BMC Gastroenterology

RESEARCH

Open Access

# Comparative efficacy of gelatin sponge, microcoils, and nbca in arterial gastrointestinal bleeding: a retrospective study

Longxiang Lai[1†], Xian Liu[1†] and Juan Su[2*]

## Abstract

**Background** Arterial gastrointestinal bleeding poses a serious threat to life that requires timely and effective intervention. This study evaluated the effectiveness of three different embolization strategies: the use of gelatin sponge alone, in combination with microcoils, and in combination with n-butyl cyanoacrylate (NBCA).

**Methods** This retrospective study included 68 patients with acute arterial gastrointestinal bleeding (Forrest F1), categorized into three embolization groups: gelatin sponge alone ($n=23$), gelatin sponge + microcoils (*$n$* = 23), and gelatin sponge + NBCA ($n=22$). Clinical success was defined as complete hemostasis without rebleeding within 30 days. Multivariate analysis adjusted for age, NSAID use, and bleeding site.

**Results** The gelatin sponge + NBCA group achieved 100% clinical success, significantly higher than gelatin sponge + microcoils (91.30%) and gelatin sponge alone (65.22%) ($P<0.001$). Rebleeding rates were lowest with NBCA (0% vs. 34.78% for gelatin sponge alone; $P<0.001$), and complication rates favored NBCA (13.6% vs. 47.8%; $P=0.013$). Multivariate analysis confirmed the superiority of combination strategies, with gelatin sponge + NBCA showing the highest odds of success (adjusted OR = 24.12, 95% CI: 2.98–195.21, $P=0.003$). Subgroup analyses revealed no significant interaction between embolic strategy and bleeding site ($P>0.05$), though upper GI cases trended toward higher success rates (92.3–100%) compared to lower GI (80–100%).

**Conclusion** The study underscores the superiority of combination embolic strategies over the application of gelatin sponge alone for managing arterial gastrointestinal bleeding. The addition of microcoils and NBCA to gelatin sponge enhances both the efficacy and durability of embolic interventions, suggesting their preferential use in clinical practice to optimize patient outcomes.

**Keywords** Arterial gastrointestinal bleeding, Embolization, Gelatin sponge, NBCA, Microcoils

## Introduction

Arterial gastrointestinal bleeding is a critical medical emergency characterized by high morbidity and mortality rates [1]. It demands prompt and effective management to mitigate serious outcomes, including hemodynamic instability and death [2]. While endoscopic techniques remain the cornerstone for initial management, not all cases are amenable to such interventions due to the nature or location of the bleeding [3, 4]. In such instances, transcatheter arterial embolization (TAE)

[†]Longxiang Lai and Xian Liu are co-first authors.

*Correspondence:
Juan Su
sujuan919@126.com
[1] Department of Interventional Radiology, Jining No. 1 People's Hospital, Shandong Province, Jining City 272000, China
[2] Department of Neurology, Jining No. 1 People's Hospital, Shandong Province, Jining City 272000, China

serves as a crucial alternative, offering a minimally invasive yet highly effective solution [5].

Embolic agents play a central role in the success of TAE, directly influencing clinical outcomes such as immediate hemostasis, rebleeding rates, and procedure-related complications [5, 6]. Among the various agents available, gelatin sponge has been widely used due to its cost-effectiveness and general availability [7]. However, the transient efficacy of gelatin sponge and its potential for rebleeding prompt the exploration of additional or other materials, including microcoils and n-butyl cyanoacrylate (NBCA) [8, 9].

Microcoils provide a mechanical barrier to bleeding, ensuring a more permanent solution compared to gelatin sponge [10]. They are particularly useful in cases where robust, long-lasting vessel occlusion is critical [11]. On the other hand, NBCA offers the advantage of rapid polymerization upon contact with blood, creating an immediate seal that is less dependent on the patient's coagulation status, which can be especially beneficial in patients with coagulopathies [12, 13].

Despite the apparent advantages of these materials, there remains a lack of consensus on their comparative effectiveness and safety. The literature is replete with studies that have examined the outcomes associated with each type of embolic agent individually, but direct comparisons within the same patient population and clinical context are rare. This gap in the literature signifies a critical barrier to evidence-based clinical decision-making.

This retrospective study addresses this knowledge gap by comparing the effectiveness and safety of three different embolization approaches for arterial gastrointestinal bleeding: gelatin sponge alone, gelatin sponge combined with microcoils, and gelatin sponge combined with NBCA. By analyzing a cohort of patients treated at a single institution, this research seeks to offer comprehensive insights into the comparative outcomes of these embolic materials. The findings are expected to guide clinicians in selecting the most appropriate embolic agent based on clinical characteristics and bleeding dynamics, ultimately improving patient outcomes in arterial gastrointestinal bleeding.

## Methods

### Patient selection

In this retrospective study, patients diagnosed with arterial gastrointestinal bleeding confirmed by digital subtraction angiography (DSA) were included. Conducted from February 2022 to August 2024 at department, hospital, the study was approved by the hospital's Institutional Review Board. Based on the type of embolization procedure performed, the 68 patients were split into three distinct groups: the Gelatin Sponge Alone Group ($n=$ 23), the Gelatin Sponge + Microcoils Group ($n=$ 23), and the Gelatin Sponge + NBCA Group ($n=$ 22). The Forrest classification was used to categorize the severity of bleeding, with only Forrest F1 patients (acute bleeding) included.

Inclusion Criteria: Patients aged ≥ 18; underwent one of the three embolization treatments; availability of complete clinical and follow-up data, including imaging and postoperative outcomes.

Exclusion Criteria: Patients with non-arterial sources of gastrointestinal bleeding; required surgical intervention as the primary treatment for bleeding; with prior gastrointestinal surgeries complicating the identification of the bleeding source; with coagulopathies (defined as INR > 2.0) or thrombocytopenia (platelet count < 50,000/$mm^3$) affecting the outcome of embolization were excluded. Coagulation status was assessed via preoperative blood tests (INR, platelet count), and clinical histories were reviewed for chronic anticoagulant/antiplatelet use; with incomplete clinical data or insufficient follow-up; younger than 18 years or those who were pregnant.

All patients meeting the inclusion criteria during the study period were enrolled consecutively to minimize selection bias. Exclusion criteria were strictly applied to eliminate confounding factors such as coagulopathies or prior surgeries.

