Significance of Single Ventilation/Perfusion Mismatches in Krypton-81m/Technetium-99m Lung Scintigraphy

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The significance of a single area of ventilation/perfusion (V/P) mismatch in lung scans performed on patients suspected of pulmonary embolism (PE) was evaluated. Ten of 20 patients with this scan finding were found to have PE. An intermediate probability of PE was found with segmental (71%) or subsegmental (45%) single V/P mismatches. Seven of 16 patients with a single V/P mismatch and without a matching radiographic opacity had PE. Three of the four patients who had a V/P mismatch and a matching radiographic opacity were found to have PE. Multiview ventilation imaging with ^{81m}Kr was found to have advantages for the evaluation of single V/P mismatches. Based on the data available at this time, a single V/P mismatch suggests an intermediate probability of PE.

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Ventilation/perfusion (V/P) lung scans are widely used to study patients suspected of pulmonary embolism (PE), and have been found to be accurate when either xenon-133 (^{133}Xe) (*1–3*) or krypton-81m (^{81m}Kr) (*4,5*) is used for the ventilation phase of the study. V/P lung scans that demonstrate two or more areas of V/P mismatch have been found to indicate a high probability of PE (*3,6*). Considerable disagreement exists, however, with regard to the significance of a single area of segmental or subsegmental mismatch. One study reported that the presence of a single segmental area of V/P mismatch indicates a high probability of PE (*3*); another reported that it indicates a low probability (*7*); and still another reported that it indicates an intermediate probability (*6*). V/P lung scans demonstrating a single subsegmental area of mismatch with angiographic correlation have been reported less frequently, though one study (*3*) suggested an intermediate probability of PE in such cases. The uncertainty with regard to the significance of a single segmental or subsegmental mismatch is largely the result of the small number of reported cases with angiographic correlation.

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We have been performing V/P lung scans using ^{81m}Kr as the ventilation agent. The short half-life (13 sec) of ^{81m}Kr and the consequently low radiation dose to the patient allow us to obtain ventilation images in as many projections as needed. This enables us to identify areas of V/P match or mismatch in all regions of the lungs. In a previous study (*5*) with ^{81m}Kr, we reported a high sensitivity and specificity for those scans reported as high and low probability for pulmonary embolism, and we reported our experience with a limited number of cases demonstrating a single area of V/P mismatch. Since then our experience with the subgroup of patients demonstrating a single area of V/P mismatch has increased. The current study reports the results of this experience.

MATERIALS AND METHODS

The study included patients from both Columbia-Presbyterian Medical Center (CPMC), New York City, and Norwalk Hospital (NH), Norwalk, CT. Twenty patients (CPMC:n = 16, NH: n = 4) met the criteria for inclusion in the study. Ten were men and ten were women, and the ages of the patients ranged from 27 to 79 yr (mean = 60). All patients included in this study had chest radiography within 24 hr and pulmonary angiography within 72 hr (15/20 within 24 hr) of

the lung scan. Patients were selected for pulmonary angiography by the referring physicians. The 20 patients with single V/P mismatches represented 19.8% of all patients having pulmonary angiography following V/P lung scintigraphy during the period of the study (CPMC:43 mo, NH:29 mo). The 20 patients with single V/P mismatches included those with normal radiographs with or without other matching V/P abnormalities, those with a matching radiographic opacity, and those with a radiography opacity in a different region of the lungs than that in which the V/P mismatch was located.

The perfusion studies included either six or eight views and were obtained with 37 photomultiplier tube cameras. At CPMC, either a low-energy, all-purpose, parallel-hole collimator or a low-energy diverging collimator were used. At NH a low-energy, all-purpose, parallel-hole collimator was used. At CPMC, patients were injected with 3–4 mCi of [^{99m}Tc]macroaggregated albumin. At NH, patients were injected with the same dose of [^{99m}Tc]human albumin microspheres. Each perfusion view contained 500,000 counts at CPMC, and 400,000 counts at NH.

At both institutions, one collimator was used for both the ventilation and perfusion images. At CPMC, 100,000 to 200,00 counts were collected for each ventilation view; 400,000 at NH. The ventilation studies consisted of six to eight views in most cases. The patient was *not moved* between the perfusion and ventilation images in each position, in order to allow optimal comparison of regional ventilation and perfusion.

