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Bronchial Artery Embolization for Massive Hemoptysis: Single-Center Experience

Fatih Öncü, Nezih Yaylı, Burak Mert Akhan, Koray Akkan, Baran Önal, Erhan Ilgıt

Department of Radiology, Gazi University School of Medicine, Ankara, Türkiye

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What is currently known about this topic?

- *Bronchial artery embolization (BAE) is widely used as a first-line treatment for massive hemoptysis with high technical and clinical success rates.*
- *Rebleeding after embolization remains a significant cause of recurrence, especially in patients with chronic lung diseases such as bronchiectasis.*
- *Variability in embolic agent selection and vascular anatomy (e.g. non-bronchial systemic collaterals) significantly impacts long-term outcomes.*

What does this study add to this topic?

- *This study presents a single-center, real-world experience in which the choice of embolizing agent was guided by patient-specific vascular anatomy, including the presence of bronchopulmonary shunts and non-bronchial systemic collaterals.*
- *The use of combined embolization strategies (e.g., polyvinyl alcohol + n-butyl-2-cyanoacrylate, coil + microsphere) is analyzed in detail, especially in cases presenting with recurrent hemoptysis or with complex vascular anatomy.*
- *The study includes long-term follow-up data up to 72 months and provides original information on recurrence mechanisms (recanalization, collateral formation) and management approaches.*

Abstract

Objective: To evaluate the feasibility and safety of bronchial artery embolization (BAE) as a first-line endovascular treatment in patients presenting to the clinic with massive hemoptysis.

Methods: In this retrospective single-center study, 43 patients (mean age: 55.6 ± 17.6 years) who underwent BAE for massive hemoptysis between 2016 and 2022 were analyzed. Patient demographics, indications, angiographic findings, embolization materials used, procedure success rates, recurrence rates (early and late), complications, and mortality rates were evaluated during a mean follow-up period of 24 months (range: 6-72 months).

Results: Technical success was achieved in 97% of patients, while early clinical success was observed in 95.3%. Early recurrence occurred in 7.1% of cases and late recurrence in 16.2%. The most common etiologies in recurrent cases were recanalization and systemic collaterals. The complication rate was 18.6% and the most common complication was transient chest pain; 1 patient had transient paraplegia. The mortality rate was 7%.

Conclusion: Bronchial artery embolization appears to be an effective and relatively safe intervention for the management of massive hemoptysis, demonstrating high technical and clinical success rates with acceptable complication and recurrence rates. Identification and management of non-bronchial systemic collaterals and selection of embolic agents on a case-by-case basis are important to minimize recurrence and improve long-term outcomes.

Keywords: Angiography, bronchial arteries, embolization, hemoptysis

Introduction

Massive hemoptysis, defined as bleeding exceeding 300 mL within 24 hours or any episode causing airway or hemodynamic compromise, is a life-threatening emergency with mortality rates reaching up to 80% if managed conservatively.[1] In about 90% of cases, the source is the bronchial circulation, while less frequently it originates from the pulmonary arteries (5%) or systemic collaterals such as the aorta and intercostal arteries.[2-4] Bronchial arteries typically originate from the thoracic aorta at the T5-T6 level, with 2 arteries on the left usually arising directly from the aorta and a single right-sided artery commonly branching from the intercostobronchial trunk (ICBT).[2] However, ectopic origins such as the subclavian, internal mammary, or coronary arteries occur in up to 20% of cases.[2] These non-bronchial systemic collaterals are often prominent in chronic inflammatory or neoplastic conditions and pose a risk for recurrence if not properly embolized.[2] Spinal artery branches, present in approximately 5% of patients and most frequently arising from the ICBT, require particular caution, as inadvertent embolization of these vessels can result in catastrophic complications such as paraplegia.[2,3] In chronic lung diseases, impaired pulmonary perfusion due to inflammation, vasculitis, hypoxic vasoconstriction, or thrombotic occlusion results in compensatory hypertrophy of the bronchial arteries, which may rupture under pressure and trigger massive hemoptysis.[3,4]

Surgical intervention in cases of hemoptysis is associated with mortality rates ranging from 7% to 18%, with this risk increasing substantially—up to 40%—when procedures are performed under emergent conditions. The decreased surgical success in such cases is often attributable

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Corresponding author: Fatih Öncü, Department of Radiology, Gazi University School of Medicine, Ankara, Türkiye
e-mail: oncufatih@gmail.com
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to the presence of diffuse chronic lung diseases, as opposed to focal lesions, as well as to the limited pulmonary reserve in affected patients. Therefore, surgical resection is generally reserved for cases with localized pathology, and even in operable patients, preoperative bronchial artery embolization (BAE) is recommended to reduce intraoperative bleeding and improve outcomes.[5,6]

Numerous studies have demonstrated the efficacy and safety of BAE as a first-line intervention for massive hemoptysis in both emergency and elective settings.[5-8] In this study, the technical and clinical success of BAE were comprehensively evaluated in patients presenting with massive hemoptysis. The causes of both early and late recurrence were also determined, the types of embolic agents used were evaluated, and the existing literature was supplemented by sharing institutional experience with embolization strategies.

