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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Utility of intra-procedural cone-beam computed tomography imaging for the determination of the artery of Adamkiewicz suspected by angiography during transarterial embolization for hemoptysis

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PURPOSE

To evaluate the role of cone-beam computed tomography (CT) performed for the determination of the artery of Adamkiewicz (AKA) suspected by angiography during trans-catheter bronchial artery embolization for hemoptysis.

METHODS

In this retrospective study, 17 patients with hemoptysis who underwent cone-beam CT for evaluation of the AKA prior to arterial embolization from December 2014 to March 2022 were included. During the angiographic session, two interventional radiologists selected the possible AKAs that were defined as obscured hairpin-curved vessels arising from the dorsal branch of the intercostal arteries and running towards the midline in the arterially enhanced phase. Contrast-enhanced cone-beam CT was performed as an adjunct to angiography to determine whether the indefinite AKA was a real AKA based on whether it was found to connect to the anterior spinal artery.

RESULTS

Selective cone-beam CT was performed at 17 possible AKAs detected by selective arteriogram of the intercostal artery (ICA). Cone-beam CT allowed for the determination of AKAs in 16 cases (94.1%). As a result of cone-beam CT findings, 9 of 16 study arteries (56.3%) were judged as definite AKAs, and the remaining 7 (43.7%) were judged as definitely not AKAs but as the musculocutaneous branching from the dorsal branch of the ICA. In 1 of 17 cases (5.9%), cone-beam CT could not determine the AKA because of poor image quality caused by inadequate breath holding. An additional anterior radiculomedullary artery arising from the dorsal branch of the lower ICA because of the inflow of the contrast medium through the anastomosis was detected in one case by cone-beam CT but not by angiography.

CONCLUSION

Intraprocedural enhanced cone-beam CT performed as an adjunctive technique to angiography is sufficient for confident determination of the AKA, which is essential for the operators to perform accurate and safe arterial embolization for hemoptysis.

KEYWORDS

3-D, angiography, artery, cone- beam computed tomography, hemoptysis, interventional, radiculomedullary artery, radiology, therapeutic embolization

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Trans-catheter bronchial artery embolization (BAE) has been widely used for the management of massive and recurrent sub-massive hemoptysis.[1,2] It works on the principle of selective embolization of both the bleeding bronchial arteries and the bleeding non-bronchial systemic collaterals, which usually arise from the intercostal artery (ICA), inferior phrenic artery, and main branches of the subclavian and axillary arteries, such as the internal mammary artery and thyrocervical trunk.

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When BAE is performed, the spinal cord blood supply must be considered. The most serious complications associated with BAE are iatrogenic spinal cord ischemia or paraplegia, which are more often related to the inadvertent embolization of the artery of Adamkiewicz (AKA), also known as the dominant anterior radiculomedullary artery.[3] Therefore, accurate identification of the AKA is paramount during BAE.

Anatomically, the AKA is a small artery (caliber 0.5–1.5 mm) that branches from the dorsal branch of the segmental artery (either the ICA or the lumbar artery), ascends to the spinal cord surface, makes a classic "hairpin" arch, then connects to the anterior spinal artery (ASA).[4,5] Digital subtraction angiography is the main imaging modality used during BAE and is also considered the gold standard technique for detecting the AKA because of its high spatial resolution.[6,7] Due to the anatomic features of the AKA, the widely used detection criteria of the AKA by selective segmental arterial angiography is the presence of a characteristic hairpin-curved vessel leading to the ASA.[8,9] However, previous studies have potentially revealed that angiography alone was inadequate to visualize the AKA.[10-15]

During BAE, in the present study, although selective angiography of the catheterized ICA sometimes demonstrated an obscured hairpin-curved vessel running towards the midline, it was impossible to confirm whether this connected to the ASA. In these cases, whether it was a real AKA could not be determined from the angiography images due to the low contrast resolution and the two-dimensional projection. Therefore, imaging modalities with increased contrast resolution and multiple-dimensional projection were required when angiography was insufficient to visualize the minute vessels.

