Case Report

Permissive untreated pseudoaneurysm concept in damage control interventional radiology for traumatic pancreaticoduodenal artery injury

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Background: Angioembolization for traumatic pancreaticoduodenal artery injury with unstable circulation, which characteristically requires a prolonged procedure time, does not yet have a standardized strategy for damage control interventional radiology.

Case Presentation: We encountered two cases of rare traumatic pancreaticoduodenal artery injury wherein the patients were saved by a multidisciplinary team with a shared goal of clinical success, rather than the procedural success of angioembolization. Both patients treated with angioembolization had residual pseudoaneurysm or faint extravasation in the pancreaticoduodenal artery arcade. We prioritized critical care with preemptive plasma transfusion and aggressive blood pressure control, and planned repeat angiography. The patients showed no clinical signs of rebleeding or pseudoaneurysm based on computed tomography during follow-up.

Conclusion: Our findings suggest that the permissive untreated pseudoaneurysm concept can be useful in developing damage control interventional radiology strategies for trauma cases with challenging time limitations, such as traumatic pancreaticoduodenal artery injury with circulatory collapse.

Key words: Interventional radiology, multidisciplinary care team, pseudoaneurysm, therapeutic embolization, traumatic shock

INTRODUCTION

HEMOSTATIC ANGIOEMBOLIZATION, A potentially life-saving treatment for traumatic hemorrhagic shock, must be a prompt and flexible procedure based on the time-sensitive strategy of damage control interventional radiology (DCIR).[1] Angioembolization has become a more common alternative for achieving hemostasis in traumatic pancreaticoduodenal artery injury (TPDAI) after abdominal trauma than surgery.[2] Angioembolization of the pancreaticoduodenal arcade artery, which is fed by both the celiac artery (CA) and the superior mesenteric artery (SMA), requires a coil-isolation technique. Pancreaticoduodenal arcade artery angioembolization therefore inherently prolongs the procedure time.[3] Thus, when performing TPDAI hemostasis by angioembolization in circulatory collapse, two conflicting aspects must be balanced: a time-conscious DCIR strategy and prolonged angioembolization procedure time. We report two life-saving cases of rare TPDAI requiring the permissive untreated pseudoaneurysm (PUP) concept as a new DCIR strategy.

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Received 22 Jul, 2022; accepted 25 Jan, 2023

CASE PRESENTATION

CLINICAL AND TRAUMATIC characteristics are shown in Table 1, and overview of resuscitation and angiography procedures are shown in Table 2.

Case 1

A 63-year-old man experienced traumatic hemorrhagic shock due to injuries sustained during a head-on collision between two minivans and was brought to our emergency department in an ambulance. After initial fluid resuscitation, a whole-body computed tomography (CT) scan revealed a pancreatic head hematoma with extravasation in the arterial

Table 1. Clinical and traumatic characteristics of two cases of traumatic pancreaticoduodenal artery injury.

	Case 1	Case 2
Age, years	63	67
Sex	Male	Male
Charlson comorbidity index	3	2
Preexisting antiplatelet agent	No	Yes
Preexisting anticoagulant	No	Yes
Mechanism of injury	Seat belt injury	Seat belt injury
Time from injury to ED admission, min	37	65
ISS	17	32
AIS for chest	0	4
AIS for abdomen	4	4
AIS for extremity	1	0
ED vital signs		
Initial GCS score	14	15
Initial respiratory rate, breaths per min	24	26
Initial heart rate, b.p.m.	64	140
Initial SBP, mmHg	92	67
Lowest body temperature, °C	35.1	35.0
ED blood tests		
Lowest hemoglobin count, g/dL	5.8	6.3
Lowest platelet count, 10^9/L	111	27
Lowest fibrinogen level, mg/dL	265	122
Highest INR	1.04	1.58
Lowest base deficit, mmol/L	−1.1	−11.2
Lowest iCa, mmol/L	1.03	0.56
Highest lactate, mg/dL	4.8	9.3
ICU stay, day	4	6
Hospital stay, day	9	36
FIM at discharge (126 points at best)	121	116
Disposition at discharge	Home	Transfer to hospital

AIS, Abbreviated Injury Scale; ED, emergency department; FIM, functional independence measure; GCS, Glasgow Coma Scale; iCa, ionized calcium; ICU, intensive care unit; INR, international normalized ratio; ISS, injury severity score; SBP, systolic blood pressure.

