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TECHNICAL NOTE

Usefulness of Amplatzer Vascular Plug for Preoperative Embolization Before Distal Pancreatectomy with En Bloc Celiac Axis Resection

Tomoyo Fuji[1] · Takuji Yamagami[2] · Wataru Fukumoto[3] · Yasutaka Baba[3] · Keigo Chosa[3] · Masaki Ishikawa[4] · Makoto Iida[3] · Akira Naito[1] · Yoshiaki Murakami[5] · Kenichiro Uemura[5] · Naru Kondo[5] · Kazuo Awai[3]

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Abstract
Purpose We evaluated the usefulness of the Amplatzer vascular plug (AVP) for preoperative embolization before distal pancreatectomy with en bloc celiac axis resection (DP-CAR).
Materials and Methods Between April 2010 and September 2017, 19 patients with locally advanced pancreatic body cancer underwent preoperative embolization of the common hepatic and the left gastric artery (CHA, LGA) with AVP or coils. We compared the embolization success rate, embolization-related complications, the time required for preoperative embolization before DP-CAR and the procedure costs in patients whose CHA was AVP- (n = 7) or coil (n = 12) embolized.
Results The success rate for preoperative AVP and coil embolization was 100% and 83.3%, respectively. The median procedure time was shorter in patients whose CHA was embolized with AVP than coils; the difference was not significant (p = 0.045). The total cost was significantly lower for AVP than coil embolization (p = 0.01).
Conclusion The AVP is useful for the preoperative embolization of the CHA before DP-CAR.

Keywords Pancreatic cancer · Distal pancreatectomy with en bloc celiac axis resection · Embolization · Amplatzer vascular plug · Coil

✉ Tomoyo Fuji
b064820@yahoo.co.jp

Takuji Yamagami
yamagami@kochi-u.ac.jp

Wataru Fukumoto
wfukumoto@hiroshima-u.ac.jp

Yasutaka Baba
ybaba@hiroshima-u.ac.jp

Keigo Chosa
chosa@hiroshima-u.ac.jp

Masaki Ishikawa
ishikawam@kure-nh.go.jp

Makoto Iida
edamako@hiroshima-u.ac.jp

Akira Naito
anaitou.0651.na@gmail.com

Yoshiaki Murakami
mura777@hiroshima-u.ac.jp

Kenichiro Uemura
umk@hiroshima-u.ac.jp

Naru Kondo
k-naru@par.odn.ne.jp

Kazuo Awai
awai@hiroshima-u.ac.jp

[1] Department of Radiology, Chugoku Rosai Hospital, 1-5-1 Hirotagaya, Kure 737-0193, Japan

[2] Diagnostic Radiology, Kochi University, Kohasu, Okocho, Nankoku, Kochi, Japan

[3] Diagnostic Radiology, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima, Japan

[4] Department of Diagnostic Radiology, National Hospital Organization Kure Medical Center and Chugoku Cancer Center, 3-1 Aoyama, Kure, Hiroshima, Japan

[5] Department of Surgery, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima, Japan

Introduction

Distal pancreatectomy with en bloc celiac axis resection (DP-CAR) is performed to treat locally advanced pancreatic body cancer which until recently has been regarded as unresectable [1–5]. DP-CAR increases the resection and survival rate in patients with locally advanced cancer of the pancreatic body and/or tail [4, 6, 7]. During DP-CAR, the pancreatic body and tail, and the spleen are resected and en bloc lymphadenectomy and ligation of the celiac artery and common hepatic artery (CHA) are performed. To prevent complications due to hepatic and gastric arterial ischemia after DP-CAR, preoperative embolization of the common hepatic artery (CHA) and left gastric artery (LGA) has been recommended to facilitate the development of collateral pathways from the superior mesenteric artery (SMA) [4, 8–11].

In the past, metallic coils were used for preoperative embolization before DP-CAR [12, 13]. Reports from Japan documented the placement of Amplatzer vascular plugs (AVP; St. Jude Medical, St. Paul, MN, USA) in patients undergoing CHA embolization [5, 14]. We retrospectively compared the embolization success and complication rate, the time required for preoperative embolization before DP-CAR, and the procedural costs between patients who underwent CHA embolization with the AVP or coils.

Materials and Methods

Study Population

This study was approved by our institutional review board. The subjects are 19 patients who had undergone both CHA and LGA embolization before DP-CAR at our institution between April 2010 and September 2017. Patient demographics are shown in Table 1.