Methods

Study Design and Patient Selection

This retrospective, single-center study was conducted in the institution, including 43 patients (31 males and 12 females) who underwent endovascular treatment for massive hemoptysis between 2016 and 2022. Data were collected from patient records, radiological imaging, and angiographic images. The study was approved by the Institutional Ethics Committee (Approval No.: 429 Date: May 22, 2023). In addition, consent forms were obtained before all endovascular procedures. The mean age of the cohort was 55.6 ± 17.6, and the mean follow-up duration was 24 months ± 8.2 (6-72 months).

Massive hemoptysis was defined as expectoration of more than 300 mL of blood within 24 hours, or any amount of bleeding leading to respiratory compromise, hemodynamic instability, or requiring emergent airway control or intervention.[8]

All patients presenting with clinically and radiologically confirmed massive hemoptysis were evaluated by a multidisciplinary team (pulmonology, thoracic surgery, and interventional radiology) before undergoing BAE. Patient selection was based on clinical stability, imaging findings on contrast-enhanced computed tomography (CT), and, when feasible, fiberoptic bronchoscopy.

Inclusion criteria were: (1) adult patients aged ≥18 years; (2) presentation with clinically and radiologically confirmed massive hemoptysis; and (3) availability of complete medical, angiographic, and follow-up data. Exclusion criteria included: (1) hemoptysis from non-bronchial arterial sources (n = 1, including 1 aortotracheal fistula); (2) uncorrectable coagulopathy (n = 1); and (3) emergent surgical intervention required prior to embolization (n = 2). In total, 4 patients were excluded based on these criteria.

Outcomes and Variables

The primary outcomes of the study were:

- Technical success (defined as successful catheterization and embolization of all identified abnormal arteries).
- Early clinical success (cessation of hemoptysis within 24 hours post-procedure).
- Recurrence (early: within 3 months; late: after 3 months).
- Complications (e.g., chest pain, post-embolization syndrome, neurological deficits).
- Mortality (procedure-related or hemoptysis-related death).

The main exposure in this study was undergoing BAE as the initial endovascular intervention.

Predictors and potential confounders included:

- Etiology of hemoptysis (e.g., bronchiectasis, malignancy).
- Vascular anatomy (presence of systemic collaterals or shunts).
- Embolic agent used (polyvinyl alcohol [PVA], n-butyl-2-cyanoacrylate [NBCA], microspheres, coils).
- Presence of bilateral disease or recurrent hemoptysis.

Patient Preparation and Pre-Procedural Evaluations

The presence of hemoptysis was confirmed by examination. Risk factors (smoking, vasculitis, etc.), medications (especially anticoagulants), trauma, biopsy, and previous surgical history were clarified.

After the presence of massive hemoptysis was confirmed, the patients were evaluated with the multidisciplinary approach of the departments of pulmonology, thoracic surgery, and interventional radiology. Before the procedure, patients were evaluated with blood parameters, sputum examination, chest x-ray, contrast-enhanced thorax CT examination (n = 43; 100%), and, if possible, fiberoptic bronchoscopy (FOB, n = 12; 27.9%).

Procedure Data

Vascular access was routinely obtained via the common femoral artery using a 5-French (F) introducer sheath. A flush thoracic aortogram was initially performed in all patients using standard 5-F diagnostic catheters (e.g., Simmons-1, pigtail) to delineate the origin of bronchial arteries and to provide a general anatomical overview. While not universally required, flush aortography has been reported in the literature to reduce recurrence rates by improving the detection of ectopic or accessory arterial feeders.[7,8]

Selective catheterization of the bronchial arteries was subsequently performed using shaped diagnostic catheters (Simmons-1, Cobra, etc.), followed by superselective catheterization through coaxial microcatheters (Renegade, Boston Scientific; Progreat 2.7 F, Terumo). The microcatheter tip was advanced 1-2 cm distal to the bronchial artery ostium to minimize the risk of non-target embolization, particularly to the spinal artery. It is also stated in the literature that the success of the embolization process is increased with superselective catheterization.[9-11]

After achieving stable microcatheter positioning, contrast injection was performed through the microcatheter using a non-ionic contrast agent. Non-bronchial systemic collaterals (e.g., internal mammary, intercostal, subclavian, axillary, and inferior phrenic arteries) were routinely assessed in all cases as part of the angiographic evaluation, particularly in situations where the bronchial source of bleeding could not be clearly identified or in cases with suspected recurrence.

Embolization was performed using various embolic agents, including PVA particles, microspheres, coils, and NBCA. Combined use of embolic materials (e.g., PVA + NBCA, coil + microspheres) was applied in select cases. To minimize the risk of distal embolization, smaller-size particles were avoided; PVA particle sizes were generally maintained between 350 and 500 μm. N-butyl-2-cyanoacrylate was diluted with Lipiodol, usually 1 : 3 to 1 : 4, to provide adequate viscosity for controlled distal embolization. In cases requiring proximal occlusion, a more concentrated mixture (up to 1 : 2) was selectively used to ensure rapid polymerization and minimize reflux. While using the described liquid embolizing agents, the embolizing material was injected until reflux occurred, and this was established by fluoroscopic imaging during the injection.

