Diagn Interv Radiol 2023; DOI: 10.4274/dir.2023.232253

INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Efficacy and safety of transcatheter arterial embolization for hemodynamically unstable bleeding after percutaneous transthoracic needle biopsy

*Su Kyeong Yeon
*Yura Ahn
Ji Hoon Shin
Sang Young Oh
Gun Ha Kim

***Contributed equally to this work and share first authorship.**

PURPOSE

To evaluate the safety and efficacy of transcatheter arterial embolization (TAE) in controlling hemodynamically unstable bleeding following a percutaneous transthoracic needle biopsy (PTNB).

METHODS

A total of seven patients (four men and three women; mean age, 62 ± 12 years) who received TAE for post-PTNB bleeding between May 2007 and March 2022 were included. The observed types of bleeding were hemothorax (n = 3), hemoptysis (n = 2), and a combination of both (n = 2). In patients with active bleeding, the technical success of TAE was defined as superselective embolization of the target artery with no active bleeding visible on post-TAE angiography. Clinical success was defined as sustained cessation of bleeding without hemodynamic instability, requirement of repeat TAE, or the need for post-TAE hemostatic surgery during the initial admission. The metrics analyzed included technical and clinical success rates, complications, and 30-day mortality.

RESULTS

All seven patients achieved technical success, with a clinical success rate of 86% (6/7). Six patients were discharged alive, while one patient died of respiratory failure accompanied by hemothorax 19 days post-biopsy. The angiographic findings associated with bleeding were contrast media extravasation or pseudoaneurysm (n = 3) and vascular hypertrophy with tortuosity (n = 2). The implicated bleeding arteries included the intercostal artery (n = 2), bronchial artery (n = 2), and internal thoracic artery (n = 1). In two cases, no clear bleeding foci were identified; nonetheless, prophylactic embolization was performed on the right intercostal artery (n = 1) and right intercostobronchial trunk (n = 1). The embolic agents utilized included microcoils (n = 1), gelatin sponge particles (n = 2), polyvinyl alcohol (PVA) with gelatin sponge particles (n = 1), PVA with microcoils (n = 1), microcoils with gelatin sponge particles (n = 1), and microcoils with n-butyl-2-cyanoacrylate and gelatin sponge particles (n = 1). The 30-day mortality rate was 14% (1/7). No ischemic complications related to TAE were observed.

CONCLUSION

The study suggests that TAE is safe and effective for controlling hemodynamically unstable bleeding following a PTNB.

KEYWORDS

Transcatheter arterial embolization, percutaneous transthoracic needle biopsy, hemoptysis, hemothorax, angiography

From the Department of Radiology and Research Institute of Radiology (S.K.Y., Y.A., J.H.S. ✉jhshin@amc.seoul.kr, S.Y.O., G.H.K.), University of Ulsan College of Medicine, Asan Medical Center, Seoul, South Korea.

Received 17 April 2023; revision requested 05 June 2023; accepted 08 August 2023.

Epub: 31.08.2023

Publication date: 07.11.2023

DOI: 10.4274/dir.2023.232253

Image-guided percutaneous transthoracic needle biopsies (PTNBs) play a pivotal role in the histopathological evaluation of pulmonary parenchymal lesions.[1] Recognized as a safe and minimally invasive diagnostic procedure, a PTNB is nonetheless associated with a risk of procedure-related complications such as pneumothorax, hemorrhage, and air embolism.[2]

You may cite this article as: Yeon SK, Ahn Y, Shin JH, Oh SY, Kim GH. Efficacy and safety of transcatheter arterial embolization for hemodynamically unstable bleeding after percutaneous transthoracic needle biopsy. *Diagn Interv Radiol.* 2023;29(6):819-825.

Risk estimates for bleeding complications following a PTNB fluctuate widely. Utilizing data from twelve single-institution retrospective case series, Wiener et al.[3] reported a median hemorrhage risk of 12%, ranging from 2% to 66%. This variation could be attributed to the differences in how the complications were defined across studies.[3] Such bleeding complications may encompass pulmonary parenchymal hemorrhage, hemoptysis, hemothorax, chest wall hematoma, and pulmonary artery pseudoaneurysm.

