



Multidetector computed tomography angiography prior to bronchial artery embolization helps detect culprit ectopic bronchial arteries and non-bronchial systemic arteries originating from subclavian and internal mammary arteries and improve hemoptysis-free early survival rate in patients with hemoptysis

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Abstract

Objectives To compare the average number of culprit arteries per patient, clinical success rate, and hemoptysis-free survival rate between hemoptysis patients with multidetector computed tomography (MDCT) angiography *prior to* bronchial artery embolization (BAE) and those without preprocedural MDCT angiography

Methods This retrospective study was approved by the institutional review board with waiver of patient informed consent. From September 2012 to March 2017, 157 consecutive hemoptysis patients had been undergoing BAE. Among them, 106 patients received preprocedural MDCT angiography (MDCT group), while 51 patients did not receive preprocedural MDCT angiography (control group). The average number of culprit arteries per patient, clinical success rate, and hemoptysis-free survival rate were compared between the two groups.

Results The average number of culprit ectopic bronchial arteries and that of non-bronchial systemic arteries originating from the subclavian and internal mammary arteries per patient in the MDCT group were both significantly higher than those in the control group (0.15 ± 0.51 vs 0.04 ± 0.20 , $p = 0.022$, and 0.17 ± 0.56 vs 0.08 ± 0.39 , $p = 0.040$, respectively). The clinical success rate of BAE with preprocedural MDCT angiography tended to be higher than that without MDCT angiography (97.2 vs 88.2%, $p = 0.057$). Importantly, patients in the MDCT group had a significantly higher hemoptysis-free early survival rate compared to those in the control group (96.1 vs 86.7%, $p = 0.031$).

Conclusions Preprocedural MDCT angiography helps detect culprit ectopic bronchial arteries and non-bronchial systemic arteries originating from subclavian and internal mammary arteries during BAE, and can improve the hemoptysis-free early survival rate, which could be recommended as a regular examination prior to BAE in patients with hemoptysis.

Key Points

- *Preprocedural MDCT angiography helps detect culprit ectopic bronchial arteries and NBSAs originating from subclavian and internal mammary arteries during BAE.*
- *Conducting MDCT angiography prior to BAE can improve hemoptysis-free early survival rate in hemoptysis patients.*

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Keywords Multidetector computed tomography · Angiography · Bronchial arteries · Non-bronchial systemic arteries · Therapeutic embolization

Abbreviations

BAE Bronchial artery embolization
MDCT Multidetector computed tomography
NBSAs Non-bronchial systemic arteries

Introduction

Hemoptysis can be a life-threatening condition without timely and thorough treatment. Bronchial artery embolization (BAE) has been regarded as an effective method to control acute massive and recurrent hemoptysis [1, 2]. However, the rate of hemoptysis recurrence after BAE can be as high as 9.8 to 57.5% [3]. The study by Zhao et al concluded that incomplete embolization due to missed diagnosis of culprit vessels by conventional angiography during BAE, especially for ectopic bronchial arteries and non-bronchial systemic arteries (NBSAs), may be a major reason for clinical failure of BAE [4]. A recent systemic review summarized that early hemoptysis recurrence within 3 months of BAE was attributed to technically inadequate or incomplete embolization due to lack of complete search for all offending vessels [3].

In 1987, Furuse et al suggested that contrast-enhanced CT could be used to help identify abnormal bronchial arteries [5]. But the accuracy of this technology in diagnosing culprit arteries is limited due to its suboptimal imaging quality. With the advent of multidetector computed tomography (MDCT), MDCT angiography is a newer technology to identify culprit arteries with high-resolution angiographic images. Many studies have reported that MDCT angiography not only can identify bleeding sources and underlying diseases for hemoptysis but also can accurately depict origins and courses of culprit arteries prior to BAE in hemoptysis patients [6–14]. Notably, MDCT angiography is particularly useful for visualizing ectopic origins of bronchial arteries and NBSAs that are easily missed on conventional angiography during BAE [4, 15–17]. Therefore, performing MDCT angiography prior to BAE can provide important anatomical information for interventional radiologists to make therapeutic decisions, and may theoretically reduce the rate of postprocedural recurrence caused by missed embolization for unrecognized culprit arteries on procedural angiography.

