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Matched Ventilation, Perfusion and Chest Radiographic Abnormalities in Acute Pulmonary Embolism

Alexander Gottschalk, Paul D. Stein, Jerald W. Henry and Bruce Relyea
Michigan State University, East Lansing, Michigan and Henry Ford Heart and Vascular Institute, Detroit, Michigan

This investigation assessed the positive predictive value of matched ventilation/perfusion (V/Q) and chest radiographic defects (triple-matched defects) for the detection of acute pulmonary embolism (PE). **Methods:** Data are from the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED). Only patients randomized for obligatory pulmonary angiography were included. Lungs were excluded if they showed any mismatched V/Q defect or any pleural effusion. **Results:** Positive predictive values of triple-matched defects in the upper plus middle zones, 1 of 27 (4%), were less frequent than in the lower zones, 13 of 57 (23%) ($p < 0.05$). Triple-matched defects that involved 25–50% of a zone showed PE in 12 of 38 (32%) which was a higher positive predictive value than with smaller or larger triple-matched defects, 2 of 46 (4%) ($p < 0.001$). **Conclusion:** Refinement of the PIOPED data by elimination of nonrandomized patients, elimination of lungs with mismatched perfusion defects and elimination of lungs with a pleural effusion indicate that triple matches with PE (radiographic pulmonary infarcts) are infrequent in the upper and middle lung zones. When a triple match with PE occurs, it is most likely to be 25–50% of a zone.

Key Words: pulmonary embolism; thromboembolism; pulmonary scintiscans; ventilaton/perfusion lung scans

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The finding of a matched ventilation/perfusion (V/Q) defect with associated matching chest radiographic opacity (the triple match) has been reported to be an intermediate (indeterminate) finding, with a positive predictive value for acute pulmonary

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For correspondence or reprints contact: Alexander Gottschalk, MD, Michigan State University, B220 Clin. Science Bldg., East Lansing, MI 48224.

embolism (PE) of 26% (*1*). This was similar to the positive predictive value for PE of a perfusion defect which matched the chest radiograph, 27% (*2*). The triple match can be caused by pulmonary embolism creating a pulmonary infarction (usually pulmonary hemorrhage) but other etiologies are more common (*1*). Worsley et al. (*1*) showed that PE was present more frequently with triple matches in the lower zones of the lung as compared with the upper or middle zones. They indicated that matching V/Q defects and chest radiographic opacities isolated to the upper and middle zones represent a low probability of PE, whereas triple-matched defects in the lower zone represent an intermediate probability for PE (*1*).

This investigation further explores the diagnostic value of triple-matched defects by using a refined subset of patients from the collaborative study, Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) (*3*).

METHODS

Data are from patients who participated in PIOPED (*3*). Only patients in arm of PIOPED who consented for randomization to obligatory pulmonary angiography as described in the original PIOPED report (*3*) were included in this investigation.

A triple-matched defect was defined as a radiographic opacity accompanied by a defect on the perfusion lung scan and a defect on the ventilation lung scan that were both equal in size to the radiographic opacity. This determination was made directly from the V/Q scan description which had been entered into the PIOPED data base.

The size of triple-matched defects was graded in PIOPED as <25% of a zone, 25–50% of a zone, 51–75% of a zone and >75% of a zone. In PIOPED, a zone of the lung was defined as the upper, middle or lower third of the lung, divided in the cranial-caudal direction without regard to lung volume (*4*). Although experienced readers of radionuclide lung scans often underestimate the size of segmental defects (*5*), there is no evidence that there is a comparable difficulty in estimating the fraction of a zone of a lung that shows a defect. Assessments were made by two experienced V/Q scan readers who agreed on the size of the defects for the PIOPED data base. Interobserver variability of these observations was not assessed in PIOPED.

To maximize the database, we evaluated individual zones of single lungs. Any lung with a moderate size or large mismatched segmental perfusion defect (any mismatch ≥25% of a segment) was excluded. Mismatched perfusion defects are associated with at least an intermediate probability for PE (*6,7*). Lungs of patients were also excluded if they showed a pleural effusion. Perfusion defects associated with a small pleural effusion that caused blunting of the costophrenic angle were associated with PE in over 20% of patients (*8*).

Each lung studied in this analysis was evaluated by pulmonary angiography. A PE was defined as being present in the zone of the triple-matched defect if the pulmonary artery or its branches in the corresponding lobe showed PE. For example, if a triple-matched defect was in the right upper zone, the right upper lobe artery or its branches must have shown PE to qualify as a right upper zone triple-matched defect with PE. The methods employed for obtaining and interpreting pulmonary angiograms and V/Q scans were described previously (*3*).