Hemoptysis is typically self-limiting, but there can be instances of massive, potentially fatal, hemoptysis following a PTNB.[4] In cases where massive hemoptysis is unmanageable through conservative methods, rigid bronchoscopy, transcatheter arterial embolization (TAE), or surgery might be employed in some centers.[5] The occurrence of significant chest wall hematoma and hemothorax, although rare, can transpire if any of the intercostal arteries or internal thoracic arteries are injured during the biopsy procedure.[6] Several studies have reported TAE of the injured arteries to be an effective treatment option for iatrogenic intercostal or internal thoracic arterial bleeding.[7-9] There are limited case reports and associated evidence concerning TAE for hemorrhage following a PTNB. This study aimed to evaluate the clinical efficacy and safety of TAE in patients with hemodynamically unstable PTNB-related hemorrhage.

Main points

- The clinical success rate of transcatheter arterial embolization for hemodynamically unstable bleeding after percutaneous thoracic needle biopsy was 86%, with no complications.
- Delayed-onset (>24 h) bleeding complications were frequent, occurring in up to 43% of cases, highlighting the necessity of patient education and close monitoring.
- The angiography identified bleeding arteries as intercostal arteries, bronchial arteries, and an internal thoracic artery, and prophylactic embolization of non-bleeding sites also achieved clinical success, emphasizing the significance of diagnostic angiography and selective embolization in managing post- percutaneous transthoracic needle biopsy bleeding.

Methods

Patients

This retrospective study received approval from the Asan Medical Center Institutional Review Board (no: S2023-0101-0001). Given its retrospective nature, the requirement for written informed consent for the procedures was waived. The study was conducted in a single tertiary referral hospital.

Between May 2007 and March 2022, a total of 18,118 consecutive PTNBs were performed on 16,576 adult patients. Among these, 356 patients (2.1%) experienced hemoptysis, and 13 (0.08%) developed hemothorax, as confirmed by imaging studies. The present study included seven patients (four men, three women; mean age, 62 ± 12 years) from this group who underwent TAE to control bleeding following a PTNB. These patients were specifically referred due to downtrending hemoglobin levels or hemodynamic instability. The median transfusion volume before and after angiography was five units of packed red blood cells (range: 0–16 units).

The medical records of each patient were reviewed to gather clinical data, including underlying diseases, clinical symptoms or signs, and laboratory findings. Initial presentation data such as vital signs, systolic and diastolic blood pressures, and coagulation study results [including hemoglobin concentration, platelet count, prothrombin time, activated partial thromboplastin time, and the international normalized ratio (INR)] were collected.

The variables analyzed in this study included the following: the time between biopsy sample collection and symptom onset; the interval from symptom onset to angiography; computed tomography (CT) findings; TAE details (e.g., angiographic findings and embolic materials used); procedure-related complications; and clinical outcomes after TAE, which comprised technical and clinical success, 30-day mortality, admission to the intensive care unit, and procedure-related complications related to post-PTNB bleeding.

Biopsy procedures

Our established protocol mandates an INR of <1.6 and a platelet count of >50,000/μL. The PTNBs were either conducted by thoracic radiology faculty members or by chest imaging fellows under their direct supervision.

All patients underwent a prearranged chest CT scan prior to the PTNB. For each procedure, the operator delineated the most efficient and secure pathway for the needle based on the CT scans. Subsequently, the patients were positioned according to the selected pathways.

The pre-, intra-, and post-procedural CT scans of patients who underwent TAE were reviewed. First, variables such as target lesion characteristics (size, lobar location, and lesion type), patient position, puncture site location, needle penetration length from the pleura, number of specimen acquisitions, and complications were recorded. Moreover, the distance from the midline (spinous process) to the biopsy site for each patient who had biopsy specimen collection in the prone position was measured.

