Use of Multidetector Row CT to Evaluate the Need for Bronchial Arterial Embolization in Hemoptysis Patients

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Key Words
Arteriography · Bronchial arteries · Bronchoscopy · Computed tomography · Embolization · Hemoptysis

Abstract

Background: Bronchial artery (BA) embolization (BAE) is recommended as a minimally invasive therapy for hemoptysis, though some patients recover after only conservative treatment. Objectives: The purpose of our study was to assess the characteristics of BAs using multidetector row computed tomography (MDCT) and identify BAs requiring BAE without BA angiography (BAG). Methods: We retrospectively studied 41 patients and classified the visualized BAs into groups based on their BAE and bleeding statuses. Patients presenting with massive hemoptysis requiring emergency BAE were excluded. Patients presenting with persistent hemoptysis requiring emergency BAE were excluded. Patients presenting with persistent hemoptysis that was resistant to conservative treatment received BAE. Radiologists measured BA diameters at the ostium, bronchial bifurcation and pulmonary hilum, and also evaluated the degree of vascularization. Results: MDCT enabled visualization of 102 ostia and 96 traceable BAs. Among the participating patients, 13 had at least one ectopic origin. We obtained a good correlation between BAG and MDCT diameters ($r = 0.709$, $p < 0.001$). The diameters of BAs responsible for bleeding and receiving BAE were apparently larger in each measured segment than those that were not ($p < 0.05$). Moreover, the diameters of arteries receiving BAE remained largely unchanged from the origin to the hilum and through the mediastinum. BAs with low MDCT scores were significantly less likely to required BAE than those with high scores ($p = 0.004$), and in multiple logistic regression analysis, ostium diameter and bleeding status were independent predictive factors for BAE. Conclusions: Evaluation of BAs on MDCT could be useful for identifying the anatomical characteristics of bleeding-related BAs and determining whether BAE is indicated or whether conservative treatment is sufficient.

Introduction

Hemoptysis is a common but alarming and potentially life-threatening symptom defined as expectoration of blood from the lower respiratory tract [1]. Emergency surgery in patients with active bleeding is associated with a high degree of morbidity and mortality, and bronchial artery (BA) embolization (BAE) is recommended for particularly high-risk patients [2–4]. But BAE occasionally causes a serious complication such as cerebral infarction or spinal cord injury [5]; moreover, some hemoptysis pa-
patients recover with only conservative treatment. To determine whether BAE is indicated, chest computed tomography (CT) is a useful noninvasive imaging modality for initial assessment of hemoptysis, determination of its etiology and origin, and affirmation of ground glass opacity suggesting hemorrhage and aspiration of blood. Although fiberoptic bronchoscopy (FOB) is essential for pathological examination, the efficacy of CT for etiology determination and patient evaluation is well established [6–8], and the combined use of high-resolution CT and FOB as complementary modalities increases the positive yield [9, 10]

Multidetector row computed tomography (MDCT) is useful for visualizing BAs and detecting ectopic origins, particularly when the patient is aged and has a tortuous aorta and/or extensive arteriosclerosis [11, 12]. Contrast material-enhanced MDCT and the created 3-dimensional images reportedly provide a more precise depiction of these vessels than does conventional bronchial arteriography (BAG). MDCT has thus emerged as a potential diagnostic tool for depicting and evaluating the systemic circulation and the trajectory of BAs and non-bronchial systemic arteries (NBSAs) causing hemoptysis [13–16]. The aim of the present study was to determine whether MDCT could be useful for identifying the anatomical characteristics of bleeding-related BAs, and for determining whether BAE is indicated or whether conservative treatment is sufficient.