A post-hoc power analysis was conducted using GPower 3.1. Based on the observed clinical success rates (65.22% for gelatin sponge alone vs. 100% for gelatin sponge + NBCA), an effect size (Cohen's h) of 0.85 was calculated. With $\alpha = 0.05$ and $\beta = 0.20$, the required sample size per group was 34. Our study included 22–23 patients per group, achieving a power of 92%.

### Embolization procedures

All embolization procedures were performed using a Philips FD20 digital subtraction angiography system. All procedures were performed by three interventional radiologists, each with over 10 years of experience in visceral embolization. To ensure consistency, operators adhered to a standardized protocol for catheter navigation, embolic material preparation, and post-embolization angiography. Each patient was carefully positioned in a supine posture to ensure stability and ease of access for the procedure. Subsequently, the right groin area underwent thorough disinfection and was draped to maintain a sterile environment, followed by the administration of local anesthesia to minimize discomfort. Using the modified Seldinger technique, the right femoral artery was punctured with precision, ensuring accurate vascular access. A 5 F arterial sheath (Terumo, Tokyo, Japan) was then gently inserted into the artery to facilitate subsequent interventions while maintaining secure arterial

access throughout the procedure. A 5 F angiography catheter (Cordis, Miami Lakes, USA) was selectively advanced into the bleeding artery under the guidance of a 0.035-inch guidewire (Terumo). To identify active bleeding, angiograms were performed using a high-pressure injector to administer iodixanol contrast (300 mgI/mL, 10 mL) at a flow rate of 5 mL/s. Active bleeding was defined by signs such as contrast extravasation or pseudoaneurysm formation. Active bleeding was defined by contrast extravasation. Pseudoaneurysm formation was considered indicative of a potential bleeding source. The choice of adjunctive embolic material (microcoils or NBCA) was determined by the following criteria: Vascular anatomy: Microcoils were preferred for vessels $\geq 2$ mm diameter with straight segments allowing stable deployment; Flow dynamics: NBCA was prioritized for high-flow lesions (contrast clearance $< 3$ s) to achieve rapid polymerization; Coagulation status: NBCA was avoided in patients with severe coagulopathy (INR $> 2.0$) due to risk of non-target embolization; Gelatin sponge served as the baseline agent in all cases, with adjuncts added selectively based on intraoperative assessment.

In the Gelatin Sponge Alone Group, a 1.98 F microcatheter (Asahi, Aichi, Japan) was guided through the vascular system and positioned within the target artery identified as the source of bleeding. Small fragments of gelatin sponge were prepared and injected through the microcatheter. These fragments were slowly introduced under fluoroscopic guidance to progressively occlude the bleeding artery (Fig. 1).

In the Gelatin Sponge + Microcoils Group, the initial embolization was performed by injecting small fragments of gelatin sponge into the target artery via a microcatheter. After partial occlusion with gelatin sponge, microcoils (Cook Medical, Bloomington, IN, USA) were introduced to provide additional mechanical occlusion. The combination of gelatin sponge and microcoils was intended to enhance embolization, where the sponge provided temporary occlusion and the microcoils created a more durable blockage (Fig. 2).

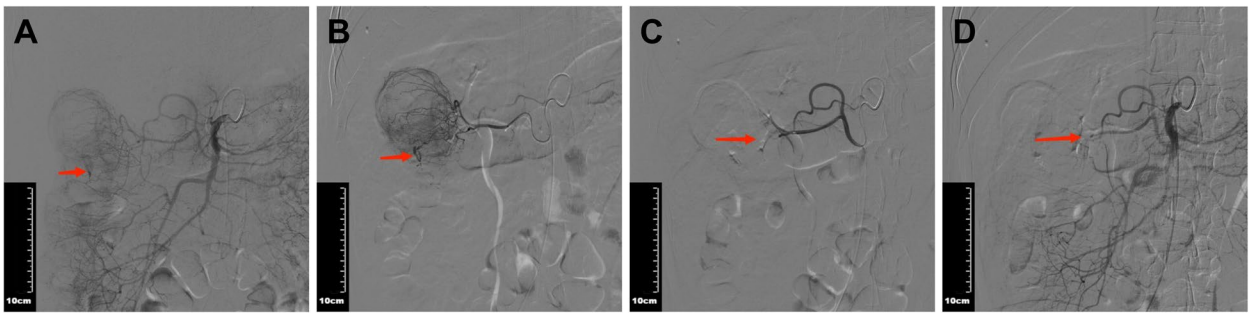


**Fig. 1** A 62-year-old male patient in the Gelatin Sponge Alone Group using gelatin sponge particles. **A** The DSA image revealed contrast leakage from a branch of the superior mesenteric artery (SMA), with the contrast dispersing slowly (arrow). **B** A microcatheter was super-selectively advanced into the responsible artery (arrow). **C** After microcatheter selection, gelatin sponge particles were used for embolization to achieve bleeding control (arrow). **D** Follow-up angiography showed no contrast extravasation, with disappearance of abnormal staining (arrow)

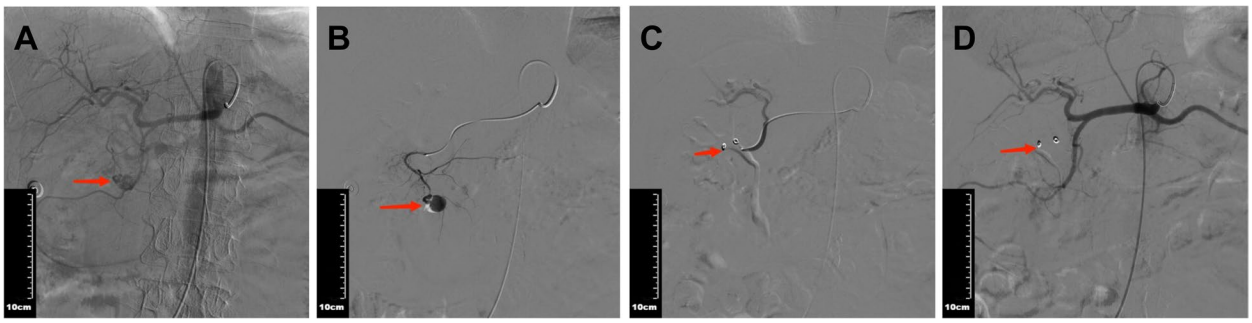


**Fig. 2** A 62-year-old male patient in the Gelatin Sponge + Microcoils Group using gelatin sponge particles and microcoils. **A** DSA image displayed contrast extravasation from a branch of the right gastric artery, with gradual dispersal of the contrast (arrow). **B** A microcatheter was super-selectively advanced into the responsible artery (arrow). **C** After microcatheter selection, gelatin sponge particles and microcoils were utilized for embolization to effectively control the bleeding (arrow). **D** Follow-up angiography showed no contrast extravasation, with disappearance of abnormal staining (arrow)