Interventional Procedure

For preoperative embolization performed before DP-CAR between 2010 and 2014, we used coils. After the AVP became commercially available in 2015, in all but one patient (case 19) we used the AVP. In this patient, we inserted coils at the first trial because the CHA rose sharply from the celiac artery and we thought it difficult to introduce a 4-F catheter.

We performed celiac arteriography on an angiography system (Aquilion LB, Toshiba Medical Systems, Ohtawara, Japan) via the right femoral artery using a 4.2-F catheter (Excellent EN catheter; Hanaco Medical, Saitama, Japan) and a 4-F sheath (Medikit, Tokyo, Japan). Then we embolized the CHA followed by that of the LGA and acquired celiac and superior mesenteric arteriograms to

Table 1 Demographic data

Patient	Sex	Age	Tumor		Diameter of the arteries (mm)	
			Size (mm)	Stage	CHA	LGA
1	*M*	79	28	*T*4	6.0	3.8
2	*M*	67	22	*T*4	3.9	2.7
3	*F*	79	16	*T*4	3.6	2.5
4	*F*	58	30	*T*3	4.0	2.0
5	*F*	67	23	*T*4	5.2	2.8
6	*M*	66	55	*T*4	6.4	1.5
7	*M*	70	55	*T*4	4.6	3.0
8	*F*	46	45	*T*4	4.9	3.0
9	*M*	77	33	*T*4	4.0	3.5
10	*M*	63	42	*T*4	5.4	2.0
11	*M*	77	16	*T*4	3.1	3.6
12	*M*	76	40	*T*4	4.9	3.4
13	*F*	72	16	*T*4	3.4	3.0
14	*F*	65	30	*T*4	3.5	2.5
15	*M*	72	27	*T*4	4.6	2.5
16	*M*	77	15	*T*4	4.9	1.8
17	*M*	67	50	*T*4	4.1	2.8
18	*M*	45	40	*T*4	5.7	3.5
19	*M*	75	8	*T*4	4.0	3.2

CHA common hepatic artery, *LGA* left gastric artery

confirm their complete embolization and the development of collateral pathways (Fig. 1).

The coils were detachable and pushable coils (GDC; Boston Scientific Japan, IDC; Boston Scientific Japan, Ruby; Penumbra, Alameda, CA). In four patients with very fast blood flow, we inserted coils under blood flow-control with a 3.3-F micro-balloon catheter (Attendant; Terumo Clinical Supply, Gifu, Japan) (Fig. 2).

For AVP embolization, we chose AVP 4; the diameter was 30–50% larger than the CHA diameter. We subsequently advanced the AVP to the tip of the catheter; 5–10 min later we performed arteriography from another catheter advanced to the celiac artery. After confirmation of collateral pathways, we released the AVP.

Assessment

We assessed the success in CHA embolization with the embolic agent used in the first trial. It was considered successful when three objectives were attained: (1) The CHA was completely embolized, (2) collateral pathways were observed, and (3) the AVP or coils were placed at the optimal site (the distal margin from the origin of the GDA ranged over 5 mm). We also assessed the total procedure time (from femoral artery puncture to post-embolization arteriography) and costs. In patient 18, CHA embolization failed and he was excluded from procedure time and cost evaluation.

