Pulmonary arteriovenous malformations (AVM) may be radiologically investigated by a variety of imaging techniques. Each technique provides anatomic and/or functional information that may overlap with data provided by the others. Since AVMs are often multiple and tend to enlarge with time, some methods of imaging are more suited to diagnosis and some to follow the natural disease progression. In cases where observation without treatment is indicated, diagnosis and follow-up can be accomplished with modalities such as tomography, fluoroscopy, or CT scanning. When surgical resection or balloon occlusion is contemplated, angiography is still the imaging procedure of choice.

**Case Reports**

**Case 1**

A 40-year-old woman with a 50-pack year smoking history was referred for evaluation of progressive dyspnea. She had no history of other pulmonary or cardiac disease, but did report recurrent epistaxis and an episode of undiagnosed GI bleeding. She presented in mild respiratory distress with a resting respiratory rate of 20. Multiple telangiectases were evident on her lips and oral mucosa. No cyanosis, clubbing, thoracic bruit, or heart murmur were detected. Her hematocrit value was 49 and room air arterial blood gas levels revealed a PaO$_2$ of 61, PaCO$_2$ of 29, and a pH of 7.48. Using her PaO$_2$ obtained after 30 minutes of breathing 100 percent oxygen, an estimated shunt of 15 percent was calculated. Pulmonary function studies confirmed moderate to severe obstructive lung disease with a marked decrease in her FEV$_1$ (1.26 L, 46 percent predicted) and hyperinflation (RV 2.5 L, 150 percent predicted). A chest roentgenogram showed hyperinflation, emphysematous bullae, and a 1 cm right lower lobe (RLL) nodule. Chest tomography (Fig 1) delineated an oval, well-marginated 1.5 cm RLL density with enlarged afferent and efferent vessels. Fluoroscopy demonstrated a slight change in size of this lesion with Valsalva and Mueller maneuvers and confirmed the “feeding vessels.” A lung perfusion scan showed markedly heterogeneous distribution of $^{99m}$TcMAA in both lungs consistent with the known emphysema, but no early tracer accumulation was detected in the kidneys or brain to suggest a right-to-left shunt. Rapid sequence bolus enhanced chest CT (Fig 2) verified the medial basal segment RLL nodule with a prominent draining vessel, but indicated no other AVM. The CT also provided an anatomic image of the extent of the emphysematous bullae. Pulmonary arteriography (Fig 3) revealed an additional 0.5 cm AVM.

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**Figure 1.** Case 1. Tomographic cut 5 cm from the back shows an oval, well-margined, 1.5 cm right lower lobe density (large arrow) with a large afferent artery and an efferent vein (small arrow).
CASE 2

A 33-year-old man presented with progressive dyspnea and recurrent epistaxis. Lip telangiectases, nailbed cyanosis, and a left anterior chest bruit were noted. His chest roentgenogram revealed a 2 cm "coin lesion" in the left midlung. Following resection of his 2 cm lingular AVM, his exercise tolerance improved. With reevaluation six years later, a new right posterobasilar nodule was identified on chest roentgenogram. With fluoroscopy, the lesion enlarged slightly during deep inspiration. Chest CT scan (Fig 4) improved the imaging of this 1.5 cm nodule with its feeding and draining vessels and disclosed an additional serpiginous density in the right midlung base. Both of these lesions showed intense enhancement following bolus contrast injection.

DISCUSSION

Arteriovenous malformations (AVM) are due to a congenital defect in capillary structure that predisposes to focal areas of microvascular dilatation. Although pulmonary AVMs may be an isolated finding, they are associated 40 to 70 percent of the time with similar telangiectases of the skin, mucosa, liver, and brain in the Osler-Weber-Rendu syndrome (hereditary hemorrhagic telangiectasia). The AVMs in the lung are often clinically silent until the third or fourth decade. Dermal and mucosal telangiectases, recurrent epistaxis, GI bleeding, or other signs of extrathoracic AVM may develop at an earlier age. In a patient with unexplained dyspnea, cyanosis, clubbing, polycythemia, a family history or symptoms and signs of hereditary telangiectasia, AVM should be considered in the differential diagnosis of a new pulmonary nodule(s). Auscultation of the chest with such a nodule in a dependent position might reveal a thoracic bruit that is augmented during inspiration. When a pulmonary AVM presents as a "coin lesion" in an asymptomatic individual with no clues to telangiectasia by history, physical examination, or chest roentgenogram, it may not be identified as an AVM until it is surgically resected.

Since pulmonary AVMs in the Osler-Weber-Rendu syndrome are more apt to be multiple, to progressively enlarge, and to be complicated by paradoxical embolus to the CNS with subsequent stroke or brain abscess, 1,2

FIGURE 2. Case 1. Computed tomography with bolus injection of contrast suggests the vascular nature of the RLL nodule and demonstrates a prominent draining vessel (arrow). No other AVM are seen.

in the right middle lobe.

FIGURE 3. Case 1. Pulmonary arteriogram verifies the RLL AVM (large arrow) and reveals an additional 0.5 cm AVM in the right middle lobe (small arrow).