Materials and Methods

Patient Population

In this retrospective investigation, we studied 41 consecutive patients (22 males and 19 females; age 64.5 ± 12.0 (mean ± SD), range 25–80 years) referred to our institution with hemoptysis between June 2004 and May 2008. They underwent contrast material-enhanced chest MDCT as part of the pre-therapeutic evaluation. This study was approved by our institutional review board and all patients were informed that the radiologic examination was primarily for clinical diagnosis and secondarily for radiological research, and all provided written consent. BAG was never performed for diagnostic purposes only. Patients presenting with massive hemoptysis (>500 ml blood during the 24 h prior to treatment) requiring emergency BAE without contrast material-enhanced MDCT were excluded. Patients presenting with persistent hemoptysis that was resistant to conservative treatment were treated with BAG and BAE. Treatment decisions were made after discussion among the attending physicians and interventional radiologists.

We classified the patients and BAs into groups according to their BAE and bleeding status. Patients were classified according to whether or not they were treated with BAE, while the BAs were classified according to whether or not they were subjected to the BAE procedure and whether or not they were the source of the bleeding. We evaluated the BAs in terms of their diameter and vascularization on MDCT.

Contrast Material and Scan Protocols for CT Examination

A 16-slice multidetector row CT scanner (Light Speed 16; GE Medical Systems, Milwaukee, Wisc., USA) with a detector configuration of 16 × 0.625 or 1.25 mm was used at 120 kVp with an auto-adjusting mAs system (Auto mA; GE Medical Systems). The scan range was from the apex of the lung to its base. To identify the cause of bleeding and the affected side, scans were initially carried out without contrast material and with 100 ml of non-ionic contrast material containing 370 mg iodine/ml (iopamiron 370; Bayer, Leverkusen, Germany) administered at a rate of 4 or 5 ml/s into an antecubital vein to add information about vascularization. This was followed by infusion of 20 ml saline. Scans were begun 5 s after the bolus-tracking program detected an increase in 50 Hounsfield units (HU) in the CT value in the aorta.

Hemorrhage Localization

Although not all bronchial bleeding occurs from enlarged BAs, these arteries were considered responsible for hemoptysis if BAG and MDCT findings revealed the vessels to be enlarged, tortuous and supplying an area of lung parenchymal shadow, including ground glass opacity, condensation, neovascularity, hypervascularity, oozing, shunting into the pulmonary artery or vein, or the rarely seen BA aneurysm or extravasation of contrast medium [17]. Definitive determination of the hemorrhage site was based on BAG or MDCT that were in agreement with FOB findings of hemorrhage from the end of a bronchus including disease-specific abnormalities. In patients who did not undergo FOB or FOB was normal or showed bilateral nonspecific abnormalities, when an infiltrative shadow in the pulmonary parenchyma and findings of angiography detected by MDCT were identical, they were also considered to be associated with bleeding and its etiology. Cases in which there was a discrepancy that prevented diagnosis of the bleeding site based on MDCT or FOB findings were defined as bleeding site unknown. We diagnosed the definitive or probable BAs as responsible for bleeding.

Bleeding Status

Each patient and BA were assigned bleeding status. They were classified as none, <100 ml/24 h, or 100–500 ml/24 h. In cases in which we could not predict the bleeding sites, bilateral BAs were given the same bleeding status. If the bleeding sites were predictable, the contralateral BAs unrelated to the hemoptysis were given a status of none.

Measurement of BA Diameter and Evaluation

MDCT images were evaluated by 2 radiologists blinded to the patients’ clinical information. The site of origin, distribution and findings were analyzed on transverse CT scans, maximum intensity projections and volume-rendered images on monitor slices of 0.625 mm. The CT value (HU) of the aortic arch was measured. BA diameters were measured in the area of origin, at the level of the bronchial bifurcation in the mediastinum, and at the pulmonary hilum. The intercostobronchial artery (ICBA), which often has a branch designated as the origin of the right BA, was measured at a proximal site where the BA branches away from the intercostal artery trunk [18].

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In patients receiving BAG, the bleeding site and vessel diameter were determined. BA diameters obtained during BAG were measured using digital angiography with the catheter diameter serving as a calibration standard and converted based on the number of pixels.

