Perfusion and Ventilation Scans in Patients with Extensive Obstructive Airway Disease: Utility of Single-Breath (Washin) Xenon-133

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The presence of extensive obstructive airway disease in many patients leads to an interpretation of intermediate or indeterminate probability for pulmonary emboli using ventilation/perfusion lung scans. We observed that patients with extensive obstructive airway disease having perfusion abnormalities matching those on a single-breath xenon image usually have a normal pulmonary angiogram. This study's objective was to further assess the utility of a single-breath image in evaluating patients with extensive obstructive airway disease and abnormal perfusion studies categorized as having intermediate or indeterminate probability of pulmonary embolism in an attempt to decrease the number of nondiagnostic studies. **Methods:** We studied retrospectively 33 patients with extensive obstructive airway disease, with abnormal perfusion scans and no infiltrates on chest x-ray categorized as having intermediate or indeterminate probability of pulmonary embolism. We established the presence or absence of matching ventilation and perfusion abnormalities by comparing perfusion scan and single-breath images. **Results:** Among 25 patients with perfusion abnormalities matching the initial ventilation pattern on single-breath images, only 1 (4%) had pulmonary emboli as documented by pulmonary angiogram. Four out of the remaining 8 patients with no matching perfusion and single-breath ventilation pattern had pulmonary emboli (50%). **Conclusion:** Patients categorized by ventilation/perfusion scintigraphy as having intermediate or indeterminate probability for pulmonary emboli due to the presence of extensive obstructive airway disease can be further subclassified using single-breath images. Patients with matching perfusion and single-breath ventilation pattern should be categorized as having low probability for pulmonary embolism, regardless of the extent of the ventilation abnormalities.

Key Words: pulmonary embolism; obstructive airway disease; ventilation; perfusion; scintigraphy

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Although a normal perfusion scan continues to exclude clinically significant pulmonary emboli with a high degree of certainty (*1–3*), abnormal perfusion scans are known to have low specificity (*4,5*). Many studies have substantiated the efficacy of ventilation imaging in increasing the specificity, with post-test predictive values approaching 90% in the high and low scan probability categories (*3,6,7*). Although ventilation imaging adds a significant degree of specificity to perfusion scanning (*8,9*), overall specificity of ventilation-to-perfusion (V/Q) scans continues to be a practical problem for the diagnosis of pulmonary embolism (*7*). The presence of focal or diffuse obstructive airway disease partly determines the probability for pulmonary embolism of a given scan with perfusion abnormalities.

The major sets of criteria for determining the probability of pulmonary embolism in V/Q scans (*2,7,10*) vary somewhat in categorizing perfusion abnormalities in the presence of severe obstructive airway disease. McNeil's (*10*) criteria indicated that V/Q matches suggest low probability with no further qualifications. Biello (*2*), on the other hand, included the perfusion defects seen in severe diffuse obstructive airway disease in the intermediate or indeterminate probability category. The PIOPED study categorized matching V/Q abnormalities as low probability if the ventilation abnormality involved less than 50% of lung fields. Perfusion abnormalities in the presence of obstructive airway disease involving more than 50% of lung fields were categorized as intermediate or indeterminate probability, although a recent revision of the interpretation criteria categorized extensive matched V/Q abnormalities as low probability regardless of their size. However, the method of establishing the matching pattern was not described (*11*).

Xenon-133 single-breath images offer a direct comparison to the perfusion images. Although it is important to evaluate the study of single-breath xenon inhalation, as well as washout patterns for the interpretation of V/Q scans (*12*), the customary way of judging obstructive airway disease when using ^{133}Xe ventilation studies depends mainly on the extent and degree of retention of the gas on washout images since they are more sensitive (*12*). If this is significant and involves more than 50% of the lung fields, the perfusion abnormalities, if present, are usually categorized as having an intermediate or indeterminate probability for pulmonary embolism.

