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INTERVENTIONAL RADIOLOGY
TECHNICAL NOTE

Embolization using warmed glue via the triaxial microballoon occlusion system for various vascular disorders

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PURPOSE
We aimed to illustrate the benefits of using warmed glue for viscosity reduction via the triaxial microballoon system for the treatment of various vascular disorders.

METHODS
Seven patients who underwent 10 treatment sessions for hemoptysis, type II endoleak, post-pancreatic surgical bleeding, spontaneous retroperitoneal bleeding, or ovarian tumor bleeding were evaluated based on technical and clinical outcomes. In the procedure, the triaxial system, consisting of a 4.5 F guiding catheter, a 2.8 F microballoon catheter, and a 1.9 F no-taper microcatheter, was advanced into the target lesion. Glue (33% n-butyl cyanoacrylate mixed with Lipiodol) warmed to 40°C was injected under balloon occlusion.

RESULTS
The common hepatic, right bronchial, intercostals, internal mammary, costocervical, lateral thoracic, superior thoracic, thoracoacromial, inferior thyroid, iliolumbar, lumbar, internal pudendal arteries, and branch of the inferior mesenteric artery were successfully embolized; 100% technical success and 100% clinical success were obtained after each session.

CONCLUSION
Our modified balloon-occluded glue embolization may lead to better handling with more distal glue penetration capability.

Adhesive properties of glue (n-butyl cyanoacrylate, B. Braun Melsungen AG) are used to achieve permanent vessel occlusions; however, glue carries the risk of organ damage due to nontarget embolization (1–3). The glue cast distribution in the vasculature depends on blood flow velocity, vessel anatomy, and glue viscosity; these factors could be controlled to some degree by modifying the preparation and/or injection devices (1–5). The flow-arrest condition under balloon occlusion produces a dense glue cast and reduces the risks of embolic reflux (2, 3). To achieve better handling with more distal penetration capability, we used warmed glue for viscosity reduction via a new triaxial microballoon system and illustrate the technical details in this report.

Technique

Patients

Between July 2018 and April 2019, 10 treatment sessions with the triaxial microballoon system using warmed glue were performed in 7 patients (5 men and 2 women; age range, 49–87 years; median age, 75 years; Table 1). The underlying diseases and symptoms of the 7 patients were as follows: hemoptysis in 1 patient due to aspergillosis; hemorrhagic shock in 3 patients due to postoperative bleeding after pancreaticoduodenectomy in 1 patient and spontaneous retroperitoneal bleeding in 2 patients; enlargement of an abdominal aortic aneurysm due to type II endoleak after endovascular aortic repair (EVAR) in 2 patients; severe anemia with coagulopathy due to bleeding within recurrent tumor of ovarian cancer in 1 patient. All patients underwent clinical follow-up 1–10 months (median, 4.5 months) postprocedure to evaluate for recurrent symptoms.

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Table. Patient characteristics, embolization data, and outcome

	Patient characteristics			Embolization data					Outcomes	
Session no.	Age (y)/ sex	Symptom	Underlying disease	Target artery	Glue ratio (%)	No. of injections	Glue amount (mL) Each[a]	Glue amount (mL) Total	Other materials	Technical success	Clinical success
1	78/M	Hemoptysis	Aspergillosis	Right bronchial, intercostal	33	2	0.6–0.4 (0.5)	1	No	Yes	Yes[b]
2				Intercostal, costocervical, thoracoacromial	33	4	0.8–1.2 (0.9)	3.8	No	Yes	Yes[b]
3				Lateral thoracic, internal mammary	33	2	1.5–2.0 (1.75)	3.5	Coil	Yes	Yes[b]
4				Superior thoracic, inferior thyroid	33	2	0.8–2.0 (1.4)	2.8	No	Yes	Yes
5	87/F	Enlargement of AAA	Type II endoleak after EVAR	Lumbar	33	1	1	1	No	Yes	Yes
6	83/M	Enlargement of AAA	Type II endoleak after EVAR	Lumbar	33	1	0.4	0.4	No	Yes	Yes
7	75/M	Hemorrhagic shock	Hemorrhage after PD	Common-proper hepatic	33	1	0.5	0.5	Coil	Yes	Yes
8	70/M	Hemorrhagic shock	Retroperitoneal hemorrhage	Lumbar, iliolumbar, iliac circumflex	33	4	0.5–0.7 (0.55)	2.3	No	Yes	Yes
9	49/M	Hemorrhagic shock	Retroperitoneal hemorrhage	Lumbar, iliolumbar, iliac circumflex	33	3	0.5–0.8 (0.5)	1.8	No	Yes	Yes
10	61/F	Anemia, coagulopathy	Hemorrhage in ovarian tumor	Internal pudendal, IMA branch	33	3	0.8–2.0 (1.6)	4.4	No	Yes	Yes

AAA, abdominal arterial aneurysm; EVAR, endovascular aortic repair; PD, pancreaticoduodenectomy; IMA, inferior mesenteric artery.
[a]Range (median); [b]Rebleeding from the other culprit vessels occurred 44–67 days later.