**Quantitative Image Analysis**

The radiologists used the following 4-point scale to evaluate BAs on MDCT images in terms of the degree of dilatation, tortuosity, and the detectability of the peripheral branches: 0 = no findings; assigned BAs were narrowing and could not be traced in the mediastinal area (fig. 1a); 1 = traceable up to the level of the pulmonary hilum with/without slight dilatation (fig. 1b); 2 = moderate dilatation traceable beyond the pulmonary hilum and with some morphological abnormal findings (fig. 1c), and 3 = maximal dilatation, tortuous and peripheral vasodilatation clearly traceable to the pulmonary parenchyma (fig. 1d).

**Statistical Analysis**

All statistical analyses were performed using StatView for Windows Version 5.0 (SAS Institute Inc., Cary, N.C., USA). Comparisons of continuous variables between groups were made using unpaired Student’s t tests. Comparisons among 3 groups were made using one-way analysis of variance followed by a post-hoc Fisher test. Categorical variables were compared using χ² or Mann-Whitney U tests. Values of p < 0.05 were considered significant.

**Results**

**Patient Characteristics**

The clinical characteristics of the patients, the causes of hemoptysis, and the BAE status are shown in table 1. Thirteen (32%) patients had a history of smoking, and 2 (5%) had used anticoagulant drugs. There was no significant demographic difference between the patients who received BAE and those who did not. To control hemorrhage (search and treatment), 8 patients received BAG; of
those, 7 received BAE in a total of 9 regions. Among the patients who received BAE, the bleeding status of 3 was <100 ml/24 h; the other 4 showed 100–500 ml/24 h. One patient died while still hospitalized. The cause of death was recurrent massive hemoptysis on day 2 after the first BAE. There were no hemoptysis-related deaths among the patients who received only conservative treatment.

**Characteristics of BAs Visualized by MDCT**

Table 2 summarizes the numbers of right and left BAs, their diameters, heights of their ostia, and bleeding sites. A total of 102 ostia and 96 traceable BAs were identified. Twelve patients had a branch from the ICBA, and 19 had 1 right BA, while 14 had 2 right BAs that could be adequately evaluated. Twenty-five patients had 1 left BA, and 9 had 2 left BAs. These included 13 patients who had BAs arising from the descending aorta as a common trunk. Of those, 3 had a unilateral BA ostium that could not be depicted, and the anatomical structures were indistinct. The site of the ostium of the BA is usually considered orthotopic when the artery originates from the descending aorta, between the levels of the 5th and 6th thoracic vertebrae; all other heights are considered ectopic [14]. All arteries that underwent BAE were clearly visualized by MDCT. Seven arteries were located in orthotopic ostia and 2 arteries in ectopic ostia. Among all 41 patients, 13 (32%) had at least 1 BA of ectopic origin, and a total of 22 ectopic BAs were depicted. Among the detectable BAs, 6 were suboptimal with respect to the measurement of their diameter and were excluded from further analysis. At their origins, the diameters of right BAs were significantly larger than the left BAs (p = 0.004).

**Bleeding Site**

Based on MDCT and FOB findings, the bleeding site was confirmed in 13 (32%) patients. MDCT angiography and lung field findings were consistent in 12 (29%) patients and the bleeding site was defined as probable. In 11 of these patients, hemoptysis originated from the right side; in 14 it originated from the left side. There were 16 (39%) patients in whom the bleeding site was unknown. FOB was performed in 30 (73%) patients. Abnormalities considered to be associated with the bleeding were detected in 20 patients (2 laterality and 18 lobes) and bilat-

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**Table 1. Patients characteristics and causes of hemoptysis**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>BAE performed (n=7)</th>
<th>BAE not performed (n=34)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender, male/female</td>
<td>4/3</td>
<td>18/16</td>
<td>0.68</td>
</tr>
<tr>
<td>Age, years, mean ± SD</td>
<td>63.6 ± 18.0</td>
<td>67.0 ± 9.7</td>
<td>0.47</td>
</tr>
<tr>
<td>Amount of hemoptysis, ml</td>
<td>&lt;100/100–500</td>
<td>23/11</td>
<td>0.39</td>
</tr>
<tr>
<td>Hemoptysis-related deaths</td>
<td>1/4</td>
<td>0</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Data are presented as numbers (n) and means ± SD. BAE = Bronchial artery embolization. The causes of hemoptysis include repetition in an underlying disease. 1 Chronic bronchitis includes diffuse panbronchiolitis.