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In our practice, we have observed that patients with perfusion defects matching abnormalities on a single-breath xenon study, in the presence of extensive obstructive airway disease involving more than 50% of the lung fields, usually have normal pulmonary angiography (*13*). Therefore this study's objective was to further assess the utility of single-breath ^{133}Xe ventilation images in evaluating patients with perfusion defects and extensive obstructive airway disease involving more than 50% of lung fields.

MATERIALS AND METHODS

All V/Q lung scans routinely performed in our institution for suspected pulmonary embolism between January 1988 and June 1992 were reviewed. During this period, 2203 scans were performed including 69 patients showing both significant obstructive airway disease involving more than 50% of lung fields and abnormal perfusion studies leading to an intermediate or indeterminate probability reading of V/Q scans. The extent of obstructive airway disease was determined subjectively by two qualified nuclear medicine physicians unaware of the results of pulmonary angiograms. Patients meeting the following criteria were selected for analysis:

1. Extensive obstructive airway disease involving more than 50% of lung fields as seen on ventilation washout images;
2. Perfusion defects seen on perfusion scans;
3. No infiltrates on a chest x-ray obtained within 24 hr of the perfusion scans; and
4. Pulmonary angiogram performed within 48 hr of the perfusion studies.

There were 33 patients fulfilling the above criteria. Ventilation studies were performed in the posterior projection using 10–20 mCi of ^{133}Xe and consisted of single-breath (washin), equilibrium and washout phases. The single-breath image was obtained immediately after the patient inhaled and retained the radioactive gas with a single deep breath. The equilibrium image was obtained after the patient rebreathed xenon in a closed system for 5 min. The washout images were obtained every 30 sec for 5 min upon opening the system to room air with the patient breathing normally. Perfusion imaging in these patients was obtained in eight views (posterior, anterior, laterals, posterior obliques and anterior obliques) after intravenous injection of approximately 3 mCi of ^{99m}Tc-macroaggregated albumin. Pulmonary angiography was performed with injection of nonionic contrast into the main pulmonary artery using a 7F pigtail catheter. Multiple film screen and/or digital subtraction images of both lungs were obtained. Pulmonary angiograms were read by a board-certified faculty radiologist.

The perfusion studies of these patients were compared to the pattern of ventilation on single-breath (washin) images. Patients were then divided into two sub-groups: those with perfusion abnormalities matching the ventilation defects on single-breath images, and those with perfusion abnormalities that were mismatched or showed mixed matching/mismatching patterns. The two groups were compared employing the chi-square test.

RESULTS

There were 19 females and 14 males among the 33 patients analyzed. Patients ranged in age from 22–79 yr. There were 26 patients with histories of smoking, 5 non-

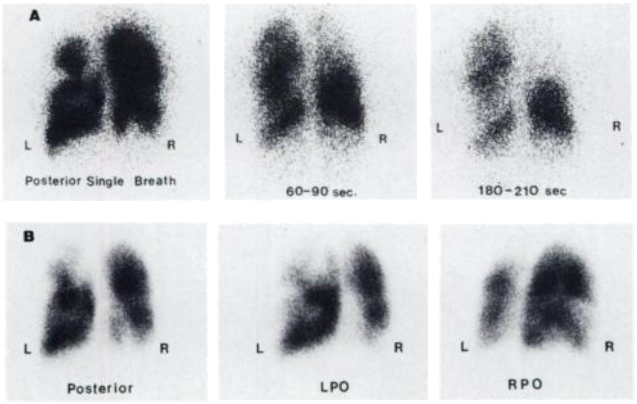

FIGURE 1. A 23-yr-old female nonsmoker on birth control pills, was referred for ventilation and perfusion scans because of sudden onset of shortness of breath. The chest x-ray showed no infiltrates. The washout images (A) reveal significant retention involving more than 50% of the lung fields. The washin ^{133}Xe image (A) shows defects matching the perfusion abnormalities seen on the posterior view (B). Pulmonary angiogram was negative for pulmonary emboli.

