	PHA	20	5.6	No	CHA-RHA	50	LHA	26	2.9	Occluded	Liver abscess
4	73	M	PD	Yes	CHA	21	6.5	Yes	CHA	25	–	893	21.3	Patent	No
5	62	M	PD	Yes	PHA	22	4.8	Yes	CHA-PHA	25	–	3,716	0.1	Occluded	No
6	72	M	PD	No	CHA	75	8	No	CHA	60	–	15	4.1	Occluded	No

POPF postoperative pancreatic fistula; *DP* distal pancreatectomy; *PD* pancreaticoduodenectomy; *CHA* common hepatic artery; *GDA* gastroduodenal artery; *PHA* proper hepatic artery; *RHA* right hepatic artery; *DPA* dorsal pancreatic artery; *LHA* left hepatic artery

*AST after treatment; **postoperative biliary fistula

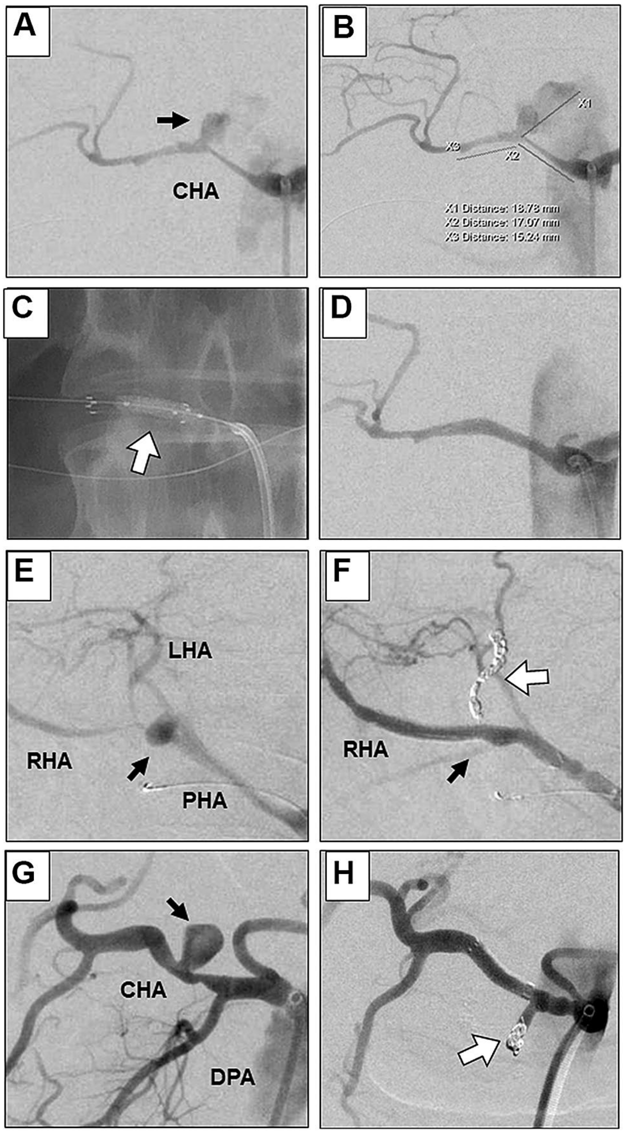

Fig. 1 (**a–d**: Case #4) **a** Celiac arteriography showing a common hepatic artery pseudoaneurysm (black arrow). **b** The diameter of the pseudoaneurysm and the distance of the parent artery were measured. **c** Deployment of a common hepatic artery stent dilated using a balloon dilation catheter (white arrow). **d** The pseudoaneurysm disappeared. (**e**, **f** Case #3) **e** Proper hepatic artery pseudoaneurysm (black arrow). **f** Embolization of the left hepatic artery (white arrow) and deployment of the stent (black arrow). (**g**, **h**: Case #1) **g** Common hepatic artery pseudoaneurysm (black arrow). The dorsal pancreatic artery was close to the aneurysm. **h** Embolization of the dorsalis pancreatic artery (white arrow) and deployment of the stent

& Associates, Inc., Phoenix, AZ, USA) were selected depending on the measured vessel diameter and length. The stent was placed at the center of the pseudoaneurysm and then deployed. The deployed stent was dilated with a Sterling™ balloon dilatation catheter (Boston Scientific Co., Ltd.) to adhere to the parent artery with as little pressure as possible (Fig. 1c: Case #4). Finally, we repeatedly performed an angiogram and confirmed the disappearance of the pseudoaneurysm (Fig. 1d: Case #4). In addition, we checked the patency of the stent and the distal blood flow of the hepatic artery. If the LHA was embolized, we evaluated the collateral circulation from the right hepatic lobe. During the endovascular procedure, 3,000 I.U of heparin sodium by intravenous infusion was administered. Post-interventional anti-platelet therapy varied among patients, depending on the bleeding risk. The patients were followed with CT every three months to assess recurrence.