However, no investigators have conducted a contemporaneous control group to evaluate the effect of preprocedural MDCT angiography on clinical success and hemoptysis-free survival rates in patients undergoing BAE for hemoptysis. Also, few clear recommendations on preprocedural MDCT angiography have been well established in the relevant guidelines [18]. The objectives of this retrospective control study

were to compare the average number of culprit arteries per patient, clinical success rate, and hemoptysis-free survival rate between hemoptysis patients with MDCT angiography prior to BAE and those without preprocedural MDCT angiography.

Materials and methods

The retrospective study was approved by the institutional review board of West China Hospital of Sichuan University (Number: 2017[306]), with waiver of patient informed consent.

Study population

From September 2012 to March 2017, 201 consecutive patients underwent BAE for considerable hemoptysis. Considerable hemoptysis was defined as massive hemoptysis (≥ 300 mL/day), moderate hemoptysis (100–300 mL/day), or mild hemoptysis (≤ 100 mL/day) more than once a month with limited lifestyle for patients [3]. All of the patients routinely received unenhanced CT with a section thickness of 10 mm prior to BAE. Patients less than 18 years old ($n = 5$), with a previous history of BAE before September 2012 ($n = 6$), or losing to follow-up ($n = 33$) were excluded from the study. Finally, 157 of these patients (113 men, 44 women; mean age, 50 years \pm 14 [standard deviation]; age range, 19 to 79 years) were included in the study. Among them, 106 patients received preprocedural MDCT angiography (MDCT group), while 51 patients did not receive preprocedural MDCT angiography (control group).

MDCT angiography technique

MDCT angiography was performed with a 256-row MDCT scanner (SOMATOM Definition Flash; Siemens). Unenhanced CT with a section thickness of 10 mm was initially undertaken to obtain the mask image. Approximately 75 to 85 mL of Omnipaque (350 mgI/mL; GE Healthcare) was injected intravenously through the antecubital vein before the scan at a rate of 5 mL/s, followed by 30 mL of normal saline solution at 5 mL/s. The scanned area was from lung tip to diaphragm. The scanning parameters were as follows: tube voltage, 120 kV; tube current, 160 mAs, determined by tube current modulation; rotation time, 0.5 s; detector collimation, 0.6 mm; pitch, 1.2; matrix, 512 \times 512; reconstructed section thickness, 1 mm; and reconstruction interval, 1 mm. An automatic bolus-triggering software program was used, with a circular region of interest positioned at the level of the

descending thoracic aorta. When the enhanced degree increased to 100 HU, a triggered data acquisition began after a 5-s delay. All MDCT angiographic data were transferred to a workstation for post-processing.

Imaging analysis

CT interpretation focused on the number, location, ostium, diameter, and course of abnormal bronchial arteries and NBSAs. Bronchial arteries included orthotopic bronchial arteries originating from the levels of T5 and T6 vertebrae and ectopic bronchial arteries from any level of the aorta except levels T5 and T6 vertebrae, or its branches. NBSAs referred to arteries which entered the lung parenchyma through adherent pleura or inferior pulmonary ligament and were not parallel to bronchia. Bronchial arteries were considered abnormal, if their diameters were more than 2 mm, their courses were tortuous, and their trajectories could be identified from their origins to the pulmonary hilum. NBSAs were considered abnormal when they were dilated and tortuous, within extra pleural fat in connection with pleural thickening. The imaging analysis was completed by two independent radiologists (H.L.B. and P.J.Z. with 11 and 10 years of working experience in reading MDCT angiography, respectively). The inconsistency was resolved by face-to-face discussion.