smokers and 2 with unknown smoking status. All 33 cases had retention of ^{133}Xe on washout images that involved more than 50% of combined lung fields as determined subjectively. All patients showed abnormal perfusion including nonsegmental, transsegmental, moderate subsegmental and/or segmental perfusion defects. Patients with only nonsegmental abnormalities or small subsegmental defects were not among the patient group analyzed as they were not included in the category of intermediate or indeterminate probability reading. There was no interobserver disagreement regarding classification of patients according to the criteria mentioned. Twenty-five of the 33 patients with diffuse obstructive airway disease fulfilling the four criteria noted above were found to have perfusion abnormalities matching the initial ventilation pattern on single-breath images and only 1 of these patients (4%) had pulmonary emboli documented by pulmonary angiogram. Figures 1 and 2 show examples from this group.

The remaining 8 patients had no matching perfusion-to-single-breath ventilation patterns. They showed a single-breath ventilation pattern that was at least partly mismatching the perfusion abnormalities (Table 1). Four of the 8 patients (50%) had positive pulmonary angiograms for pulmonary embolism. Figure 3 shows an example of a patient in this group. Among the 28 patients who had no pulmonary emboli, 10 showed one or more segmental defects matching single-breath abnormalities.

DISCUSSION

More than one-third of the V/Q scans for patients with suspected pulmonary emboli are categorized as intermediate probability (*14*). A V/Q scan showing an intermediate probability for pulmonary emboli does not usually assist the clinician in the diagnosis of pulmonary emboli but often provides post-test odds which require pulmonary angiography. Intermediate probability studies are the most fre-

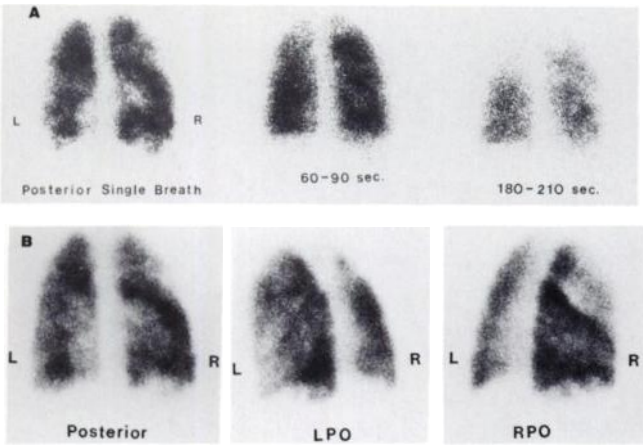

FIGURE 2. A 50-yr-old male referred for V/Q scan to rule out pulmonary emboli because of increasing shortness of breath. Chest x-ray showed no infiltrates. The ventilation study (A) reveals obstructive airway disease involving more than 50% of combined lung fields as seen particularly on the washout image of 180–210 sec. The single-breath image reveals multiple focal areas of decreased to absent ventilation in both lungs that match the areas of decreased to absent perfusion seen mainly on posterior view (B). Note that determining this matching pattern using washout images is difficult. Pulmonary angiography performed the same day was negative for pulmonary emboli.

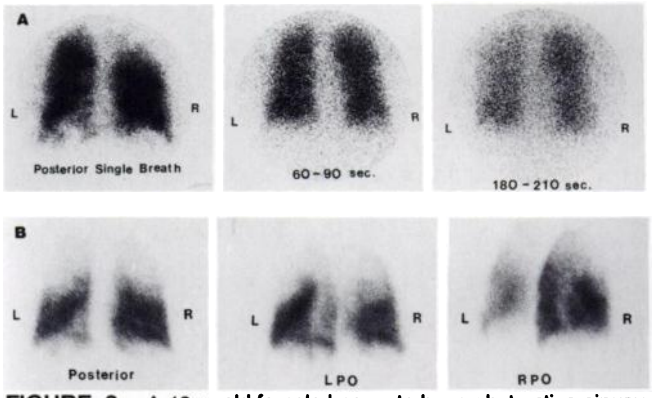

FIGURE 3. A 40-yr-old female known to have obstructive airway disease was referred for a V/Q scan to rule out pulmonary emboli after sudden worsening of shortness of breath. The patient had a history of smoking (30 pack-yr). Chest x-ray showed no infiltrates. The ventilation study (A) reveals significant retention of xenon in both lungs. The pattern of ventilation on single-breath image partly matches and partly mismatches the perfusion abnormalities on posterior projection of the perfusion study (B). On the other hand, washout images show diffuse retention of xenon involving areas with and without perfusion abnormalities. Pulmonary angiogram subsequently performed shows multiple pulmonary emboli.

