Single Perfusion Defect and Pulmonary Embolism: Angiographic Correlation

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One hundred and thirty-three ventilation-perfusion scans (V-P) with angiographic correlation were retrospectively reviewed to evaluate the frequency of pulmonary emboli (PE) in single perfusion defects (SPD), regardless of ventilation or radiographic findings. By angiography, 15 of 30 SPD cases had PE. Demographic data and clinical presentation were similar for PE and non-PE patients. However, 9 out of 15 patients with PE had recent surgery compared to none of the non-PE patients. SPD were seen in areas of ventilation and chest x-ray abnormalities in 12 of 15 PE and 11 of 19 non-PE cases. Size of the actual lesion was underestimated by scintigraphy in most cases. In 7 of 15 PE cases, the perfusion defect was larger than the corresponding ventilation abnormality. Most SPD were located at the bases. Twelve of 15 SPD in the PE group were at the posterior basilar segment. In the appropriate clinical setting, SPD carries at least a moderate probability for PE. When the clinical suspicion is high, a pulmonary angiography will be needed to confirm the diagnosis.

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The interpretation of single perfusion defects (SPD) in the evaluation of pulmonary embolism (PE) remains controversial. Solitary defects have been assigned low (*1*), and intermediate probabilities (*2*, *3*) or have been considered indeterminate (*4*, *5*) for PE. Biello (*6*) included solitary large perfusion defects (75% of a segment or larger), unmatched by ventilation or chest x-ray abnormalities, in the high probability group. In the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) trial study, SPD were placed in the low probability group (*7*, *8*).

To gain insight on the nature of SPD, we reviewed ventilation-perfusion studies (V-P) with SPD that had a pulmonary angiogram. We studied the scintigraphic patterns, radiological findings and clinical presentation, to determine whether there are unique characteristics that allow the identification of patients with PE.

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MATERIALS AND METHODS

Of 2,283 lung scans performed from 1981 to 1987, 135 patients had pulmonary angiography within 72 hr of the scan. These cases were retrospectively reviewed without knowledge of the angiographic or clinical findings. The scans were initially read according to criteria summarized in Table 1, as high, moderate and low probabilities, or as indeterminate. These criteria are largely based on those advanced by Neumann et al. (*9*). In the moderate probability group we included segmental defects that are partially matched by chest x-ray findings with normal ventilation. The indeterminate reading is reserved for those cases where extensive lung disease precludes an appropriate diagnosis. In the low probability group we include single and multiple subsegmental defects that are matched by ventilation and chest x-ray abnormalities. When there are less than two subsegments and a normal ventilation and chest x-ray, the study is also considered low probability.

The scans were then reread for this retrospective evaluation without knowledge of clinical or angiographic results, this time identifying SPD as an additional category (Table 2). We define SPD as a solitary, peripheral perfusion defect, apparently no more than one segment in size, regardless of ventilation and chest x-ray findings.

TABLE 1
Scintigraphic and Radiographic Patterns and Corresponding Probability Estimate

Probability	Scintigraphic patterns*
High	P: 2 or more segments or segmental equivalents
	CXR: Negative
	V: Normal
Moderate	P: Less than 2 segments or more than 1.5 segmental equivalents
	CXR: No matching or partially matching abnormalities
	V: Normal
Low	P: Single or multiple subsegments
	CXR: Normal or matching abnormalities
	V: Matching abnormalities
Indeterminate	Extensive lung disease: perfusion, ventilation, and chest x-ray abnormalities

* P = perfusion; V = ventilation; and CXR = chest x-ray.

TABLE 2
Interpretation of Lung Scans and Presence of PE

Probability	PE/Total	(%)
High	10/10	(100)
Moderate	19/26	(73)
SPD	15/30	(50)
Low	7/36	(19)
Indeterminate	4/31	(13)
Normal	0/2	(0)
Total	55/135	(41)

Subsequently, the scans were correlated with radiological and clinical findings. The size and location of the perfusion abnormalities were compared to ventilation and chest x-ray findings.

The lung scans were performed with a large field of view gamma camera. The ventilation study was performed in the posterior projection, using 15–20 mCi (555–740 MBq) of xenon-133 administered as a single bolus. A 15-sec single-breath image, obtained following a deep inspiration, was followed by an equilibrium image at 3 min, and by six 30-sec wash-out images.

