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Pulmonary Angiograms and Isotope Lung Scans — Their Role in the Diagnosis of Pulmonary Embolism

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Experience gained in the study of 307 patients by pulmonary angiograms and/or isotope lung scans has led to concepts regarding the limitation and usefulness of each. The scan is ideally useful when the patient with suspected pulmonary embolism has a negative chest film. Angiograms should be performed when there are parenchymal infiltrations on the chest radiograph or when a definite diagnosis is necessary. Either study should be performed early in the course of the patient’s illness to permit diagnostic study.

It has been repeatedly emphasized that clinical diagnosis of pulmonary embolism is difficult and that the ability of the clinician to recognize its occurrence is at best uncertain.1,2 Since the recommended forms of treatment are potentially hazardous, the need for substantiating the diagnosis and mapping the extent of the disease is important, particularly when embolectomy is contemplated. Pulmonary angiograms3,4 and lung scans,5,6 utilizing human serum albumin macroaggregates labeled with 131I, have become the accepted procedures for confirming the clinical diagnosis of pulmonary embolism. The nonspecificity of lung scans is intuitively apparent; the limitations of pulmonary angiography are less appreciated. This paper summarizes the results of our considerable experience in the use of these two diagnostic methods and defines the indications and limitations of each.

Three hundred and seven patients examined for suspected pulmonary embolism are included in this study. The angiograms of 140 patients and the lung scans of 212 patients were evaluated with the assumption that pulmonary embolism had occurred prior to the definitive study (unless a different diagnosis was ultimately established by other means). There is a bias favoring the accuracy of the angiograms and lung scans in diagnosing pulmonary embolism since the clinical diagnosis was undoubtedly influenced by the interpretation of the scan or angiogram. The time between the onset of pulmonary embolism and the lung scan or pulmonary angiogram was determined from the patients’ medical records. Size, number, and location of emboli were deter-

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mined from the angiogram, lung scan, or autopsy when performed. Parenchymal infiltration on the chest radiographs were assumed to represent pulmonary infarction unless otherwise explainable.

Pulmonary angiograms are classified as positive, negative, or questionable. A positive angiogram is one in which there is a localized intraluminal defect within a pulmonary artery producing a variable amount of obstruction. A negative angiogram is one in which all vessels are well displayed and a uniform parenchymal blush is present in the late arterial phase. Vessels may be crowded and tortuous and flow may be retarded, but the peripheral branches are filled. A questionable angiogram is one in which there is delayed opacification of the subsegmental or smaller vessels, the distal portions of the vessels are never completely opacified, there is an absence of small vessel filling, and the parenchymal blush is reduced or absent.

Seventy-one pulmonary angiograms were positive for pulmonary emboli. Twenty-five of the angiograms demonstrated occlusion of 40% or more of the pulmonary arteries. Twenty angiograms showed 15% to 40% occlusion of the vascular bed. Sixteen angiograms demonstrated one or more segmental arteries occluded, and 10 angiograms demonstrated varying degrees of small vessel occlusion. In patients with multiple emboli all lobes of the lungs were equally involved. However, solitary emboli were confined to the lower halves of the lung fields with the majority lodging in the basilar segments of the lower lobes. There was no apparent lateralization. The longest time interval between an apparent single embolic episode and a positive angiogram was 46 days. However, the majority of angiograms were obtained within one week of the onset of symptoms and 26 were performed within three days of the occurrence of embolization.

There were 39 questionable pulmonary angiograms. Twenty of these patients were ultimately considered to have had pulmonary embolism. No angiographic feature distinguished the patient with pulmonary emboli from those having other explanations for their signs and symptoms. The majority of the patients had parenchymal infiltra­tions indicating that pulmonary infarction had occurred. Perhaps, the utilization of tomography simultaneously with opacification of the vessels, as published by Scatilf et al., would have demonstrated obscure intraluminal defects. With two exceptions the abnormalities in the questionable angiograms were confined to the lower lobes. These patients had embolization to the right middle lobe and one of these had associated involvement of the right lower lobe.

Thirty-five pulmonary angiograms were negative. Nine patients within this group are classified as having had pulmonary embolism with or without subsequent pulmonary infarction. There was convincing evidence of pulmonary embolism in three of the patients. One patient had a pulmonary angiogram, demonstrating multiple pulmonary emboli, 15 days prior to the negative angiogram. A second patient had symptoms of pulmonary embolism and a negative pulmonary angiogram. Twenty days following the initial study, after recurrence of symptoms for one day, a progress angiogram revealed multiple pulmonary emboli occluding approximately 30% of the vas-
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Following a negative study seven days after onset of symptoms, a third patient, autopsied 10 days later, showed extensive emboli in the most terminal arterioles. Five additional patients had no confirmed diagnoses and their clinical symptoms were never explained. They may have had small pulmonary emboli. An additional patient developed evidence of pulmonary infarction subsequent to a negative angiogram. He may have had an additional pulmonary embolus, although his physical findings and symptoms showed no sudden alteration following angiography.