quent cause for performing pulmonary angiography among all categories of V/Q scans (*15,16*). High and low probability scans help in the clinical management of this potentially fatal disease, particularly when the preclinical odds agree with the scan interpretation (*5,15*).

Over the years, several modifications of the major sets of diagnostic criteria have been made in an attempt to improve the sensitivity and specificity of V/Q lung scans. Decreasing the number of scans included in the category of intermediate probability should help decrease the number of scans that are not diagnostic for pulmonary emboli.

Although washout ventilation images are more sensitive than single-breath images in the evaluation of obstructive airway disease (*12*), single-breath images permit a more

TABLE 1
Summary of Patients with Nonmatching or Mixed Matching and Nonmatching Perfusion and Single-Breath Patterns

Patient no.	Age (yr)	Sex	Smoking history	Chest x-ray findings	Perfusion scan findings	Perfusion/single breath patterns	Pulmonary angiogram
1	65	Female	Yes	No OAD*	4 moderate subsegmental defects in both lungs	Mismatching	Positive
2	35	Male	Yes	No OAD	4 transsegmental and nonsegmental defects in both lungs	Mismatching	Negative
3	42	Female	Yes	OAD	8 moderate and large subsegmental defects in both lungs	Mixed	Negative
4	48	Male	Yes	No OAD	2 moderate subsegmental and 1 transsegmental defects in both lungs	Mismatching	Positive
5	54	Male	Yes	No OAD	2 transsegmental and 2 moderate subsegmental defects in both lungs	Mixed	Positive
6	79	Female	No	No OAD	3 moderate, one large and two nonsegmental defects in both lungs	Mixed	Negative
7	22	Female	No	No OAD	3 segmental defects in left lung (both lungs showed OAD)	Mixed	Negative
8	40	Female	Yes	No OAD	3 transsegmental defects in both lungs	Mixed	Positive

*Radiographic changes of obstructive airway disease (OAD).

direct comparison with the perfusion study. With severe obstructive airway disease, abnormalities present on the single-breath image are probably the most focal and severe, as little air can enter these areas. Perfusion abnormalities matching these areas are probably secondary to reflex vasoconstriction from this focal airway obstruction or from adjacent scarring. On the other hand, later washout images will show retention that is often more diffuse and widespread than the abnormal single-breath foci. Therefore it may be difficult to establish whether these abnormalities match the perfusion defects in this group of patients who have severe obstructive airway disease. Scans are often categorized as intermediate or indeterminate primarily by depending mainly on washout images for correlation.

Although we studied a highly selected group of patients with a scan pattern of intermediate or indeterminate probability who all had angiograms presumably because of high pretest clinical suspicion, our study indicates that not all abnormal perfusion scans with extensive obstructive airway disease seen on washout images should be categorized as having an intermediate probability for pulmonary embolism. A subgroup with a single-breath pattern matching the perfusion abnormalities and not associated with chest x-ray abnormalities showed a low prevalence of pulmonary emboli (4%) compared to the subgroup with the ventilation abnormalities not matching the perfusion scan pattern with a higher prevalence of pulmonary emboli (50%). The difference between prevalence of pulmonary emboli in the two groups was significant ($0.02 > p > 0.01$).

The authors do not suggest that the image of the lungs following a single breath of ^{133}Xe is as good as the complete ventilation study, which should continue to be used in the interpretation of V/Q scans. In general, it was reported that single-breath images may not be suitable as the sole determinant of the presence or absence of a matching ventilation and perfusion pattern in the diagnosis of pulmonary emboli (*12*). However, in patients with extensive obstructive airway disease, it can be difficult to establish the matching pattern primarily using washout images.