Main points

- Accurate identification of the artery of Adamkiewicz (AKA) is important during bronchial artery embolization for the management of hemoptysis.
- It was very difficult to determine whether the possible arteries of Adamkiewicz were real based on single planar angiography images alone.
- Cone-beam computed tomography is sufficient to provide adequate information for the confident determination of arteries of AKA during arterial embolization for massive hemoptysis.

Intraprocedural cone-beam computed tomography (CT) can provide CT-like images in multiple viewing planes, while eliminating the need to move the patient to the CT room and allow contrast injection into catheterized vessels to offer more subtle vascular and soft tissue information than angiography. Moreover, cone-beam CT provides higher soft-tissue attenuation resolution than angiography.[16-18] Therefore, the present study incorporates intraprocedural cone-beam CT as an adjunct to angiography for the identification of an AKA suspected by angiography.

Methods

Study population

This retrospective study was approved by the institutional review board (decision number of ethics committee approval: JN-2014010021), and informed consent was obtained from each patient or patient's family.

From December 2014 to March 2022, 279 consecutive patients who experienced massive or moderate hemoptysis underwent BAE in the department of interventional radiology. Seventeen of the 279 patients (6.1%) who underwent cone-beam CT for evaluation of an AKA were included in the present study. The mean age of the 17 patients (13 men, 4 women) was 56.3 years (range 32–87 years).

Angiography technique and embolization

All the interventional procedures were performed by two experienced radiologists with 11 and 19 years of experience, respectively. Patients underwent BAE in an interventional angiography suite (Artis Zee; Siemens Healthcare, Germany) equipped with the cone-beam CT option with continuous hemodynamic monitoring. The intervention was performed under local anesthesia through the right-side transfemoral approach. First, a 4FR Cobra (Cook, USA) or Simmons catheter (Cordis, USA) was used to catheterize the bronchial arteries and non-bronchial systemic collaterals. During this step, a coaxial microcatheter (Progreat 2.7F, Terumo, Japan or Stride 2.6F, Asahi Intecc, Japan) used for selective catheterization was useful but not mandatory. The following angiography using a nonionic iodinated contrast medium (Iodixanol, 320 mg I/mL; GE Healthcare, USA) was performed to localize the bleeding site.

A bleeding vessel was defined as a vessel with abnormal angiographic appearances of bronchial or peribronchial hypervascularity, contrast extravasation, arterial enlargement, systemic–to–pulmonary artery or venous shunting, aneurysms or pseudoaneurysms, vessel cut-off, or tortuosity of the bronchial artery. Then embolic agents were injected into the bleeding vessels under continuous fluoroscopic guidance to the point of stasis of flow without reflux. The embolic agents were 300–500 µm-sized polyvinyl alcohol particles (Cook, USA).

Protocol to avoid inadvertent embolization of the artery of AKA.

Of note, when a bleeding bronchial artery branching from the intercostobronchial trunk was visualized during angiography, highly selective catheterization of the bleeding bronchial artery was performed with a microcatheter advancing distally beyond the intercostal branch prior to embolization to avoid reverse flow that may potentially branch off an AKA.

In embolization occurs in the bleeding ICA, care must be taken to ensure whether there is an AKA arising from the ICA detected on pre-embolization angiography. The typical angiographic sign of an AKA is the presence of a hairpin-curved vessel branching from the dorsal branch of the ICA and connecting to the ASA in the arterially enhanced phase (Figure 1). Once an AKA is visualized during selective angiography of the bleeding ICA, the embolization in that ICA should be abandoned.