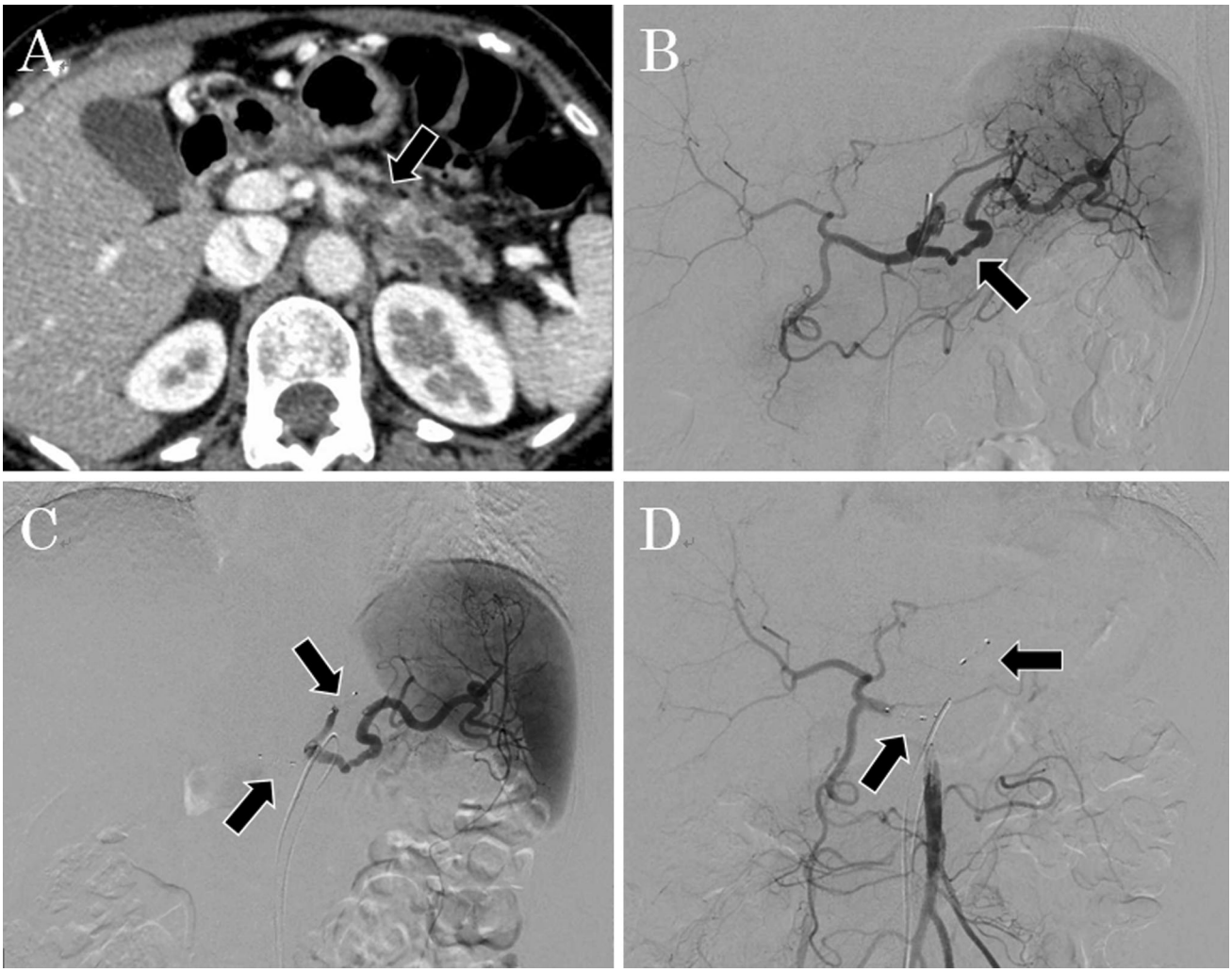

Fig. 1 AVP embolization. Patient 4. A 58-year-old woman with advanced cancer of the pancreas body. **A** Preoperative contrast-enhanced image (arterial phase) showing the pancreatic cancer (arrow). Note infiltration along the splenic artery to the celiac trunk and CHA. **B** Pre-embolization celiac arteriogram showing encasement at the proximal portion of the splenic artery (arrow). **C** Post-embolization celiac arteriogram obtained 5 min after expansion of the AVP (arrows) showing complete embolization of the CHA and LGA. **D** Post-embolization superior mesenteric arteriogram showing blood flow to the intrahepatic artery via the pancreatic arcade