The pulmonary arteriograms were performed similarly at the two institutions. A selective injection of contrast agent was made into the artery supplying the region that had demonstrated the mismatched perfusion defect on the lung scan. If emboli were found, the study was terminated. If no emboli were found at that site, further selective injections were made until emboli were found or until all abnormal regions on the scan had been evaluated. An intraluminal defect had to be identified for an angiogram to be interpreted as positive.

All studies were reviewed retrospectively by an experienced nuclear medicine physician without knowledge of the results of pulmonary angiography. Perfusion defects were categorized as segmental or subsegmental as reported by Biello et al. (*3*). Defects larger than 75% of a bronchopulmonary segment were considered segmental in size. Defects that were between 25 and 75% of a bronchopulmonary segment were reported as subsegmental in size. Defects that did not correspond to pulmonary segmental anatomy and appeared to cross pulmonary segments were reported as regional. The location of the mismatch was also categorized as follows: anterior mismatches included those located in the upper lobes (except for the posterior segment), the middle lobe or lingula, and the anterior basal segment of the lower lobes. Posterior mismatches included those located in the lower lobes (except for the anterior basal segment) and the posterior segment of the upper lobes.

RESULTS

Pulmonary angiographic correlation was available for 20 patients whose V/P lung scans demonstrated a single area of V/P mismatch. As shown in Table 1, 50% were found to have PE; five of seven with a single segmental mismatch, five of 11 with a single subsegmental mismatch, and neither of the two with a single regional defect.

Patients were divided into three groups: (a) those whose chest radiographs were normal (Fig. 1); (b) those whose chest radiographs were clear in the location of the V/P mismatch seen on lung scintigraphy but had a radiographic opacity (with a V/P match) in a different region; and (c) those with a radiographic opacity at the location of the V/P mismatch (Fig. 2). PE was found in seven of the 16 patients who had a single mismatch without a radiographic opacity in the same region (Table 1). Three of five such patients with a single segmental mismatch had PE, as did four of ten patients with a single subsegmental mismatch. One patient with a single regional mismatch did not have PE. Since emboli can sometimes present with a radiographic opacity and a matching V/P abnormality, we

TABLE 1
Frequency of PE in Patients with Single V/P Mismatch*

Defect appearance	Normal radiograph	Radiographic opacity in different region	Radiographic opacity in same region	Total
Segmental	1/3	2/2	2/2	5/7 (71%)
Subsegmental	2/6	2/4	1/1	5/11 (45%)
Regional	—	0/1	0/1	0/2 (0%)
Total	3/9	4/7	3/4	10/20 (50%)

* Patients with PE/number of patients in subgroup.

