New Hemostatic method with Preserving Peripheral Blood Flow for Visceral Artery Bleeding: An Experimental Study in Swine

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**Purpose**

Visceral artery pseudoaneurysm is a rare but serious complication of abdominal surgery, trauma, infection, or inflammatory disease [1]. Rupture of a pseudoaneurysm into the gastrointestinal tract or peritoneal cavity is often associated with massive, life-threatening hemorrhage.

Transcatheter arterial embolization (TAE) is currently considered the first choice of treatment for massive bleeding [2-3]. Nevertheless, proximal artery occlusion by TAE sometimes causes critical distal end-organ damage and often results in death despite achieving hemostasis. The absence of collateral arteries due to a previous surgical procedure can be a main cause of hepatic failure as a complication of TAE that results in postoperative bleeding after pancreaticoduodenectomy or hepatic lobectomy [4-5].

We developed a new hemostatic procedure that preserves peripheral artery flow using coil embolization and an indwelling catheter with side holes to prevent distal end-organ complication arising from TAE. Here, we assessed the ability of this method to control visceral artery bleeding in pigs.
Methods and Materials

Animals

Our institutional Animal Care and Use Committee approved the study protocols and laboratory animals were handled and maintained according to institutional guidelines. General anesthesia was induced in 10 healthy female pigs (age, 3 - 4 months; average weight, 47 kg, range, 37 - 51 kg) by intramuscular injections of medetomidine and ketamine hydrochloride at 80 µg/kg and at 5 mg/kg, respectively. The animals were intubated and ventilated using a mixture of nitrous oxide, oxygen and 1.5 - 3% sevoflurane, and euthanized with a lethal injection of potassium chloride after completing the experiment.

Experiment 1: Preliminary investigation

We evaluated whether peripheral blood flow in the SMA (superior mesenteric artery) of six pigs could be preserved via a 5F Anthron® P-U catheter (Toray, Tokyo, Japan) with a single hole created manually in the side 5 cm proximal from the tip. The maximal diameter of the side hole was adjusted to 5 mm.

A 5F introducer sheath was inserted via the internal carotid artery. Vascular anatomy and SMA blood flow was assessed from an abdominal aortogram that was obtained using a 4F head-hunter angiographic catheter (Terumo, Tokyo, Japan). Another 5F introducer sheath was then inserted via the common femoral artery. After selective catheterization into the SMA using a 4F J-shaped angiographic catheter (Terumo), a 0.035-inch guidewire (Radifocus, Terumo) was advanced into the SMA. The angiographic catheter was withdrawn while holding the guidewire in place, and a 5F Anthron®P-U catheter was inserted over the guidewire and advanced into the SMA. The SMA was ligated with silk between the catheter tip and the side hole through an abdominal incision, taking care not to occlude the catheter lumen. Abdominal aortography proceeded immediately thereafter and at one and two hours later to evaluate whether peripheral blood flow via the side hole through the catheter could be preserved.

Experiment 2: Technical feasibility

Structure of the catheter

A 6F Anthron® P-U catheter with two symmetrically arranged side holes and a maximal diameter between 2.43 and 2.85 mm was placed 5 cm proximal from the catheter tip. These catheters were custom-made by Toray Corp. (Tokyo, Japan)
The mean and minimal tensile strength of the catheter was 34.1 and 31.9 N, respectively. The mean tensile strength of the catheter before creating the side hole was 66.6 N and that of the catheter with two side holes was about 2-fold lower than that of the unprocessed catheter.

*Technical procedure*

We evaluated the ability of our hemostatic method to preserve peripheral blood flow in four pigs. After abdominal aortography as described in Experiment 1, the SMA was selectively catheterized with a 4F angiographic catheter introduced through a 6F sheath via the common femoral artery. A 0.035-inch guidewire was advanced into the SMA. The angiographic catheter was withdrawn while holding the guidewire in place, and the 6F Anthron® P-U catheter was inserted over the guidewire and advanced to the orifice of the SMA.