All patients were administered local anesthesia. The procedures were conducted under CT guidance, fluoroscopic guidance, or without imaging guidance, selecting the optimal route to circumvent ribs, vessels, fissures, and intercostal nerves. A standard core biopsy incorporating a coaxial technique was used, which employed a 19-G coaxial introducer and 20-G cutting needle (Stericut; TSK Laboratory). All specimens were immediately evaluated for diagnostic sufficiency. If the initial specimen was deemed insufficient, further aspirations were performed, with a maximum of three aspirations in one setting. Following the procedure, the patients were instructed to rest in the supine position. A chest X-ray follow-up was conducted 2–4 h post-biopsy to detect any procedure-related complications.

The CT-guided PTNB was performed with either a single-slice spectral detector CT scanner (HiSpeed CT/I; GE Healthcare) or 64-multidetector CT scanners (SOMATOM Definition AS; Siemens Healthineers) with parameters set to 100 or 120 kVp and 1.5 or 3.0 mm in axial slice thickness. The needle was inserted at an optimal angle until its tip reached the lesion's edge, as confirmed by several small-scale CT scans throughout the procedure. Once sufficient tissue samples were procured and the needle removed, a post-procedural CT was conducted to identify any complications.

During the fluoroscopic biopsy, the exposure parameters were set to 60 kVp. To mitigate radiation exposure, the operator manipulated the needle introducer using surgical forceps during fluoroscopy procedures. Real-time imaging was intermittently employed to visualize the position of the advancing needle tip.

Angiography and embolization techniques

Prior to embolization, the hemorrhage was located using pre-procedural CT scans or biopsy results. Thoracic aortography, bronchial arteriography, internal thoracic arteriography, and intercostal arteriography were performed with a specific reference to the CT-identified hemorrhage. Contrast extravasation, the existence of pseudoaneurysms or hypertrophy, and vascular tortuosity were indicators of active bleeding.[10] Experienced interventional radiologists, with a clinical tenure of 10–20 years in endovascular treatments, conducted the angiography and embolization procedures. The standard protocol included local anesthesia administration, specifically lidocaine, followed by routine access to the right common femoral artery. A 5F catheter (RH or C2 catheter, Cook Medical) and a 0.035-inch hydrophilic guidewire (Radifocus, Terumo Inc.) were employed. Descending thoracic aortography was performed with a 5F pigtail catheter, and the abnormal culprit arteries were evaluated. A selective bronchial arteriogram was then performed using either reverse-curved catheters (Mikaelson, SOS Omni) or forward catheters (Cobra). If the anomalous bronchial arteries remained unidentified, a thorough exploration of non-bronchial systemic arteries, including intercostal arteries, was pursued. The patients who had biopsies performed in a supine position underwent additional internal thoracic arteriography. Superselection of the bleeding arteries was accomplished with a 2.0F–2.4F microcatheter (Progreat, Terumo Inc.; Renegade, Boston Scientific). If the bleeding site could not be localized, prophylactic embolization was performed on the most-suspected arteries, with consideration of the previous biopsy site.

Embolic materials, chosen as per the operator's preference and based on angiographic findings, included microcoils (MicroNester or Tornado; Cook Medical), n-butyl-2-cyanoacrylate (NBCA) (Histoacryl, B. Braun), polyvinyl alcohol (PVA) (PVA 355–500 μm; Boston Scientific), or gelatin sponge particles (Spongostan; Johnson & Johnson). To ensure target vessel occlusion or cessation of contrast extravasation, completion angiography was performed post-embolization.

Definitions

Coagulopathy was defined as an INR >1.5 or a platelet count of <50,000/μL.[11] Hemodynamic instability was characterized by either hypotension (systolic blood pressure <100 mmHg) or tachycardia (heart rate >100 beats/min). Any bleeding complications that occurred >24 h following biopsy specimen collection were deemed delayed events.[12]

In patients with active bleeding, technically successful TAE was defined as an embolization that successfully superselected the target artery, with no evidence of active bleeding noted in the post-TAE angiography. Clinical success was defined as the sustained cessation of bleeding without signs of hemodynamic instability, negating the need for either repeat TAE or post-TAE hemostatic surgery during the initial admission. Any complications were categorized as either major or minor based on the guidelines provided by the Society of Interventional Radiology Standards of Practice Committee.[13]

Statistical analysis

The numerical results of the clinical data and measurements were expressed as means ± standard deviations or medians (ranges).