Microspheres were also preferred for their uniform shape and lower risk of catheter occlusion. In cases involving shunts to the pulmonary circulation, proximal occlusion was preferred using

coils or large-diameter particles to prevent systemic embolization. These choices regarding embolic agent selection and delivery technique are consistent with recommendations in the literature, which emphasize the importance of particle size, agent properties, and vascular anatomy in minimizing complications and ensuring effective hemostasis.[11-14] All procedures and imaging evaluations were performed jointly by 2 interventional radiologists, each with over 10 years of experience in vascular interventions and embolization techniques, to ensure consistency in interpretation and minimize observer bias. Procedural steps are demonstrated in Figure 1.

Statistical Analysis

Statistical analyses were performed using descriptive methods. Continuous variables were expressed as mean ± SD, while categorical variables were presented as frequencies and percentages.

Results

A total of 43 patients (31 males, 12 females; mean age, 55.6 ± 17.6 years) who underwent BAE for massive hemoptysis were included in the analysis. The mean follow-up duration was 24 ± 8.2 months (range, 6-72 months). The demographic, clinical, radiologic, and angiographic characteristics of the cohort are summarized in Table 1.

Idiopathic bronchiectasis was the most frequent etiology (30.2%), followed by malignancies (13.9%) and cystic fibrosis (13.9%). The right bronchial artery was the most common bleeding source (51.2%), followed by the left bronchial artery (23.3%) and

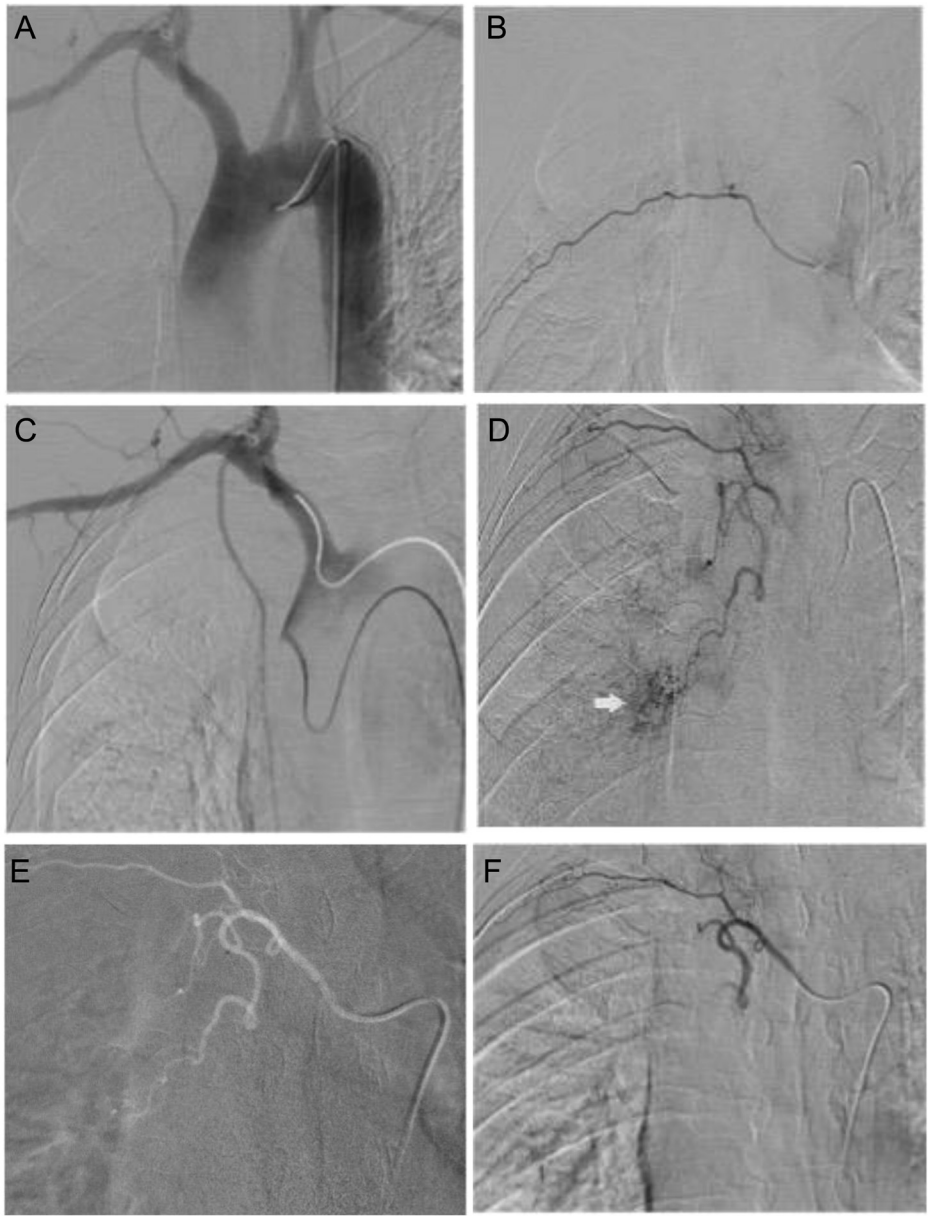


Figure 1. A 56-year-old male patient presenting with massive hemoptysis secondary to a right upper lobe mass. (A) A flush thoracic aortogram was performed. (B, C) Intercostal and subclavian arteries were evaluated for potential systemic collaterals. (D) Atypical parenchymal opacification, hyperemia, and hypervascularity indicating neovascularization were observed in the right upper lobe and are marked with a white arrow. (E) Superselective catheterization of the distal intercostobronchial trunk was achieved, and 350-500 μm PVA particles were injected. (F) Complete resolution of hyperemia and hypervascularity was observed on post-procedural angiography.