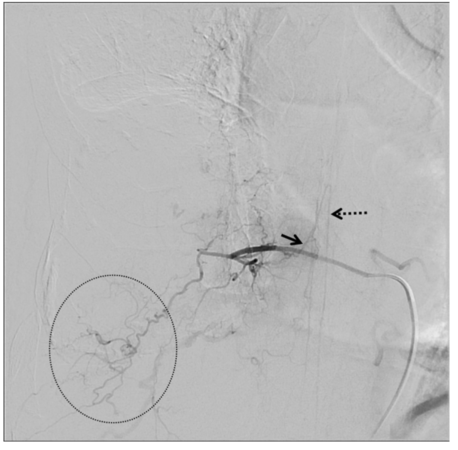

Figure 1. Intraprocedural images of a 45-year-old male patient. Selective angiography of the right tenth intercostal artery (ICA) clearly demonstrated a hairpin-curved vessel (arrow) originating from the dorsal branch of the ICA and connecting to the anterior spinal artery (dotted arrow) in the arterially enhanced phase. This hairpin-curved vessel was considered as an artery of Adamkiewicz. The sign of distal hypervascularity (dotted circle) indicated the ICA was involved in bleeding.

Cone-beam computed tomography protocol

During selective angiography of a bleeding ICA, a possible AKA was defined as an obscured hairpin-curved vessel arising from the dorsal branch of the ICA and running toward the midline in the arterially enhanced phase. Although possible AKAs were suspected from the morphologic "hairpin curve," it was very difficult to confirm the presence or absence of the ASA and to confirm whether the possible AKA connected to the ASA based on the obscured angiographic sign. Thus, whether the possible AKA was a real AKA could not be determined based on the angiography images alone. Selective cone-beam CT was performed when the aforementioned two interventional radiologists simultaneously confirmed the presence of a possible AKA.

Selective cone-beam CT was performed at the catheterized ICA with 6–9 mL of 100% contrast medium injected automatically at a rate of 2–3 mL/s according to the ICA diameter for 3 s with an imaging delay of 2 s. For each cone-beam CT scan, images were acquired during an 8s acquisition time, covering a 208° clockwise rotation. The region of interest was positioned covering the dorsal portion of the aorta from which the ICA rose and the proximal portion of the ICA from which the possible AKA originated. Multiplanar reformation images were reviewed by using 2-mm-thick slices, and three-dimensional visualization was obtained on a dedicated workstation (Leonardo with DynaCT; Siemens Healthcare, Germany).

Image analysis criteria

The two interventional radiologists independently viewed the angiography images and corresponding arterial cone-beam CT images using the paging method to (1) confirm the presence or absence of the ASA, which was defined as a contrast-enhanced vessel on the anterior spinal cord surface, running in the cranio-caudal direction detected on the oblique coronal images or as a dot enhancement continuing cranio-caudally detected on the axial images; (2) confirm or exclude the connection between the study artery and the ASA using the oblique coronal or axial images in the cases in which the ASAs were present; and (3) track the trajectory, distribution, and termination of the study artery using axial images in the cases in which the ASAs were absent.

The study artery was determined by the consensus of the two interventional radiologists using the uniform diagnostic criteria as follows: (1) the study artery was judged as definitely an AKA or definitely not an AKA based on whether it was found to connect to the ASA; and (2) among the study arteries that were judged as definitely not AKAs, a study artery was further considered as a musculocutaneous branch when it ran toward and terminated in the dorsal erector spinae muscle and skin without entering the intervertebral foramen or spinal cord enhancement.

The anatomic level of the ICA was defined as the level of the rib below which the ICA ran. The level of the rib was determined by fluoroscopic examination.

Discrepancies in the evaluations were resolved by consensus. Whether to perform embolization at the bleeding ICA that branched a possible AKA was determined by the cone-beam CT findings as follows: (1) embolization was performed at the bleeding ICA that branched where there was definitely not an AKA, as judged by cone-beam CT acquisitions; (2) embolization was not performed at the bleeding ICA that branched off a definite AKA, as judged by cone-beam CT acquisitions; and (3) embolization was not performed at the bleeding ICA that branched off a possible AKA that was indeterminate from the cone-beam CT.