BAE procedure

BAE procedures were performed by two interventional radiologists (Y.W. and F.M.J. with 10 and 5 years of work experience in vascular embolotherapy, respectively). Angiographic procedures were conducted with 5F catheters through the femoral arterial access. In the control group, non-selective aortography was performed to search culprit arteries, while in the MDCT group, selective catheterizations of abnormal bronchial arteries and NBSAs were conducted according to preprocedural MDCT angiography. 5F pigtail configured catheters (Terumd) were used for aortography, and 5F curved catheters including cobra (Terumd) and left gastric artery catheters (Terumd) were used for selective cannulation. Superselective catheterization of abnormal arteries was conducted with 2F to 3F microcatheters (Cook Medical) when necessary. Embolization for culprit vessels was conducted, when one of the following angiographic findings was observed: (a) arterial hypertrophy and/or tortuosity, (b) contrast extravasation, (c) parenchymal staining, or (d) bronchial artery fistula. Embolic agents were polyvinyl alcohol (size, 350–550 μm ; Cook Medical), spring coil (Cook Medical), and the combination of polyvinyl alcohol and spring coil, or polyvinyl alcohol and gelfoam (Biosphere Medical S.A.), or spring coil and gelfoam.

Outcome measures

Patients' demographic information, imaging data, procedural data, and clinical data for follow-up were obtained from medical records. The primary outcomes included clinical success and hemoptysis-free early survival rates. The secondary outcomes were the average number of culprit arteries per patient, technical success rate, hemoptysis-free survival rate, and hemoptysis-free late survival rate. Clinical success referred to complete cessation of hemoptysis or tiny hemoptysis (≤ 10 mL) without limited lifestyle within 24 h of BAE [19]. Technical success was defined as the ability to cannulate and embolize all visualized abnormal arteries [19]. Hemoptysis-free survival referred to survival without hemoptysis recurrence after BAE, which was further divided into hemoptysis-free early survival within 3 months of BAE and hemoptysis-free late survival after 3 months of BAE [3]. The follow-up period was defined as the duration from the date of discharge after BAE until the date of death, the last day available for follow-up, or the end date of follow-up, 30 June 2017.

Statistical analysis

The baseline characteristics between the MDCT group and the control group were compared by using Student's *t* test for continuous variables and χ^2 analysis for non-categorical variables. The average numbers of culprit arteries per patient between the two groups were compared by Mann-Whitney *U* test. Comparisons of clinical success and technical success rates were conducted with the continuity correction method. Hemoptysis-free survival, hemoptysis-free early survival, and hemoptysis-free late survival rates were estimated by using the Kaplan-Meier method. Univariate analysis and multivariate analysis by Cox proportional hazards regression models were done to predict possible factors for hemoptysis-free early survival. A *p* value less than 0.05 was defined as statistical significance. Statistical software (SPSS version 22) was applied for data analysis.

Results

Patient characteristics

One hundred fifty-seven eligible patients were included in the study. Baseline demographic data are presented in Table 1. There were no significant differences in age, male-to-female ratio, amount of hemoptysis, underlying disease, the number of involved lungs, and embolic material between the MDCT group and the control group. The mean follow-up duration in the control group was longer than that in the MDCT group (33.6 months ± 19.1 [standard deviation] vs 27.3 months ± 14.8 [standard deviation], *p* = 0.042). No patient underwent dysphagia, spinal cord ischemia, transient ischemia, and cortical blindness.

Table 1 Baseline characteristics between MDCT and control groups

Patient characteristics	MDCT (<i>n</i> = 106)	Control (<i>n</i> = 51)	<i>p</i> value
Age* (years)	50.33 ± 14.17	50.35 ± 14.65	0.993
Male/female ratio	77/29	36/15	0.788
Hemoptysis amount			0.361
Massive	27 (25.4%)	17 (33.3%)	
Moderate	43 (40.6%)	22 (43.2%)	
Mild	36 (34.0%)	12 (23.5%)	
Etiology			0.836
Bronchiectasis	53 (50.0%)	23 (45.1%)	
Tuberculosis	18 (17.0%)	9 (17.6%)	
Others†	35 (33.0%)	19 (37.3%)	
Disease extent			0.841
Single lung	60 (56.6%)	28 (54.9%)	
Double lung	46 (43.4%)	23 (45.1%)	
Embolic material			0.579
Polyvinyl alcohol	85 (80.2%)	38 (74.5%)	
Spring coil	7 (6.6%)	3 (5.9%)	
Combination&	14 (13.2%)	10 (19.6%)	
Follow-up duration* (months)	27.3 ± 14.8	33.6 ± 19.1	0.042