We punctured the main trunk of the SMA using an 18 gauge metal needle with a plastic sheath to create a bleed from the SMA through an abdominal incision. A 6F Anthron® P-U catheter was advanced into the SMA immediately after puncture, and the midpoint between the tip and the side holes of the catheter was adjusted to conform to the puncture site. A microcatheter was coaxially inserted into the SMA through the indwelling catheter and passed through the side hole. The SMA was embolized using microcoils (Vortx, Boston Scientific Corp., MA, USA) placed around the catheter to achieve hemostasis.

Hemostasis and ischemic changes of the intestine were directly observed. Peripheral blood flow was assessed by abdominal aortography immediately after these procedures, and at one and two hours thereafter.
Fig. 1: Catheter used in Experiment 1. Single side hole created manually 5 cm from tip of 5F Anthron® P-U catheter.

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Fig. 2: Catheter used in Experiment 2. Two side holes (arrow) are symmetrically positioned 5 cm from tip of 6F Anthron® P-U catheter.

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Results

Experiment 1: Preliminary investigation

The catheters were precisely positioned and the SMA blood flow around the catheter was completely disrupted by the ligation. Peripheral blood flow via the side hole through the catheter was preserved without stagnation for up to two hours in all six pigs. No ischemic changes of the intestine were evident.

Experiment 2: Technical feasibility

The catheters were easily and precisely placed at the intended position in all four pigs. Coil embolization of the SMA was achieved with a microcatheter inserted coaxially into the SMA through the indwelling catheter and passed through the side hole. Hemostasis of the SMA was achieved immediately after embolization and peripheral blood flow via the side hole through the catheter was preserved without stagnation for up to two hours in all four pigs. Ischemic changes in the intestine were not visible.

There were no vascular adverse events during or after the procedure, such as intimal dissection, thromboembolic occlusions or any vascular damage of the SMA and its branches.

Our hemostatic method using an indwelling catheter with side holes and coil embolization enabled the preservation of blood flow in the peripheral artery, and this prevented distal end-organ ischemic damage. Since coil embolization around the catheter has been used in hepatic arterial infusion chemotherapy (HAIC) with a subcutaneously implanted port, the value of coil embolization has already been established [6-7]. On the other hand, this study is original because we used a catheter with side holes to preserve peripheral artery flow.

Stent grafts could serve as an alternative hemostatic procedure, as arterial patency is preserved and midterm results are favorable [8]. However, several potential disadvantages are associated with stent grafts, including risk of arterial rupture derived from the insertion of a large, stiff delivery system through a fragile vascular wall, more time being required to achieve hemostasis than TAE due to technical difficulties, and the availability of stock stent grafts [3-4]. When placing stent grafts is technically difficult because of a tortuous artery or if an appropriate stent graft is unavailable, our hemostatic method could serve as an alternative procedure.

The present study has several limitations. Firstly, we implemented the study only during the acute phase for up to two hours. Secondly, we did not evaluate the splenic or common
hepatic arteries that are particularly vulnerable to damage or postoperative bleeding caused by pseudoaneurysm rupture with pancreatic fistula.
Fig. 3: Abdominal laparotomy in Experiment 1. SMA isolation and ligation with silk after catheter placement.

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Fig. 4: Abdominal aortogram obtained before catheter placement in Experiment 1. Spastic stenosis of SMA (arrow) due to vessel isolation.

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Fig. 5: Abdominal aortography at two hours after procedures. Complete disruption of SMA around catheter at ligation site (arrow) and preserved peripheral blood flow (arrowheads).

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**Fig. 6:** Puncture of SMA with 18 gauge metal needle and plastic sheath in Experiment 2.

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**Fig. 7:** Abdominal aortogram immediately after catheter placement and coil embolization (arrow) in Experiment 2. Peripheral blood flow of SMA (arrowheads) is preserved without extravasation.

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**Fig. 8:** Abdominal aortogram two hours after procedure. Peripheral blood flow of SMA is preserved (arrowheads).

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Conclusion

Our new hemostatic method is a technically feasible way to control acute visceral artery bleeding while preserving peripheral artery blood flow. The present findings indicate that this method will be clinically useful, particularly for patients without collateral arteries who are likely to develop serious ischemic complications.
References