Pulmonary arterial pressure was recorded in all but 18 of the 140 patients who underwent angiography. There was no useful correlation between the presence or size of the embolus and the elevation in pressure, but the degree of pulmonary hypertension was one of the factors considered in selecting patients with massive pulmonary emboli for pulmonary embolectomy. Patients with markedly elevated pulmonary artery pressures had grave prognoses.

Isotope lung scans were performed on 212 patients. Lung scans were classified as positive, predictably positive, patchy, or negative. A positive scan is one in which there are one or more defined areas of markedly decreased or absent activity, unrelated to obvious disease which shows on the chest film. A predictably positive scan has an appearance identical to a positive scan, but with obvious disease evident on the chest film, corresponding to the defect on the scan. A patchy scan is one in which activity is unevenly distributed over the lung fields, but with no circumscribed defect. A negative scan has a homogeneous appearance. There may be a gradation of activity from one area of the lung to another.

Table I summarizes the scans in the two hundred and twelve patients studied. In 111 of these, pulmonary embolism was established as the final clinical diagnosis.

<table>
<thead>
<tr>
<th>Scan</th>
<th>Pulmonary Emboli</th>
<th>Other Conditions</th>
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<tbody>
<tr>
<td>Positive</td>
<td>53</td>
<td>9</td>
</tr>
<tr>
<td>Predictably Positive</td>
<td>33</td>
<td>22</td>
</tr>
<tr>
<td>Patchy</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Negative</td>
<td>20</td>
<td>54</td>
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</table>
In the rest other conditions were ultimately found. A number of the patients had only anterior scans, sometimes because recent abdominal surgery or severe congestive failure precluded more complete studies. In those patients who did not have pulmonary emboli, but had positive lung scans, the final diagnoses were pneumonia, asthma, and pulmonary tuberculosis. Predictably positive scans were obtained in subdiaphragmatic abscess, postoperative atelectasis, congestive heart failure with effusion, tumor, chronic lung diseases such as fibrothorax with linear scars, old healed tuberculosis, pulmonary fibrosis and silicosis; pneumonia, and pulmonary emphysema, as well as pulmonary embolism with infarction. Patchy scans were obtained in the chronic lung diseases, congestive heart failure, bronchiectasis, and pulmonary embolism.

Pulmonary emboli were demonstrated on the angiograms in 24 of the 45 patients who had had both lung scans and pulmonary angiograms (Table II). Of these 24 patients, 17 had positive lung scans, five had predictably positive scans, one patient, thirty-two days after angiography had a patchy scan, and one patient had only an anterior lung scan which was negative. There was close correlation between the site of emboli on the pulmonary angiograms and the defects produced in the lung scans. Greater involvement of the lower lobes was demonstrated on the angiograms than was predicted from the scans.

<table>
<thead>
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<th>TABLE II</th>
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<tbody>
<tr>
<td>45 patients had lung scans and pulmonary angiograms</td>
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<tr>
<td>24 patients had angiograms positive for pulmonary emboli</td>
</tr>
<tr>
<td>17 positive lung scans</td>
</tr>
<tr>
<td>5 predictably positive scans</td>
</tr>
<tr>
<td>1 patchy scan (32 days after angio.)</td>
</tr>
<tr>
<td>1 negative scan (anterior scan only due to patient's condition)</td>
</tr>
</tbody>
</table>

Discussion:

Neither isotope lung scans nor pulmonary angiograms are completely successful in conclusively demonstrating all pulmonary emboli. A significant number of patients with evidence of pulmonary infarction in the lower lobes had questionable angiograms in which there were no defined intraluminal defects (Figs. 1 & 2). The vessels in the involved segments filled slowly and often had the appearance of “a pruned tree” with reduction or absence of small peripheral arterioles. Although this appearance is
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Figure 1
This 37-year-old man developed acute pleuritic chest pain, cough, and hemoptysis two months following an injury to his knee.

Figure 1a
Chest radiograph: (12-22-67) There are infiltrations in both lung bases and the right middle lobe.