Results

During the angiographic session, a total of 17 possible AKAs in 17 patients were detected by selective ICA angiography. Selective cone-beam CT was performed for the ICAs with a total of 17 cone-beam CT acquisitions.

Cone-beam CT allowed for the determination of AKAs in 16 of the 17 cases (94.1%). In one case (5.9%), cone-beam CT did not allow for the determination of an AKA because of the poor image quality caused by inadequate breath holding.

As a result, 9 of 16 study arteries (56.3%) were judged as definite AKAs (Figure 2). In these nine cases, both the ASA and the connecting AKA were clearly shown on the cone-beam CT images. The AKA was seen to originate from the left seventh ICA in one case, the left eighth ICA in one case, the left ninth ICA in three cases, the left tenth ICA in two cases, the left eleventh ICA in one case, and the right ninth ICA in one case. The remaining seven study arteries (43.7%) were judged as definitely not AKAs and were further considered as musculocutaneous branches from the dorsal branch of the ICA (Figure 3). In all cases, there was an agreement between the two interventional radiologists.

In one case in which the study artery was judged as a definite AKA, one additional vessel was observed in the cone-beam CT, because of the inflow of the contrast medium through the anastomosis, that originated from the dorsal branch of the lower ICA and ran straight towards the midline. This additional vessel was also evaluated by the two interventional radiologists. As a result, this vessel without the morphologic "hairpin curve" was found to connect to the ASA. Due to the presence of a confirmed AKA (i.e., the dominant anterior radiculomedullary artery), this additional vessel was considered as another anterior radiculomedullary artery by the consensus of the two interventional radiologists (Figure 2). This was in contrast to the angiography, where this anterior radiculomedullary artery was not detected.

The abnormal angiographic appearances of bleeding ICAs were systemic–to–pulmonary artery shunting in 13 cases (76.5%) and marked hypervascularity in 4 cases (23.5%). An abnormal angiographic appearance of contrast extravasation was not found. According to the aforementioned embolization protocol at the bleeding ICA, embolization was performed at the seven bleeding ICAs that branched off where there was definitely not an AKA, as judged by the cone-beam CT acquisitions. Embolization was not performed at the nine bleeding ICAs that branched off the definite AKAs, as judged by the cone-beam CT acquisitions, and at one bleeding ICA that branched off a possible AKA that was indeterminate by cone-beam CT.

