Regional Ventilation in the Differential Diagnosis of Pulmonary Embolism

By Jose R. Medina, M.D., Philippe L’Heureux, M.D., James P. Lillehei, M.D., and Merle K. Loken, M.D., Ph.D.

With the technical assistance of Richard Ponto, B.A.

SUMMARY

In the diagnosis of pulmonary embolism by lung scanning, clinical errors of interpretation may arise. Diseases that affect the distribution of pulmonary blood flow, such as pulmonary emphysema and bronchial asthma, may be confused with pulmonary embolism.

With the addition of ventilation studies with $^{133}$Xenon to the perfusion scans, distinct differences appear between patients with emboli and those with obstructive lung disease. In patients with pulmonary emboli, ventilation is preserved in the areas of decreased perfusion, whereas patients with obstructive lung disease show both decreased ventilation and perfusion in the affected areas.

Additional Indexing Words:
$^{133}$Xenon  Ventilation-perfusion  Pulmonary embolism  Lung scans

LUNG SCANNING with macroaggregates of albumin labelled with radioactive isotopes is widely used in the diagnosis of pulmonary emboli. Errors in the interpretation of defects evidenced in lung scans may be due to technical or clinical factors. Technical errors are related to the particle size, to the equipment used, and to the resolution achieved. Clinical errors of interpretation arise when other diseases altering the distribution of pulmonary blood flow are confused with pulmonary embolism. Such entities include pulmonary emphysema, bronchial asthma, and cystic lesions of the lung.

The purpose of this paper is to report our experience with the clinical application of a $^{133}$Xenon and Anger scintillation camera technic, with emphasis on the contribution which regional ventilation studies can make in the differential diagnosis of abnormalities of pulmonary perfusion.

Methods

Twelve normal volunteers, ages 25 to 32 years, nine patients with pulmonary emboli without infarction, and 20 patients with obstructive lung disease underwent ventilation and perfusion studies with $^{133}$Xenon and the Anger scintillation camera. The diagnosis of pulmonary embolism was confirmed by pulmonary arteriograms in seven of the nine patients and thought to be almost certain on the basis of clinical findings in the other two. Six of these patients were studied within 24 to 48 hours after the onset of symptoms. The emboli occurred 3 weeks prior to the xenon study in one patient, and 3 months prior to the study in two others. In the latter three patients, the lung regions showing perfusion defects by the xenon study corresponded to the defects on the original scans and arteriograms.

The 20 patients with obstructive lung disease were selected from a larger group of such patients because they showed localized defects in distribution of pulmonary blood flow on the xenon studies. The clinical diagnosis in these patients was pulmonary emphysema in 19 and bronchial asthma in one. All the patients had severe obstructive lung disease as evidenced by mean values for $\text{FEV}_1/\text{VC}^*$ of 39% ± 13%, for vital

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From the Departments of Medicine and Radiology, the University of Minnesota Medical School, Minneapolis, Minnesota.

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capacity of 60 ± 14% of predicted value, and for 
RV/TLC* of 62 ± 10%.

The xenon studies were done with the subjects 
seated and with the camera crystal positioned 
over the posterior surface of the chest. The Anger 
camera has a crystal, 11 inches in diameter, that 
encompasses most of the lungs. In patients with 
large chests, a portion of the bases was 
excluded.

Assessment of pulmonary perfusion was made 
by the intravenous injection of a bolus of 3 to 5 
millicuries of ¹³³xenon dissolved in saline solution. 
Xenon is carried to the pulmonary circulation and 
diffuses immediately into the alveoli. If the 
subject holds his breath, there is no redistribution 
of radioactivity. A scintiphotograph obtained 
during breath-holding, therefore, represents 
regional perfusion. Once the patient resumes 
breathing, xenon washes out of the lungs and 
serial scintiphotographs are obtained. These 
photographs demonstrate regional clearance of xenon 
from the lung.

Ventilation was studied separately by having 
the patient breathe 3 to 5 mc of ¹³³xenon gas from 
a closed-circuit spirometer. After the first 
inhalation of ¹³³xenon, the patient held his breath and a single breath scintiphograph was 
obtained. Then the patient rebathed the xenon-air mixture to attain a uniform distribution of xenon 
within the lung. The spirometer was then removed 
and the subject was allowed to breathe room air 
while xenon cleared from the lungs. Scintiphotographs 
were obtained during rebreathing and 
clearance.