Table 1. Demographic, Clinical, Radiologic, and Angiographic Characteristics of Patients with Massive Hemoptysis Undergoing Bronchial Artery Embolization

Parameter	n (%) or Mean ± SD
Demographics	
Age (years)	55.6 ± 17.6
Gender (Male/Female)	31 (72)/12 (28)
Follow-up duration (months)	24 ± 8.2 (6-72)
Etiology/Indications	
Idiopathic bronchiectasis	13 (30.2)
Cystic fibrosis	6 (13.9)
Malignancy (primary = 4, metastatic = 2)	6 (13.9)
Tuberculosis	5 (11.6)
Cryptogenic	5 (11.6)
Vasculitis	4 (9.3)
Pneumonia (pyogenic = 2, fungal = 2)	4 (9.4)
CT findings*	
Bronchiectasis	30 (69.8)
Alveolar hemorrhage	26 (60.5)
Hypertrophied/tortuous bronchial arteries	28 (65.1)
Angiographic findings*	
Hyperemia/hypervascularity	36 (83)
Tortuous or hypertrophic bronchial artery	30 (69)
Bronchial–pulmonary artery shunt	3 (7)
Bleeding source	
Right bronchial artery	22 (51.2)
Left bronchial artery	10 (23.3)
Right intercostobronchial trunk	5 (11.7)
Bilateral bronchial arteries	3 (6.9)
Non-bronchial systemic arteries (intercostal arteries, n = 2; subclavian artery, n = 1)	3 (6.9)

CT, computed tomography.
*Since patients may have more than 1 imaging finding, the sum of the rates exceeds 100%.

right intercostobronchial trunk (11.7%). Non-bronchial systemic arteries and bronchial–pulmonary shunts were each identified in 3 cases (6.9%). Bilateral BAE was performed in 3 patients (6.9%) due to bilateral arterial hypertrophy or diffuse parenchymal disease. The most common CT findings were bronchiectasis in 30 patients (69.8%), alveolar hemorrhage in 26 patients (60.5%), and tortuous or hypertrophied bronchial arteries in 28 patients (65.1%). The most common angiographic findings were hyperemia and hypervascularity (83%), followed by tortuous and hypertrophic bronchial arteries (69%). Bronchial artery–pulmonary artery shunts were identified in 3 patients (7%). An illustrative case is shown in Figure 2.

The types and characteristics of embolic agents used during BAE are summarized in Table 2. The most commonly used embolic agents were PVA particles (46.6%) and microspheres (30.3%). To minimize the risk of distal embolization, small diameter PVA particles were deliberately avoided; instead, particles with an average size of 350-500 μm were preferred. Microspheres were selected in many cases because of their uniform spherical shape and lower incidence of proximal catheter occlusion compared to PVA.

Generally, proximal occlusion with large diameter embolic materials was avoided because this would lead to distal collateral vessel formation. Therefore, coils, large microspheres, and similar agents were used selectively, especially in cases involving bronchopulmonary shunts. In these scenarios, proximal embolization using coils or large particles was preferred to prevent non-target embolization to the pulmonary circulation. An illustrative case is shown in Figure 3.

Of the 43 patients who underwent BAE, 4 (9.3%) were lost to follow-up after 3 months and 2 (4.6%) died within the early period (1 early mortality within 24 hours and 1 following early recurrence). Consequently, late recurrence was assessed in 37 patients. As summarized in Table 3, patients who underwent endovascular treatment for hemoptysis were evaluated in terms of technical and clinical success, procedure-related complications, early and late recurrence, mortality, and the need for additional interventions.

Although definitions vary in the literature, early clinical success is most commonly defined as the complete cessation of hemoptysis within the first 24 hours following embolization.[14-17] In this series, early clinical success was achieved in 41 patients (95.3%). Among the 2 patients, 1 underwent emergency lobectomy and the other died within the first 24 hours.

Technical success is generally defined as the successful catheterization and embolization of all abnormal arteries identified during angiographic evaluation.[17,18]

In this series, microcatheter stability could not be achieved in 1 patient due to respiratory motion and vascular tortuosity. Embolization was successfully performed in the remaining 42 patients (97.6% technical success).

Early recurrence, defined as rebleeding within 3 months of the procedure, occurred in 3 patients (7.1%). Late recurrence (>3 months after embolization) was observed in 6 patients (16.2%). The median time to late recurrence in the cohort was 24 months (range: 6-72 months).

A total of 8 patients (18.6%) experienced complications, the most frequent being transient chest pain (n = 4) and post-embolization syndrome (n = 3). Post-embolization syndrome is characterized by leukocytosis, fever and pain, and is a temporary and self-limiting condition. One patient developed transient paraplegia despite the absence of spinal artery opacification by superselective catheterization and angiographic evaluation of the intercostal arteries. Neurological symptoms resolved completely within 1 week under close monitoring and corticosteroid therapy.

Table 4 summarizes the clinical and angiographic data of patients presenting with recurrent hemoptysis.