Patient follow-up

Following TAE, all patients were closely monitored for clinical indications of ischemic complications or recurrent bleeding until either discharge or death. These clinical observations were augmented by laboratory studies, vital signs, and chest radiographs. The patients' long-term outcomes and mortality rates were established through a review of the medical charts. It is worth noting that conducting a CT scan following embolization is not standard practice within this hospital unit.

Results

Clinical characteristics

The characteristics and outcomes of the seven patients are summarized in Tables 1, 2. No coagulopathy was detected in any of the patients. The median INR was 1.09 (range: 0.93–1.22), and the median platelet count was 183,000/μL (range: 90,000–353,000/μL).

The median interval between biopsy sample collection and symptom onset was 2.0 h (mean: 50.0 h; range: 0.3–156.7 h). Hemoptysis occurred within 1 h post-biopsy in 43%

Table 1. Clinical characteristics

No/ sex/age (years)	Image guidance	Bleeding type	Symptom or sign	Time interval (h)		Hemoglobin (g/dL)		Transfusion (units of pRBCs)	TXA administration duration (days)	Pathology	Underlying disease
				Biopsy and symptom onset	Symptom onset and angiography	Before	After				
1/M/69	None	Hemothorax	Chest pain	2	5.3	6	8.8	5		Non-specific benign	DM, HTN, CKD
2/M/74	CT	Hemoptysis	Hemoptysis	0.6	1.5	8.4	10.6	3	4	Lung cancer	No
3/F/50	Fluoro	Hemothorax, hemoptysis	Dyspnea, hemoptysis	35.6	85.9	9.8	10.5	16	5	Lung cancer	No
4/F/64	CT	Hemothorax	Dyspnea, chest pain	153.88	65.8	7.1	10.3	8		Lung cancer	HTN, hyperthyroidism
5/M/63	CT	Hemothorax, hemoptysis	Hemoptysis	0.4	5.1	6.9	8.1	5	1	Non-specific benign	HTN, CKD, kidney amyloidosis
6/F/52	CT	Hemothorax	Chest pain, dizziness	156.7	9.5	8.8	11.6	2		Non-specific benign	HTN, Takayasu arteritis
7/M/62	CT	Hemoptysis	Hemoptysis	0.3	3.3	7.5	9.4	4	2	Lung cancer	DM, HTN, CKD, 3VD, HCC

CKD, chronic kidney disease; CT, computed tomography; DM, diabetes mellitus; F, female; pRBCs, packed red blood cells; Fluoro, fluoroscopy; M, male; HTN, hypertension; HCC, hepatocellular carcinoma; TXA, tranexamic acid; 3VD, three-vessel disease.

Table 2. Endovascular interventions and outcomes

No/sex/age (years)	Indication	Angiographic findings	Embolized vessels	Embolic materials	Technical success	Clinical success	Complications
1/M/69	Hb↓, BP↓	PSA	Left ICA (10th)	Coils	Yes	Yes	None
2/M/74	Hb↓, BP↓	Hypertrophic and tortuous	Left BA	PVA, GSP	Yes	Yes	None
3/F/50	Hb↓, BP↓	Hypertrophic and tortuous	Right ICBT, right ITA	Coils, GSP	Yes	No	None
4/F/64	Hb↓, BP↓	CE, PSA	Right ITA	NBCA, coils, GSP	Yes	Yes	None
5/M/63	Hb↓	Normal	Right ICA (8th, 9th, 10th)	GSP	Yes	Yes	None
6/F/52	Hb↓, BP↓	CE	Right ICA (8th)	PVA, coils	Yes	Yes	None
7/M/62	Hb↓, BP↓	Normal	Right ICBT	GSP	Yes	Yes	None

BA, bronchial artery; BP, blood pressure; CE, contrast extravasation; F, female; GSP, gelatin sponge particle; Hb, hemoglobin; ICBT, intercostobronchial trunk; ICA, intercostal artery; ITA, internal thoracic artery; M, male; NBCA, n-butyl-2-cyanoacrylate; PSA, pseudoaneurysm; PVA, polyvinyl alcohol.