Data are the number of patients, and data in parentheses are percentages except where indicated

MDCT multidetector computed tomography

* Data are mean ± standard deviation

† Other etiologies include aspergilloma (*n* = 3), lung cancer (*n* = 4), pneumonia (*n* = 3), lung abscess (*n* = 1), chronic obstructive pulmonary disease (*n* = 5), pneumoconiosis (*n* = 2), rheumatic heart disease (*n* = 1), pulmonary embolism (*n* = 1), and unknown cause (*n* = 15) in the MDCT group, and include aspergilloma (*n* = 1), lung cancer (*n* = 3), pneumonia (*n* = 1), chronic obstructive pulmonary disease (*n* = 3), pulmonary sequestration (*n* = 1), and unknown cause (*n* = 10) in the control group

& Combined materials mean the combination of polyvinyl alcohol and spring coil, or polyvinyl alcohol and gelfoam, or spring coil and gelfoam

Detection of culprit vessels

The numbers of culprit vessels of the MDCT group and the control group in 157 hemoptysis patients undergoing BAE are summarized in Table 2. In the MDCT group, the matching rate of diagnosis for culprit arteries between preprocedural MDCT angiography and procedural angiography was as high as 98.8% (238/241). Two hundred forty arteries were treated as abnormal vessels by preprocedural MDCT angiography, of which two orthotopic bronchial arteries were identified as normal vessels by procedural angiography. Two hundred thirty-nine arteries were diagnosed as culprit vessels by preprocedural angiography, of which one NBSA which originated from a subclavian artery branch was missed by MDCT angiography. Therefore, 238 out of 241 arteries were identified as abnormal arteries both by preprocedural MDCT angiography and procedural angiography. In the control group, 96 arteries were identified as culprit vessels by procedural angiography.

The average number of culprit ectopic bronchial arteries per patient in the MDCT group was significantly higher than that in the control group (0.15 ± 0.51 [standard deviation] vs 0.04 ± 0.20 [standard deviation], $p = 0.022$)

(Table 3). No significant differences were observed for the average number of culprit orthotopic bronchial arteries ($p = 0.149$) and NBSAs ($p = 0.603$) per patient between the two groups. Of note, preprocedural MDCT angiography was associated with significantly higher diagnoses for NBSAs originating from subclavian and internal mammary vessels according to subgroup analysis stratified to origins of NBSAs (0.17 ± 0.56 [standard deviation] vs 0.08 ± 0.39 [standard deviation], $p = 0.040$).

Rates of clinical success, technical success, and hemoptysis-free survival

A numerically higher rate of clinical success was obtained in the MDCT group, with a marginal statistical significance (97.2% [103/106] vs 88.2% [45/51], $p = 0.057$) (Table 3). As for technical success, similar results were observed between the two groups (96.2% [102/106] vs 94.1% [48/51], $p = 0.852$). In the MDCT group, four patients encountered catheterization failure due to dissection (*n* = 3) and tortuosity (*n* = 1) of culprit vessels, of whom three patients were followed by uncontrolled hemoptysis immediately after BAE, and then

Table 2 Culprit vessels of the MDCT and control groups

Culprit arteries	MDCT (<i>n</i> = 106)		Control (<i>n</i> = 51)
	MDCT angiography	Procedural angiography	Procedural angiography
Orthotopic bronchial			
Left bronchial	68	68	22
Right bronchial	26	25	11
Common bronchial	40	40	19
RIBT	54	53	27
Total	188	186	79
Ectopic bronchial			
Aortic arch	5	5	0
Subclavian and its branches	10	10	2
Internal mammary	3	3	0
Total	18	18	2
NBSAs			
Intercostal	19	19	11
Subclavian and its branches	10	11	3
Internal mammary	5	5	1
Total	34	35	15