In the Gelatin Sponge + NBCA Group, after initial embolization with gelatin sponge fragments, NBCA glue (Glubran-2, GEM Italy) was combined with lipiodol (Hengrui, Jiangsu, China) in a 1:4 or 1:3 ratio depending on the complexity of the case, the NBCA-to-lipiodol ratio was standardized based on objective angiographic parameters: (1) Vessel diameter: A 1:4 ratio (NBCA: lipiodol) was used for small-caliber arteries (≤ 2 mm in diameter, e.g., distal SMA branches) to achieve controlled polymerization and avoid distal embolization, while a 1:3 ratio was applied to larger vessels (2 mm, e.g., gastroduodenal artery) to enhance occlusion stability. (2) Flow velocity: High-flow lesions (contrast clearance < 3 s) received a 1:4 ratio to prevent premature glue solidification, whereas low-flow lesions were treated with a 1:3 ratio. These adjustments were protocol-driven and guided by pre-procedural DSA measurements to minimize operator-dependent variability. The gelatin sponge was first injected to partially block the bleeding artery. This was followed by careful injection of the NBCA-lipiodol mixture under real-time fluoroscopic guidance to avoid non-target embolization. The exact ratio of NBCA to lipiodol was chosen based on clinical factors, with higher concentrations of lipiodol used in more challenging cases to enhance radiopacity and control glue polymerization (Fig. 3).

### NBCA embolization protocol

Catheter navigation and angiography: After confirming the bleeding artery via digital subtraction angiography (DSA) using a 5 F angiographic catheter (Terumo, Japan), a 2.6 F microcatheter (Asahi, Japan) was advanced coaxially over a 0.018-inch microwire (Asahi, Japan) to achieve superselective cannulation of the target vessel.

Pre-embolization Preparation: The microcatheter lumen was flushed with 5% dextrose solution to eliminate ionic residues, preventing premature polymerization of NBCA within the catheter.

NBCA-Lipiodol mixture preparation: NBCA (Glubran-2, GEM Italy) was mixed with lipiodol (Hengrui, China) at a ratio of 1:3 (for larger vessels > 2 mm) or 1:4 (for smaller vessels ≤ 2 mm or high-flow lesions) under sterile conditions.

Embolization execution: Under continuous fluoroscopic guidance, the NBCA-lipiodol mixture was injected slowly through the microcatheter. Injection was halted immediately upon observing reflux into proximal vessels or complete occlusion of the target artery.

Post-embolization verification: The microcatheter and 5 F catheter were withdrawn promptly after embolization. The catheters were flushed again with 5% dextrose to prevent glue retention.

Post-embolization angiography was performed to confirm technical success. Repeat embolization was conducted if residual bleeding was detected.

### Data collection

Data on baseline characteristics, intraoperative factors, and postoperative outcomes were collected from patient records. Baseline characteristics included age, gender, weight, non-steroidal anti-inflammatory drugs (NSAIDs) usage, hemoglobin concentration, platelet count, and bleeding site. Intraoperative factors included operation time, intraoperative complications, packed red blood cells (PRBC) transfusion units, and operation success rate, which was defined as complete embolization confirmed by angiography.

Postoperative outcomes were assessed, including the primary clinical success rate, which was defined as the complete stoppage of bleeding with no recurrence within 30 days. Other outcomes evaluated were the rate of rebleeding within 30 days following the procedure, length of hospital stay, the need for secondary interventions

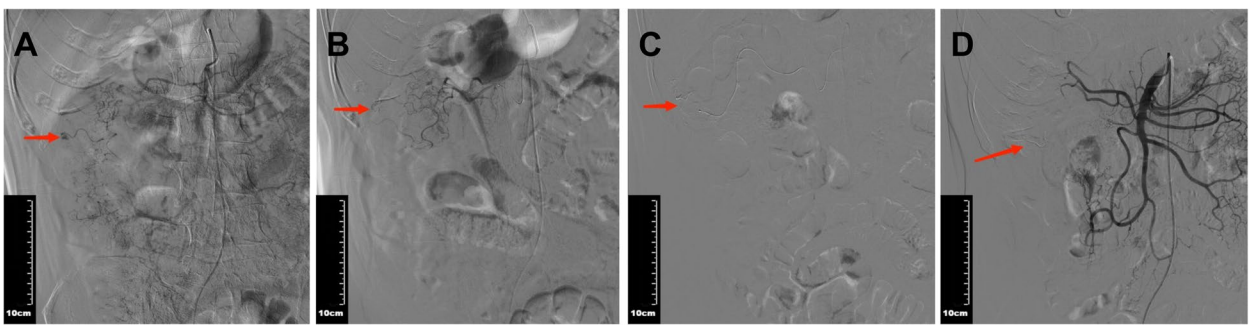


**Fig. 3** An 80-year-old male patient in the Gelatin Sponge + NBCA Group using gelatin sponge particles and NBCA glue. **A** DSA image showed contrast extravasation from a branch of the SMA, with slow dissipation of the contrast (arrow). **B** A microcatheter was super-selectively advanced into the responsible artery (arrow). **C** After microcatheter selection, embolization was performed using gelatin sponge particles and NBCA glue to control the bleeding (arrow). **D** Follow-up angiography showed no contrast extravasation, with disappearance of abnormal staining (arrow)

(such as repeat embolization or surgery), 30-day mortality, and the occurrence of postoperative complications such as abdominal pain, fever, or rectal perforation. Postoperative outcomes were assessed through a combination of structured clinic visits (at 7 and 30 days post-procedure) and electronic medical record (EMR) review. Patients unable to attend in-person visits were contacted via telephone to document symptoms (e.g., hematemesis, melena) and vital signs. Hemodynamic instability or suspected rebleeding prompted immediate imaging (CT angiography or repeat DSA), and incomplete records (e.g., loss to follow-up) were excluded during patient selection, as per the exclusion criteria. Postoperative adverse events were classified as clinically significant if they met the following criteria: (1) Required pharmacological or procedural intervention (e.g., analgesics for abdominal pain persisting >24 h); (2) Led to prolonged hospitalization or additional diagnostic evaluations (e.g., imaging for suspected ischemia); Self-limited symptoms (e.g., transient nausea resolving within 24 h) were documented but excluded from major complication analyses. Postoperative complications were graded using the Society of Interventional Radiology (SIR) Adverse Event Classification [14]: Mild: Self-limited symptoms (e.g., transient abdominal pain resolving within 24 h without intervention). Moderate: Requiring pharmacological treatment or brief hospitalization (e.g., persistent pain managed with analgesics). Severe: Life-threatening or requiring surgical intervention (e.g., bowel ischemia).