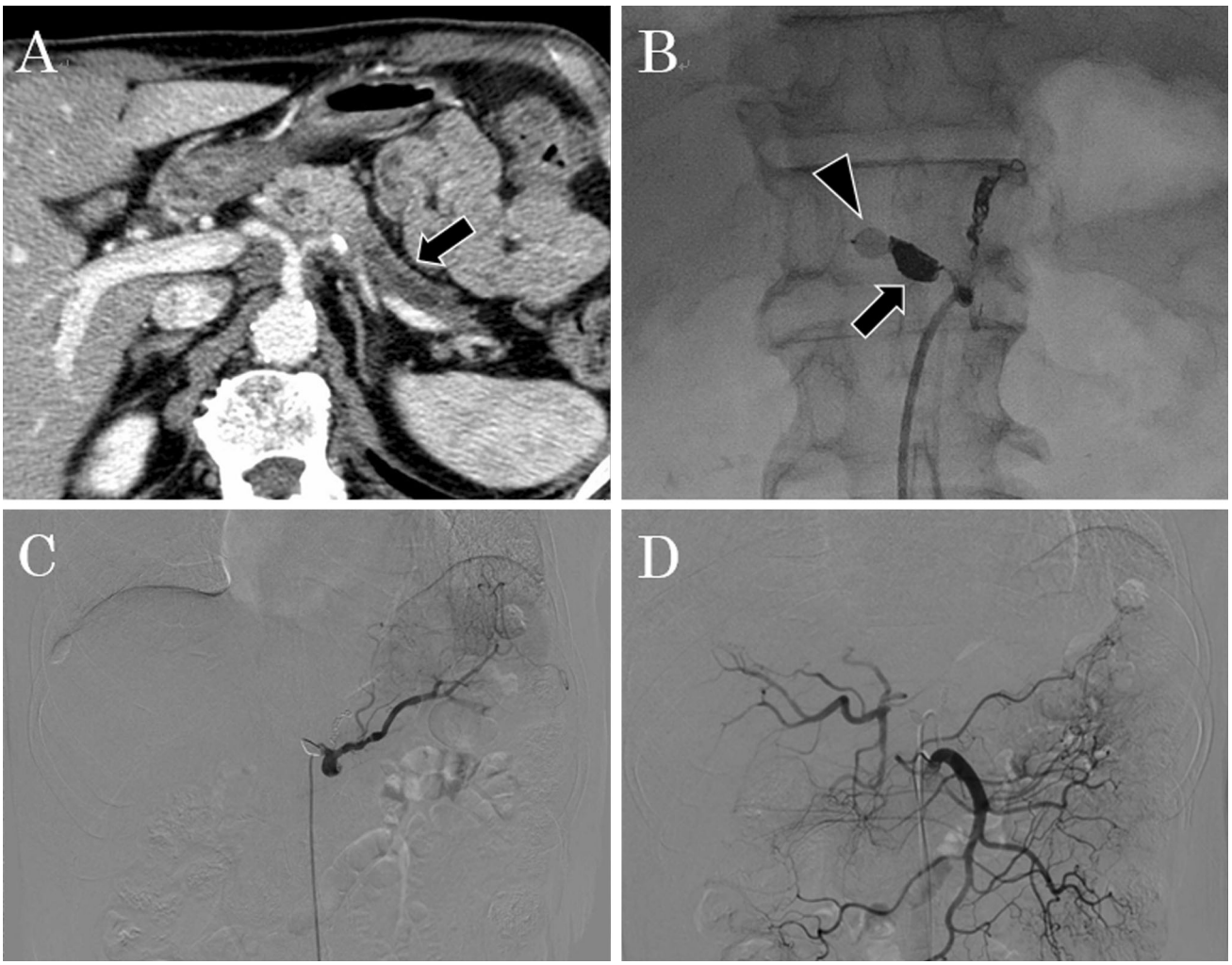

Fig. 2 Coil embolization. Patient 16. A 77-year-old man with advanced cancer of the pancreas body. **A** Preoperative contrast-enhanced image (arterial phase) showing the pancreatic cancer (arrow). Note infiltration along the splenic artery to the celiac trunk and the CHA. **B** After LGA embolization, the CHA was coil-embolized (arrow) under micro-balloon inflation (arrowhead). **C** Post-embolization celiac arteriogram showing complete embolization of the CHA and LGA with coils. **D** Post-embolization superior mesenteric arteriogram showing blood flow to the intrahepatic artery via the pancreatic arcade

Statistical Analysis

To compare the procedure time and costs, we used the Mann–Whitney *U*-test. To avoid statistical multiplicity, we compared only the total costs without analyzing the cost of embolic materials and other devices separately. Differences of $p < 0.05$ were considered significant.

Results

DP-CAR was successful in all patients; none developed complications such as hepatic or gastric ischemia. Embolic agents used for CHA embolization are listed in Table 2. CHA embolization at the first attempt was successful in all seven patients subjected to AVP placement and in 10 of 12 (83.3%) coil-embolized patients.

The median procedure time was 90 min for AVP and 106 min for coil embolization ($p = 0.045$) (Table 3). The median cost of the embolic materials and other devices is shown in Table 4. The median total procedural cost was 386,390 and 605,295 (Japanese Yen: JPY) respectively, and there was statistically significant difference in total cost ($p = 0.01$).