During follow-up, 9 patients were rehospitalized with massive hemoptysis. Angiographic evaluation revealed systemic collaterals (intercostal arteries) in 3 patients (33%) and recanalization of previously embolized vessels in 5 patients (55%). Surgical intervention was performed in 1 patient with malignancy without repeat angiographic evaluation. Of the patients presenting with recurrent hemoptysis, 6 were treated with repeat embolization and 3

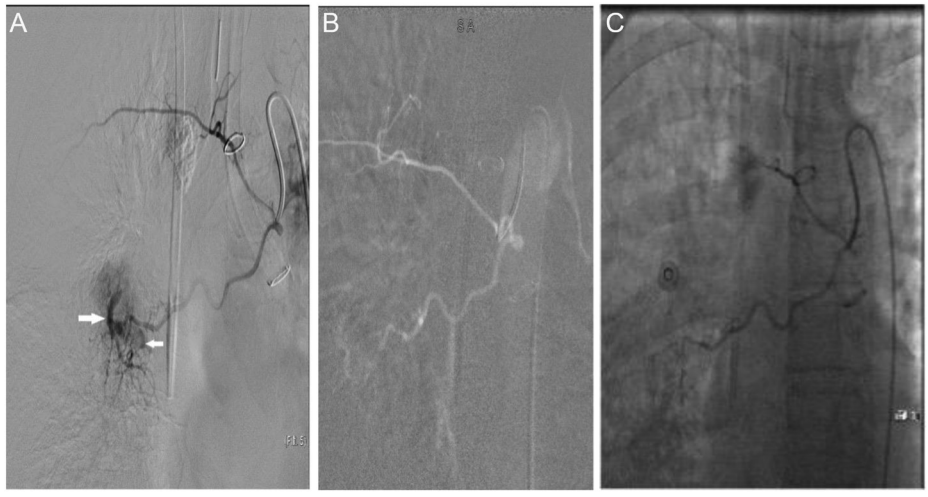


Figure 2. A 55-year-old patient with post-tuberculous sequela bronchiectasis presented with massive hemoptysis. (A) Pre-embolization angiography demonstrated active parenchymal extravasation and a bronchial–pulmonary artery shunt. The upper arrow indicates a bronchial–pulmonary artery shunt, while the lower arrow marks active parenchymal extravasation. (B) Superselective catheterization was performed, followed by embolization using a combination of microspheres and NBCA. (C) Post-embolization angiography showed complete occlusion of the shunt.

underwent surgical resection. The most commonly used embolic agents in second-line treatments were NBCA and coils.

Among recurrent cases, especially in late-phase recurrences, the most common underlying etiology was bronchiectasis. As examples of recurrence due to recanalization and collateral formation, 2 representative cases are demonstrated in Figures 4 and 5.

Discussion

Massive hemoptysis remains a life-threatening respiratory emergency with significant mortality. Bronchial artery embolization has been recognized in the literature as an effective first-line intervention for immediate hemorrhage control. Numerous studies report high technical success rates ranging from 85% to 98% and early clinical success rates ranging from 70% to 97% in a variety of patient populations.[5,6,8,14] Consistent with this, the present study demonstrates high technical (97%) and early clinical success rates (95.3%) in patients undergoing BAE for massive hemoptysis, supporting the continued role of BAE as a first-line treatment modality.

Etiological factors in massive hemoptysis vary among populations. While malignancy, cystic fibrosis, and vasculitis are more prominent in Western cohorts, post-tuberculosis sequelae and idiopathic bronchiectasis are frequently reported in Eastern countries.[19,20] In the present data, bronchiectasis (idiopathic, post-tuberculosis, and cystic fibrosis-related) and mass lesions are common underlying causes.

The right bronchial artery (51.2%) was the most common source of bleeding, consistent with previous angiographic studies.[12] In this study, the most common angiographic findings were hyperemia and hypervascularity (83%) and tortuous, hypertrophic bronchial arteries (69%), consistent with prior reports. Bronchial–pulmonary artery shunts were less frequent (7%), aligning with previously reported ranges.[8,20]

We observed that PVA particles and microspheres were the most frequently used embolic agents, similar to the literature.[13,14] However, in selected cases (especially in cases with broncho-pulmonary shunts), proximal occlusion using coils or large particles was preferred to minimize the risk of off-target systemic embolization. This approach was consistent with the current literature.[14,15]

In this series, 3 patients underwent bilateral embolization (7%). Fruchter et al[12] also reported a similar rate (7.7%) of bilateral BAE in their long-term follow-up study. Although bilateral procedures require careful angiographic assessment of spinal artery anatomy in particular, no procedure-related complications were observed in these cases.[11]

The recurrence rates observed in this study (7.1% early, 16.2% late) fall within the range reported in prior series (9.8%-57.5%).[20-22] Most recurrent cases were again linked to bronchiectasis, which

Table 2. Types of Embolization Materials

Embolizing Agent	Frequency, n (%)	Size
Polyvinyl alcohol (PVA)	20 (46.6)	350-700 (mean 300-500 μm)
Microspheres	13 (30.3)	400-1000 (mean 400-800 μm)
Coil	3 (6.9)	1-3 mm
N-butyl-2-cyanoacrylate (NBCA)	3 (6.9)	–
Combined (microspheres + NBCA, PVA + NBCA, coil + PVA, coil + microspheres)	4 (9.3)	–