To mitigate observer bias, postoperative outcomes (e.g., clinical success, rebleeding) were assessed independently by two blinded radiologists not involved in the procedures. Discrepancies were resolved through consensus or consultation with a third senior radiologist. Intraoperative success was defined objectively as complete angiographic occlusion of the bleeding vessel, with no subjective interpretation required.

### Statistical analysis

Statistical analysis was conducted using SPSS software 25.0 (IBM SPSS Inc. Chicago, IL). Categorical variables were expressed as percentages. Comparisons of categorical variables were made using the chi-square test. To address the risk of type I error due to multiple comparisons, the Bonferroni correction was applied for pairwise group comparisons, with a revised significance threshold of $P < 0.017$ (0.05/3 comparisons). All reported *P*-values reflect this adjustment. Continuous variables were assessed for normality using Shapiro–Wilk tests. For non-normally distributed data or small subgroups, non-parametric tests (Kruskal–Wallis, Fisher's exact) were applied. Continuous variables were expressed as mean ± standard deviation (SD) and compared across the three groups using one-way analysis of variance (ANOVA). Multivariate logistic regression was performed to identify independent predictors of clinical success. Variables included in the model were selected based on clinical relevance and univariate associations ($P < 0.10$): embolic strategy (Gelatin Sponge Alone as reference), age (continuous), NSAID use (yes/no), bleeding location (upper vs. lower GI), and baseline hemoglobin level (continuous). Results are presented as adjusted odds ratios (OR) with 95% confidence intervals (CI). $P < 0.05$ was considered statistically significant.

## Results

### Baseline characteristics

Table 1 presents comparable mean age, gender distribution, body weight, and NSAID use, with no statistically significant differences observed among the three groups ($P > 0.05$). Similarly, there were no notably differences in bleeding site distribution, comorbidities, baseline hemoglobin levels, or platelet counts among these groups ($P > 0.05$).

### Intraoperative factors

Table 2 details the intraoperative factors, including operation time, intraoperative complications, and success rate. Compared to the Gelatin Sponge Alone Group, the Gelatin Sponge + NBCA Group exhibited a significantly longer mean operation time ($P = 0.012$). Compared to the Gelatin Sponge + Microcoils Group, the Gelatin Sponge + NBCA Group had a longer mean operation time, though the difference was not statistically significant ($P = 0.242$). However, no significant difference was observed between the Gelatin Sponge Alone Group and the Gelatin Sponge + Microcoils Group ($P > 0.05$). Intraoperative complications were rare, with only one case of vasospasm (4.35%) occurring in the Gelatin Sponge Alone Group, while no complications were reported in the other two groups. Despite this, the difference in complication rates was not markedly significant ($P = 0.226$). The mean number of PRBC transfusion units was lowest in the Gelatin Sponge Alone Group, followed by the Gelatin Sponge + NBCA Group, and highest in the Gelatin Sponge + Microcoils Group. However, the differences among these groups were not notably significant ($P = 0.593$). The embolization success rate was slightly lower in the Gelatin Sponge Alone Group (95.65%) compared to the Gelatin Sponge + Microcoils and Gelatin Sponge + NBCA groups, both of which had a 100% success rate ($P = 0.371$).

### Postoperative outcomes

Postoperative outcomes, including clinical success rates, rebleeding rates, secondary interventions, and 30-day

**Table 1** Baseline characteristics

| Variable | Gelatin sponge alone ($n=23$) | Gelatin sponge + microcoils ($n=23$) | Gelatin sponge + NBCA ($n=22$) | P |
|---|---|---|---|---|
| Age (years) | 63.61 ± 12.92 (58.1–69.1) | 60.57 ± 15.84 (53.7–67.4) | 67.09 ± 15.01 (60.3–73.9) | 0.333 |
| Gender (Male/Female) | 16/7 (69.6% [47.1–85.4]) | 14/9 (60.9% [38.8–79.5]) | 15/7 (68.2% [45.1–85.3]) | 0.800 |
| Weight (kg) | 62.91 ± 9.28 (58.9–66.9) | 62.30 ± 7.30 (59.1–65.5) | 63.27 ± 6.80 (60.2–66.3) | 0.917 |
| NSAID use (Yes/No) | 14/9 (60.9% [38.8–79.5]) | 11/12 (47.8% [27.4–68.9]) | 10/12 (45.5% [24.9–67.8]) | 0.534 |
| Bleeding site (%) | | | | 0.600 |
| - Small intestine | 6 (26.1% [11.1–48.1]) | 8 (34.8% [17.2–57.2]) | 5 (22.7% [8.6–45.6]) | |
| - Duodenum | 1 (4.3% [0.1–21.9]) | 6 (26.1% [11.1–48.1]) | 4 (18.2% [5.9–40.9]) | |
| - Stomach | 12 (52.2% [31.3–72.2]) | 7 (30.4% [14.1–52.9]) | 11 (50.0% [29.0–71.0]) | |
| - Colon | 4 (17.4% [5.7–38.6]) | 2 (8.7% [1.5–28.0]) | 2 (9.1% [1.6–29.0]) | |
| Hemoglobin (g/L) | 83.79 ± 9.01 (80.0–87.6) | 85.26 ± 10.55 (80.5–90.0) | 83.45 ± 9.85 (79.0–87.9) | 0.805 |
| Platelet count ($\times 10^9$/L) | 198.65 ± 32.09 (184.7–212.6) | 183.30 ± 27.41 (171.2–195.4) | 189.91 ± 28.86 (176.9–202.9) | 0.217 |
| Comorbidities (%) | | | | |
| Cirrhosis | 3 (13.0% [3.2–34.3]) | 2 (8.7% [1.5–28.0]) | 4 (18.2% [5.9–40.9]) | 0.602 |
| Cardiovascular Disease | 5 (21.7% [8.3–43.7]) | 6 (26.1% [11.1–48.1]) | 4 (18.2% [5.9–40.9]) | 0.798 |
| Diabetes Mellitus | 7 (30.4% [14.1–52.9]) | 5 (21.7% [8.3–43.7]) | 6 (27.3% [11.7–50.0]) | 0.817 |
| Chronic Kidney Disease | 2 (8.7% [1.5–28.0]) | 3 (13.0% [3.2–34.3]) | 1 (4.5% [0.1–23.2]) | 0.576 |