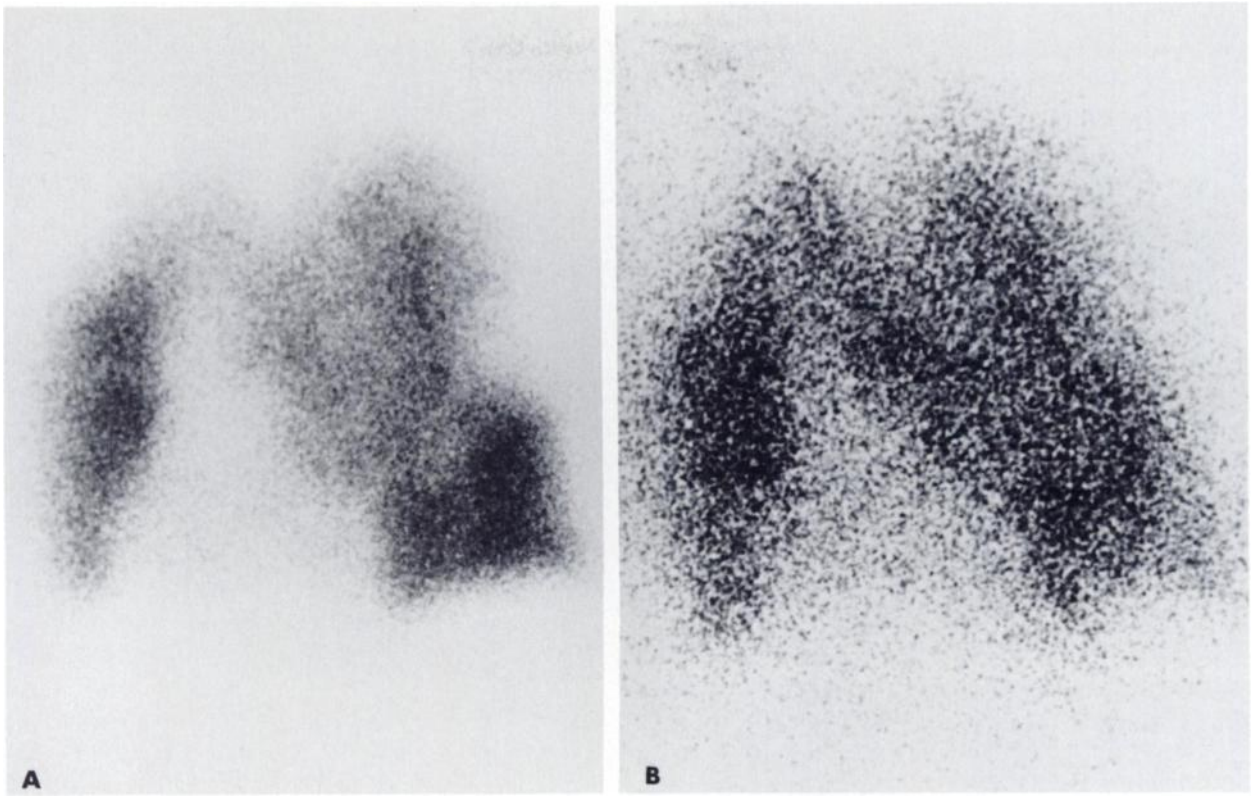

FIGURE 1
Left anterior oblique perfusion (A) and ventilation (B) images demonstrate single V/P mismatch. Chest radiograph was normal

sought to determine if the presence of those findings in addition to a single V/P mismatch elsewhere indicated a higher likelihood of PE than did the finding of a single mismatch alone. As shown in Table 1, there was no significant difference in the frequency of PE in these two subgroups.

While the presence of a radiographic opacity is most commonly associated with a V/P match on lung scan, four patients were found to have a single area of V/P mismatch in an area of the lung with a radiographic opacity of comparable size. Three of four such patients were found to have PE. The one patient without PE had a mismatch that was characterized as regional.

The studies of patients who had entirely clear lung fields on chest radiography were reviewed to determine how many had areas of V/P matching in addition to their single area of V/P mismatch. This was done in order to determine if the presence of V/P matches suggesting obstructive lung disease altered the probability of these patients having PE. Six patients were found to have additional areas of V/P match, and one was found to have PE. Two of the three patients without other areas of V/P matching (i.e., a solitary V/P mismatch) had PE.

A further review of the overall population of patients with a single V/P mismatch was performed to determine the frequency with which the mismatch was found in different locations. This information was sought as an indirect measure of the ability of multiview ^{81m}Kr ventilation scanning to evaluate the question of single mismatches relative to that of ^{133}Xe scanning which is most commonly performed posteriorly. The area of the V/P mismatch was found in the lower lobes in 11 patients, the middle lobe or lingula in six, and the upper lobes in three. The areas of mismatch were further characterized as anterior (upper lobes except posterior segment + middle lobe + lingula + anterior basal segment) or posterior (lower lobes except anterior basal + posterior segment of upper lobes.) Twelve of the 20 patients had an anterior mismatch and eight demonstrated a posterior mismatch.

The scans were also reviewed to determine the number of views on which the single mismatch could be seen and to determine which view demonstrated the abnormality best. In 19 of the 20 cases the mismatch was seen on more than one view (three or more views in ten cases). The single mismatch was most often seen best on the posterior oblique views (ten cases). In only three cases was the abnormality seen best on the posterior view.