FIGURE 4. Case 2. Bolus-enhanced CT improves the imaging of the 1.5 cm RLL nodule with its feeding and draining vessels (arrow). On a lower CT cut (not shown), an unsuspected serpiginous AVM is seen in the right midlung base.
a family history or physical examination consistent with this syndrome necessitates a careful early imaging search for lung involvement. On a standard PA and lateral roentgenogram, a pulmonary AVM appears as a homogeneous, circumscribed, noncalcified nodule up to several cm in diameter. Blood vessels connecting it to the hilus may be seen. The majority are located in the mid-to-lower lung fields. Multiple AVMs are present in one third to one half of these patients.\(^1\,2\) Tomography is helpful in better defining the afferent "feeding" artery(s) coming from the hilus and the efferent vein(s) "draining" into the left atrium. Tomography is also useful in demonstrating additional AVM or in locating suspected AVM in a patient with the Osler-Weber-Rendu syndrome. Fluoroscopy has often helped us to locate and to define the lesion with more accuracy. Pulsation of the nodule or an increase in its size with the Valsalva maneuver are useful but variable fluoroscopic findings.

The vascular nature of an AVM might be suggested by a lung perfusion scan.\(^3,4\) Technetium labelled albumin microaggregates (\(^{99m}\)TcMAA) injected intravenously are normally trapped in the pulmonary capillary bed. Through the right-to-left shunt of a pulmonary AVM, they may escape to reach the systemic circulation where they are detected as uptake in the brain and kidneys. The AVM itself appears as a cold spot on the scan. Our first case demonstrates that, as in the evaluation of pulmonary emboli, the presence of underlying pulmonary parenchymal disease limits the usefulness of a perfusion scan in isolating vascular lesions. It was not surprising in the woman with moderate to severe COPD that the perfusion scan "matched" her prominent underlying disease and "missed" her other reason for dyspnea. Contrast echocardiography is another method for identifying shunt.\(^5,6\) Indocyanine green dye or normal saline solution, injected intravenously, appear as tiny bubbles or cavitations that are normally filtered by the pulmonary capillaries; but in the presence of an AVM may be seen to enter the left heart and aorta. This technique may verify the presence of a right-to-left shunt, but was not used in the evaluation of our patients since it would not be expected to add anatomic definition or functional quantitation of their disease.

The CT scanning of the chest, especially with lesion enhancement after a bolus injection of contrast, may offer a reasonable alternative to demonstrate the feeding and draining vessels and to delineate the vascular nature of an AVM.\(^7\) This may prove to be the best replacement for arteriography in following these lesions when an operative approach is not warranted. A repeat rapid sequence (dynamic) CT with cuts at the level of the suspected AVM can, using time-density curves, allow comparison of the time of peak opacification of the nodule with the time of peak opacification of the right ventricle and aorta. This demonstrates whether the AVM is fed by a pulmonary or a systemic artery(s). Smaller AVMs may be beneath the resolution capability of current conventional CT scanning.

Pulmonary angiography, which provides information similar to that of dynamic contrast-enhanced CT, has the disadvantage of being more invasive. This disadvantage is counterbalanced by angiography's ability to provide better anatomic detail and to reliably identify multiple AVMs. In one study of 20 patients undergoing angiography for the evaluation of pulmonary AVM, ten AVMs not suspected by chest roentgenogram or tomography were revealed.\(^3\) These smaller AVMs may be of no physiologic consequence but should be documented or excluded by arteriography if treatment is contemplated.

A New Approach to Management

With these advances in medical imaging, we would like to propose an approach to the management of pulmonary AVMs. In patients with the Osler-Weber-Rendu syndrome, the conventional PA and lateral chest roentgenogram may not be adequate as baseline screening for the presence of AVMs. Whole lung tomography or dynamic chest CT with contrast may be more sensitive tools to identify and to follow asymptomatic AVMs in these patients. We would not advocate an operative approach to any lesion found by this screening approach unless the appropriate physiologic dysfunction is documented. In the investigation of a "coin lesion" found on routine chest roentgenogram with a family history, symptoms, physical findings, or roentgen signs suggestive of AVM, another approach is indicated. As an initial step, physiologic evidence of a right-to-left shunt should be obtained by analysis of arterial blood gases on 100 percent \(O_2\) and calculation of the A-a gradient. An alternative approach might be to evaluate for shunt contrast echocardiography or perfusion scan. The limitations of the latter two techniques have been mentioned previously.

To better define the anatomy and vascular nature of the lesion and to search for additional nodules, we have found dynamic CT with contrast to be equivalent in value to the combination of whole lung tomography and fluoroscopy. Little is added by performing all three procedures in the same patient, and follow-up can be reasonably accomplished by any of the three modalities. The importance of an imaging technique's sensitivity in finding small lesions in a nonoperative candidate is unknown.

Surgical resection or balloon occlusion is indicated when 1) the shunt associated with the AVM(s) is large enough to cause symptoms, 2) a complication has occurred, 3) there is evidence of progressive enlargement of the AVM(s), or 4) the AVM is fed by a systemic artery.\(^1,2\) The goal of therapy is to minimize symptoms...
and to lessen the risk of hemothorax or paradoxic embolization to the CNS. Unfortunately, those with the greater risk of these complications (Osler-Weber-Rendu patients) are also the most likely to have multiple AVMs and to show progressive enlargement of their lesions. Successful removal or balloon occlusion of AVMs evident at initial evaluation may well offer symptomatic relief and reduced risk of complications that are only transient. If treatment is contemplated, then more sensitive imaging techniques should be employed. Since CT of the chest, even with rapid sequence cuts and time-density curves, does not provide equivalent preoperative data, pulmonary angiography is still required prior to surgical resection or balloon occlusion of an AVM. As in our second case, the finding on reevaluation of one or several “new” AVMs poses the question of retreatment. If pulmonary parenchyma can be preserved, some authors recommend multiple thoracotomies. The feasibility of multiple or repeated balloon occlusions is currently under investigation. If treatment is not indicated, the diagnosis and follow-up of pulmonary arteriovenous malformations can be accomplished with imaging modalities less invasive than angiography.

REFERENCES