Table 3. Pre-, intra-, and post-procedural parameters and computed tomography findings

No/sex/age (years)	Nodule type	Nodule size (mm)	Biopsy number	Location	Total depth (mm)	Depth from pleura (mm)	Position	Distance from spinous process (mm)	Puncture site (intercostal space)	Pneumothorax	Parenchymal hemorrhage
1/M/69	NA	NA	4	Left hemithorax	28	5	Prone	89	Left 10th	No	No
2/M/74	Subsolid	32	3	LUL	48	26	Supine		Right 3rd	Yes	Yes
3/F/50	Solid	80	3	RLL	52	40	Prone	82	Right 7th	No	No
4/F/64	Solid	26	3	RUL	68	27	Supine		Right 1st	No	No
5/M/63	Solid	39	2	RLL	57	32	Prone	79	Right 7th	No	Yes
6/F/52	Solid	20	2	RLL	73	32	Prone	110	Right 8th	No	Yes
7/M/62	Subsolid	14	2	RUL	94	56	Supine		Right 2nd	No	Yes

NA, not available; M, male; F, female.

of the patients (3/7), while in another 43% (3/7), symptom onset was delayed until >24 h after the collection of the biopsy specimen. Four patients who had active hemoptysis were administered a 500 mg (5 mL) dose of tranexamic acid, combined with 5 mL of distilled water, four times daily. The median duration of this treatment was 2.5 days (range, 1–5 days).

Computed tomography findings

The procedural parameters and CT findings of the study patients are summarized in Table 3. Four patients underwent the PTNB in the prone position, with the remaining three in the supine position. Among these patients, four exhibited solid lesions and two presented subsolid lesions. Patient 1 had a significant pleural effusion without a demonstrable mass or enhancing lesion and thus underwent a pleural biopsy. The mean size of the target lesion was 35.1 mm (median: 29.0 mm; range: 14.0–80.0 mm).

The mean distance from the skin to the target lesion was 61.3 mm (median: 62.5 mm; range: 28.0–94.0 mm). In patients who were in the prone position, distances from the biopsy sites to the spinous processes were measured, yielding a mean value of 90.0 mm (median: 85.5 mm; range: 79.0–110.0 mm). For these four patients, the needle insertion sites were located at the right seventh intercostal space (n = 2), the right eighth intercostal space (n = 1), and the left tenth intercostal space (n = 1).

Embolization details and outcomes

The angiographic details are shown in Table 2. The median interval between symptom onset and angiography was 5.3 h (mean: 25.2 h; range: 1.5–85.9 h).

In terms of angiographic findings, active bleeding indicators, such as contrast media extravasation or pseudoaneurysms, were evident in three patients. Two other patients exhibited vascular hypertrophy and tortuosity, whereas the final two patients presented no signs of active bleeding. Angiography identified the bleeding arteries as intercostal arteries (n = 2) (Figure 1), bronchial arteries (n = 2) (Figure 2), and an internal thoracic artery (n = 1) (Figure 3). The two patients without demonstrable bleeding sites underwent prophylactic embolization of an intercostal artery (n = 1) and the intercostobronchial trunk (n = 1). The embolization procedures were technically successful for all seven patients. Three patients were treated using single embolic agents: one with microcoils and two with gelatin sponge particles. In contrast, four patients were treated using a combination of embolic agents: PVA with gelatin sponge particles (n = 1), PVA with microcoils (n = 1), microcoils with gelatin sponge particles (n = 1), and microcoils with NBCA and gelatin sponge particles (n = 1).

Clinical success was achieved in six patients (86%, 6/7). One patient (patient 3) experienced rebleeding with respiratory failure and died 19 days after the biopsy procedure. This resulted in a 30-day mortality rate of 14%. No embolization-related complications were observed.