MDCT multidetector computed tomography, NBSAs non-bronchial systemic arteries, RIBT right intercostobronchial trunk

were given tranexamic acid and carbazochrome sodium sulfonate. In the control group, three patients underwent technical failure because of the acute angle of a culprit NBSA (*n* = 1) and tortuosity of culprit bronchial arteries (*n* = 2). Clinical failure occurred in six patients, of whom one patient died due to uncontrolled hemoptysis, two patients were given tranexamic acid and carbazochrome sodium sulfonate, and three patients received postprocedural MDCT angiography, which showed additional culprit ectopic bronchial arteries and NBSAs that were not visualized by the previous procedural angiography. The three patients finally underwent repeated embolization and got stable condition.

Figure 1a exhibits Kaplan-Meier estimated curves of hemoptysis-free survival in 148 patients with clinical success. No significant differences were observed in hemoptysis-free survival rates between the MDCT group and the control group (88.3% [91/103] vs 80.0% [36/45], *p* = 0.174). Importantly, the hemoptysis-free early survival rate in patients with preprocedural MDCT angiography was significantly higher than that in patients without preprocedural MDCT angiography (96.1% [99/103] vs 86.7% [39/45], *p* = 0.031) (Fig. 1b). Among 138 patients without early recurrence, hemoptysis-free late survival rates were similar between the two groups (91.9% [91/99] vs 92.3% [36/39], *p* = 0.869) (Fig. 1c).

Table 3 Statistical analysis of angiographic findings and immediate efficacy of BAE between the MDCT and control groups

Parameter	MDCT (<i>n</i> = 106)	Control (<i>n</i> = 51)	<i>p</i> value
Culprit orthotopic bronchial arteries	1.75 ± 0.75	1.57 ± 0.58	0.149
Culprit ectopic bronchial arteries	0.15 ± 0.51	0.04 ± 0.20	0.022
Culprit NBSAs	0.36 ± 0.84	0.25 ± 0.66	0.603
Intercostal arteries	0.19 ± 0.59	0.18 ± 0.39	0.466
Non-intercostal arteries [†]	0.17 ± 0.56	0.08 ± 0.39	0.040
Clinical success [*]	103 (97.2%)	45 (88.2%)	0.057
Technical success [*]	102 (96.2%)	48 (94.1%)	0.852

Data are the average number of culprit arteries per patient ± standard deviation except where indicated
BAE bronchial artery embolization, MDCT multidetector computed tomography, NBSAs non-bronchial systemic arteries

^{*} Data are the number of patients, and data in parentheses are percentages

[†] Non-intercostal arteries mean NBSAs originating from subclavian and internal mammary arteries

