Anterior Spinal Cord Infarction following Bronchial Artery Embolization

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Embolization of an anterior spinal artery is a rare complication that can occur during bronchial artery embolization, typically performed for massive hemoptysis. Embolization of this important blood supply to the anterior spinal cord can result in infarction and paralysis. Every interventional radiologist should have an intimate knowledge of bronchial artery anatomy and must make every effort to delineate spinal artery feeders during the procedure.

Case Report

A 70-year-old black man with a history of remote right upper lobe resection for non-small cell lung cancer presented with aspergillosis and aspergilloma of the residual surgical cavity. The infectious complications led to his seeking medical treatment for progressive episodes of hemoptysis. During his hospital stay, his hemoptysis progressively worsened requiring transfer to the medical intensive care unit and intubation.

In an effort to control his hemoptysis, the patient was taken to the interventional radiology suite and underwent angiography, which demonstrated moderate bronchial artery hypervascularity in the right upper lobe paramediastinal region related to the aspergilloma. The right bronchial artery was initially selected with a 5F Mickelson (Cook Medical Inc., Bloomington, IN) catheter; following initial diagnostic angiography via the base catheter, a microcatheter was placed beyond the midline using a microcatheter system. Embolization was performed via the microcatheter using 300 to 500 μ m polyvinyl alcohol (PVA) particles (Boston Scientific, Natick, MA). Postembolization angiography demonstrated near complete stasis of flow. Due to the location of the pulmonary abnormality, angiography was also performed of the right supreme intercostal artery. Because angiography demonstrated hypervascularity in the right apical region; this vessel was also selectively catheterized and embolization was performed with 300 to 500 μ m PVA (Boston Scientific). Finally, angiography was performed for the right seventh intercostal artery that failed to demonstrate significant feed-

ing blood vessels to the right upper lung field. Of note, none of the vessels undergoing angiography demonstrated anterior spinal artery feeders.

The day following the procedure, the patient demonstrated acute lower extremity weakness and skin temperature changes. Magnetic resonance imaging (MRI) of the thoracic spine revealed abnormal T2 signal at the T1–T5 levels consistent with edema from infarction.

The patient did regain some function in his lower extremities with rehabilitation, but his pulmonary status continued to deteriorate. He experienced recurrent episodes of hemoptysis and was taken back to the angiography suite, but no bleeding or hypervascularity amenable to embolization was visualized. He eventually died of respiratory failure after repeated episodes of hemoptysis.

Anatomy

Bronchial arterial anatomy is highly variable and commonly associated with arterial supplies to other structures including pulmonary arteries, mediastinum, esophagus, and pericardium. The bronchial arteries may originate directly from the aorta or with an intercostal artery from a common intercostobrachial trunk (ICBT). In up to 90% of patients, bronchial arteries originate below the ligamentum arteriosum at the level of the T5–6 vertebral bodies.^{1,2} Bronchial arteries that arise directly from the aorta typically arise on the ventral or ventrolateral aspect of the aorta and follow a meandering course toward the pulmonary hilum. Conversely, intercostal arteries arise laterally or dorsolaterally from the aortic wall and assume a craniad course before following the undersurface of the ribs.¹

Although numerous possible variations in bronchial artery origin are possible, Caudwell described the classic four patterns of bronchial artery origin in 1948. Type 1 (41% of patients) is distinguished by two separate left bronchial arteries and one right artery originating from an ICBT. Type 2 (21%) demonstrates a single left and a single right bronchial artery arising from an ICBT. Type 3 (21%) has two separate left

and two right bronchial arteries, one of which is an ICBT. Type 4 (10%) includes one left and two right arteries, including one right artery arising from an ICBT. Variant anatomy includes a single right bronchial artery (60%) and a common intercostal origin of a right bronchial artery (70 to 80%); only 5% of patients have a common intercostal and left bronchial artery origin.²

Anomalous bronchial arteries that originate outside of the T5–T6 level comprise 10 to 30%, with most of these arteries arising primarily cephalad to the ligamentum arteriosum. However, systemic sources including internal mammary, inferior thyroidal, inferior phrenic, subclavian, coronary, and brachiocephalic arteries can also give rise to bronchial arteries. These are recognizable as bronchial arteries despite their anomalous origin by their characteristic course along the bronchi.³

Spinal arterial supply that may be visible on angiography includes both radicular and medullary arteries. Radicular arteries arise from segmental spinal arteries to supply the dorsal and ventral roots. Medullary arteries most commonly arise from multiple levels of intercostal arteries and have a characteristic hairpin appearance as they course medial to the vertebral pedicle. Early in embryologic development, each

vertebral body level has paired medullary arteries supplying the cord. During development, most of these branches regress leaving adults with only six to eight arterial branches to the anterior spinal artery, which supplies the anterior 80% of the cord including the corticospinal tracts. Blood supply to the anterior spinal artery at the level of the bronchial arteries typically consists of a single T4 or T5 medullary artery that arises from a left intercostal artery.¹ Importantly, although uncommon, a medullary artery may arise from the intercostal branch of a right ICBT in 5 to 10% of patients.^{2,3} The artery of Adamkiewicz, the largest anterior medullary branch to the anterior spinal artery, supplies the lower two thirds of the spinal cord and is located at T9–T12 in 74% of patients and T5–T8 in 15%. It is usually a single artery with a left-side origin (80%).