Discussion

Reports pertaining to embolization for active bleeding post-PTNB are currently limited. This study highlights the high technical feasibility and effectiveness of TAE for managing hemodynamically unstable bleeding complications following a PTNB, with a technical success rate of 100% and a clinical success rate of 86%. In the study cohort, the incidence of hemoptysis following a PTNB was 2.1%, which aligns with previously reported ranges of 2.8%–6.1% post-PTNB.[14-19] Although post-PTNB hemoptysis is generally self-limited,[20] it can sometimes be massive and life-threatening.[21] The medical literature typically defines massive hemoptysis as an episode involving >600 mL of hemoptysis within a 24-h span. The medical management of hemoptysis involves addressing the underlying etiology and administering tranexamic acid, an antifibrinolytic drug.[22] In instances where hemoptysis cannot be managed conservatively, TAE represents a viable therapeutic alternative.[5]

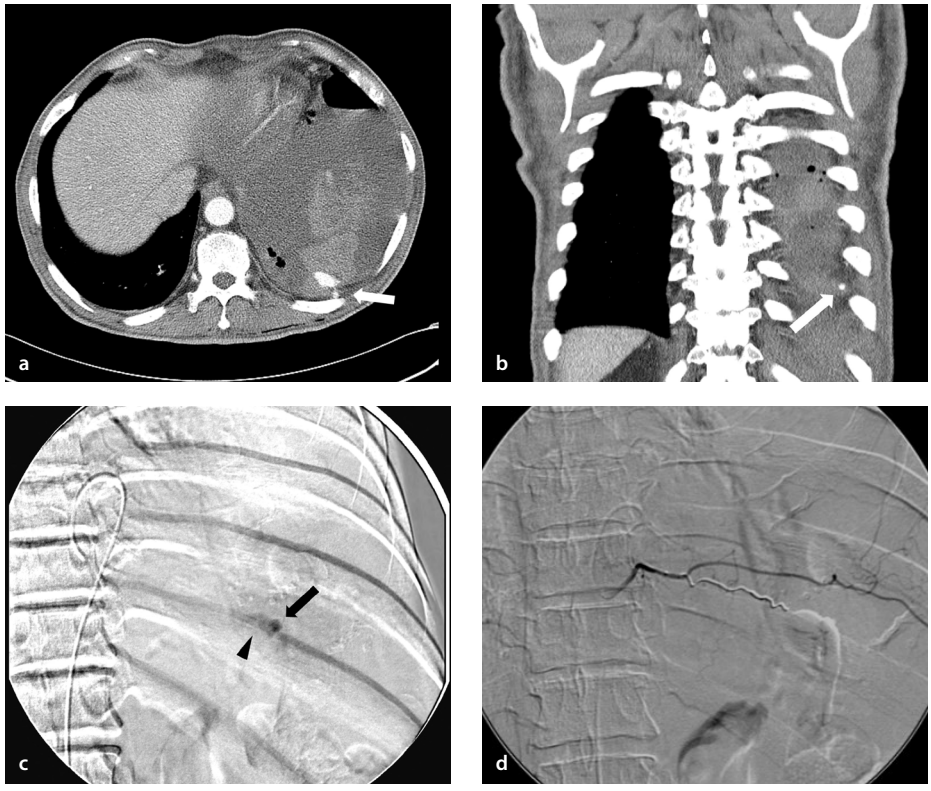

Figure 1. A 69-year-old man (no: 1) developed a hemothorax following a percutaneous thoracic needle biopsy (PTNB) of left pleural tissue. **(a, b)** Computed tomography images obtained immediately after a PTNB showed a hemorrhagic pleural effusion with extravasation of contrast medium at the left 10th intercostal artery. **(c)** The left intercostal angiogram showed a definite pseudoaneurysm (arrow) and contrast extravasation (arrowhead) at the left 10th intercostal artery. **(d)** The bleeding focus was embolized using two microcoils, and the completion angiogram showed no further bleeding.