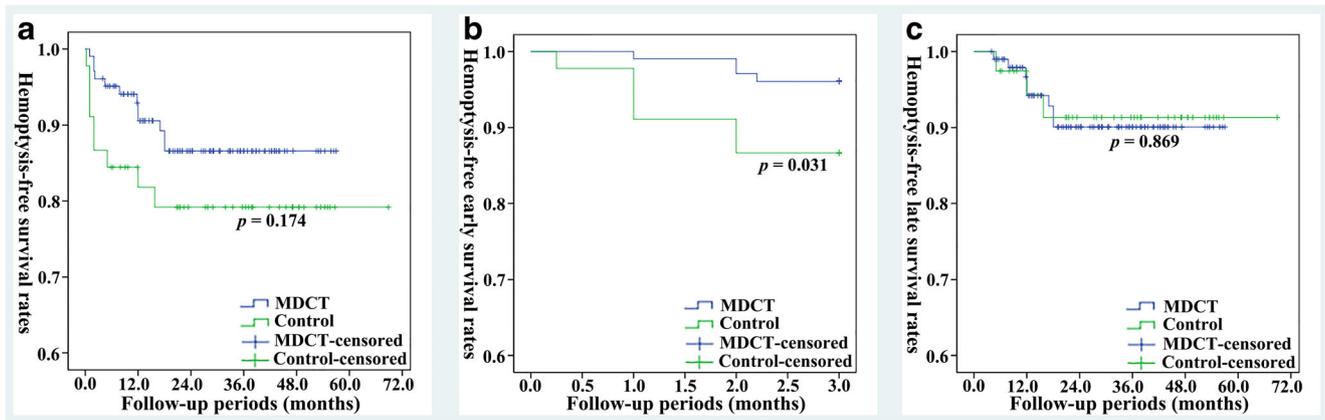


Fig. 1 Kaplan-Meier estimated curves of hemoptysis-free survival in 148 patients with clinical success (a), hemoptysis-free early survival in 148 patients with clinical success (b), and hemoptysis-free late survival in 138

patients without early recurrence (c) between MDCT and control groups. MDCT multidetector computed tomography

Figure 2 shows images of a 36-year-old male patient with massive hemoptysis caused by tuberculosis sequela, who benefited from MDCT angiography examination prior to his second BAE.

Predictive factors for early recurrence

The possible predictive factors for early recurrence in 148 patients with clinical success are shown in Table 4. Conducting MDCT angiography prior to BAE or not was

significantly related to early recurrence according to univariate analysis (hazard ratio 0.276, 95% confidence interval [0.078 to 0.978], $p = 0.046$). No significant correlations were obtained among the remaining possible factors including disease extent, age, sex, hemoptysis amount, etiology, and embolic material. Multivariate Cox regression analysis indicated that preprocedural MDCT angiography was an independent protective factor for early recurrence in patients with BAE (hazard ratio 0.271, 95% confidence interval 0.076 to 0.961, $p = 0.043$).

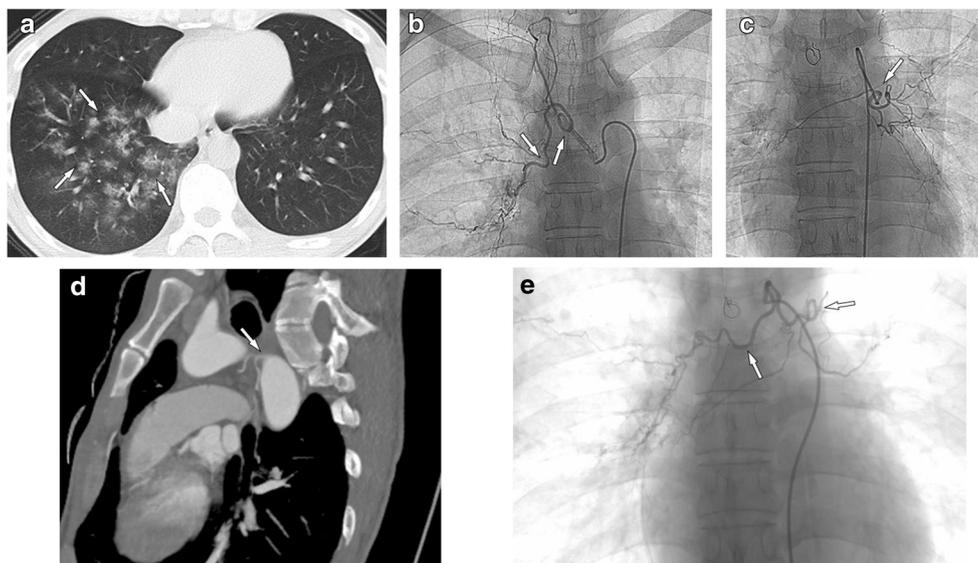


Fig. 2 Images of a 36-year-old male with massive hemoptysis caused by tuberculosis sequela, who underwent the first BAE without preprocedural MDCT angiography and received the second BAE for hemoptysis recurrence 2 months later with the guidance of preprocedural MDCT angiography. a Unenhanced CT with a section thickness of 10 mm prior to the first BAE exhibits a large area of ground-glass opacity in the right lung (white arrows). b, c The first procedural angiography shows an engorged right intercostobronchial trunk (white arrows in b)

and an engorged common bronchial artery (white arrow in c). d MDCT angiography prior to the second BAE shows an ectopic common bronchial artery from the aortic arch (white arrow). e The second procedural angiography confirms the engorged ectopic common bronchial artery (white arrows). No hemoptysis recurrence occurred after the second intervention, with a follow-up period of 15 months. BAE bronchial artery embolization, MDCT multidetector computed tomography