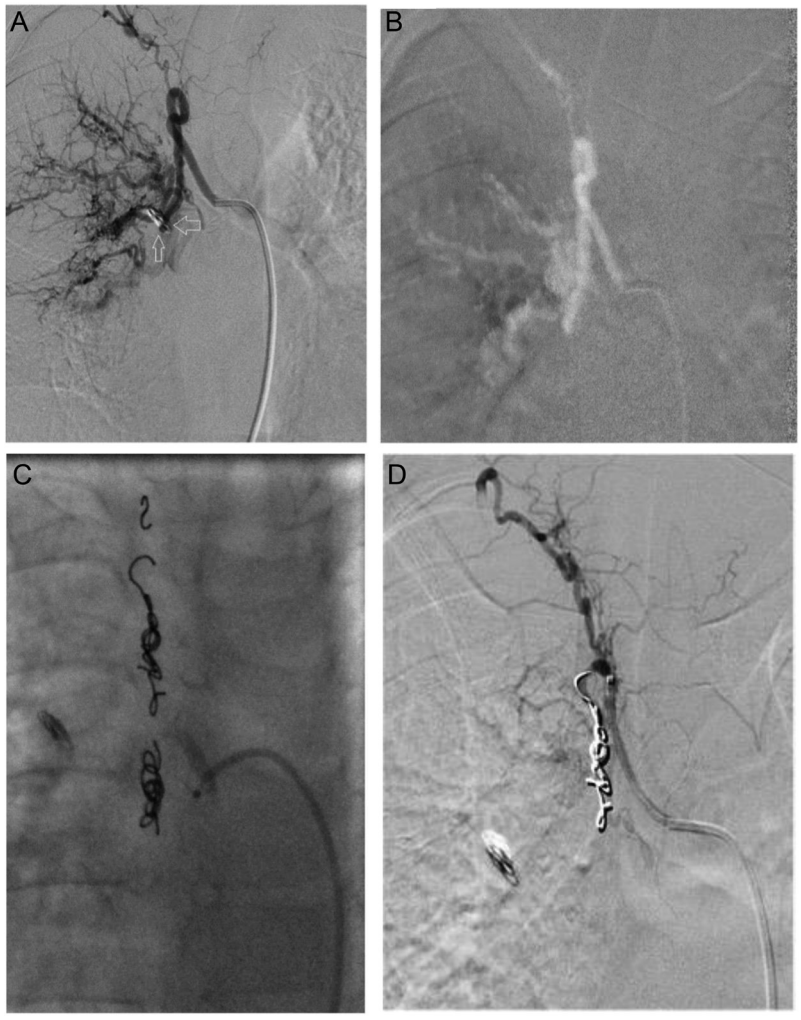


Figure 3. An 18-year-old patient with a history of previous tracheoesophageal fistula repair presented with massive hemoptysis. (A) Angiographic imaging demonstrated a bronchial–pulmonary artery shunt, which is indicated by arrows. (B, C) To prevent systemic embolization, proximal embolization was performed using 1-3 mm coils. (D) Post-embolization angiography confirmed complete occlusion of the shunt.

Table 3. Treatment Outcomes and Complications

	Frequency, n (%)
Outcome	
Technical success	42 (97)
Early clinical success	41 (95.3)
Early recurrence	3 (7.1)
Late recurrence*	6 (16.2)
Mortality	3 (7)
Complications (n = 8)	
Transient chest pain	4 (9.3)
Post-embolization syndrome	3 (6.9)
Paraplegia	1 (2.3)

*Four patients (9.3%) were lost to follow-up after 3 months and were excluded from the late recurrence analysis. Two patients died within the first 3 months (1 early mortality within 24 hours and 1 after early recurrence), and 1 additional patient died following late recurrence.

is a well-known risk factor for delayed rebleeding due to diffuse and fragile vascular beds.[6,13,20,22]

Six patients presenting with recurrence underwent embolization therapy, mostly using NBCA and coils, while surgery was reserved for localized disease or previous embolization failure in 3 cases, reflecting current recommendations that position surgery as a secondary option in selected patients.[8,20,21] Although previous studies have reported the use of multiple embolic agents in BAE, few have described their selective application according to vascular anatomy or recurrence pattern. In this study, multi-agent embolization (e.g., PVA + NBCA, coil + microspheres) was selectively used in complex or recurrent cases to achieve both distal and proximal occlusion and enhance long-term hemostatic durability. Besides 1 recurrent case, this strategy was also applied in 3 technically challenging cases characterized by tortuous vascular anatomy, strong collateral flow, or suboptimal distal embolization. This tailored use of dual agents provided more durable occlusion and minimized the risk of non-target embolization.

This study has several limitations. First, it was conducted in a single center with a relatively small sample size. Second, the retrospective design may have introduced selection and information biases because some clinical and procedural data were based on

Table 4. Recurrence Cases and Their Management

Etiology	Time Range	Source	Fırst Treatment	Second Treatment
Malignancy	Early	Systemic collaterals (intercostal arteries)	PVA (300-500 µm)	NBCA
Bronchiectasis	Early	Recanalization	Microsphere (600 µm)	Coil (2 mm) and microsphere (600 µm)
Malignancy	Late	Recanalization + Systemic collaterals (intercostal arteries)	PVA (300-500 µm)	NBCA
Bronchiectasis	Late	Recanalization	Microsphere (400-600 µm)	Coil (2 mm)
Bronchiectasis	Late	Recanalization	PVA (300-500 µm)	Surgery (lobectomy)
Post-tuberculous sequela	Late	Recanalization	PVA (300-500 µm)	NBCA
Malignancy	Early	Recanalization	Microsphere (600 µm)	Surgery (lobectomy)
Malignancy	Late	–	PVA (300-500 µm)	Direct surgery (lobectomy)
Bronchiectasis	Late	Recanalization	PVA (300-500 µm)	Coil (2 mm)

NBCA, n-butyl-2-cyanoacrylate; PCA, polyvinyl alcohol.