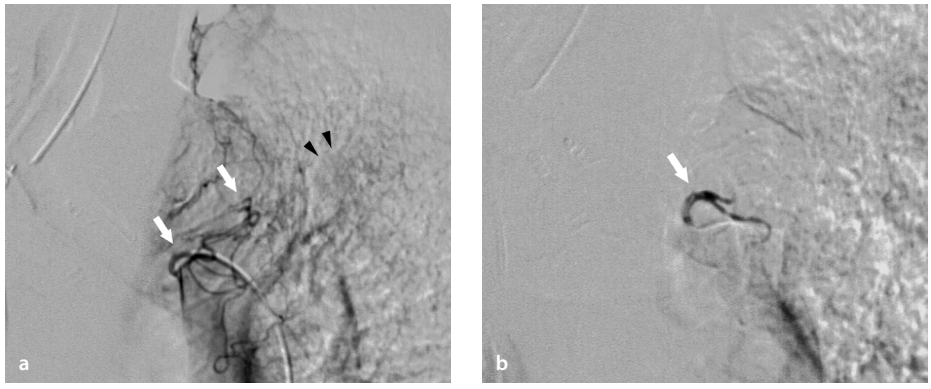

Figure 2. A 74-year-old man (no: 2) with massive hemoptysis following a percutaneous thoracic needle biopsy (PTNB) for an adenocarcinoma in the left upper lobe. **(a)** Selective left bronchial angiogram showing tortuous branches (arrows) that supply a hypervascular area, and mass staining (arrowheads). Hypertrophied left bronchial artery was embolized with polyvinyl alcohol (355–500 um) and gelatin sponge particles. **(b)** Postembolization angiogram revealing occlusion of the left bronchial artery with no opacification of the hypervascular lesion (arrow).

The incidence of hemothorax following a CT-guided PTNB is <0.1%; however, its occurrence is associated with substantial morbidity and mortality.[23,24] In the study patient group, hemothorax following a PTNB was observed in 0.08% of cases. One of these patients experienced a progressively worsening hemothorax and died despite intervention. Vascular structures vulnerable to injury during a PTNB primarily include large central vessels and certain systemic arteries, such as the subclavian, axillary, internal thoracic, and intercostal arteries.[25] Conventionally, the supracostal approach is the most frequently used and safest puncture route to circumvent intercostal artery injury during transthoracic puncture. However, the dynamics of target lesion positions during respiration and a limited intercostal window may necessitate deviation from this approach. Additionally, tortuosity is often observed among the third to eighth posterior intercostal arteries, increasing their exposure within the intercostal spaces in the first 6 cm from the spine, particularly in individuals over 60 years of age.[26,27] Of the four patients in the study who were in a prone position during their PTNB procedures, the mean distance from the biopsy site to the spinous process was 90.0 mm. The puncture sites were located at the right seventh to eighth intercostal spaces in 75% of these patients (3/4). Findings from a cadaveric study led to the recommendation that surgical instruments entering any of the third to eighth intercostal spaces should ideally be placed at least 120.0 mm lateral to the midline of the spinous processes.[27] Therefore, during such procedures, it is critical to consider these anatomical principles, particularly those concerning the intercostal arteries and collateral vessels. It is important to note that, given the high likelihood of tortuosity, supracostal puncture does not necessarily circumvent lacerations.

Diagnostic angiography is recommended when patients exhibit hemodynamic instability, progressively decreasing hemoglobin levels, or when follow-up CT scans demonstrate evidence of bleeding.[28] Even in instances with seemingly normal aortograms, an attempt at selective catheterization of the bronchial arteries should be made, as bleeding may originate from vessels of standard diameter.[29] A prior study confirmed complete clinical responses in patients who