Figure 1b
Anterior lung scan: (12-22-67).
Figure 1c
Right lateral lung scan: (12/22/67). Uptake is absent in the right middle lobe and patchy at the left base. The scan is predictably positive.

Figure 1d
Pulmonary angiogram: (12/26/67). There is an intraluminal defect in the right lower pulmonary artery partially occluding the origin of the middle lobe artery. There is delay in flow through the lower lobes with reduction in small vessel filling and parenchymal blush is absent. The appearance in the lower lobes would be questionable without the obvious embolus in the origin of the right middle lobe artery.
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Figure 2
This 46-year-old man, with chronic congestive failure developed chest pain, cough, and hemoptysis. At the time of catheterization the mean pulmonary artery pressure was 70 mm Hg and the wedge pressure was 30 mm Hg. Three films from the angiogram obtained at 1 second, 4 seconds, and 6 seconds demonstrate delay in flow through the lower lobe arteries. There is reduction in filling of the small peripheral vessels and an absence of parenchymal blush.

characteristic of pulmonary infarction, it is not specific since other conditions, such as atelectasis with or without secondary infection, produce an identical appearance. Emboli may be smaller than the smallest vessel visible on the angiogram and unless secondary changes are present the angiogram will be negative. In this situation the isotope lung scan may also be negative or patchy.

The isotope lung scan is nonspecific. Only the distribution of pulmonary blood flow through the lungs is recorded and thus any condition which interferes with perfusion of portions of the lung parenchyma will produce in the scan areas of reduced or absent activity (Fig. 3). Asthma, bronchogenic carcinoma, pneumonia, and chronic inflammatory diseases are only a few of the conditions which may produce false positive scans. Parenchymal consolidation seen on the chest film will produce a defect on the scan so unless an additional defect is present the study will not be
This 38-year-old woman developed left pleuritic chest pain, hemoptysis, and mild shortness of breath two weeks following an injury to her thigh.

Figure 3a
The PA chest x-ray on 10-2-67 shows an infiltration in the left lower lobe and lingula of the left upper lobe.
Legend for Figure 3b and c

Pulmonary angiogram: (10-67) There is delay in flow of contrast through the left lower lung field. The vessels are patent. There was a parenchymal blush in the late phase.

Figure 3d

Anterior lung scan: (10-4-67) There is an absence of activity over the left lower lung field. This is a predictably positive scan and is not diagnostic. The final diagnosis was pneumococcal pneumonia.
This 67-year-old woman with chronic thrombo-phlebitis had two days of chest pain and dyspnea.

**Figure 4a**
PA chest film: (5-18-67) There is infiltration in the right lower lung.

**Figure 4b**
Anterior lung scan: (5-19-67) Activity is absent over the right lower one third of the lung. This is a predictably positive defect. On the left there is a scalloped lateral margin which is an additional positive defect.
Figure 4c and d
Pulmonary angiogram, anterior-posterior and right posterior oblique projections: (5-19-67)
There are multiple intraluminal defects in the peripheral arteries of the right middle and left upper lobes. There are large intraluminal defects within the right lower lobe artery extending into the segmental divisions. Obstruction is incomplete.
diagnostic (Fig. 4). Small defects in the mid and upper lung fields are more easily recognized than similar changes at the bases. This may be related to the inability to define accurately the level of the diaphragm and to decreased activity over the thin normal lung in the posterior sulci.

Timing is important since emboli tend to be ephemeral. They are absorbed, reduce in size, or fragment and pass into vessels too small to be visible on an angiogram. Thus, pulmonary angiograms and isotope lung scans, which may be positive early in the course of the patient’s illness, will be non-diagnostic at a later date.

**Conclusion:**

Isotope lung scans and pulmonary angiograms should not be considered competitive in the diagnosis of pulmonary embolism. The angiogram is more conclusive in the demonstration of the pulmonary vasculature, and should be performed when there is need for the greatest confidence in the exclusion or confirmation of a pulmonary embolus. In less compelling situations, isotope lung scans are recommended for patients with negative chest radiographs and for following the resolution of altered lung perfusion. Lung scans are not usually diagnostic in patients with parenchymal densities in the lungs and angiograms are recommended for such patients with suspected pulmonary infarction.

A lung scan will exclude massive embolization but if the scan is positive there is still need for a pulmonary angiogram to better visualize the extent and location of emboli. Because of the rarity of embolism in the upper lobes an angiogram is recommended for further evaluation when lung scans demonstrate solitary perfusion defects in these areas. Either study should be performed early in the course of the disease to increase the opportunity of producing a diagnostic examination.

**REFERENCES**