Discussion

Chronic inflammatory conditions including cystic fibrosis, tuberculosis, aspergillosis, and bronchogenic cancer can result in lung tissue destruction and local hypoxia that leads to angiogenic recruitment and hypertrophy of bronchial

Figure 1 Images obtained during the embolization procedure in the case report. (A) Unsubtracted mask image obtained just prior to angiography demonstrating multiple overlying artifacts not removed prior to the angiogram. (B) Unsubtracted angiogram from the base catheter demonstrating hypertrophied right bronchial artery supplying a hypervascular distribution (arrows). (C) Unsubtracted angiogram from the microcatheter just prior to the embolization procedure, demonstrating the level from which the embolization procedure was performed (arrow). Note that the catheter was placed well beyond the midline. (D) T2-weighted magnetic resonance imaging demonstrating increased signal in the anterior spinal cord in the upper thoracic spine, compatible with acute ischemic injury to the cord.

arteries. These hypertrophied arteries, defined by luminal diameter of 3 mm (versus 1.5 mm in normal arteries), have friable walls and are surrounded by inflammation. This constant insult can lead to arterial leakage and rupture, resulting in massive hemoptysis.

A total of 90% of hemoptysis is of bronchial artery origin. Bronchial artery embolization has become a highly effective therapy in such patients, especially with recent advances in microcatheter and superselective embolization techniques. However, knowledge of bronchial artery anatomy is key to successful embolization and avoidance of complications. The greatest and most feared complication, as presented here, is inadvertent embolization of a spinal artery leading to ischemia and paralysis.

The incidence of spinal artery ischemia from bronchial artery embolization is reported to be between 1.4% and 6.5%.³ Even though radicular arteries exist at every level to supply the dorsal and ventral roots, only a few medullary arteries supply the anterior spinal artery. The embryologic regression of blood supply to the anterior spinal cord and the relatively large area supplied by each anterior spinal artery makes it quite vulnerable to disastrous ischemia during intervention.¹

The assertion that visualization of a spinal artery is a contraindication to embolization has been allayed somewhat by the introduction of more advanced microcatheter systems that allow catheter placement distal to the spinal artery feeder. Even if the microcatheter can be advanced distally, embolization should only proceed if one can be absolutely certain that no embolic material will enter the artery of Adamkiewicz distribution. Currently, investigators suggest that visualization of a radicular medullary artery does not preclude embolization; however, visualization of the artery of Adamkiewicz remains a strong relative contraindication to bronchial artery emboliza-

tion.³ Incidence of neurogenic compromise has not been reported with inadvertent radicular artery embolization.³

As demonstrated by the current case, even judicious use of microcatheter systems and position distal to the expected location spinal artery feeders does not eliminate the risk of spinal artery embolization. Use of larger molecule particulate embolic agents (>350 μ m) is theoretically safe because these agents would be too large to enter the small blood vessels supplying the cord.⁴ Although published, the suggestion of safety in using larger particles is rarely followed if the artery of Adamkiewicz is actually visualized. Additionally, several authors have found that spinal artery feeders were not visible on angiography in patients whose treatment was complicated by spinal infarction. This may suggest that spinal arteries can have angiographically invisible connections to bronchial arteries or become visible only after embolization of the nearby hypertrophied vessels and blood flow is redirected.⁵

The case presented here demonstrates the plausibility of embolization causing spinal ischemia despite all typical precautions. In retrospect there were, however, many mistakes made during this particular procedure. Chief among these is that the procedure occurred in less than ideal circumstances in a very ill patient. First, as noted by the images presented, there were significant overlying radio-opaque artifacts obstructing the area of concern on the angiographic images. Second, there was significant motion artifact during the angiograms due to respiratory compromise, the reason that unsubtracted angiographic images are presented here (►Fig. 1). Third, intermittent angiograms were not performed during the embolization procedure that might have allowed for interval visualization of the spinal artery branches (►Fig. 2). Finally, in the interest of performing the embolization procedure as quickly as

Figure 2 Schematic diagram representing potential changes in flow dynamics during bronchial artery embolization procedures. (A) Prior to embolization, blood flow is directed entirely into the distal bronchial artery distribution. (B–D) As embolization proceeds, distal outflow is compromised (solid arrows) by the particulate embolic agents (circles), redirecting flow into the anterior spinal artery supply (open arrows) resulting in potential embolic material entering the latter distribution.

possible, the angiographic images obtained were reviewed only at the tableside rather than at a dedicated workstation.

Teaching Points

1. Spinal artery feeders have a classic hairpin appearance on angiography, and all angiograms must be closely scrutinized for spinal artery feeders. Visualization of a medullary artery is not a definite contraindication to embolization.
2. Incidence of spinal ischemia during bronchial artery embolization is 1.4 to 6.5%.
3. Large particle PVA >350 μm should be used but does not guarantee avoidance of embolization.
4. Intermittent angiograms during embolization should be performed to assess for interval appearance of spinal artery supply.

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