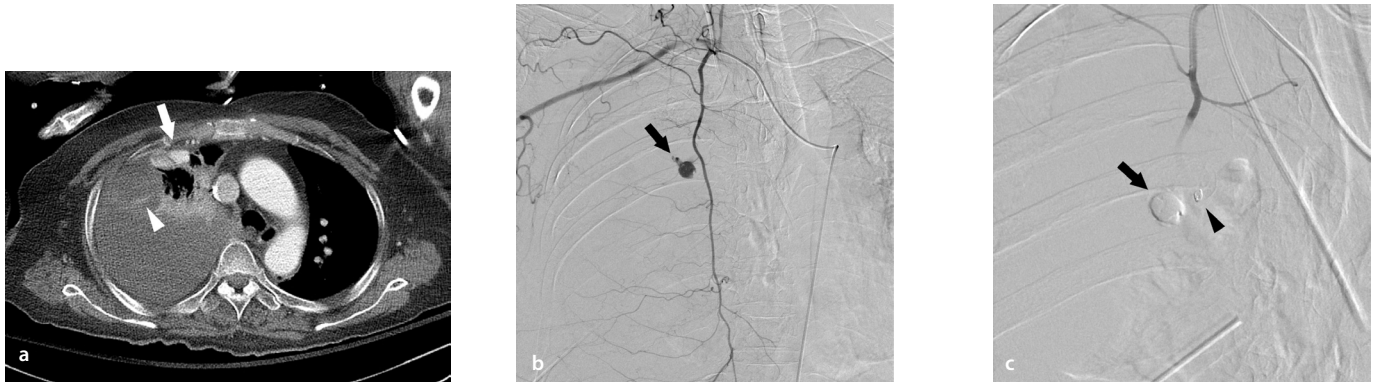

Figure 3. A 64-year-old woman (no: 4) developed a massive hemorrhagic pleural effusion following a percutaneous thoracic needle biopsy (PTNB) for an adenocarcinoma in the right upper lobe. **(a)** A computed tomography image obtained nine days after a PTNB showing a pseudoaneurysm (arrow) with linear contrast extravasation (arrowhead) from the right internal thoracic artery. **(b)** The right internal thoracic arteriogram shows a pseudoaneurysm and contrast extravasation (arrow). **(c)** The right internal thoracic artery distal to the pseudoaneurysm was embolized with one microcoil (arrowhead), and the pseudoaneurysm was embolized with n-butyl-2-cyanoacrylate and gelatin sponge particles (arrow), with no further bleeding.

underwent bronchial artery embolization with non-hypertrophied bronchial arteries.[30] In the present study, the angiograms of five patients exhibited evidence of bleeding; however, such evidence was absent for two patients. These two patients, without observable active bleeding, underwent prophylactic embolization of the intercostal arteries and the intercostobronchial trunk, respectively, both achieving clinical success.

Although instances of post-PTNB bleeding are infrequent, when they do occur, they can prove fatal. Upon the onset of bleeding, the likelihood of hemostasis is contingent upon platelet function and coagulation activity.[11] Patients suffering from chronic liver or kidney disease may exhibit hemorrhagic tendencies due to thrombocytopenia or platelet dysfunction.[31] In the study cohort, three patients had chronic kidney disease, with one of them also having concurrent chronic liver disease and hepatocellular carcinoma. However, no patient had a confirmed coagulopathy, which may have positively impacted the high technical and clinical success rates. A frequently occurring delayed onset (>24 h) of bleeding complications was observed in this study. All patients requiring immediate intervention post-PTNB presented with hemoptysis, whereas the three delayed-onset hemothorax cases displayed non-specific symptoms, such as dyspnea or chest pain. One of the three patients with delayed-onset hemothorax eventually succumbed to continuous bleeding despite the TAE. Therefore, educating patients about the signs and symptoms of bleeding is critical. Furthermore, close monitoring of clinical and radiologic characteristics is essential for the early identification of signs potentially indicative of early or delayed bleeding.

When interpreting the results of the study, certain limitations should be taken into consideration. First, the data collection was retrospective; as such, some patients with delayed symptom onset may have been overlooked in the analysis. Second, a relatively small number of patients underwent embolization for post-PTNB bleeding. Given the low incidence of clinically significant bleeding after a PTNB, this limitation was unavoidable despite the large pool of patients who underwent a PTNB. Third, a potential limitation was the absence of standardized protocols regarding the types of embolic materials and TAE techniques.

In conclusion, TAE demonstrated a high technical success rate and clinical effectiveness in managing patients who experienced bleeding post-PTNB.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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