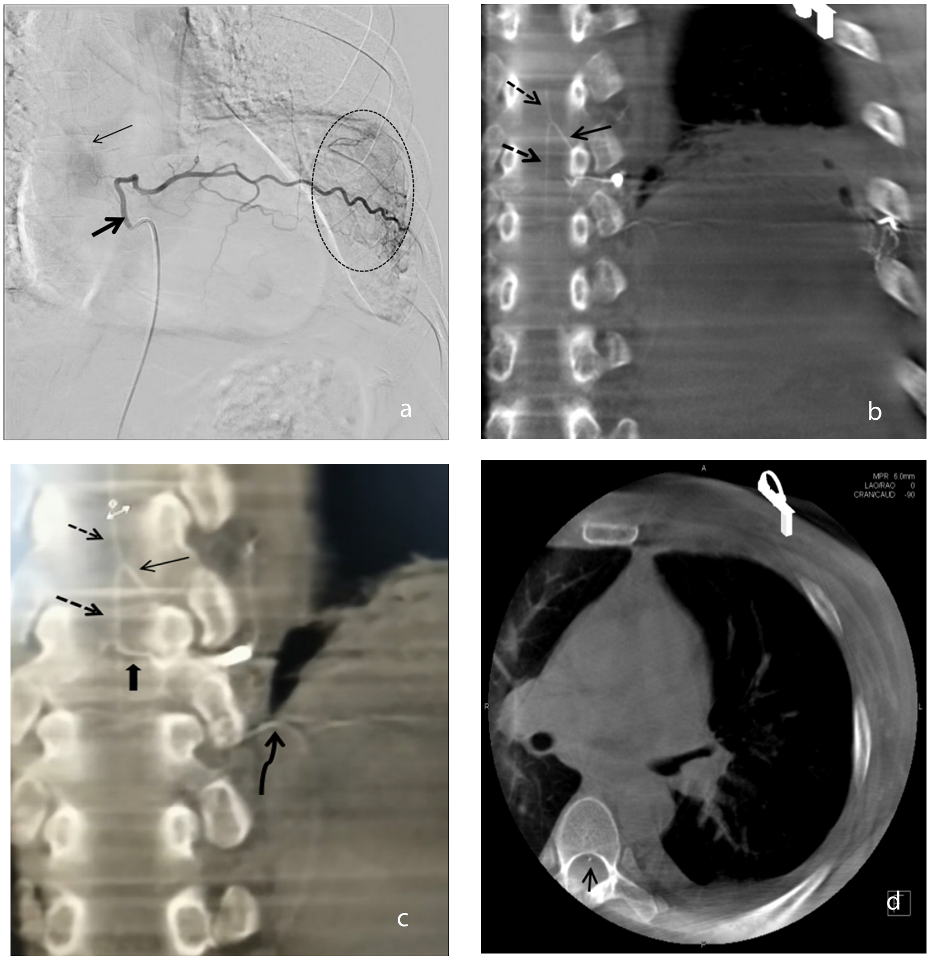

Figure 2. (a-d) Intraprocedural images of a 66-year-old female patient. Selective angiography **(a)** of the left eighth intercostal artery (ICA) (thick arrow) demonstrated the ICA branching off an obscured hairpin-curved vessel (thin arrow) that ran towards the midline in the arterially enhanced phase. This obscured hairpin-curved vessel was barely recognizable with very careful observation and was determined by two interventional radiologists to be a possible artery of Adamkiewicz (AKA). The sign of systemic–to–pulmonary artery shunting (dotted circle) indicated the ICA was involved in bleeding. The corresponding contrast-enhanced oblique coronal cone-beam computed tomography (CT) images **(b, c)** of the left ICA clearly demonstrated the hairpin-curved AKA **(arrow in b, c)** connecting to the anterior spinal artery (ASA) **(dotted arrow in b, c)** and the presence of an additional anterior radiculomedullary artery **(thick arrow in c)** that originated from the dorsal branch of the left ninth ICA **(curved arrow in c)** because of the inflow of contrast medium through the anastomosis, which was not detected on angiography. The corresponding contrast-enhanced axial cone-beam CT image **(d)** of the left ICA demonstrated the ASA, which was considered as a dot enhancement (arrow) continuing cranio-caudally on the anterior spinal cord surface.

Discussion

Cone-beam CT images allow the users to "page through" different planes of images to confirm the accurate correlation of the target vessel with the adjacent vessels and soft-tissue structures. They also allow contrast injection into catheterized vessels to provide more subtle vascular and soft tissue information, which is instrumental in improving the visualization of the selected vessel or structure within a region of interest. Therefore, cone-beam CT has been widely used, especially when the target vessel or structure is invisible or cannot be visualized on angiography.[19,20]

In this study's department, intraprocedural cone-beam CT was routinely used as an adjunct to angiography during BAE for hemoptysis. In the experience of BAEs, most patients received selective embolization in multiple bleeding vessels, including bronchial and non-bronchial systemic arteries. The present study reports the usefulness of cone-beam CT performed as an adjunctive technique to angiography for the determination of the feeding vessels responsible for hemoptysis.[21]