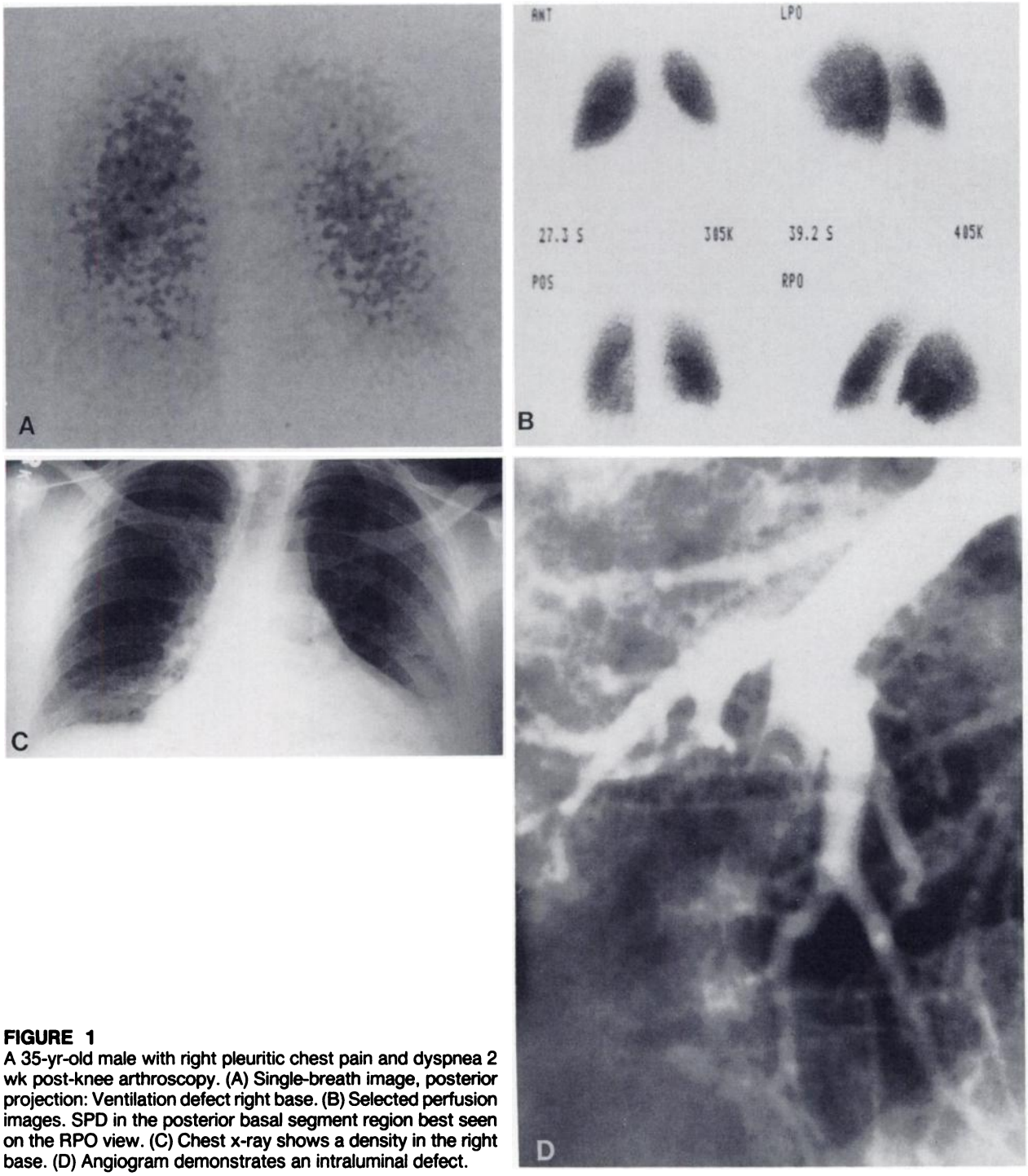

FIGURE 1
A 35-yr-old male with right pleuritic chest pain and dyspnea 2 wk post-knee arthroscopy. (A) Single-breath image, posterior projection: Ventilation defect right base. (B) Selected perfusion images. SPD in the posterior basal segment region best seen on the RPO view. (C) Chest x-ray shows a density in the right base. (D) Angiogram demonstrates an intraluminal defect.