All scintiphotographs were obtained with 
30,000 counts.

Results

After intravenous injection of ¹³³xenon, the 
scintiphotographs of normal subjects (fig. 1) 
showed uniform distribution of radioactivity 
throughout both lungs. Patients with pulmo-
nary emboli and patients with pulmonary 
emphysema showed filling defects on the 
perfusion scintiphotographs (figs. 2 and 3). 
On the clearance scintiphotographs, marked 
differences became apparent. Patients with 
emphysema retained radioactivity in the areas 
of decreased perfusion, indicating that 
ventilation was impaired in these areas as 
well. Normal subjects and patients with 
pulmonary emboli showed uniform clearance 
of the injected xenon.

After a single inhalation of ¹³³xenon gas, 
radioactivity was uniformly distributed in 
normal subjects and in patients with 
pulmonary emboli. After rebreathing, the 
clearance of ¹³³xenon also was uniform and 
rapid. All patients with pulmonary emphy-
sema demonstrated decreased radioactivity 
after a single breath of ¹³³xenon in the region 
where perfusion was decreased. Prolonged 
rebreathing of ¹³³xenon was necessary to 
visualize these areas. During clearance, these 
same areas showed marked retention of 
radioactivity.

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Scintiphotographs of a patient with pulmonary embolism. Note the multiple areas of decreased radioactivity on the perfusion photograph particularly in the left lower and mid-lung field. In contrast, the single breath ventilation photograph shows uniform distribution of radioactivity, and the clearance photograph obtained 1 min after washout began shows uniform background only.

Scintiphotographs of a patient with pulmonary emphysema. The perfusion and single breath ventilation photographs show marked decrease in radioactivity in both bases. The clearance photograph obtained 4 min after beginning of washout shows marked retention of radioactivity in the same areas.

The correlation of lung scanning with macroaggregates with the perfusion scintiphotographs and the pulmonary arteriograms was good (fig. 4A and B).

**Discussion**

Lung scans with labelled macroaggregates of albumin have proved to be useful in the diagnosis of pulmonary emboli. In the presence of a normal chest roentgenogram, concave- or triangular-shaped defects at the periphery of the lung are strongly suggestive of pulmonary emboli. Such patterns are not specific for emboli, however, since patients with chronic obstructive pulmonary disease can show similar defects.

By adding ventilation studies to the perfusion scans, we have found distinct differences between patients with emboli and
Figure 4

(A) The macroaggregate scan shows a large perfusion defect at the right base and smaller defects at the left base in a patient with pulmonary embolism. The pulmonary arteriogram, which is reversed to correspond to the scan, shows complete occlusion (arrow) of the right lower lobe pulmonary artery and pruning of the left lower lobe arteries.

(B) The scintiphotographs show a large area of decreased radioactivity at the right base during perfusion similar to the defects shown in figure 4A. The ventilation photograph (single breath) shows uniform distribution of radioactivity.
those with obstructive lung disease. The scintiphotographs of patients with pulmonary emboli showed preserved ventilation in the areas of decreased perfusion, while patients with obstructive lung disease showed both decreased ventilation and perfusion in the affected areas.

Our patients with pulmonary emboli were studied 24 hours or more after the onset of symptoms, and the hypoperfused areas were well ventilated. Similar findings were reported by Bass and associates.7 Experimental work in dogs suggests that during the first 24 hours after acute embolization ventilation and perfusion are both decreased in the affected region; thereafter, ventilation returns while perfusion is still decreased. No studies of regional ventilation have been reported on human beings during the first 24 hours after embolization.

Our initial studies with 133xenon and the scintillation camera indicate that this technic will have considerable practical usefulness in the differential diagnosis of pulmonary emboli. The speed and resolution achieved permit performance of the entire study in only a few minutes, and it can be done on seriously ill patients. Where a scintillation camera is not available, lung areas showing abnormal perfusion on a macroaggregate scan can be evaluated for ventilation 24 hours later by means of 133xenon and small scintillation detectors.9

Although xenon injection, inhalation, and rebreathing were performed separately in our study, we now feel that the necessary information for the differential diagnosis of pulmonary emboli can be obtained from the intravenous injection alone.10 Scintiphotographs made during breath-holding after injection of 133Xe depict perfusion, and those made during clearance represent regional ventilation.

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References

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