With the anatomic complexity and small vessel size of the AKA anatomy, one of the most important challenges in performing BAE is the pre-embolization identification of the AKA. According to the experience of BAEs, the AKAs were sometimes too small or obscured to be identified confidently. The possible reasons for the inability to visualize the AKAs by angiography were as follows: (1) the AKA caliber was sometimes very small, (2) the AKA was surrounded by high-density osseous formations that sometimes interfered with the recognition of the AKA and its connection with the ASA, and (3) the presence of the other dorsal branches of the segmental artery sometimes curving similarly toward the spinal cord in the anteroposterior view made the AKA less visible. In the present study, all the definite AKAs, as judged by cone-beam CT, were obscured on angiography and were therefore easy to overlook. Furthermore, an additional anterior radiculomedullary artery in one case was visualized by cone-beam CT but was not detected on angiography. These findings are consistent with previous studies in which some AKAs or spinal artery feeders were detected by CT but were invisible on arteriography.[10,11,13] Thus, it is believed the cone-beam CT may be incorporated as a substitute for angiography to identify the AKAs or the fine spinal artery feeders. It is believed that the application of cone-beam CT used in the evaluation of the AKA anatomy has not been reported previously in the literature. Therefore, the present study describes the outcome of cone-beam CT incorporated as an adjunct to angiography for the determination of AKAs.

In the present study, when selective contrast-enhanced cone-beam CT was performed, undiluted contrast medium and only the arterial cone-beam CT scan images were used. A clear visualization of arterial anatomy was desired, and the identification of an AKA was based on arterially enhanced images.

In the present study, cone-beam CT allowed for the visualization of the ASA and its connection with an AKA, and this enabled the determination of AKAs that were suspected by angiography in most cases. As a result of cone-beam CT, 43.7% of possible AKAs were judged as definitely not AKAs but as musculocutaneous branches. The potential reason for the high ratio of vessels judged as definitely not AKAs may be that some angiographic signs might be artifacts resulting from inadequate breath holding or the surrounding high-density osseous formations. Another reason may be that cone-beam CT can provide higher contrast resolution than angiography.