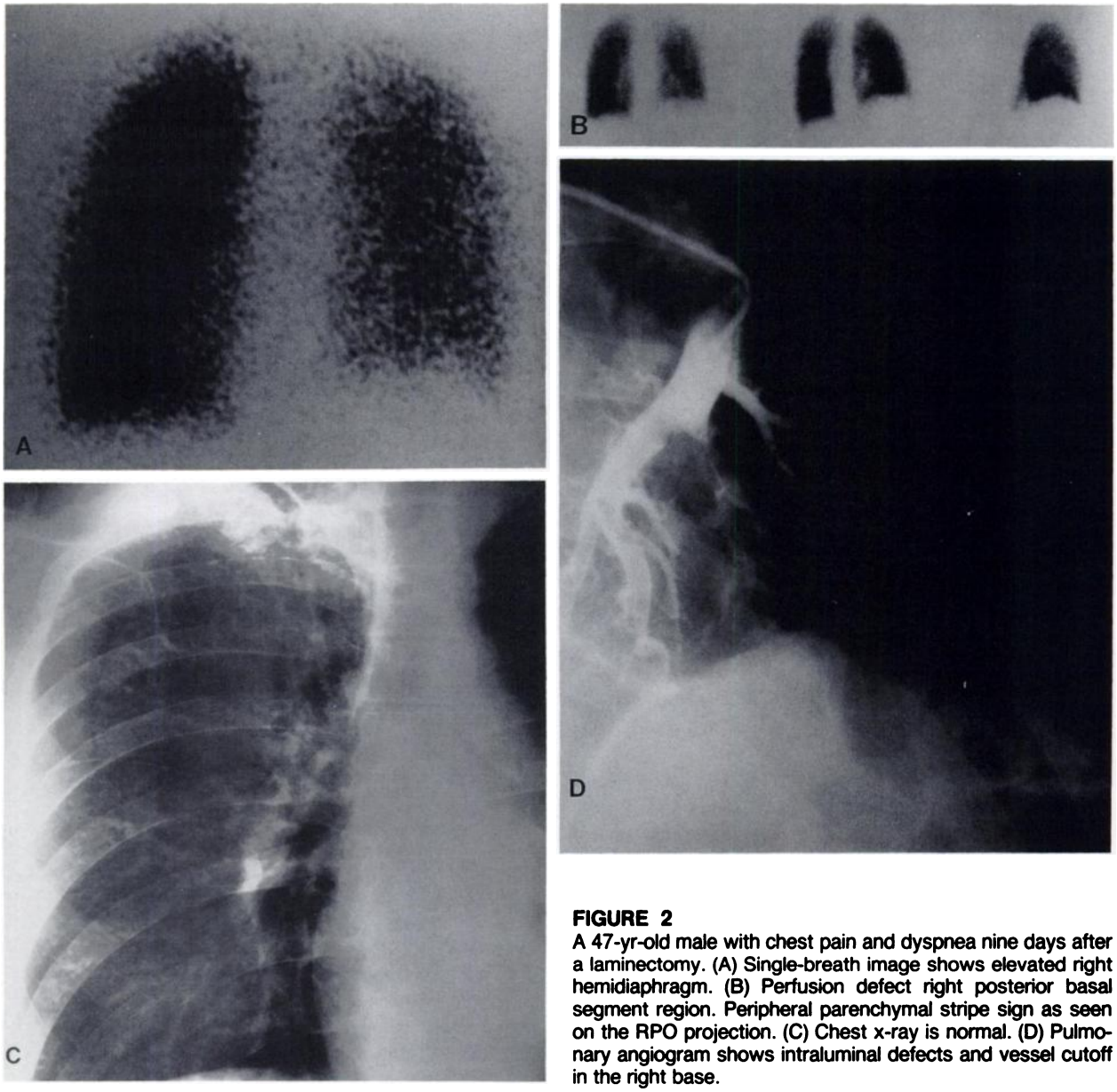

FIGURE 2
A 47-yr-old male with chest pain and dyspnea nine days after a laminectomy. (A) Single-breath image shows elevated right hemidiaphragm. (B) Perfusion defect right posterior basal segment region. Peripheral parenchymal stripe sign as seen on the RPO projection. (C) Chest x-ray is normal. (D) Pulmonary angiogram shows intraluminal defects and vessel cutoff in the right base.

Eight-view, perfusion lung scans were performed with 4 mCi (148 MBq) of ^{99m}Tc-macroaggregated albumin (MAA). The patients were injected lying supine and scanned upright when possible. In 28 patients, a chest x-ray was obtained within 4 hr of the lung scan. In two cases the chest x-rays were obtained within 12 hr.