Results

The interventional results and post-interventional clinical course in each patient are summarized in Table 1. The mean interval from pancreatic resection to pseudoaneurysms was 49 days (range 20–122 days). The mean time of endovascular interventions was 81 ± 22 min. All patients had pseudoaneurysm or active extravasation determined by angiography. The size of the pseudoaneurysms ranged from 4.8 to 9.0 mm, with a mean diameter of 6.6 mm. All pseudoaneurysms disappeared after successful stent placement. There was no change in the serum transaminase level after intervention in patients without a ruptured pseudoaneurysms. As the hepatic arterial flow was maintained through the CHA stent, there was only slight liver damage with the interventional procedure (Case #1–3, 6). In contrast, patients with ruptured pseudoaneurysms showed elevated serum AST levels due to the shock liver that rapidly decreased by hepatic reperfusion (Case #4, 5).

There were no cases of re-bleeding, endo-leak, or hospital death among the patients who had no intervention-related complications during the hospital stay. Regarding the long-term outcomes, no re-bleeding or endo-leak occurred during the follow-up period. The median patency time was 4.1 months (95% confidence interval 1.6–6.6 months), and the 1-year patency rate was 41.7%. In case #5, the stent was occluded after just three days. However, eCT showed the development of collateral circulation from the left gastric artery or inferior phrenic artery, and the patient had no liver-related complications. Case #6 also had stent occlusion after 4.1 months, but sufficient collateral circulation from the left gastric artery had developed by that point. In contrast, case #3 had stent occlusion 2.9 months after the EMAS placement and subsequently developed a small liver abscess that was successfully treated by percutaneous drainage. There were no mortalities in the observed period.

Discussion

Although radiological embolization technique has been the main stream for controlling ruptured or impending ruptured hepatic arterial pseudoaneurysm due to pancreas leakage, serious adverse events, including hepatic infarction with possible liver failure or biliary infarction with recurrent refractory cholangitis caused by sudden obstruction of hepatic arterial flow [3, 11], have been the issues to be overcome. A previous report showed that 33–66% of patients died due to liver failure after CHA embolization for CHA, GDA or PHA pseudoaneurysm [6, 7]. Therefore, an EMAS, which seals out a pseudoaneurysm while preserving the hepatic arterial inflow, has an advantage over simple embolization of the hepatic artery. Maintaining the hepatic arterial flow early after EMAS placement was considered to contribute to the reduction of complications. There have been reports of diverting coronary stents to hepatic arteries [12, 13], but the present report describes a new method using a stent specialized for peripheral arteries.

However, an EMAS might become occluded during long-term follow-up, as anticoagulant therapy sometimes cannot be sufficiently performed after pancreatic resection and bleeding. As reported by Zhang et al. [14], with the administration of clopidogrel (75 mg/day) and aspirin (100 mg/day), none of the patients with stented celiac arteries for spontaneous celiac artery aneurysms developed stent occlusion. However, it is difficult to administer the above anticoagulant therapy for cases of pseudoaneurysm after pancreatic resection because the bleeding risk differs completely between these patients and our series. If it is judged that the risk of re-bleeding is low, we performed the same antiplatelet therapy as soon as possible. The technical points for ensuring the long-term patency of a stent are placing the stent straight without bending and selecting a stent with a size that matches the diameter of the artery. This is because a bent artery is likely to cause a thrombus due to turbulent flow. Similarly, selecting a stent with a diameter smaller than that of the artery facilitates thrombus formation. In addition, we selected stents with heparin applied to the lumen to prevent occlusion. Although the 1-year patency rate was only 41.4%, minor ischemic hepatic events were observed in just one case. Gradual stenosis to occlusion over time might have allowed more time for collateral vessels to grow with the EMAS. Thus, it is important to control the rupture of a pseudoaneurysm and gain time for collateral circulation to develop.

Furthermore, the EMAS has a lower incidence of arterial re-rupture, a fatal consequence, than embolization therapy. Kalva et al. [15] reported that the 24-h and 30-day re-bleeding rates were 4 and 17%, respectively, with embolization therapy with particulate materials, coils, N-acetyl cyanoacrylate, or their combination, and mortality occurred in just three cases. When placing an EMAS, the key point for preventing recurrent arterial rupture is to prevent endo-leak after stenting. Cui et al. [16] reported type I endo-leak after hepatic arterial stent for arterial pseudoaneurysm in just 6% of cases. We developed two approaches to achieve similar good outcomes. First, the EMAS was pressed to the arterial vascular wall using a balloon catheter after its deployment to prevent type I endo-leak. Second, we embolized the surrounding arteries, such as the dorsalis pancreatic artery or LHA, to prevent type II endo-leak. These methods helped to prevent endo-leak, re-bleeding, morbidity and mortality.