Table 2. Overview of resuscitation and angiography in two cases of traumatic pancreaticoduodenal artery injury.

	Case 1	Case 2
MTP activation	No	Yes
Time from ED admission to blood product delivery, min	51	7
Blood transfusion in the ED		
Plasma, units[†]	10	48
Platelets, units[‡]	0	20
RBC, units[§]	10	32
Blood transfusion by 24 h		
Plasma, units[†]	18	84
Platelets, units[‡]	0	40
RBC, units[§]	10	48
Crystalloid volume, mL	3,000	10,000
Emergency physicians specializing in IR on patient arrival	Available	Available
Whole-body CT scan before AG	Yes	Yes
Time from ED admission to initial CT scan, min	29	17
ED chest drainage	No	Yes
ED thoracotomy for resuscitation	No	No
ED laparotomy for damage control surgery	No	Yes
ED use of REBOA	Yes	Yes
REBOA total inflation time, min	18	50
Time from ED admission to first AG, min	78	45
First AG		
SBP at the beginning of the procedure, mmHg	123	76
Procedure duration, min	63	90
Residual AG findings	Pseudoaneurysm	None
Second AG		
SBP at the beginning of the procedure, mmHg	116	67
Procedure duration, min	97	80
Residual AG findings	Pseudoaneurysm	Faint extravasation in the delayed phase

phase (Fig. 1A). Angiography was initiated in the emergency department, with rapid blood transfusion after resuscitative endovascular balloon occlusion of the aorta (REBOA). Extravasation was confirmed by CA angiography, and the posterior superior pancreaticoduodenal artery (PSPDA) was embolized as the culprit vessel using N-butyl-2-cyanoacrylate glue (NBCA) (Fig. 1B). The pseudoaneurysm persisted on postembolization CA angiography, but not on SMA angiography (Fig. 1C,D). We scheduled

Table 2. (Continued)

	Case 1	Case 2
Third AG	(Not undertaken)	
SBP at the beginning of the procedure, mmHg	–	109
Procedure duration, min	–	41
Residual AG findings	–	None
Antihypertensive infusions in the initial ICU admission	Yes	Yes
Rebleeding or pancreatitis after last AG	None	None
Pancreatic fistula associated with trauma	None	None
Residual pseudoaneurysms in follow-up CT before discharge	None	None

AG, angiography; CT, computed tomography; ED, emergency department; ICU, intensive care unit; IR, interventional radiology; MTP, massive transfusion protocol; RBC, red blood cell; REBOA, resuscitative endovascular balloon occlusion of the aorta; SBP, systolic blood pressure.
†Plasma: 1 unit contains 120 mL in Japan.
‡Platelets: 1 unit contains 20 mL in Japan.
§RBC: 1 unit contains 140 mL in Japan.

reangiography to shorten the procedure time and transferred him to the intensive care unit. Second-look CA and SMA angiographies were carried out in the radiology department's angiography room, while coagulopathy correction and antihypertension therapy were administered. However, the culprit vessel of the pseudoaneurysm could not be identified using CT angiography (Fig. 1E,F). Subsequently, the patient did not have clinical signs of rebleeding or pancreatic fistula. On CT performed on the seventh day postinjury, the pseudoaneurysm had disappeared.

Case 2

A 67-year-old man who was driving a minivan experienced shock after sustaining injuries from a collision with a cargo truck. He was brought to our emergency department on an emergency helicopter, and was receiving rapid fluid infusion. Right hemothorax was found on ultrasonography; therefore, a thoracic drain was inserted and CT was performed while the patient underwent rapid blood transfusion. Computed tomography in the arterial phase showed a large hematoma around the pancreatic head with extravasation (Fig. 1G) and right diaphragmatic injury. After another drop in blood pressure, we immediately initiated laparotomy with REBOA placement and performed angiography for the first time in our emergency department. Damage control surgery (DCS) was performed with a quick repair of the right diaphragmatic injury and abdominal gauze packing. After confirming multiple extravasations by CA and SMA angiography, we performed NBCA embolization of the PSPDA from the CA side and coil embolization of a branch of the inferior pancreaticoduodenal artery (IPDA) from the SMA side (Fig. 1H,I). Repeat CT showed residual extravasation in the hematoma around the pancreas, and a second angiography was performed in the emergency department. Extravasation from the IPDA branch of the SMA side that was embolized in the initial angiography was observed. The IPDA was recanalized with the transverse pancreatic artery branch through the dorsal pancreatic artery from the CA side, then re-embolized with NBCA (Fig. 1J). Although faint extravasation was still seen in the delayed phase of postembolization SMA angiography (Fig. 1K), we transferred the patient to the intensive care unit and planned to repeat the angiographs. Third-look CA and SMA angiographies in the radiology department, after coagulopathy correction and antihypertensive therapy, demonstrated that the extravasation had disappeared (Fig. 1L). Subsequently, no clinical signs of rebleeding or pancreatic fistula were noted. Follow-up CT on the 10th day postinjury showed no pseudoaneurysm recurrence.