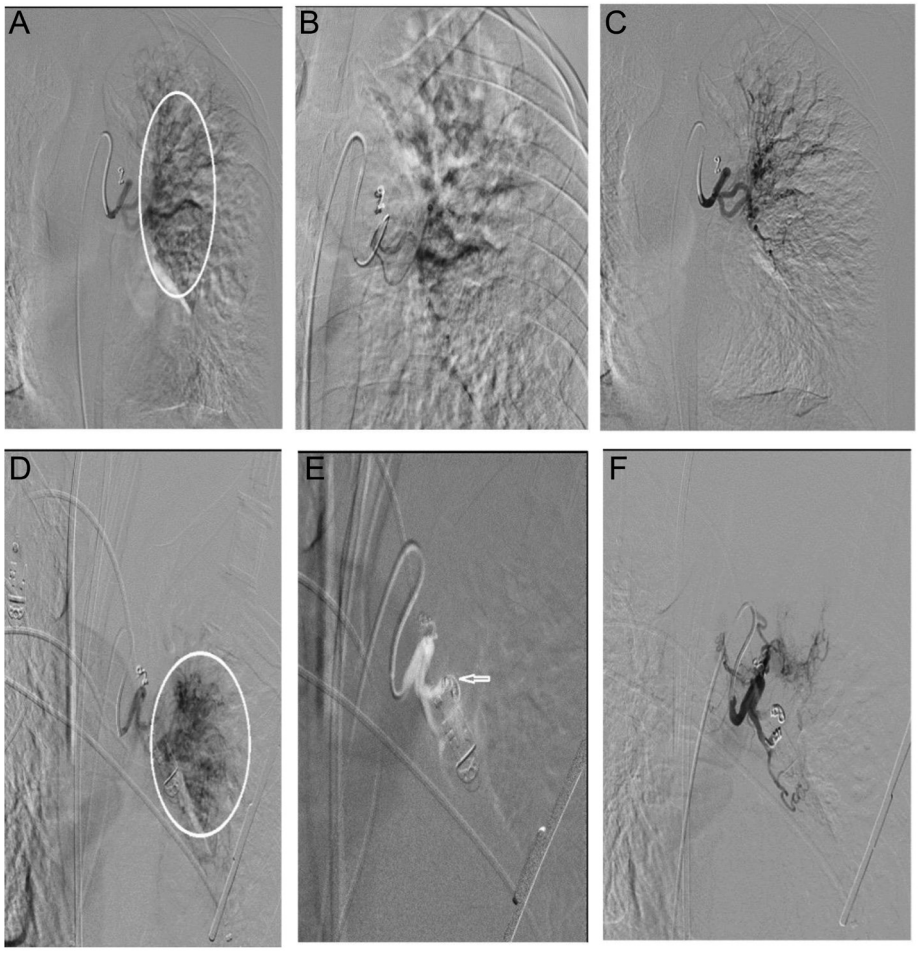


Figure 4. A 27-year-old male patient with cystic fibrosis and bronchiectasis presented with massive hemoptysis. (A) Initial aortography demonstrated prominent hyperemia and hypervascularity in the left lung, which are indicated by a circle, especially in the intermediate and hilar regions. (B) After achieving stable catheter positioning, embolization was performed using 600 µm microspheres. (C) Post-embolization angiography showed significant regression of hyperemia. The same patient was readmitted with recurrent massive hemoptysis 1 month later. (D) Repeat angiographic imaging revealed similar areas of hyperemia in the left lung, marked with a circle, consistent with recanalization of previously embolized vessels. (E) During the second procedure, embolization was performed using 600 µm microspheres and 2-mm coils, which are marked with an arrow. (F) Complete resolution of hyperemia was observed on post-procedural angiography.