Continuous variables are expressed as"mean ± standard deviation (95% CI)", and categorical variables are expressed as"proportion (95% CI)"

**Table 2** Intraoperative factors

| Variable | Gelatin sponge alone ($n=23$) | Gelatin sponge + microcoils ($n=23$) | Gelatin sponge + NBCA ($n=22$) | P |
|---|---|---|---|---|
| Operation time (minutes) | 48.61 ± 15.62 (41.9–55.3) | 55.17 ± 17.73 (47.2–63.1) | 64.86 ± 21.25 (54.8–74.9)* | 0.015 |
| Intraoperative complications (%) | 1 (4.3% [0.1–21.9]) | 0 (0% [0.0–14.8]) | 0 (0% [0.0–15.4]) | 0.226 |
| PRBC transfusion (units) | 4.39 ± 2.74 (3.2–5.6) | 5.13 ± 2.30 (4.1–6.1) | 5.00 ± 2.74 (3.8–6.2) | 0.593 |
| Embolization success rate (%) | 22 (95.7% [76.0–99.8]) | 23 (100% [83.2–100.0]) | 22 (100% [82.4–100.0]) | 0.371 |

* vs gelatin sponge alone group

* $P < 0.05$

Continuous variables were expressed as"mean ± standard deviation (95% CI)", and categorical variables were expressed as"proportion (95% CI)". Packed Red Blood Cells (PRBC)

mortality, are summarized. Compared to the Gelatin Sponge Alone Group (65.22%), the primary clinical success rate was significantly higher in both the Gelatin Sponge + NBCA Group (100%) and the Gelatin Sponge + Microcoils Group (91.30%) (Table 3). Specifically, the Gelatin Sponge + Microcoils Group exhibited a notable improvement over the Gelatin Sponge Alone Group (P = 0.032), and the Gelatin Sponge + NBCA Group demonstrated an even greater improvement ($P = 0.004$). The rebleeding rate was also significantly different among the groups ($P < 0.001$). The rebleeding rate was highest in the Gelatin Sponge Alone Group (34.78%), markedly exceeding that of the Gelatin Sponge + Microcoils Group (8.70%, $P = 0.032$) and the Gelatin Sponge + NBCA Group (0%, $P = 0.004$). No significant difference in rebleeding rates was found between the Gelatin Sponge + Microcoils Group and the Gelatin Sponge + NBCA Group ($P = 0.136$).

In terms of secondary interventions, the Gelatin Sponge Alone Group showed the highest rate of requiring repeat embolization or surgery (21.74%), while the Gelatin Sponge + Microcoils Group (8.70%) and the Gelatin Sponge + NBCA Group (0%) had significantly lower rates ($P = 0.017$). Specifically, the Gelatin Sponge + NBCA Group had a significantly lower intervention rate than the Gelatin Sponge Alone Group (P = 0.049), but the difference between the Gelatin Sponge + Microcoils and Gelatin Sponge Alone groups was not statistically significant ($P = 0.414$). The 30-day mortality rates were 17.39% (4/23), 13.04% (3/23), and 9.09% (2/22) in the Gelatin Sponge Alone, Gelatin Sponge + Microcoils, and Gelatin Sponge + NBCA groups, respectively. However, due to the limited number of events (4, 3, and 2 deaths), statistical comparisons of mortality outcomes are underpowered and should be interpreted as exploratory observations rather than definitive results. Similarly,

**Table 3** Postoperative outcomes

| Variable | Gelatin sponge alone ($n=23$) | Gelatin sponge + microcoils ($n=23$) | Gelatin sponge + NBCA ($n=22$) | P |
|---|---|---|---|---|
| Primary clinical success rate (%) | 15 (65.2% [42.7–82.7]) | 21 (91.3% [70.5–98.5])* | 22 (100% [82.4–100.0])** | < 0.001 |
| Rebleeding (%) | 8 (34.8% [17.2–57.2]) | 2 (8.7% [1.5–28.0])* | 0 (0% [0.0–15.4])** | < 0.001 |
| Secondary intervention (%) | 5 (21.7% [8.3–43.7]) | 2 (8.7% [1.5–28.0]) | 0 (0% [0.0–15.4])* | 0.017 |
| 30-day mortality (%) | 4 (17.4% [5.7–38.6]) | 3 (13.0% [3.2–34.3]) | 2 (9.1% [1.6–29.0]) | 0.415 |
| Hospital stay (days) | 7.42 ± 3.56 (5.9–8.9) | 7.45 ± 4.12 (5.7–9.2) | 7.67 ± 3.84 (6.0–9.3) | 0.443 |
| Hemoglobin (g/L) | 92.57 ± 13.54 (86.6–98.5) | 112.17 ± 14.71 (105.5–118.8)*** | 117.86 ± 13.78 (111.6–124.1)*** | < 0.001 |
| Platelet count ($\times 10^9$/L) | 168.17 ± 18.72 (159.7–176.6) | 153.30 ± 24.37 (142.3–164.3) | 162.91 ± 25.56 (151.1–174.7) | 0.093 |

* vs gelatin sponge alone group

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$; Categorical variables are expressed as"proportion (95% CI)"

the length of hospital stay did not differ significantly among the groups (P = 0.443).

Postoperative hemoglobin levels (g/L) showed a significant increase in both the Gelatin Sponge + NBCA Group and the Gelatin Sponge + Microcoils Group compared to the Gelatin Sponge Alone Group (P < 0.001). Significant differences were identified in pairwise comparisons between the Gelatin Sponge + NBCA Group and the Gelatin Sponge Alone Group (P < 0.001) and between the Gelatin Sponge + Microcoils Group and the Gelatin Sponge Alone Group (P < 0.001). However, no notable difference was observed between the Gelatin Sponge + NBCA and Gelatin Sponge + Microcoils groups ($P=$ 0.131). Furthermore, postoperative platelet counts showed no significant variation among the groups ($P=$ 0.093).

### Postoperative complications

Postoperative complications, detailed in Table 4, were notably less frequent in the Gelatin Sponge + NBCA Group. Overall, the Gelatin Sponge + NBCA Group showed the lowest rate of postoperative complications, with a statistically significant difference compared to the Gelatin Sponge Alone Group ($P=$ 0.013). With $P > 0.05$, the complication rate in the Gelatin Sponge + Microcoils Group was moderate at 26.09%, showing no significant difference from the rates in the Gelatin Sponge Alone and Gelatin Sponge + NBCA groups.