Table 4 Univariate and multivariate Cox regression analyses of predictive factors for early recurrence after BAE

Variables	Univariate analysis		Multivariate analysis	
	HR (95% CI)	<i>p</i> value	HR (95% CI)	<i>p</i> value
Examination prior to BAE				
With MDCT angiography	0.276 (0.078, 0.978)	0.046	0.271 (0.076, 0.961)	0.043
Without MDCT angiography	1		1	
Disease extent				
Single lung	0.334 (0.086, 1.292)	0.112	0.327 (0.085, 1.266)	0.106
Double lung	1		1	
Age (years)				
≤ 50	0.713 (0.201, 2.528)	0.601		
> 50	1			
Sex				
Men	1.555 (0.330, 7.323)	0.577		
Women	1			
Hemoptysis amount				
Massive	1.183 (0.239, 5.860)	0.837		
Moderate	1.020 (0.228, 4.557)	0.979		
Mild	1			
Etiology				
Bronchiectasis	0.414 (0.099, 1.732)	0.227		
Tuberculosis	0.911 (0.177, 4.697)	0.911		
Others	1			
Embolitic material				
Polyvinyl alcohol	0.720 (0.149, 3.465)	0.682		
Spring coil	1.161 (0.105, 12.808)	0.903		
Combination	1			

BAE bronchial artery embolization, CI confidence interval, MDCT multidetector computed tomography, HR hazard ratio

Discussion

The present study retrospectively evaluated the clinical impact of preprocedural MDCT angiography in 157 hemoptysis patients undergoing BAE. Angiography during BAE with the guidance of preprocedural MDCT angiography could detect more culprit ectopic bronchial arteries and NBSAs originating from subclavian and internal mammary arteries per patient than that without MDCT angiography. Conducting MDCT angiography prior to BAE could increase the hemoptysis-free early survival rate and tended to improve the clinical success rate.

Localization of bleeding sources prior to BAE is important to help interventional radiologists find culprit vessels for hemoptysis efficiently during the procedure. As early as 1987, CT scan was applied to assist in diagnosing causes of hemoptysis and depicting bleeding sites [5]. However, the imaging quality of the CT scan is not enough to find abnormal bronchial arteries exactly. Introduction of MDCT angiography brings high-resolution angiographic images to detect and depict origins and ostia of culprit NBSAs as well as bronchial arteries

[6–14]. The conclusion is also supported by our result that the matching rate of diagnosis for culprit arteries between preprocedural MDCT angiography and procedural angiography was as high as 98.8%. But there are still no well-established recommendations regarding conducting preprocedural MDCT angiography in hemoptysis patients undergoing BAE. Although the SEPAR guideline by Cordovilla et al suggested that MDCT angiography prior to BAE should be performed in patients with massive or recurrent hemoptysis, the strength of recommendation is low according to the GRADE system [18]. Whether performing MDCT angiography prior to BAE is often determined by individualized decision and institutional availability. The lack of relevant guidelines might be caused by poor data on clinical benefits of preprocedural MDCT angiography in hemoptysis patients undergoing BAE.