The disadvantages of incorporating the contrast-enhanced cone-beam CT includ-

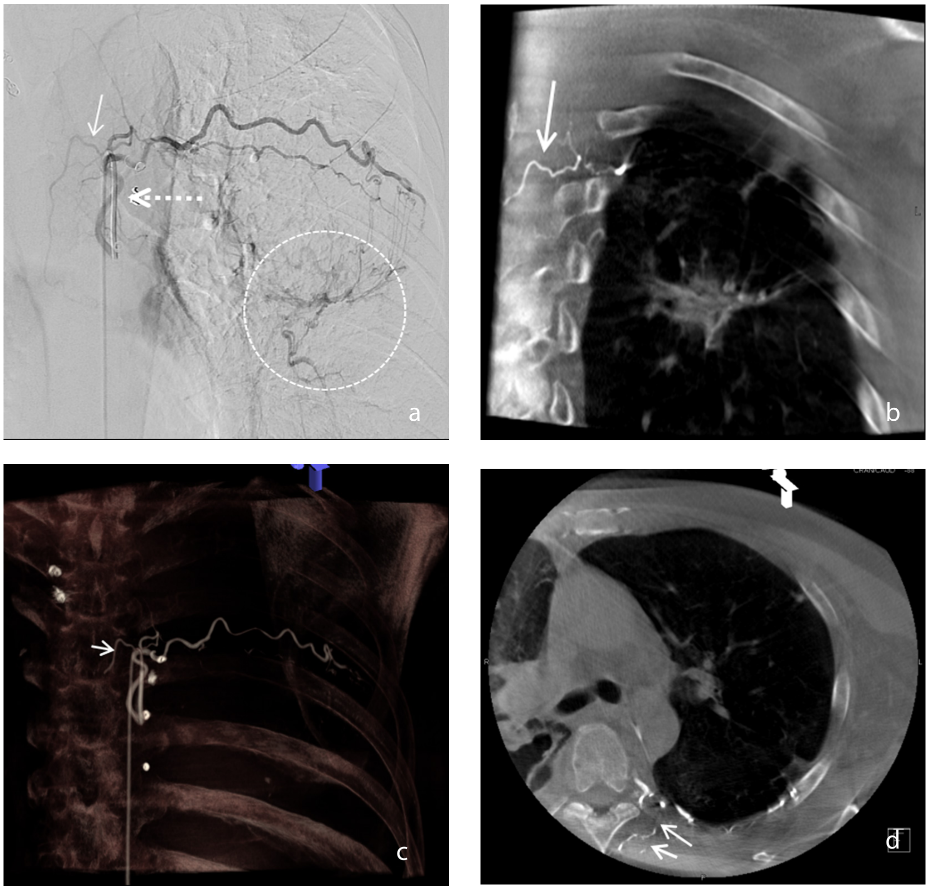

Figure 3. (a-d) Intraprocedural images of a 69-year-old male patient. Selective angiography **(a)** of the left seventh intercostal artery (ICA) (dotted arrow) demonstrated the ICA branching off an obscured hairpin-curved vessel (arrow) running towards the midline in the arterially enhanced phase. This obscured hairpin-curved vessel was determined by two interventional radiologists to be a possible artery of Adamkiewicz (AKA). The sign of systemic–to–pulmonary artery shunting (dotted circle) indicated the ICA was involved in bleeding. The corresponding contrast-enhanced oblique coronal cone-beam computed tomography (CT) image **(b)** and the three-dimensional volume-rendered image **(c)** from the contrast-enhanced cone-beam CT of the ICA clearly demonstrated the possible AKA (arrow) and the absence of the anterior spinal artery (ASA). The corresponding contrast-enhanced axial cone-beam CT image **(d)** of the right ICA demonstrated the absence of intradural enhancement, which indicated the absence of the ASA, and the possible AKA (arrow) running toward and terminating in the dorsal muscle and skin without entering the intervertebral foramen.

ed the additional contrast medium used and motion artifacts caused by inadequate breath holding that sometimes interfered with the image quality. The present study found that adequate breath holding was sometimes difficult for patients suffering from massive or moderate hemoptysis. The poor image quality of cone-beam CT acquisition in one case was attributed to inadequate breath holding.

The present study has four limitations. First, this paper showed angiography alone was found to produce false negatives in 43.7% of the cases, indicating that the reliability of angiography alone was low. Thus, a major limitation was that only suspicious cases were evaluated by cone-beam CT. Second, there may have been potential selection bias due to the retrospective nature of the present study. Third, the sample size was small in the present study. This was because cone-beam CT was only performed in the bleeding ICAs that branched off possible AKAs that were indeterminate by angiography because at that time selective angiography was widely accepted as the gold standard technique for identifying AKAs. Fourth, the exact radiation dose or procedure time was not measured because embolization procedures were performed emergently; therefore, the impact of using cone-beam CT on procedural duration and radiation doses could not be determined.