DISCUSSION

WE RECONSIDERED THE management of pseudoaneurysm in DCIR because the angioembolization procedure time for TPDAI is longer than that for other injuries. Pancreaticoduodenal arcade artery embolization from the CA side increases retrograde blood flow from the SMA, leading to rapid development of pseudoaneurysms and rebleeding.[4] Treating large numbers of embolized arteries and regions using angioembolization in trauma patients results in prolonged procedure duration,[5] which conflicts with the time-sensitive nature of the procedure. Therefore, besides the conventional time-saving DCIR strategy of NBCA and nonselective embolization,[1] we applied a new PUP treatment concept, "aggressive preservation of untreated pseudoaneurysm," which involved planned repeat angiography because of severe circulatory instability and coagulopathy. Our experience with the two TPDAI cases suggests that a pseudoaneurysm without identifiable feeder-artery on angiography may have low blood flow. As in the

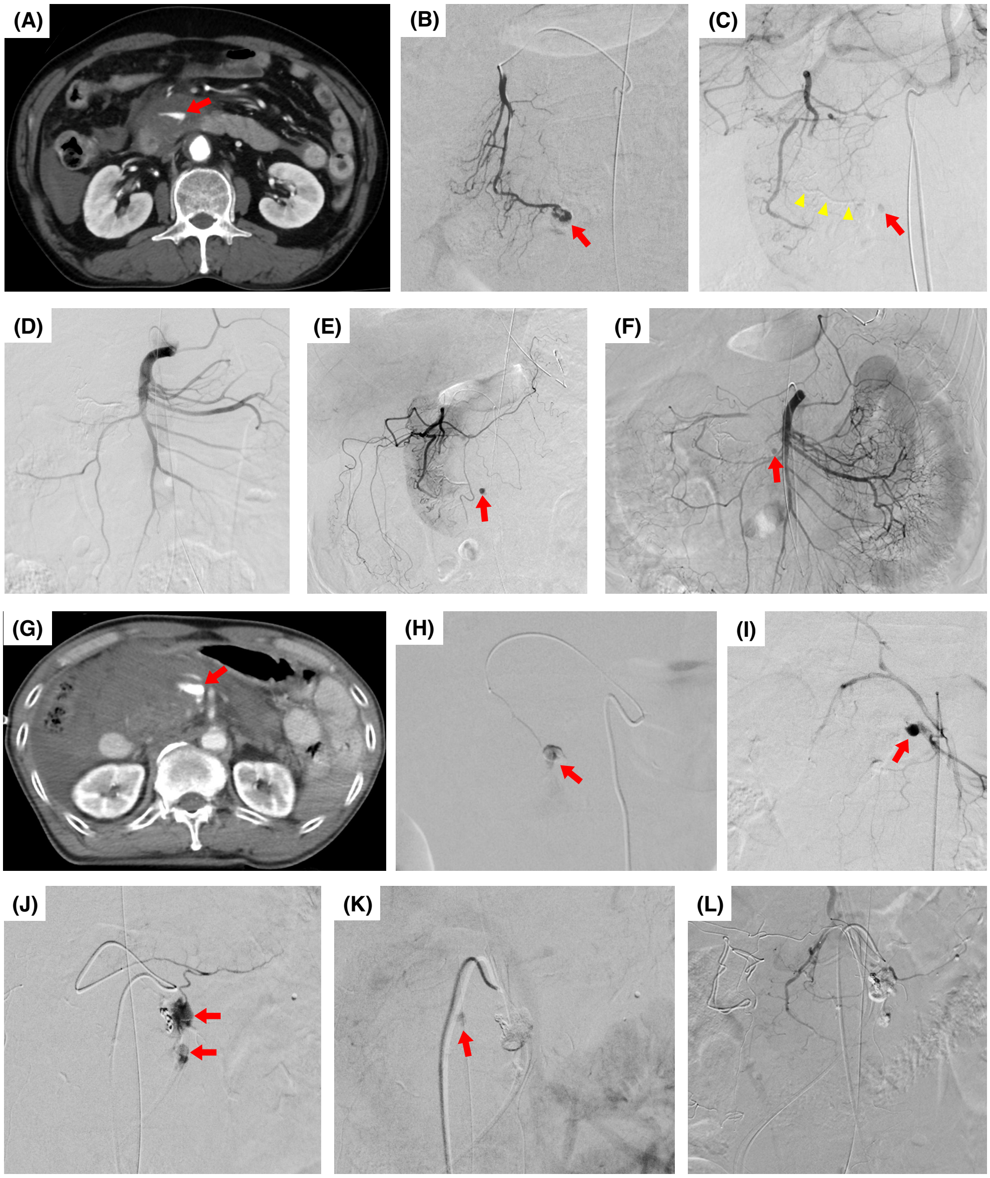

Fig. 1. A–F, Imaging of a 63-year-old man with traumatic pancreaticoduodenal artery injury. A, Contrast-enhanced computed tomography (CT) showing a pancreatic head hematoma with extravasation (arrow) in the arterial phase. B, Angiography of the posterior superior pancreaticoduodenal artery (PSPDA) in the first angiography session showed extravasation. C, Celiac artery (CA) angiography showed a cast-like embolization of PSPDA (arrowheads) and disappearance of extravasation, although a pseudoaneurysm of unknown origin (arrow) appeared after embolization with n-butyl-2-cyanoacrylate (NBCA). D, Superior mesenteric artery (SMA) angiography after PSPDA embolization showed no pseudoaneurysm. E, Gastroduodenal arteriography in the second angiography session after stabilization in the intensive care unit showed a residual pseudoaneurysm (arrow), although the culprit vessel could not be identified. F, The final SMA angiograph also shows a residual pseudoaneurysm (arrow) without identification of the culprit vessel. G–L, Imaging of a 67-year-old man