**Table 2. Summary of BA findings on MDCT: anatomical characteristics and BAE/bleeding status**

<table>
<thead>
<tr>
<th>Location</th>
<th>right</th>
<th>left</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects</td>
<td>Ostium</td>
<td>55</td>
<td>47</td>
</tr>
<tr>
<td>Bifurcation</td>
<td>49</td>
<td>39</td>
<td>0.004</td>
</tr>
<tr>
<td>Hilar level</td>
<td>37</td>
<td>30</td>
<td>0.004</td>
</tr>
<tr>
<td>Height of ostium</td>
<td>Th5</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Th6</td>
<td>25</td>
<td>23</td>
<td>0.004</td>
</tr>
<tr>
<td>Ectopic</td>
<td>12</td>
<td>10</td>
<td>0.004</td>
</tr>
<tr>
<td>BA status [BAE(+)/(–)]</td>
<td>5/50</td>
<td>4/43</td>
<td>0.004</td>
</tr>
<tr>
<td>Bleeding status [bleeding(+)/(–)]</td>
<td>15/40</td>
<td>14/33</td>
<td>0.004</td>
</tr>
<tr>
<td>Bleeding site, n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper lobe</td>
<td>3</td>
<td>6</td>
<td>0.004</td>
</tr>
<tr>
<td>Middle lobe</td>
<td>4</td>
<td>2</td>
<td>0.004</td>
</tr>
<tr>
<td>Lower lobe</td>
<td>3</td>
<td>5</td>
<td>0.004</td>
</tr>
<tr>
<td>Diameter of ostium, mm</td>
<td>2.6 ± 0.8*</td>
<td>2.2 ± 0.6</td>
<td>0.004</td>
</tr>
<tr>
<td>Diameter at bronchial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bifurcation, mm</td>
<td>2.3 ± 0.8</td>
<td>2.1 ± 0.6</td>
<td>0.004</td>
</tr>
<tr>
<td>Diameter at hilum, mm</td>
<td>2.0 ± 0.8</td>
<td>2.0 ± 0.7</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Data are presented as numbers (n) and means ± SD. BA = Bronchial artery; MDCT = multidetector row computed tomography; BAE = bronchial artery embolization; BAE(+)/(–) = arteries receiving (+) or not receiving (–) BAE; bleeding(+)/(–) = bronchial artery diagnosed as a source of bleeding (+) or not a source of bleeding (–). * p < 0.05 vs. left bronchial artery.
eral nonspecific abnormality in 3; the FOB results were normal in the remaining 7 patients. We detected lung cancer in 2 cases and bronchial erosion by metastatic lymph node invasion in 1 case.

**Comparison MDCT and BAG**

When we compared the diameters of BAs at 3 points (ostium, bronchial bifurcation and pulmonary hilum) using both BAG and MDCT, we obtained a good correlation between diameters estimated using the two techniques ($r = 0.709, p < 0.001$; fig. 2).

**BA Diameters on MDCT according to BAE/Bleeding Status**

The diameters of BAs according to whether or not they bled [bleeding(+) or bleeding(–)] and received BAE [BAE(+) or BAE(–)] are summarized in table 3. The average diameters in each segment of BAs in the BAE(+)/bleeding(+) group were significantly larger than those in the 2 BAE(–) groups. Moreover, the diameters of the BAE(+)/bleeding(+) arteries remained largely unchanged from their origin through the mediastinum. By contrast, the diameters of BAE(–) arteries were smaller at the hilum and bronchial bifurcation than at their origin, whether or not the artery was the source of the bleeding. The sensitivity in the detection of the arteries at the level of the pulmonary hilum compared to the number of its ostium was high in both the BAE(+) (88%) and BAE(–) (66%; $p = 0.26$) groups. The only exception among the BAE(+) group was a dilated BA that originated from the left subclavian artery and projected directly to the ipsilateral lung parenchyma with no detectable hilar path.