Procedure

Transarterial access was gained using the femoral or the brachial artery under local anesthesia. In the triaxial system (Fig. 1), a 4.5 F guiding catheter (Parent Plus 45, Medikit) was advanced into an orifice of the first or second branch of the aorta, a 2.8 F microballoon catheter with a 0.027-inch inner diameter (Pinnacle Blue 27, Tokai Medical Products) was advanced into the intermediate portion of the targeted artery, and a 1.9 F no-taper microcatheter (Carnelian Marvel NT, Tokai Medical Products) was advanced into the branch as distally as possible (Fig. 2a). The ratio of the glue mixture to iodized oil (Lipiodol, Guerbet) was fixed at 33% to standardize the procedure. The glue-filled syringe was warmed to 40°C using a water bath (HWA-50A, AS ONE) immediately before each injection. The glue was then slowly injected via the Carnelian Marvel NT under flow arrest using the Pinnacle Blue 27 (Figs. 3 and 4). During injection, the Carnelian Marvel NT was slowly pulled back to a more proximal segment of the branch and removed after the branch was filled with glue cast. The balloon was deflated when full polymerization and stabilization of the cast were visually confirmed after each injection. Then, the next branch was selected using a new Carnelian Marvel NT and embolized until all targeted vessels were occluded (Fig. 2).

Main points

- Nontarget organ ischemia during glue embolization is a primary concern with currently available techniques.
- Triaxial microballoon occlusion system may improve the safety of glue injection with better handling than the single balloon occlusion system.
- Warmed glue has lower viscosity than glue at room temperature and achieves more distal penetration capability.

Assessment

The safety and effectiveness of the procedures were retrospectively evaluated based on technical and clinical outcomes. Technical success was defined as complete angiographic hemostasis of the target artery, and clinical success was defined as the cessation of bleeding symptom within 30 days after the procedure (6). This study was approved by the Institutional Review Board of our hospital and was performed in accordance with the Declaration of Helsinki principles. Informed consent was obtained from all individual participants included in the study.

Results

Data from 10 treatment sessions are shown in the Table. An angiographic embolization effect was achieved in all sessions, and technical success was 100%. The number of times of glue injection was 1–4 (median, 2). The amount of glue was 0.4–2.0 mL (median, 0.73 mL) per injection. One patient with hemoptysis due to aspergillosis underwent 4 sessions of treatment with intervals of 44–67 days in 6 months (sessions 1–4). Although this patient had persistent hemoptysis and rebled from the newly developed hyperplastic vasculatures each time, each culprit vessel was permanently embolized. In one session of this patient (session 3), coils (C-Stopper; Piolax Medical) were placed in the internal mammary artery prior to injection from the upstream. In another patient with bleeding after pancreaticoduodenectomy (session 7), coils (Target XL; Stryker Neurovascular) were placed in the proper hepatic artery before glue injection from the common hepatic artery