However, there are several limitations associated with this method. Since the stent is inserted through a 6-Fr sheath, the stent cannot be delivered if the CHA is 6 Fr or smaller in diameter. Furthermore, if the hepatic artery is bent or twisted, an EMAS is not suitable. In addition, because both ends of the stent must adhere to normal arteries, there is no indication if the arterial wall around the pseudoaneurysm is ruptured.

In conclusion, the EMAS may be a suitable first-line treatment for pseudoaneurysm after pancreatic surgery in terms of maintaining the hepatic arterial inflow and preventing re-rupture of the pseudoaneurysm due to endo-leak.

Compliance with ethical standards

Conflict of interest The authors have no conflict of interest.

References

1. Wei HK, Wang SE, Shyr YM, Tseng HS, Tsai WC, Chen TH, et al. Risk factors for post-pancreaticoduodenectomy bleeding and finding an innovative approach to treatment. Dig Surg. 2009;26:297–305.
2. Tien YW, Lee PH, Yang CY, Ho MC, Chiu YF. Risk factors of massive bleeding related to pancreatic leak after pancreaticoduodenectomy. J Am Coll Surg. 2005;201:554–9.
3. de Castro SM, Kuhlmann KF, Busch OR, van Delden OM, Lameris JS, van Gulik TM, et al. Delayed massive hemorrhaging after pancreatic and biliary surgery: embolization or surgery? Ann Surg. 2005;241:85–91.
4. Shirai Y, Shiba H, Horiuchi T, Saito N, Furukawa K, Sakamoto T, et al. Assessment of outcome after pancreaticoduodenectomy by junior surgeons. Anticancer Res. 2016;36:3505–10.
5. Kleespies A, Rentsch M, Seeliger H, Albertsmeier M, Jauch KW, Bruns CJ. Blumgart anastomosis for pancreaticojejunostomy minimizes severe complications after pancreatic head resection. Br J Surg. 2009;96:741–50.
6. Fujii Y, Shimada H, Endo I, Yoshida K, Matsuo K, Takeda K, et al. Management of massive arterial hemorrhaging after pancreatobiliary surgery: does embolotherapy contribute to successful outcome? J Gastrointest Surg. 2007;11:432–8.
7. Ding X, Zhu J, Zhu M, Li C, Jian W, Jiang J, et al. Therapeutic management of hemorrhaging from visceral artery pseudoaneurysms after pancreatic surgery. J Gastrointest Surg. 2011;15:1417–25.
8. Harvey J, Dardik H, Impeduglia T, Woo D, DeBernardis F. Endovascular management of hepatic artery pseudoaneurysm hemorrhaging complicating pancreaticoduodenectomy. J Vasc Surg. 2006;43:613–7.
9. Wang MQ, Liu FY, Duan F, Wang ZJ, Song P, Fan QS. Stent-grafts placement for treatment of massive hemorrhaging from

ruptured hepatic artery after pancreaticoduodenectomy. World J Gastroenterol. 2010;16:3716–22.
10. Veith FJ, Baum RA, Ohki T, Amor M, Adiseshiah M, Blankensteijn JD, et al. Nature and significance of endoleaks and endotension: Summary of opinions expressed at an international conference. J Vasc Surg. 2002;35:1029–35.
11. Choi SH, Moon HJ, Heo JS, Joh JW, Kim YI. Delayed hemorrhaging after pancreaticoduodenectomy. J Am Coll Surg. 2004;199:186–91.
12. Fujioka S, Suzuki F, Funamizu N, Okamoto T, Munakata K, Ashida H, et al. Stent graft placement and balloon dilation for pseudoaneurysm complicated by distal arterial stenosis of the hepatic artery after pancreaticoduodenectomy. Surg Case Rep. 2015;1:60.
13. Asai K, Watanabe M, Kusachi S, Matsukiyo H, Saito T, Kodama H, et al. Successful treatment of a common hepatic artery pseudoaneurysm using a coronary covered stent following pancreatoduodenectomy: report of a case. Surg Today. 2014;44:160–5.
14. Zhang W, Fu YF, Wei PL, Bei E, Li DC, Xu J. Endovascular repair of celiac artery aneurysm with the use of stent grafts. J Vasc Interv Rad. 2016;27:514–8.
15. Kalva SP, Yeddula K, Wicky S, Fernandez del Castillo C, Walshaw AL. Angiographic intervention in patients with a suspected visceral artery pseudoaneurysm complicating pancreatitis and pancreatic surgery. Arch Surg. 2011;146:647–52.
16. Cui L, Kong L, Bai YH, Li XH, Wang XQ, Hao JJ, et al. Covered stent placement for hepatic artery pseudoaneurysm. Abdom Radiol. 2020;45:3337–41.