Left BAs defined as bleeding(+) or considered to be related to the bleeding based on MDCT and/or FOB findings were significantly larger ($p < 0.05$) at the origin, bronchial bifurcation and pulmonary hilum than arteries defined as bleeding(–). The sensitivity in the detection of bleeding(+) arteries (96%) at the level of the hilum was significantly greater than that of bleeding(–) arteries (56%; $p < 0.001$). Among bleeding(+) arteries, there was no significant difference in diameter at the origin ($p = 0.13$) between those in the BAE(+) and BAE(–) groups, though a significant difference was seen at the bronchial bifurcation ($p = 0.049$) and pulmonary hilum ($p = 0.03$).

**Relationships between MDCT Score and BAE Status**

The relationship between MDCT score and the BAE status for each BA is shown in figure 3. Among the BAE(+) group, there were 5 arteries with a score of 2, and 4 with a score of 3. In the BAE(–) group, there were 32 arteries with a score of 0, 22 with a score of 1, 15 with a score of 2, and 18 with a score of 3. No BAs with MDCT scores of 0

### Table 3. Relation between BA diameters and the BAE/bleeding status

<table>
<thead>
<tr>
<th></th>
<th>BAE(+)/bleeding(+) (n = 9)</th>
<th>BAE(-)/bleeding(+) (n = 20)</th>
<th>BAE(-)/bleeding(-) (n = 67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter at ostium, mm</td>
<td>3.2 ± 1.2$^a$</td>
<td>2.7 ± 0.7$^a$</td>
<td>2.2 ± 0.6</td>
</tr>
<tr>
<td>Diameter at bronchial bifurcation, mm</td>
<td>2.9 ± 1.0$^{a,b}$</td>
<td>2.4 ± 0.6$^a$</td>
<td>2.0 ± 0.6</td>
</tr>
<tr>
<td>Diameter at hilum, mm</td>
<td>3.0 ± 1.2$^{a,b}$</td>
<td>2.1 ± 0.6$^a$</td>
<td>1.8 ± 0.6</td>
</tr>
</tbody>
</table>

Data are presented as means ± SD. BA = Bronchial artery; BAE = bronchial artery embolization; BAE(+) = arteries diagnosed a source of bleeding and receiving BAE; BAE(–)/bleeding(+) = arteries diagnosed as a source of bleeding but not receiving BAE; BAE(–)/bleeding(–) = arteries diagnosed as not a source of bleeding and not receiving BAE.

$^a p < 0.05$ vs. BAE(–)/bleeding(–).

$^b p < 0.05$ vs. BAE(–)/bleeding(+).
0 or 1 were administered BAE, and the probability that BAE would be required declined significantly with lower MDCT scores (p = 0.004). In multiple logistic regression analysis, ostium diameter and the amount of expectorated blood were independent predictive factors for BAE.

**Discussion**

In over 90% of hemoptysis cases requiring intervention with BAE or surgery, a BA is responsible for the bleeding [17]. BAE is mainly performed as an initial treatment, particularly in high-risk patients, because it is safer and less invasive than emergency surgery [3, 19–21], but the decision as to which BA should be embolized must take into account the possible necessity of an invasive BAG procedure. BA anatomy is highly variable and shows a great deal of individual difference; indeed, ectopic BAs can originate from the lower thoracic aorta, subclavian arteries, thyrocervical trunk, costocervical trunk, brachiocephalic artery, internal mammary artery, pericardiophrenic artery or inferior phrenic artery. In cases of hemoptysis, ectopic BAs, including NBSAs and the hard tortuous aortas seen in older patients, sometimes make catheterization, and thus conventional angiography, difficult. In many cases, this difficulty can be overcome with MDCT, as detection of BAs on MDCT is in good agreement with conventional angiographic findings in 86% of cases [15]. In addition, MDCT enables detection of 36% of ectopic origins and provides key information useful when making decisions about the management of hemoptysis [12]. Similarly, we detected ectopic BAs in 32% patients in the present study.