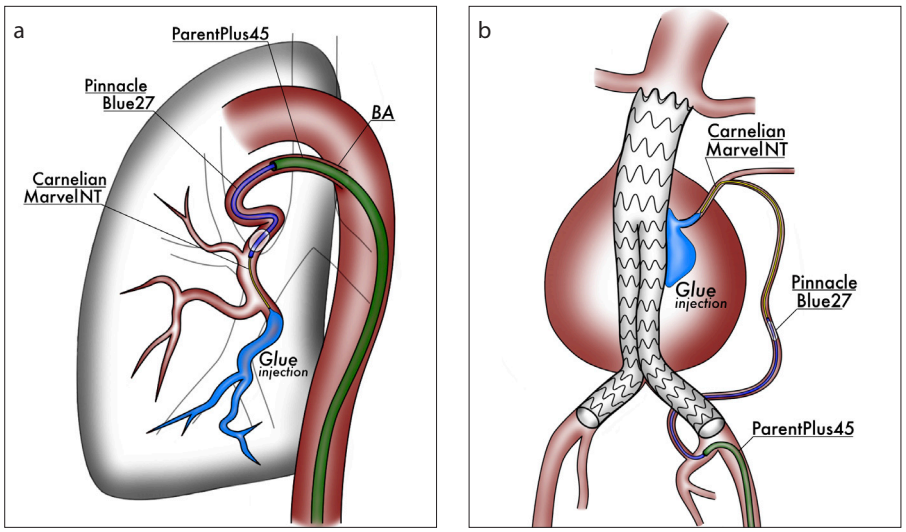

Figure 1. a, b. Schematics of glue embolization via the triaxial microballoon system for hemoptysis **(a)** or type II endoleak after EVAR **(b)**. The triaxial system was established with the Parent Plus 45 in an orifice of the first or second branch of the aorta, the Pinnacle Blue 27 in the intermediate portion of the targeted artery, and the Carnelian Marvel NT in the distal branch. Glue was then injected via the Carnelian Marvel NT under flow arrest using the Pinnacle Blue 27. BA, bronchial artery.

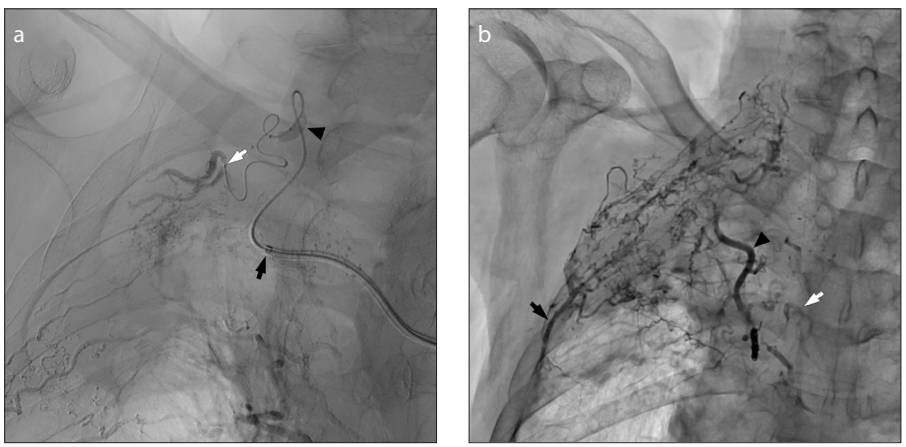

Figure 2. a, b. Case of hemoptysis. A 78-year-old man with aspergillosis presented with persistent hemoptysis and underwent 4 sessions of treatment. In the second session **(a)**, the right costocervical artery was approached with the triaxial system, consisting of a guiding catheter in the brachiocephalic artery *(black arrow)*, the Pinnacle Blue 27 in the costocervical trunk *(arrowhead)*, and the Carnelian Marvel NT in the distal branch *(white arrow)*. Chest radiograph after the fourth session **(b)** shows the glue cast remaining within the territories of all the embolized arteries: right bronchial *(white arrow)*, intercostals, internal mammary *(arrowhead)*, costocervical, lateral thoracic *(black arrow)*, superior thoracic, thoracoacromial, and inferior thyroid artery.

to close a pseudoaneurysm in the gastroduodenal arterial stump. In the remaining 8 sessions, only glue was used for embolization. In all sessions, the intended technical outcome was achieved without nontarget embolization or unexpected glue migration. One patient, after treatment for hemoptysis, developed transient minor fever within 1 week, but no other complications or adverse events occurred. No recurrent symptoms were observed during the follow-up period in all patients, and clinical success was 100%.

Discussion

Glue is used for the transcatheter embolization of various vascular disorders, including cerebral or peripheral arteriovenous malformations (1), traumatic vascular injuries, gastrointestinal bleeding, EVAR-related embolization (5), and other idiopathic arterial bleeding (3). Various techniques have been attempted so far, such as mixing with glacial acid (1) or ethanol (4) or using a microballoon catheter (2), to prevent proximal embolization, reflux, or unexpected behavior under turbulent flow. In this study, we evaluated the benefit of our new modifications regarding the glue preparation and delivery.

The conventional triaxial catheter technique using a microcatheter with a 0.027-inch inner diameter and a 1.9 F no-taper microcatheter (Carnelian Marvel NT) was introduced for superselective catheterization (5). A newly designed 2.8 F microballoon catheter with 0.027-inch inner diameter (Pinnacle Blue 27) is compatible with the Carnelian Marvel NT for the triaxial system (Fig. 1). In this system, the Pinnacle Blue 27 can be fixed to the vascular wall by balloon inflation and works as a stable backup during distal access with the Carnelian Marvel NT. Glue injection via the distally advanced Carnelian Marvel NT decreases the risk of glue adhesion to the balloon surface compared with direct injection via a microballoon catheter. Furthermore, in cases requiring repeated injections, only the Carnelian Marvel NT needs to be changed; hence, it could be more cost-effective. Meanwhile, there are some disadvantages. The Pinnacle Blue 27 requires a guiding catheter with at least a 0.058-inch inner diameter. Moreover, different flow conditions, depending on the distance between the balloon and targeted territory, as well as potential backflow through collaterals should be cautiously evaluated. Glue reflux occurs more frequently with the triaxial system than with direct injection via a microballoon catheter. Although the contact area between the tip part of the Carnelian Marvel NT and the glue cast is smaller than that of the balloon surface, excessive reflux can cause the adhesion of the catheter to the vascular wall.