## Multivariate logistic regression analysis

Categorical variables were assigned as shown in Table 5. Multivariate logistic regression (Table 6) demonstrated that combination strategies significantly improved clinical success compared to gelatin sponge alone, even after adjusting for confounders. The Gelatin Sponge + NBCA group had the highest adjusted odds of success (OR = 24.12, 95% CI 2.98–195.21, $P=$ 0.003), followed by Gelatin Sponge + Microcoils (OR = 5.87, 95% CI 1.72–20.07, $P=$ 0.005). Age, NSAID use, and baseline hemoglobin level were not independently associated with clinical success ($P > 0.05$).

**Table 4** Postoperative complications

| Variable | Gelatin sponge alone ($n=23$) | Gelatin sponge + microcoils ($n=23$) | Gelatin sponge + NBCA ($n=22$) | P |
|---|---|---|---|---|
| Complications (%) | 11 (47.8% [27.4–68.9]) | 6 (26.1% [11.1–48.1]) | 3 (13.6% [3.4–35.6])* | 0.038 |
| - Abdominal pain | 6 (26.1% [11.1–48.1]) | 4 (17.4% [5.7–38.6]) | 2 (9.1% [1.6–29.0]) | |
| - Abdominal distention | 1 (4.3% [0.1–21.9]) | 0 (0% [0.0–14.8]) | 0 (0% [0.0–15.4]) | |
| - Vomiting | 1 (4.3% [0.1–21.9]) | 1 (4.3% [0.1–21.9]) | 0 (0% [0.0–15.4]) | |
| - Nausea | 1 (4.3% [0.1–21.9]) | 1 (4.3% [0.1–21.9]) | 1 (4.5% [0.1–23.2]) | |
| - Fever | 1 (4.3% [0.1–21.9]) | 0 (0% [0.0–14.8]) | 0 (0% [0.0–15.4]) | |
| - Rectal perforation | 1 (4.3% [0.1–21.9]) | 0 (0% [0.0–14.8]) | 0 (0% [0.0–15.4]) | |

* vs gelatin sponge alone group

* $P < 0.05$. Categorical variables are expressed as"proportion (95% CI)"

**Table 5** Variable definitions and coding for multivariate analysis

| Variable | Definition/Assignment |
|---|---|
| Embolic Strategy | - 0: Gelatin Sponge Alone |
| | - 1: Gelatin Sponge + Microcoils |
| | - 2: Gelatin Sponge + NBCA |
| Age | Continuous (years) |
| NSAID Use | - 0: No |
| | - 1: Yes |
| Bleeding Location | - 0: Lower GI (Small intestine/Colon) |
| | - 1: Upper GI (Stomach/Duodenum) |
| Hemoglobin | Continuous (g/L) |

### Subgroup analyses

Subgroup analyses stratified by bleeding site demonstrated no significant interaction between embolic strategy and clinical success ($P > 0.05$) (Table 7).

## Discussion

This study evaluated the efficacy of three embolization materials—gelatin sponge alone, gelatin sponge combined with microcoils, and gelatin sponge combined with NBCA—in managing arterial gastrointestinal bleeding. Our findings clearly demonstrate the superior clinical outcomes of combination therapies, highlighting significant advantages in terms of clinical success, rebleeding rates, and postoperative complications.

Traditionally favored for its cost-effectiveness and availability, gelatin sponge's role as an embolic material is tempered by its limitations [15]. This study identified a notably higher rebleeding rate associated with its use—only a 65.22% clinical success rate when used independently. The sponge's primary function as a temporary physical barrier is insufficient for durable hemostasis, often unable to withstand prolonged blood flow which leads to potential rebleeding [16]. This aligns with Ini' C et al. [17], who have reported similarly transient efficacy when gelatin sponge is used without supplemental support.

Integrating microcoils or NBCA with gelatin sponge markedly improves the durability and stability of embolization. Microcoils enhance the physical blockade provided by gelatin sponge, ensuring long-term vascular closure and thereby reducing the likelihood of rebleeding [18]. This combination achieved a clinical success rate of 91.30%, echoing the observations of Guan et al. [19], who have noted significant enhancement in the quality and persistence of embolization. Similarly, NBCA has demonstrated outstanding results owing to its swift polymerization upon contact with blood, providing instant and long-lasting vascular occlusion [20–22]. The gelatin sponge-NBCA combination achieved a near 100% clinical success rate in our study, underscoring the synergistic effect of these materials when used in tandem.

The results highlight the critical need to consider both the chemical and physical properties of embolic materials when selecting an embolization strategy, particularly for managing high-risk bleeding points [23]. The physical robustness provided by microcoils and the chemical rapid-sealing action of NBCA cater to the urgent requirements of arterial gastrointestinal bleeding control [24].

**Table 6** Multivariate logistic regression analysis of factors associated with clinical success

| Variable | Adjusted OR | 95% CI | *P*-value |
|---|---|---|---|
| Embolic Strategy | | | |
| - Gelatin Sponge Alone | 1.00 (Ref) | – | – |
| - Gelatin Sponge + Microcoils | 5.87 | 1.72–20.07 | 0.005 |
| - Gelatin Sponge + NBCA | 24.12 | 2.98–195.21 | 0.003 |
| Age (per 1-year increase) | 0.98 | 0.94–1.03 | 0.412 |
| NSAID Use (Yes vs. No) | 1.21 | 0.45–3.27 | 0.708 |
| Bleeding Location (Upper vs. Lower GI) | 1.05 | 0.32–3.47 | 0.937 |
| Baseline Hemoglobin (per 1-g/L increase) | 1.02 | 0.97–1.07 | 0.442 |

*OR* Odds Ratio, *CI* Confidence Interval, *Ref* Reference. Model adjusted for age, NSAID use, bleeding location, and baseline hemoglobin

**Table 7** Subgroup analysis by bleeding site and embolic strategy

| Bleeding Site | Gelatin Sponge Alone (%) | Gelatin Sponge + Microcoils (%) | Gelatin Sponge + NBCA (%) | *P*-value (Interaction) |
|---|---|---|---|---|
| Upper GI ($n = 41$) | 7/13 (53.8) | 12/13 (92.3) | 15/15 (100) | 0.452 |
| Lower GI (n = 27) | 8/10 (80.0) | 9/10 (90.0) | 7/7 (100) | 0.587 |

Values represent clinical success rates (successful cases/total cases, %). *P*-value for interaction between embolic strategy and bleeding site

Multivariate analysis demonstrated that combination embolization strategies (gelatin sponge + microcoils/NBCA) significantly improved clinical success rates, with the NBCA group exhibiting the most pronounced advantage (OR = 24.12). This outcome may stem from NBCA's rapid polymerization properties and synergistic interaction with gelatin sponge, enabling simultaneous immediate occlusion and durable vascular closure, thereby reducing recanalization risks. Similar conclusions were reported by Chevallier et al. [25] in a meta-analysis, which highlighted NBCA's efficacy in reducing rebleeding rates for non-variceal gastrointestinal bleeding (OR = 0.31, $P < 0.01$), aligning with our findings.