Our findings indicated that BAs categorized as bleeding [BAE(+)/bleeding(+) or BAE(−)/bleeding(+)] were significantly larger than those categorized as not bleeding [BAE(−)/bleeding(−)]. BAs receiving BAE had larger diameters that did not change from the ostium of the artery through the mediastinum to the hilum. We also found that there is a good correlation between the BA diameters visualized on BAG and MDCT, though estimates tended to be larger with MDCT than with BAG. Earlier reports suggest that most BAs of >2 mm in diameter on conventional contrast CT should be considered abnormal and dilated [17, 22]. Based on autopsies of adult human lungs, one would expect normal BA diameters to be approximately 1.5 mm at the hilum and decline to 0.5–0.75 mm at the point of entry into the lung parenchyma [23]. Our investigation showed that, for BAs other than those in the BAE(+)/bleeding(+) group, diameters at the level of the pulmonary hilum were significantly smaller than at the ostium, and that diameters tended to become smaller as one measured more peripherally. At the hilum, diameters of BAE(−)/bleeding(−) arteries averaged 1.8 ± 0.6 mm on MDCT, which is larger than previously reported. But considering that our investigation was limited to patients presenting with hemoptysis and included no healthy individuals, this would seem a reasonable estimate. Our estimates of BA diameter on MDCT would also be affected by a vessel’s trajectory, its volume, the surrounding tissues, and the scanning technique [24]. In addition, BAs too small to detect would be excluded from our analysis; consequently, we may overestimate the diameters of BAs not responsible for hemorrhage. Yoon et al. [14] reported that BAs responsible for bleeding can frequently be visualized and traced from their origin to the level of the pulmonary hilum (74%), whereas only 11% of BAs not responsible for hemorrhage can be traced that far. In our investigation, we were able to visualize 96% of BAs responsible for bleeding and 56% of those not responsible for bleeding. Our greater ability to visualize the arteries, regardless of their bleeding status, is likely the result of our administration of high-density contrast material. Following injection of the contrast medium, the CT number in the descending aorta was 463 ± 84 HU, which is...
sufficient to visualize arteries smaller than the previously reported hepatic and coronary arteries [25, 26].

BAs with low MDCT scores were significantly less likely to require BAE than those with high MDCT scores. And in multiple logistic regression analysis, it was found that detection of a larger ostial diameter and the bleeding status, whether or not the BA under study was a source of the hemoptysis, affected the radiologists’ decision as to which BA should be embolized. Although the BA that is the source of the hemoptysis may not always have a large diameter, its diameter and peripheral traceability are important reciprocal factors contributing to the MDCT score. BAs that did not pass through the mediastinum were not suitable for our quantitative image analysis, however. Moreover, the amount of hemoptysis is not equal to that seen in the lower respiratory tract; consequently, the amount of bleeding may be underestimated. We therefore suggest that it is also important to take the patient’s cardiorespiratory status and risk of asphyxiation into account, since BAE could prevent development of the next life-threatening hemoptysis. That said, because we had only one hemoptysis-related death, our findings for determining appropriate initial management of hemoptysis; that is, whether conservative treatment is sufficient or whether a patient should be readied for emergency BAE.

In summary, by using contrast material-enhanced MDCT, we were able to identify individual anatomical variations, including ectopic origins and probable bleeding-related BAs, as well as bilateral small BA diameters with low MDCT scores not requiring BAE, in patients not presenting with massive hemoptysis. From a practical standpoint, BA evaluation with MDCT could be useful for determining appropriate initial management of hemoptysis; that is, whether conservative treatment is sufficient or whether a patient should be readied for emergency BAE.

References