In conclusion, cone-beam CT performed as an adjunct to angiography is sufficient for confident determination of AKAs, which is essential for the operators to perform accurate and safe embolization during BAE for hemoptysis.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Mal H, Rullon I, Mellot F, et al. Immediate and long-term results of bronchial artery embolization for life-threatening hemoptysis. *Chest*. 1999;115(4):996-1001. [CrossRef]
2. Panda A, Bhalla AS, Goyal A. Bronchial artery embolization in hemoptysis: a systematic review. *Diagn Interv Radiol.* 2017;23(4):307-317. [CrossRef]
3. Burke CT, Mauro MA. Bronchial artery embolization. *Semin Intervent Radiol.* 2004;21(1):43-48. [CrossRef]
4. Santillan A, Nacarino V, Greenberg E, Riina HA, Gobin YP, Patsalides A. Vascular anatomy of the spinal cord. *J Neurointerv Surg.* 2012;4(1):67-74. [CrossRef]
5. Lazorthes G, Gouaze A, Zadeh JO, Santini JJ, Lazorthes Y, Burdin P. Arterial vascularization of spinal cord: recent study of the anastomotic substitution pathways. *J Neurosurg.* 1971;35(3):253-262. [CrossRef]
6. Savader SJ, Williams GM, Trerotola SO, et al. Preoperative spinal artery localization and its relationship to postoperative neurologic complications. *Radiology.* 1993;189(1):165-171. [CrossRef]
7. Kieffer E, Fukui S, Chiras J, Koskas F, Bahnini A, Cormier E. Spinal cord arteriography: a safe adjunct before descending thoracic or thoracoabdominal aortic aneurysmectomy. *J Vasc Surg.* 2002;35(2):262-268. [CrossRef]
8. Lopez JK, Lee HY. Bronchial artery embolization for treatment of life-threatening hemoptysis. *Semin Intervent Radiol.* 2006;23(3):223-229. [CrossRef]
9. Williams GM, Roseborough GS, Webb TH, Perler BA, Krosnick T. Preoperative selective intercostal angiography in patients undergoing thoracoabdominal aneurysm repair. *J Vasc Surg.* 2004;39(2):314-321. [CrossRef]
10. Kodama Y, Sakurai Y, Yamasaki K, Yokoo K. High false-negative rate of the anterior spinal artery by intercostobronchial trunk arteriography alone compared to CT during arteriography. *Br J Radiol.* 2021;94(1123):20210402. [CrossRef]
11. van den Heuvel MM, Els Z, Koegelenberg CF, Naidu KM, Bolliger CT, Diacon AH. Risk factors for recurrence of haemoptysis following bronchial artery embolisation for life-

threatening haemoptysis. *Int J Tuberc Lung Dis.* 2007;11(8):909-914. [CrossRef]

12. Maramattom BV, Krishna Prasad BP, Padmanabhan S, Baby J. Spinal cord infarction after bronchial artery embolization. *Ann Indian Acad Neurol.* 2016;19(1):156-157. [CrossRef]
13. Maki H, Shimohira M, Hashizume T, et al. Visualization of the spinal artery by CT during embolization for pulmonary artery pseudoaneurysm. *Pol J Radiol.* 2016;81:382-385. [CrossRef]
14. Brown AC, Ray CE. Anterior spinal cord infarction following bronchial artery embolization. *Semin Intervent Radiol.* 2012;29(3):241-244. [CrossRef]
15. Ramakantan R, Bandekar VG, Gandhi MS, Aulakh BG, Deshmukh HL. Massive hemoptysis due to pulmonary tuberculosis: control with bronchial artery embolization. *Radiology.* 1996;200(3):691-694. [CrossRef]
16. Orth RC, Wallace MJ, Kuo MD; Technology Assessment Committee of the Society of Interventional Radiology. C-arm cone-beam CT: general principles and technical considerations for use in interventional radiology. *J Vasc Interv Radiol.* 2008;19(6):814-820. [CrossRef]
17. Wallace MJ. C-arm computed tomography for guiding hepatic vascular interventions. *Tech Vasc Interv Radiol.* 2007;10(1):79-86. [CrossRef]
18. Loffroy R, Lin M, Yenokyan G, et al. Intraprocedural C-arm dual-phase cone-beam CT: can it be used to predict short-term response to TACE with drug-eluting beads in patients with hepatocellular carcinoma? *Radiology.* 2013;266(2):636-648. [CrossRef]
19. Miyayama S, Yamashiro M, Hashimoto M, et al. Identification of small hepatocellular carcinoma and tumor-feeding branches with cone-beam CT guidance technology during transcatheter arterial chemoembolization. *J Vasc Interv Radiol.* 2013;24(4):501-508. [CrossRef]
20. Tacher V, Radaelli A, Lin M, Geschwind JF. How I do it: Cone-beam CT during transarterial chemoembolization for liver cancer. *Radiology.* 2015;274(2):320-334. [CrossRef]
21. He G, Li T, Tang J, Zhang G. Utility of cone-beam CT imaging for the determination of feeding vessels during arterial embolization for massive hemoptysis. *Diagn Interv Radiol.* 2018;24(6):372-377. [CrossRef]