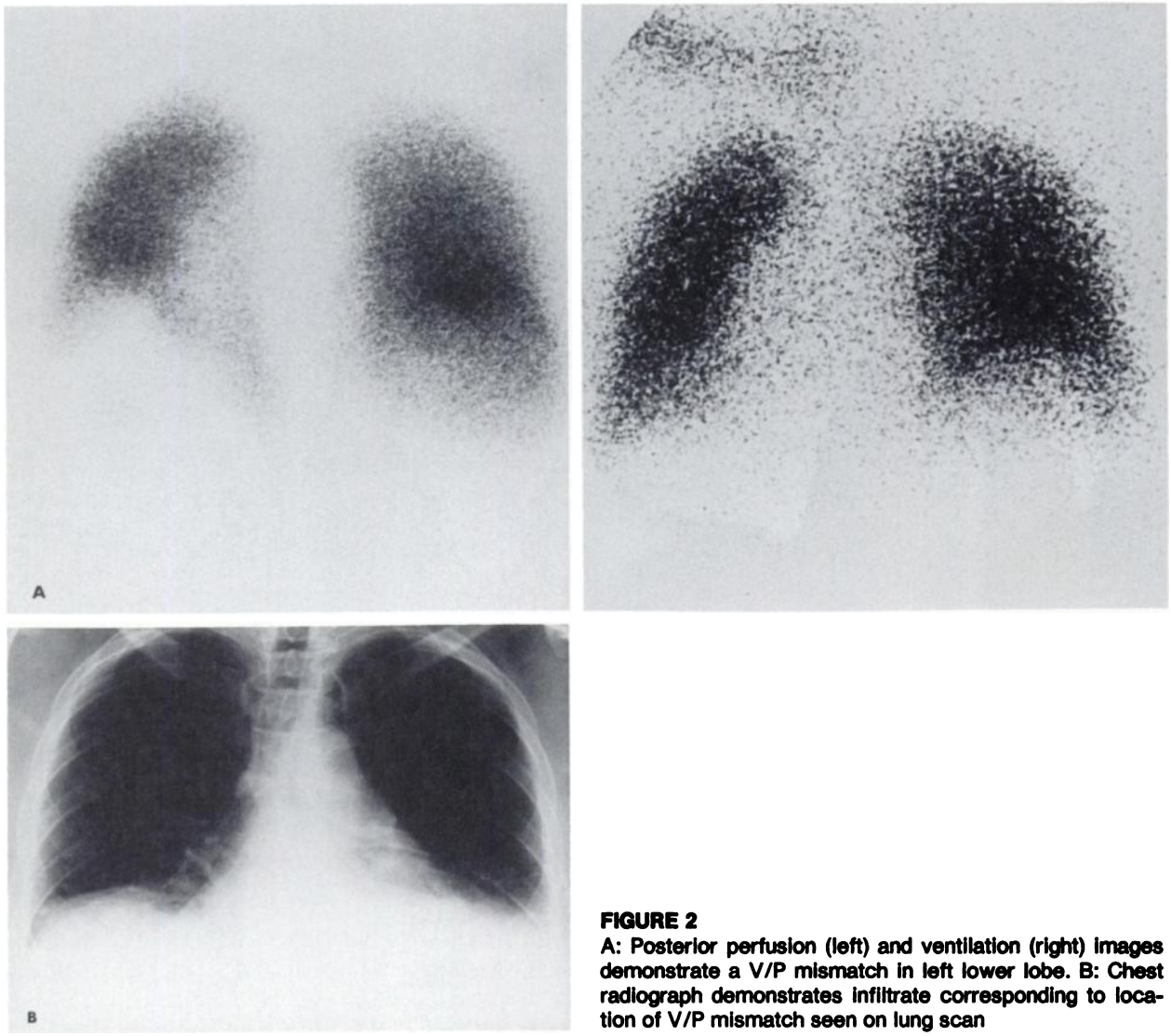

FIGURE 2
A: Posterior perfusion (left) and ventilation (right) images demonstrate a V/P mismatch in left lower lobe. B: Chest radiograph demonstrates infiltrate corresponding to location of V/P mismatch seen on lung scan