In subgroup analyses, although no significant interaction was observed between embolic strategies and bleeding sites (upper vs. lower GI, $P > 0.05$), the clinical success rates of combination therapies were marginally higher in upper GI bleeding (92.3%–100%) compared to lower GI (80%–100%). This discrepancy may relate to anatomical advantages in upper GI vasculature favoring superselective embolization. Fontana et al. [26] also noted minimal impact of bleeding site on outcomes in their single-center study, though limited sample sizes may have underpowered statistical significance, warranting larger-scale validation.

While combination therapies demonstrated superior clinical success, potential risks associated with microcoils and NBCA warrant consideration. Microcoil embolization carries risks of vascular injury, including dissection or perforation, particularly in tortuous arteries [27]. In our cohort, no such complications occurred, likely due to strict adherence to anatomical criteria. NBCA, despite its rapid hemostasis, risks non-target embolization if injection control is suboptimal [28], yet our protocol (ionic-free catheter flushing, real-time fluoroscopy) achieved a 0% incidence, aligning that standardized glue-to-lipiodol ratios reduce this risk. Notably, the Gelatin Sponge + NBCA group exhibited the lowest adverse event rate (13.64%), suggesting procedural precision mitigated traditional NBCA drawbacks. These results underscore that operator expertise and protocol-driven techniques are critical to minimizing complications while harnessing the benefits of combination strategies.

Previous studies have shown that NBCA and microloops are more expensive than gelatin sponges, which poses a major obstacle to their routine use in resource-limited environments [29]. However, reduced need for repeated interventions may reduce long-term medical costs for facilities that can make upfront investments. Future cost–benefit analyses will be necessary to guide agreement adjustments in different economic contexts. While gelatin sponge remains cost-effective and widely accessible, the superior clinical outcomes of combination strategies (gelatin sponge + NBCA/microcoils) must be weighed against their higher material costs. Although this study did not perform a formal cost–benefit analysis, the near-zero reintervention rates and reduced hospitalization needs in the combination groups may offset initial expenses in resource-rich settings. Conversely, in lower-resource environments, gelatin sponge alone may still serve as a pragmatic first-line option when balancing efficacy and affordability.

This study has limitations inherent to its single-center, retrospective design. First, while gelatin sponge offers cost and procedural efficiency advantages, combining it with microcoils or NBCA may offset these benefits. However, our primary aim was to evaluate the synergistic effects of combination therapies rather than comparing individual embolic agents in isolation. Future studies directly comparing standalone microcoils, NBCA, and gelatin sponge are warranted to assess cost-effectiveness and clinical trade-offs. Second, although bleeding sites (upper vs. lower GI) were balanced across groups, the heterogeneous etiologies and hemodynamic profiles of these subtypes may require tailored embolic strategies, which were not explored in this cohort. Third, due to the retrospective design, long-term outcomes such as vessel recanalization, delayed rebleeding beyond 30 days, or imaging follow-up (e.g., CT angiography) were not systematically assessed. Prospective studies with standardized imaging protocols are needed to evaluate the durability of embolic occlusion over extended periods. Fourth, the 100% clinical success rate observed in the NBCA group may reflect selection bias, as complex cases requiring surgical intervention or patients with unstable hemodynamics were excluded per protocol. Additionally, the technical precision required for NBCA use (e.g., glue-to-lipiodol ratio adjustments, real-time fluoroscopic control) likely depends on operator expertise. All procedures were performed by highly experienced interventional radiologists (> 10 years of practice), which may limit generalizability to centers with less specialized training. In addition, these findings are derived from a single tertiary care center with standardized embolization protocols. Variations in procedural techniques, patient demographics, or institutional practices at other centers may influence outcomes. Multi-center collaborations are warranted to validate these results across diverse clinical settings.

In conclusion, this study significantly contributes to the field by elucidating the importance of selecting embolization materials that combine physical and chemical properties optimally suited to the clinical scenario. The use of gelatin sponge in conjunction with microcoils or NBCA not only enhances the effectiveness of treatments but also sets a precedent for improving clinical guidelines and

practices in the management of arterial gastrointestinal bleeding.

## Conclusion

This study demonstrates that combining gelatin sponge with microcoils or NBCA significantly enhances the efficacy of arterial gastrointestinal bleeding management. These combinations reduce rebleeding rates and improve clinical outcomes compared to the use of gelatin sponge alone. The novel insights offered by this research emphasize the importance of selecting embolic materials based on their mechanical and chemical properties to tailor treatments to specific clinical scenarios, thereby improving patient care in urgent gastrointestinal bleeding situations. These findings suggest that combining gelatin sponge with microcoils or NBCA may enhance embolization efficacy in arterial gastrointestinal bleeding, offering a promising alternative to gelatin sponge alone.

**Acknowledgements**
Not Applicable.

**Authors' contributions**
LXL and XL wrote the main manuscript. LXL and JS prepared the data collection. XL and JS prepared figures and tables. LXL and XL analyse and interpret of results. All authors reviewed the results and approved the final version of the manuscript. All authors would be informed each step of manuscript processing including submission, revision, revision reminder, etc.

**Funding**
The work was not funded by any funding.

**Data availability**
The datasets used and analysed during the current study available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**
This study was approved by the Ethics Committee of the Jining No. 1 People's Hospital (2024-IIT-FAST 042). Informed consent was obtained from all the participants. All methods were carried out in accordance with Declaration of Helsinki.

**Consent for publication**
All the authors confirming that WRITTEN INFORMED consent was obtained from all subjects and/or their legal guardian (s).