We have found that the single-breath image, even in the presence of severe obstructive airway disease, can establish the presence of a matching V/Q pattern which is more difficult to ascertain when washout images are mainly used. Our findings indicate that when single-breath images in patients with severe obstructive airway disease show the presence of a matching V/Q abnormality, this pattern indicates a low probability of pulmonary emboli (4% in our data) regardless of the pattern seen on washout images.

SUMMARY

Patients categorized by V/Q scintigraphy as having intermediate or indeterminate probability for pulmonary embolism due to the presence of diffuse obstructive airway disease can be further subclassified using single-breath images. Patients with perfusion abnormalities matching the ventilation pattern on single-breath xenon images should be categorized as having low probability for pulmonary embolism, regardless of the extent of the ventilation abnormalities.

REFERENCES

1. Kipper MS, Moser KM, Kortman KE, et al. Long term follow-up of patients with suspected pulmonary embolism and a normal lung scan. *Chest* 1982;82:411–415.
2. Biello DR. Radiological (scintigraphic) evaluation of patients with suspected pulmonary thromboembolism. *JAMA* 1987;257:3257–3259.
3. Kelley MA, Carson JL, Polensky HI, et al. Diagnosing pulmonary embolism: new facts and strategies. *Ann Intern Med* 1991;114:300–306.
4. Alderson PO, Martin EC. Pulmonary embolism: diagnosis with multiple imaging modalities. *Radiology* 1987;164:297–312.
5. Wellman HN. Pulmonary thromboembolism: current status report on the role of nuclear medicine. *Semin Nucl Med* 1986;16:236–274.
6. Palevski HI, Alan A. A noninvasive strategy for the management of patients suspected of pulmonary embolism. *Semin Nucl Med* 1991;21:315–331.
7. Alderson PO, Rujanavech N, Secker-Walker RH, et al. The role of ^{133}Xe ventilation studies in the scintigraphic detection of pulmonary embolism. *Radiology* 1976;120:633–640.
8. Alderson PO, Biello DR, Sachariah G, et al. Scintigraphic detection of pulmonary embolism in patients with obstructive pulmonary disease. *Radiology* 1981;138:661–666.
9. The PIOPED investigators. Value of the ventilation/perfusion scans in acute pulmonary embolism. Results of the prospective investigations of pulmonary embolism diagnosis (PIOPED). *JAMA* 1990;263:2753–2759.
10. McNeil BJ. Ventilation-pulmonary studies and the diagnosis of pulmonary embolism: concise communication. *J Nucl Med* 1980;21:319–323.
11. Gottschalk A, Sostman D, Coleman E, et al. Revised scintigraphic criteria for the interpretation of ventilation/perfusion scan for pulmonary embolism: observations based on the PIOPED data. *J Nucl Med* 1993;34:P17.
12. Alderson PO, Biello DR, Rhan AR, et al. Comparison of ^{133}Xe single-breath and washout imaging in the scintigraphic diagnosis of pulmonary embolism. *Radiology* 1980;137:481–486.
13. Elgazzar AH, Hughes JA. Perfusion and ventilation scans in patients with severe diffuse obstructive airway disease: utility of single breath ^{133}Xe [Abstract]. *J Nucl Med* 1992;33:1072.
14. Stein P, Coleman E, Gottschalk A, et al. Diagnostic utility of ventilation/perfusion lung scans in acute pulmonary embolism is not diminished by pre-existing cardiac or pulmonary disease. *Chest* 1991;100:604–606.
15. Frankel N, Coleman RE, Pryor DB, et al. Utilization of lung scans by clinicians. *J Nucl Med* 1986;27:366–369.
16. Biello DR, Mattar AG, Osei-Wusu A, et al. Interpretation of intermediate lung scintigrams. *Radiology* 1979;133:189–194.