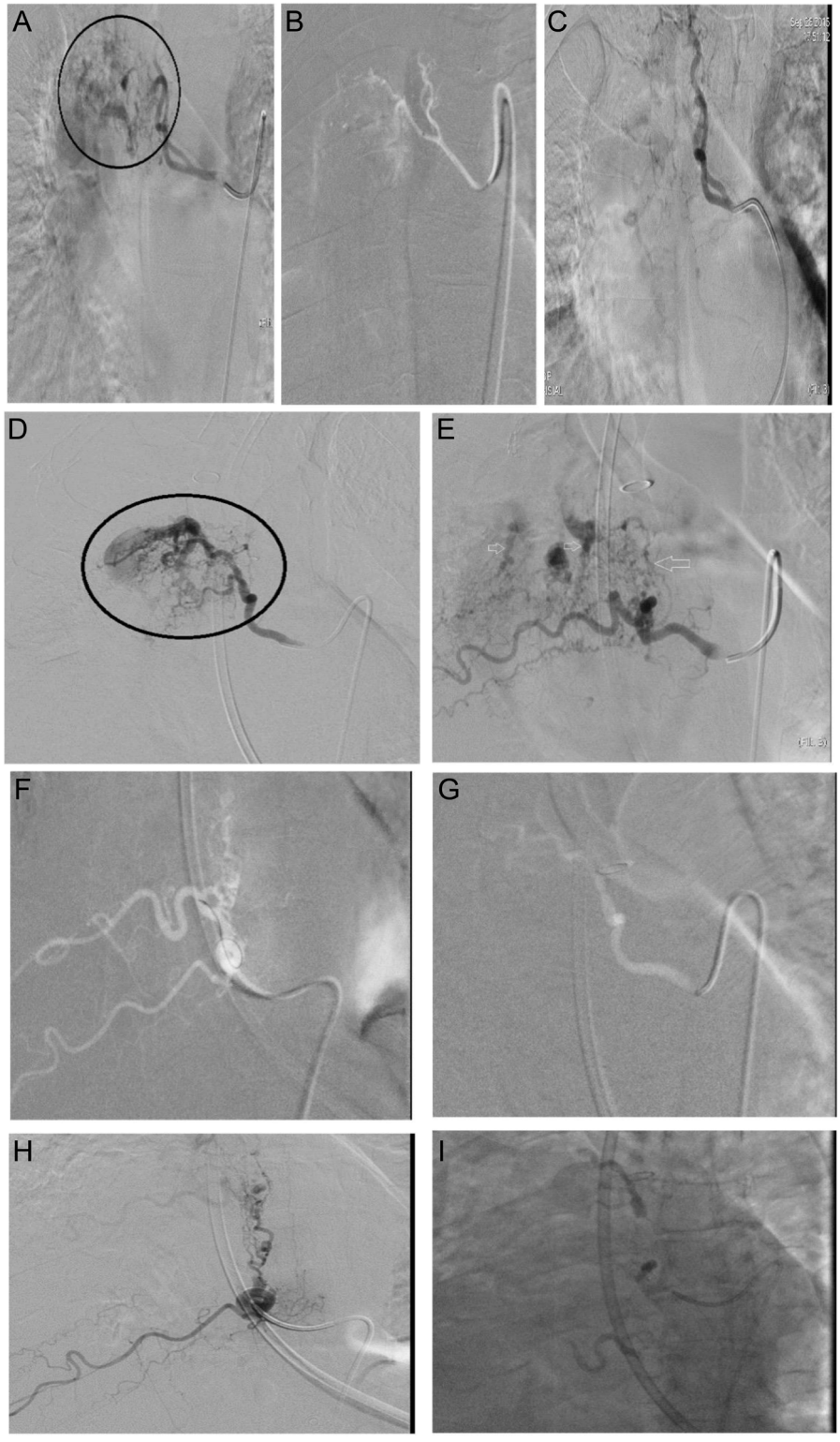


Figure 5. A 60-year-old female patient with primary lung malignancy was admitted with massive hemoptysis. (A) Initial angiography demonstrated hypervascularity and parenchymal hyperemia at the level of a mass in the right upper lobe, along with tortuosity and hypertrophy of the right bronchial artery. All findings are highlighted with a circle. (B) Embolization was performed using PVA particles (350-500 μm) via microcatheter targeting the bleeding site. (C) On post-procedure control angiography, the abnormal parenchymal opacification had resolved. Two years later, the patient was readmitted with recurrent massive hemoptysis. (D) Repeat angiography revealed recurrent hyperemia at the mass level and tortuosity of the right bronchial artery which are demonstrated with a circle. (E) In addition to bronchial artery involvement, 2 adjacent intercostal arteries were also identified as sources of bleeding. The intercostal arteries are marked with arrows. (F,G) All 3 culprit arteries—the bronchial and 2 intercostals—were selectively catheterized using a microcatheter and embolization was performed using NBCA (H,I) Final control angiograms showed complete resolution of hypervascularity in both bronchial and intercostal arteries.

limited medical records. Third, 4 patients were lost to follow-up after 3 months, which may have led to an underestimation of the late recurrence results.

Furthermore, as mentioned above, the existence of different etiologies according to geographical regions and the variety of embolizing materials used may limit the generalizability of these results. Multicenter studies with larger and more diverse populations are needed to further confirm these results and develop individualized embolization strategies.

Overall, these results are in line with previous studies regarding indications, technical success, and recurrence outcomes. However, this experience adds a new practical perspective by demonstrating how selective use of combined embolic agents can be applied in complex or recurrent cases. This approach is believed to support a more individualized embolization strategy and may help optimize long-term outcomes in patients with massive hemoptysis.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethical committee approval was received from the Institutional Ethics Committee of Gazi University Faculty of Medicine (Approval No.: 429; Date: May 22, 2023).

Informed Consent: Written informed consent was obtained from all patients prior to the procedures.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – F.Ö.; Design – F.Ö.; Supervision – F.Ö., K.A., B.Ö., E.I.; Resources – F.Ö., N.Y.; Materials – B.M.A., K.A., B.Ö.; Data Collection and/or Processing – N.Y., B.M.A.; Analysis and/or Interpretation – B.M.A., E.I.; Literature Search – N.Y., E.I.; Writing – F.Ö., N.Y.; Critical Review – F.Ö., E.I.

Declaration of Interests: The authors declare that they have no competing interests.

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