with traumatic pancreaticoduodenal artery injury. G, Initial contrast-enhanced CT of the arterial phase showing massive extravasation of the pancreatic head (arrow). H, Extravasation is seen on PSPDA angiography from the CA side in the first angiography session (arrow) and embolized with NBCA. I, Extravasation is seen at the inferior pancreaticoduodenal artery branch from the SMA side (arrow) and embolized using NBCA in combination with microcoils. J, Rebleeding from the dorsal pancreatic artery through the CA side is seen in the second angiography session (arrows) and embolized with NBCA. K, Faint extravasation is seen in the delayed phase of postembolization CA angiography (arrow), but it was difficult to identify the culprit vessel. L, In the third angiography session, extravasation disappeared in both CA and SMA angiographies.

multicenter retrospective review of the natural history of blunt splenic injuries,[6] we hypothesize that such low-flow pseudoaneurysms can be spontaneously thrombosed. We also comprehensively applied the PUP approach to the faint extravasation that appeared gradually in the delayed phase of angiography in case 2 because of its similarity to a pseudoaneurysm. Permissive untreated pseudoaneurysm concept may be generalized as a DCIR strategy to be applied in situations where time is limited and searching for the culprit vessel of a pseudoaneurysm in severe multiple traumas is not possible. Park *et al*.[2] reported that planning angioembolization procedures by an interventional radiologist using CT likely reduces the number of angiographies required. However, we believe the trauma team should plan multiple short angiographies for DCIR of hemorrhagic shock, as needed. In other words, the trauma team takes the risk of temporarily lessening the priority of procedural pseudoaneurysm treatment in severe trauma to achieve eventual clinical success. Our proposed PUP methodology of DCIR as a trauma team approach is similar to DCS; planned repeat surgery became a mainstay treatment during the paradigm shift in trauma surgery approximately 30 years ago.[7]