In two patients, we failed to obtain complete CHA embolization with coils because their blood flow was too fast. Patient 18 was treated before the AVP became commercially available and in patient 19 we initially placed coils because the CHA rose sharply from the celiac artery and we thought it difficult to push the 4-F catheter to the CHA and LGA. However, the coils migrated to the distal

Table 2 Technical information

Patient	Embolic agent used first	Outcome	Coil migration	AVP (size × number)		Coils (number)		Cost (JPY)			Procedure time (min)
				CHA	LGA	CHA	LGA	Total	Embolic agents	Other devices	
1	AVP	*S*	n.a.	7 mm × 1	4 mm × 1			273,090	258,000	15,090	110
2	AVP	*S*	n.a.	5 mm × 1	5 mm × 1			286,390	258,000	28,390	80
3	AVP	*S*	n.a.	5 mm × 1	4 mm × 1			273,090	258,000	15,090	90
4	AVP	*S*	n.a.	6 mm × 2	4 mm × 1			402,090	387,000	15,090	60
5	AVP	*S*	n.a.	8 mm × 1	5 mm × 1			286,390	258,000	28,390	60
6	AVP	*S*	n.a.	8 mm × 1			1	334,090	249,000	85,090	90
7	AVP	*S*	n.a.	8 mm × 1			2	399,680	306,000	93,680	100
8	Coils	*S*	No			2	2	571,100	476,000	95,100	162
9	Coils	*S*	No			5	12	842,190	729,400	112,790	151
10	Coils	*S*	No			2	4	441,390	328,600	112,790	94
11	Coils	*S*	No			8	11	1,295,790	1,183,000	112,790	155
12	Coils	*S*	No			5	3	524,180	416,200	107,980	95
13	Coils	*S*	No			4	4	389,880	282,800	107,080	50
14	Coils	*S*	No			3	3	257,720	197,400	60,320	106
15	Coils	*S*	No			8	4	1,222,570	1,151,000	71,570	100
16	Coils	*S*	No			1	2	639,490	432,000	207,490	140
17	Coils	*S*	No			5	5	671,690	494,000	177,690	105
18	Coils	*F**	Yes				3				
19*	Coils	*F*/*S***	Yes	8 mm × 1	6 mm × 1						

S success, *F* failure, *CHA* common hepatic artery, *LGA* left gastric artery, *AVP* Amplatzer vascular plug

*Changed from coils to an AVP

**Excluded from cost and procedural time evaluation

Table 3 Procedure time

Embolic materials	Procedure time (min)	*p* value
AVP	90 (60–110)	0.04
Coil	105 (50–155)	

Numbers indicate the median, and number in the parenthesis the range

Procedure cost is shown in Japanese Yen (JPY)

AVP Amplatzer vascular plug

artery. By switching to the AVP, we were able to embolize the vessels successfully.

Discussion

Traditionally, metallic coils were used for preoperative embolization before DP-CAR [9, 12, 13]. This technique is technically complicated, and coil migration must be avoided. In some patients, a micro-balloon must be deployed to

Table 4 Procedure cost

Embolic materials	Total cost (range)	Embolic materials cost (range)	Other device cost (range)
AVP	286,390 (273,090–402,090)	258,000 (249,000–387,000)	28,390 (15,090–93,680)
Coils	605,295 (257,720–1,295,790)	454,000 (197,400–1,183,000)	110,385 (60,320–207,490)
p value	0.01	N/A	N/A

Numbers indicate the median, number in parenthesis the range

The procedure cost is shown in Japanese Yen

AVP Amplatzer vascular plug

control arterial flow [12, 13]. Moreover, as complete embolization may require many coils, it is time-consuming and expensive.

Recently, reports of preoperative embolization before DP-CAR with the AVP have been shown [5, 14–16]. These reports suggested this technique is simple and safe. The AVP is an embolic device comprised of self-expandable nitinol wire mesh. As it can be positioned precisely, the risk for migration is low, and complete embolization can be achieved with a single embolic device [17, 15, 18]. AVP embolization does not require the deployment of expensive micro-catheters and wires and when flow in the collaterals is suboptimal, the plug can be retrieved.

Our study has some limitations. It was non-randomized, retrospective, and the number of patients was small. Our cost studies are Yen-based and the cost of embolization using other currencies must be performed.

Our findings suggest that both, AVP and coil embolization of the CHA before DP-CAR, yielded equivalent procedural success rates and AVP embolization elicited no complications. However, the total costs are significantly lower and the procedure time is significantly shorter when the AVP rather than coils are used. Additional studies are needed to determine whether the AVP is the optimal embolic device for preoperative embolization before DP-CAR.

Compliance with Ethical Standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical Approval All procedures in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent This study was approved by our institutional review board; prior informed patient consent was waived because ours was a retrospective study.

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