DISCUSSION

Different opinions about the significance of a single area of V/P mismatch have appeared in the literature. Biello et al. (*3*) considered a single segmental area of V/P mismatch as an indication of a high probability of PE and considered a single subsegmental mismatch to indicate an intermediate probability of PE. They did not report how many of their high probability scans demonstrated a single segmental mismatch. They did report, however, that one of three patients with a single subsegmental mismatch was found to have PE. McNeil (*7*) reported four patients with a single segmental mismatch and none had PE. Alderson et al. (*2*) found that one of three patients with a single segmental mismatch (in addition to other areas of V/P match) had PE. We previously reported our experience with a limited number of patients with single V/P mismatches and angiographic confirmation (*5*); two of six patients with a subsegmental mismatch had PE. Only two patients had scans demonstrating a single segmental mismatch, and both had PE. In our current study, we found that seven of 16 patients with a single mismatch without matching radiographic opacity had PE, which represents an intermediate probability of PE. An intermediate probability of PE was found with both segmental and subsegmental single V/P mismatches in the current study. Thus, we recommend an indeterminate report for scans demonstrating a single mismatch, whether it is segmental or subsegmental.

Scans demonstrating a V/P mismatch in an area that also demonstrates a radiographic opacity are encountered less frequently. Strauss et al. (*8*) recently reported the angiographic findings in six such cases, and found that all six patients had PE. Therefore, they suggested that a V/P mismatch in association with a radiographic opacity indicated PE. In our study, three of four such patients were found to have PE. This brings the published total to ten such cases, with nine of the ten patients having PE. The one patient with a negative

pulmonary arteriogram was one whose lung scan demonstrated a regional mismatch. This might suggest that scans demonstrating a segmental or subsegmental mismatch in association with a radiographic opacity be considered as high probability for PE. However, we also encountered one patient whose scan demonstrated a multisegmental area of V/P mismatch in association with a radiographic opacity. This patient's pulmonary arteriogram was negative for emboli. Since the number of arteriographically confirmed cases of a single V/P mismatch in association with a radiographic opacity still is small, we do not yet report these cases as high probability of PE. As more experience is accumulated, it may be possible to recategorize such cases.

Alderson et al. (*6*) established that the presence of matching ventilation and perfusion abnormalities, such as those seen with obstructive pulmonary disease, did not preclude a high probability for PE diagnosis from V/P scintigraphy. There were six patients in the current study whose single mismatch was associated with V/P matches elsewhere in the lung and a normal radiograph. Only one of these patients was found to have PE while two of three patients without areas of V/P matching had PE. It is possible that a single V/P mismatch in a scan demonstrating co-existent obstructive pulmonary disease has a somewhat lower probability of PE than such a mismatch in a patient with otherwise normal-appearing lungs. However, the experience with cases in this category is still too small to allow us to recommend removal from the intermediate probability category.

Due to the invasive nature of pulmonary angiography, and the associated risks, clinical considerations are taken into account by the referring physicians when selecting patients with indeterminate lung scans for angiographic correlation. This may introduce some bias into the results of any study correlating lung scan results with pulmonary angiography, probably increasing the observed probability of PE in patients with a single V/P mismatch.

Most of the earlier reports on ventilation/perfusion imaging deal with ventilation studies were performed with ^{133}Xe. Xenon-133 ventilation studies are usually performed in a single projection (most often posterior) or in limited projections. In contrast, ^{81m}Kr ventilation studies are performed in many projections and might, therfore, be expected to have an advantage in evaluating anteriorly located abnormalities. A review of our cases demonstrated that the abnormality was frequently located anteriorly (12 of 20 cases). Furthermore, oblique views, especially posterior oblique views, were more frequently the best view for evaluating the abnormality than were posterior views. This suggests an advantage for ^{81m}Kr multiview imaging in evaluating single V/P mismatches.

The differences in opinion about the significance of single V/P mismatches in the literature have, in part, been due to the difficulty in accumulating enough experience with angiographically proven cases. Based on the larger experience reported in this study, our data suggest that all patients with scans demonstrating a single V/P mismatch, including scans demonstrating segmental and subsegmental abnormalities, should be classified as having an intermediate level of probability of PE. Additional data on certain subgroups, when available, may allow certain patterns to be reclassified into categories with more firm diagnostic implications.

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