Although we regard PUP as an important component of future damage control strategies for a trauma team, interventional radiologists must carefully decide on its indication criteria. The first criterion is when a prolonged procedure time is anticipated. Our actual angiography took approximately 60–90 min per session, including embolization of the extravasation (Table 2). We suggest considering the PUP approach when angiography with multiple findings requiring embolization is expected to take longer than 60 min. Second, it is difficult to apply PUP when there is bleeding into the free space in the torso. Permissive untreated pseudoaneurysm methodology is more likely to be applied to a retroperitoneal hematoma, where it may produce a tamponade effect, than to an intrathoracic or intraperitoneal hemorrhage. Third, hemodynamic alterations on angiography can affect PUP indication. Permissive untreated pseudoaneurysm should be considered in cases of severe vasospasm with shock or traumatic artery-to-artery/arteriovenous communication leading to difficulty in catheterization to the feeding artery. In all cases, surgical hemostasis should always be considered. Overall, the clinical decision-making process to reach to a risk–benefit balance between the loss of tamponade effect by opening the retroperitoneal hematoma and producing surgical hemostasis under direct visualization is quite controversial.

Essential requirements for PUP implementation in traumatic hemorrhagic shock are close circulatory control, preemptive plasma transfusion with massive transfusion protocol, and prompt complementary DCS. In our two cases without brain injury, we specifically implemented antihypertensive control with a target systolic blood pressure of approximately 90–100 mmHg to avoid excessive hypertension and hypotension.[8] Aggressive blood pressure control and massive transfusion protocol with a high ratio of plasma[8] may help spontaneously thrombose pseudoaneurysms. Additionally, a comprehensive multidisciplinary approach with complementary use of DCS and DCIR is an important life-saving strategy, especially in fatal and complex trauma and polytrauma.[9] In both shock cases, REBOA was useful in providing temporary circulatory support. Conversely, PUP should be contraindicated in situations where these damage control strategies have not been promptly initiated.

In conclusion, the strategy of prioritizing clinical success should be shared by an emergency physician/trauma surgeon skilled in angioembolization techniques, an interventional radiologist, and the trauma team leader and multidisciplinary team members to ensure understanding of damage control strategies and aid in the effective use of PUP.

DISCLOSURE

APPROVAL OF THE research protocol with approval no. and committee name: N/A.

Informed consent: Informed consent for publication was obtained from the patients and/or families.

Registry and registration no. of the study/trial: N/A.

Animal studies: N/A.

Conflict of interest: None.

REFERENCES

1 Matsumoto J, Lohman BD, Morimoto K, Ichinose Y, Hattori T, Taira Y. Damage control interventional radiology (DCIR) in prompt and rapid endovascular strategies in trauma occasions (PRESTO): a new paradigm. Diagn. Interv. Imag. 2015; 96: 687–91.

2 Park Y, Kim Y, Lee J, Cho BS, Lee JY. Pancreaticoduodenal arterial hemorrhage following blunt abdominal trauma treated with transcatheter arterial embolization: two case reports. Medicine 2020; 99: e22531.

3 Ikeda O, Nakasone Y, Tamura Y, Yamashita Y. Endovascular management of visceral artery pseudoaneurysms: transcatheter coil embolization using the isolation technique. Cardiovasc. Intervent. Radiol. 2010; 33: 1128–34.

4 Hasegawa T, Seiji K, Ota H *et al*. Rapid development of new aneurysms in the adjacent pancreatic arcade arteries after urgent embolization of pancreaticoduodenal artery aneurysms in cases with celiac stenosis. J. Vasc. Interv. Radiol. 2018; 29: 1306–1308.e2.

5 Aoki M, Matsumoto S, Toyoda Y *et al*. Factors associated with prolonged procedure time of embolization for trauma patients. Acute Med. Surg. 2022; 9: e743.
6 Zarzaur BL, Dunn JA, Leininger B *et al*. Natural history of splenic vascular abnormalities after blunt injury: a Western Trauma Association multicenter trial. J. Trauma Acute Care Surg. 2017; 83: 999–1005.
7 Rotondo MF, Schwab CW, McGonigal MD *et al*. 'Damage control': an approach for improved survival exsanguinating penetrating abdominal injury. J Trauma 1993; 35: 375–83.
8 Spahn DR, Bouillon B, Cerny V *et al*. The European guideline on management of major bleeding and coagulopathy following trauma: fifth edition. Crit. Care 2019; 23: 98.
9 Asensio JA, Petrone P, Garcí-Núñez L, Kimbrell B, Kuncir E. Multidisciplinary approach for the management of complex hepatic injuries AAST-OIS grades IV—V: a prospective study. Scand. J. Surg. 2007; 96: 214–20.