The other element applied here was viscosity reduction of glue by warming. N-Butyl cyanoacrylate is not a viscous fluid per se, and its viscosity depends on mixed Lipiodol, which could be altered by temperature (7). Higher temperature results in lower viscosity and may improve distal penetration. We used a temperature of 40°C, at which the glue viscosity is estimated to be half of what it is at room temperature (20°C) in the 33% mixture with Lipiodol. The ratio of the glue mixture to Lipiodol can also modify the properties of glue as an embolic agent (8); a higher amount of Lipiodol decreases the polymerization tendency. A lower-concentration glue without warming might be an alternative option in a similar situation; however, there is also some difficulty in predicting its distribution, because

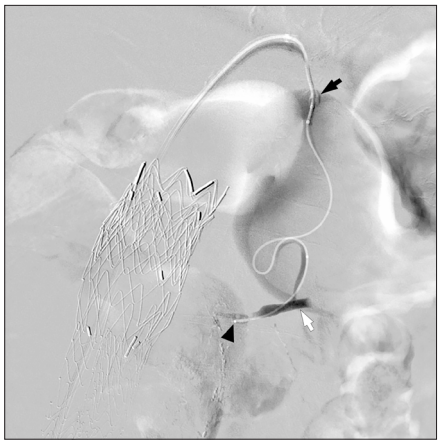

Figure 3. Case of type II endoleak. An 83-year-old man with enlargement of an abdominal aortic aneurysm due to type II endoleak via the psoas branch directly arising from the aorta underwent treatment 3 years after EVAR. Digital subtraction angiography during glue injection and pulling back of the Carnelian Marvel NT *(arrowhead)* under balloon occlusion of the Pinnacle Blue 27 *(black arrow)* shows the formation of a continuous glue cast in the psoas branch and the left second lumbar artery *(arrow)*, which communicated with the aneurysm *(white arrow)*.

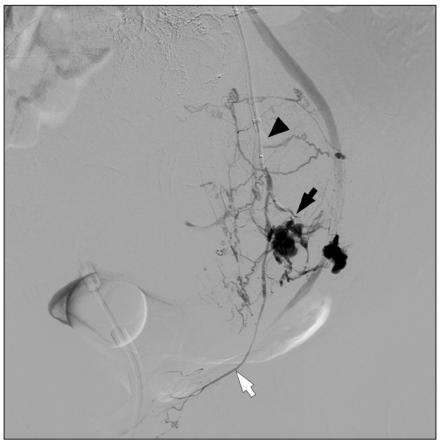

Figure 4. Case of intratumor bleeding. A 61-year-old woman presented with severe anemia and coagulopathy due to bleeding within the huge recurrent ovarian tumor. The bilateral internal pudendal arteries and abnormal branches of the inferior mesenteric artery were embolized as main feeders. Glue was injected from the left internal pudendal artery *(black arrow)* under balloon occlusion of the internal iliac artery *(arrowhead)*, and the cast distributed into tumor vasculature along with multiple bleeding sources. The obturator artery *(white arrow)* was simultaneously embolized; however, no symptom occurred.

the amount of Lipiodol is also associated with viscosity (8). Polymerization tendency and viscosity are the two contradictory properties of glue, and we fixed the ratio to 33% and adopted a temperature of 40°C to reduce the viscosity with warming as a preliminary clinical trial. We need to verify the advantages of all the key factors of polymerization process, including other temperatures and mixture ratios, and to arrange the application methods according to the various anatomical conditions in further clinical and experimental studies.

Based on the present outcome, the triaxial microballoon system provides adequate flow control with stable back-up, and glue warming improves distal penetration. Each element works in a complementary manner, and the combination could be a useful technical arrangement, especially for anatomically complicated vascular lesions, such as persistent hemoptysis or type II endoleak, and multiple bleeding sources due to coagulopathy.

This study has several limitations. The number of patients was insufficient for comparison with other techniques. The side effects of warming on the polymerization process and the difference in glue distribution versus other temperatures were not well evaluated. Thus, further research of these topics is warranted.

In conclusion, the triaxial microballoon system with warmed glue may provide better handling with more distal penetration capability and serve as a new optional strategy for treating various vascular disorders.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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