Selective pulmonary angiography was performed within 24 hr in 27 cases, and within 72 hr in three cases (one of these three patients had PE). In all cases the angiographer was aware of the scintigraphic findings, therefore the abnormal area was always properly explored. Selective injections of lobar vessels was performed, followed by oblique projections and magnification images. The study was terminated when unequivocal demonstration of PE was achieved. The demonstration of an intraluminal defect or of vessel cutoff was taken as evidence of PE. The inferior vena cava was visually inspected in all patients following a hand injection of contrast. Angiographic inferior vena cava evaluation was performed in 7 patients (5 with PE).

RESULTS

Of the 135 patients studied by angiography, 55 had PE (40.7%). There were 30 SPD cases in this study (22%), and PE was demonstrated in 15 SPD cases (50%) (Table 2). In contrast, PE was present in only 7 of the 36 patients in the low probability group (19%). The illustrations show examples of the scintigraphic findings (Figs. 1 and 2).

Demographic data and the most frequent clinical findings for all SPD cases are shown in Table 3. The only significant finding was prior history of a surgical procedure (few days to 12 wk before the study) in nine

TABLE 3
Demographic and Clinical Data of 30 SPD Cases with (15) and without (15) PE

	PE	No PE
Age (Years)	48 ± 13	57 ± 19
Range (Age)	29–70	22–86
Male:Female	9:6	7:8
Chest pain	11	11
Dyspnea	6	5
Hemoptysis	4	3
Fever	3	3
Cough	2	1
Pleural Effusion	2	2
Atelectasis	9	11
Malignancy	2	1
Prior Surgery	9	0

patients with PE. This factor was not present in the non-PE group.

Tables 4–6 compare the size and congruence of perfusion, ventilation and chest x-ray findings for patients with and without PE. Seven of nine patients with perfusion defects larger than their ventilation defects had PE, while PE was found in only eight of 20 patients with a perfusion defect equal to or smaller than the ventilation abnormality. In five patients there was a perfusion-chest x-ray mismatch. Two of these five patients had PE.

Three of five patients with defects larger than radiographic abnormality had PE, while PE was present in 10 of 20 patients whose perfusion defects were equal to or smaller than the x-ray density. Twelve out of 15 patients with PE and 11 of 14 patients without PE had a matched perfusion, ventilation and chest x-ray abnormality.

Table 7 compares the size of perfusion defects of patients with and without PE. Only one patient with PE had a defect that was small in size (25% or less of a segment), compared to six patients in the non-PE group.

The distribution of the perfusion defects in the 30 patients showed a predilection for the pulmonary bases. In the PE group, 14 of 15 defects involved the bases and one the right middle lobe. Twelve of the 14 were localized in the right posterior basilar segment region. In the group without PE, 13 of 15 were in the bases, one in the right upper lobe and one in the right middle lobe. Of the 13 lower lobe lesions, five were on the right.

TABLE 5
Comparison of Size of Perfusion (P), Chest X-Ray (CXR) Abnormalities in 30 SPD Cases

	PE	No PE
Normal CXR	2	3
P > CXR	3	2
P = CXR	3	6
P < CXR	7	4

DISCUSSION

Single perfusion defects are not specifically mentioned in some classifications, leaving interpretation to individual judgment. Biello et al. (*6*) considered single, large segmental defects with normal ventilation and negative chest x-ray as high probability, reserving the intermediate category for single defects of moderate size without corresponding ventilation and chest x-ray abnormalities. Others placed SPD in the low (*1*) or intermediate (*2, 3*) probability groups. In the PIOPED trial, solitary perfusion abnormalities were considered low probability for PE, an assumption that should be reviewed based on the available published evidence of higher incidence of PE in this group.

A review of 94 SPD cases in the literature, summarized in Table 8, shows that solitary perfusion abnormalities are associated with PE in 47% of the cases. PE was demonstrated in 40% of unmatched perfusion defects but in only 15% of matched perfusion-ventilation defects with normal chest x-rays. In contrast, 10 of 11 (91%) SPD with normal ventilation and abnormal chest x-ray had PE. Interestingly, PE was present in 56% of solitary SPD matched by ventilation and chest x-ray. This group is particularly important since it is the most likely to be considered in the low probability range. Strauss et al. (*10*) reported 50% incidence of PE in ten cases where the defect was matched by ventilation and

TABLE 4
Comparison of Size of Perfusion (P) and Ventilation (V) Abnormalities in 29 SPD Cases*

	PE	No PE
Normal V	2	1
P > V	5	1
P = V	6	9
P < V	2	3

* One case not included because of suboptimal ventilation scan in the region of the perfusion defect.