**Competing interests**
The authors declare no competing interests.

Received: 22 October 2024 Accepted: 20 May 2025
Published online: 27 May 2025

**References**

1. Kumar R, Mills AM. Gastrointestinal bleeding. Emergency Medicine Clinics. 2011;29(2):239–52.
2. Stanley AJ, Laine L. Management of acute upper gastrointestinal bleeding. BMJ. 2019;364:l536.
3. Mullady DK, Wang AY, Waschke KA. AGA clinical practice update on endoscopic therapies for non-variceal upper gastrointestinal bleeding: expert review. Gastroenterology. 2020;159(3):1120–8.
4. Chevallier O, Comby P-O, Guillen K, et al. Efficacy, safety and outcomes of transcatheter arterial embolization with N-butyl cyanoacrylate glue for non-variceal gastrointestinal bleeding: A systematic review and meta-analysis. Diagn Interv Imaging. 2021;102(7–8):479–87.
5. Lee S, Kim T, Han SC, et al. Transcatheter arterial embolization for gastrointestinal bleeding: Clinical outcomes and prognostic factors predicting mortality. Medicine. 2022;101(31):e29342.
6. Minici R, Guzzardi G, Venturini M, et al. Transcatheter arterial embolization (TAE) of cancer-related bleeding. Medicina. 2023;59(7):1323.
7. Lee SM, Jeong SY, Shin JH, et al. Transcatheter arterial embolization for gastrointestinal bleeding related to pancreatic adenocarcinoma: clinical efficacy and predictors of clinical outcome. Eur J Radiol. 2020;123:108787.
8. Fontana F, Piacentino F, Ossola C, et al. Transcatheter arterial embolization in acute non-variceal gastrointestinal bleedings: A ten-year single-center experience in 91 patients and review of the literature. J Clin Med. 2021;10(21):4979.
9. Gong M, Liu Z, Kong J, et al. Transcatheter arterial embolization using N-butyl-2 cyanoacrylate Glubran® 2 for acute massive pancreati coduodenal arterial hemorrhage. Frontiers in Materials. 2022;9:1003539.
10. Li X, Ullah MW, Li B, et al. Recent Progress in Advanced Hydrogel-Based Embolic Agents: From Rational Design Strategies to Improved Endovascular Embolization. Adv Healthcare Mater. 2023;12(17):2202787.
11. Kos S, Huegli R, Bongartz GM, et al. MR-guided endovascular interventions: a comprehensive review on techniques and applications. Eur Radiol. 2008;18:645–57.
12. Pathuri S, Rodriguez P, Mascitelli JR. Endovascular management of ruptured choroidal aneurysms associated with moyamoya syndrome: a two-patient case report & review of the literature. Clin Neurol Neurosurg. 2021;209:106906.
13. Clements W, Lukies M, Zia A, et al. Let us settle the controversy—gelfoam is a safe intravascular embolic agent. Br J Radiol. 2024;97(1157):933–7.
14. Sacks D, McClenny TE, Cardella JF, Lewis CA. Society of Interventional Radiology clinical practice guidelines. J Vasc Interv Radiol. 2003;14(9 Pt 2):S199–202. https://doi.org/10.1097/01.rvi.0000094584.83406.3e.
15. Dai M, Li M, Gong J, et al. Silk fibroin/gelatin/calcium alginate composite materials: Preparation, pore characteristics, comprehensive hemostasis in vitro. Mater Des. 2022;216:110577.
16. Yang Y, Zhang H, Zeng F, et al. A quaternized chitin derivatives, egg white protein and montmorillonite composite sponge with antibacterial and hemostatic effect for promoting wound healing. Compos B Eng. 2022;234:109661.
17. Ini' C, Distefano G, Sanfilippo F, et al. Embolization for acute nonvariceal bleeding of upper and lower gastrointestinal tract: A systematic review. CVIR endovascular. 2023;6(1):18.
18. Luo X, Zou D. Li L. Cardiovascular Therapeutic Devices: Material and Fabrication Progress. Biomaterials and Materials for Medicine. CRC Press; 2021. p. 1–34.
19. Zhang X, Kuwatsuru R, Toei H, Yashiro D, Sokooshi H, Kuwatsuru Y. Long-term volume reduction in renal angiomyolipomas embolized by gelatin sponge particles with or without supplementary microcoil embolization. J Int Med Res. 2023;51(4):3000605231170098. https://doi.org/10.1177/03000605231170098.
20. Ko G, Choi JW, Lee N, et al. Recent progress in liquid embolic agents. Biomaterials. 2022;287:121634.
21. Pal A, Blanzy J, Gómez KJR, et al. Liquid embolic agents for endovascular embolization: A review. Gels. 2023;9(5):378.
22. Musmar B, Adeeb N, Ansari J, et al. Endovascular management of hemorrhagic stroke Biomedicines. 2022;10(1):100.
23. Vollherbst D F, Chapot R, Bendszus M, et al. Squid or PHIL? Liquid Embolic Agents for the Embolization of Cerebral Arteriovenous Malformations and Dural Arteriovenous Fistulas. Clin Neuroradiol. 2022;32(1):25–38. https://doi.org/10.1007/s00062-021-01066-6.
24. Milenkovic U, Cocci A, Veeratterapillay R, et al. Surgical and minimally invasive treatment of ischaemic and non-ischaemic priapism: a systematic review by the EAU Sexual and Reproductive Health Guidelines panel. Int J Impot Res. 2024;36(1):36–49.
25. Chevallier O, et al. Efficacy, safety and outcomes of transcatheter arterial embolization with N-butyl cyanoacrylate glue for non-variceal

gastrointestinal bleeding: A systematic review and meta-analysis. Diagn Interv Imaging. 2021;102(7–8):479–87.
26. Fontana F, et al. Transcatheter arterial embolization in acute non-variceal gastrointestinal bleedings: A ten-year single-center experience in 91 patients and review of the literature. J Clin Med. 2021;10(21):4979.
27. Ahmed O, Jilani D, Sheth S, Giger M, Funaki B. Long-term results of microcoil embolization for colonic haemorrhage: how common is rebleeding? Br J Radiol. 2015;88(1051):20150203. https://doi.org/10.1259/bjr.20150203.
28. Shi Y, Chen L, Zhao B, Huang H, Lu Z, Su H. Transcatheter arterial embolization for massive hemobilia with N-butyl cyanoacrylate (NBCA) Glubran 2. Acta Radiol. 2022;63(3):360–7. https://doi.org/10.1177/0284185121992971.
29. Razavilar N, Taleshi JM. Cost-Effectiveness Analysis of Transcatheter Arterial Embolization Techniques for the Treatment of Gastrointestinal Bleeding in the United States. Value Health. 2021;24(4):477–85. https://doi.org/10.1016/j.jval.2020.10.027.

## Publisher's Note