The present study suggested that BAE with preprocedural MDCT angiography could improve hemoptysis-free early survival than the procedure without MDCT angiography. A recently published systematic review summarized that inadequate embolization due to lack of complete search for all offending vessels, or inability to embolize all of the culprit

vessels due to extensive collateralization contributed to early recurrence in patients undergoing BAE for hemoptysis [3]. In our study, technical success rates were similar between patients with preprocedural MDCT angiography and those without MDCT angiography, which equated the similar ability to embolize all of the visible culprit arteries. We thus speculated that more adequate detection for culprit vessels by MDCT angiography to guide embolization may be responsible for a higher rate of hemoptysis-free early survival in the MDCT group. This hypothesis was demonstrated by our findings that the average number of culprit ectopic bronchial arteries and that of NBSAs originating from subclavian and internal mammary vessels per patient in the MDCT group were both significantly higher than those in the control group. Besides, postprocedural MDCT angiography for the three patients with clinical failure in the control group identified additional culprit ectopic bronchial arteries and NBSAs, which were not visualized by the previous procedural angiography. After the repeated sessions of BAE, these patients got stable condition.

Except improving hemoptysis-free early survival, preprocedural MDCT angiography may contribute to decreased BAE procedure time and X-ray exposure in our study. Without preprocedural MDCT angiography in the control group, non-selective aortography was needed to search for culprit arteries during BAE. In comparison, in the MDCT group, preprocedural MDCT angiography could recognize origins and courses of abnormal bronchial arteries and NBSAs prior to BAE, facilitate the selection of catheters, and thus help save procedural time and reduce X-ray exposure caused by non-selective aortography.

Similar to our results, the study by Zhao et al concluded that MDCT angiography can precisely identify the number of culprit vessels, and multiple unrecognized abnormal ectopic bronchial arteries and NBSAs may be major reasons for failure of BAE [4]. In this study, postprocedural MDCT angiography revealed 18 additional culprit vessels which were missed on conventional angiography in eight patients with hemoptysis recurrence immediately after the first BAE. Among these culprit arteries, four orthotopic arteries, eight ectopic arteries, and four NBSAs were embolized within 24 h after the first procedure, and the remaining two arteries were not embolized due to anatomic inaccessibility. No further hemoptysis recurrence occurred after the second BAE with a mean follow-up of 7.7 months. Other three studies also demonstrated that preprocedural MDCT angiography is critical to avoid missing ectopic bronchial arteries during BAE [15–17]. But all of these studies were descriptive researches without contemporaneous controls.

As high as 94.3% of patients with hemoptysis achieved immediate clinical success of BAE in the current study, which agreed with previous studies that reported a range of high clinical success rates from 93.5 to 99% in hemoptysis patients with BAE [20–27]. Moreover, our study indicated that the

clinical success rate of BAE with preprocedural MDCT angiography tended to be higher than that without MDCT angiography (97.2 vs 88.2%). Enlarging the sample size may make the result reach statistical significance.

There were several limitations in the present study. First, this was a retrospective study and thus had inherent limitations. But almost all of the baseline characteristics and operation technique were similar between the two groups, which largely made the results comparable. Second, MDCT angiography can increase extra X-ray exposure for patients, but this may be offset by decreased procedural time and procedural X-ray exposure caused by non-selective aortography, as mentioned above. Finally, the mean follow-up duration in the MDCT group was shorter than that in the control group. In the most recent years during the study period, more physicians realized that MDCT angiography could detect and depict origins and ostia of culprit NBSAs as well as bronchial arteries, and thus tended to suggest hemoptysis patients to conduct MDCT angiography prior to BAE, which may be the main reason for a shorter mean follow-up period in the MDCT group. But the mean follow-up periods in both groups were far beyond 3 months, which thus had no effect on the evaluation of hemoptysis-free early survival.

In conclusion, preprocedural MDCT angiography helps detect culprit ectopic bronchial arteries and NBSAs originating from subclavian and internal mammary arteries during BAE, and can improve the hemoptysis-free early survival rate, which could be recommended as a regular examination prior to BAE in patients with hemoptysis.

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Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Ye Wang at West China Hospital, Sichuan University.

Conflict of interest The authors declare that they have no competing interests.

Statistics and biometry No complex statistical methods were necessary for this paper.

Informed consent Written informed consent was waived by the institutional review board, as this was a retrospective study.

Ethical approval Institutional review board approval was obtained.

Methodology

- Retrospective
- Observational study
- Performed at one institution

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