TABLE 6
Perfusion (P), Ventilation (V), Chest X-Ray (CXR) Abnormalities in 29 SPD Cases*

	PE	No PE
P	1	1
P, V	1	2
P, CXR	1	0
P, V, CXR	12	11

* One case not included because of suboptimal ventilation scan in the region of the perfusion defect.

TABLE 7
Comparison of SPD Size in Patients With and Without PE*

	PE	No PE
Small	1	6
Moderate	5	5
Large	9	4

* Small SPD ≤ 25% of a segment; moderate SPD 25%–75% of a segment; large SPD > 75% of a segment.

chest x-ray. Cavaluzzi et al. (*11*) reported PE in three out of 10 cases of unilateral V-P defects matched by chest x-ray. However, this latter paper gives few details regarding size, appearance or location of the perfusion abnormalities, and therefore their results are excluded from Table 8.

Our study was not limited to mismatched V-P defects, nor to large abnormalities involving more than one segment. We define SPD as being apparently no more than a segment, irrespective of ventilation and chest x-ray findings. Large perfusion abnormalities (75% or more than a segment) were seen in 60% of patients with PE and in 27% of patients without PE, while defects that were ~50% of a segment were seen with identical frequency in both groups.

The comparison of the perfusion defect size with the size of radiological abnormality may be misleading, especially when the SPD is located at the bases where size can be underestimated. In effect, only 5 of 15 PE cases had a perfusion defect larger than the x-ray abnormality. The difficulty in determining the size of basilar perfusion abnormalities results from the mobility of the diaphragm and the common coexistence (60% of our cases) of basilar atelectasis which effectively reduces the regional lung volumes and conceals the diaphragmatic edge of the defect. Furthermore, local topographic changes allow adjacent, better perfused lung parenchyma to overlap and obscure the defect.

Comparison of perfusion with ventilation findings showed that PE was present in 78% of perfusion defects that were unmatched or larger than ventilation defects.

In our patients with PE, the right posterior basilar segment was the most frequently afflicted, probably the result of preferential blood flow to dependent lung regions increasing the likelihood that emboli would lodge in these areas. The preferential right lower lobe location of pulmonary infarcts has been observed in autopsy studies (*12*).

The limitations of retrospective studies are well known. In our case, the analysis was centered on a group of patients that required a pulmonary angiogram to resolve a diagnostic dilemma unanswered by clinical, scintigraphic or radiographic evaluation. This selection of patients can explain the higher incidence of PE in the low probability group. It may also explain the apparent disproportionate number of SPD cases (22%) in the 135 patients that underwent angiography, compared with an SPD incidence of only 6% in 325 consecutive lung scans performed in our institution. The only clinical factor peculiar to SPD patients that have PE, as opposed to those with negative angiograms, was a previous surgical procedure.

Since size cannot be accurately estimated, particularly for SPD located at the pulmonary bases, it should not be used as an exclusive criteria for comparison with chest x-ray, unless there is a large size discrepancy. A history of recent surgical procedure increases the probability for PE. Many of the SPD cases however, will require a pulmonary angiogram to confirm the diagnosis.

We conclude that SPD should be interpreted as a special scintigraphic presentation of PE, where simple probability estimates may not be applicable. A SPD larger than 25% of a segment, should be classified as a moderate probability for PE. For large (75% of a segment) SPD with normal ventilation, irrespective of chest x-ray findings, the likelihood of PE is even higher. Matched single V-P defects with normal chest x-ray have a low probability of PE.

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TABLE 8
Pulmonary Emboli in Single Perfusion Defects

	P	P, V	P, CXR	P, V, CXR	Total
Biello et al. (Reference *6*)	1/10	1/10	—	—	2/20
Rosen et al. (Reference *3*)	7/16	—	3/4	—	10/20
Spies et al. (Reference *2*)	6/9	—	—	—	6/9
Strauss et al. (Reference *10*)	—	—	6/6	5/10	11/16
Catania, Caride 1988	1/2	1/3	1/1	12/23	15/29
Total	15/37	2/13	10/11	17/33	44/94
Percent	40	15	91	56	47

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