We previously showed that stratification according to prior cardiopulmonary disease improves the V/Q assessment in some circumstances (*6*). Therefore, patients in this analysis were included only if they had a known history of the presence or absence of prior cardiopulmonary disease. Patients were categorized as having no prior cardiac disease if, according to the PIOPED clinical physician, they had no history or evidence of valvular heart disease, coronary artery disease, "other heart disease," and no history of left- or right-side heart failure prior to the episode of suspected acute pulmonary embolism. Patients were categorized as having no prior pulmonary disease if they had no history of asthma, chronic obstructive pulmonary disease, interstitial lung disease, "other lung disease" and no recognized acute pneumonia or acute respiratory distress syndrome at the time of evaluation for the suspected PE, and no history of a prior PE.

TABLE 1
Positive Predictive Value of Triple-Matched Defects According to Lung Zone

	Gottschalk* PE/No. of zones (%)	Worsley† PE/No. of zones (%)
Upper zone	0/13 (0)	4/36 (11)
Middle zone	1/14 (7)	6/52 (12)
Lower zone	13/57 (23)‡	61/187 (33)§
Total	14/84 (17)	71/275 (26)

*Data from Gottschalk et al. (*4*).
†Data from Worsley et al. (*1*).
‡$p < 0.05$ Upper + middle zone versus lower zone.
§$p < 0.005$ Upper zone versus lower zone; middle zone versus lower zone.

Statistical Methods

Positive predictive value was defined as the frequency of PE with triple-matched defects. A chi square test was used to compare various positive predictive values. The 95% confidence intervals were determined on the basis of the exact binomial distribution.

RESULTS

The following results are from 66 patients among whom 70 lungs had 84 zones with triple-matched defects. The pulmonary diagnoses in 25 patients with triple-matched defects who did not have PE were pneumonia (n = 11), pulmonary carcinoma (n = 5), pulmonary fibrosis (n = 2), atelectasis (n = 2), chronic obstructive pulmonary disease (n = 2), tuberculosis (n = 1), pulmonary eosinophilia (n = 1) and heart failure (n = 1). In 29 patients who did not have PE, the cause of the triple match was not indicated in the computerized data.

Positive Predictive Value of Triple-Matched Defects According to Zone

The positive predictive value for PE of all triple-matched defects was 14 of 84 (17%) (95% CI 9–26%). Pulmonary embolism was infrequent in the upper or middle zones (Table 1). The positive predictive value in the lower zone, 13 of 57 (23%) (95% CI 13–36%), was higher than in the upper plus middle zones 1 of 27 (4%) (95% CI 0–19%) ($p < 0.05$) (Table 1).

Positive Predictive Value of Triple-Matched Defects According to Size

Triple-matched defects that involved 25–50% of a zone showed a positive predictive value for PE of 12 of 38 (32%) (95% CI 18–49%) (Table 2). Triple-matched defects of 25–50% of a zone showed a higher positive predictive value than defects smaller than 25% of a zone, 2 of 23 (9%) ($p < 0.05$). Triple-matched defects of 25–50% of a zone also showed a higher positive predictive value than defects larger than 50% of a zone, 0 of 23 (0%) ($p < 0.01$).

Stratification According to Prior Cardiopulmonary Disease

Stratification according to prior cardiopulmonary disease showed a comparable positive predictive value for PE of

TABLE 2
Positive Predictive Value of Triple-Matched Defects According to Size

Size of triple-match (% of zone)	Gottschalk* PE/No. of zones (%)	Worsley† PE/No. of zones (%)
<25	2/23 (9)	23/86 (27)
25–50	12/38 (32)‡	34/125 (27)
51–75	0/11 (0)	8/36 (22)
>75	0/12 (0)	6/28 (21)

*Data from Gottschalk et al. (*4*).
†Data from Worsley et al. (*1*).
‡$p < 0.05$, 25%–50% versus <25%; 25%–50% versus 51%–75%; 25%–50% versus >75%.

triple-matched defects in the lower zones of patients with prior cardiopulmonary disease and patients without prior cardiopulmonary disease 8 of 37 (22%) versus 5 of 20 (25%) (NS). The positive predictive value for PE was also comparable in the upper plus middle zones, 0 of 19 (0%) versus 1 of 8 (13%) (NS).

DISCUSSION

Triple-matched defects in the same lung as mismatched perfusion defects were not excluded by Worsley et al. (*1*). In PIOPED, the angiographic data identified only the lobar artery that showed thromboemboli. The location of the branch to particular segments was not identified. Therefore, it was not always possible to determine if a PE shown on the pulmonary angiogram caused the triple-matched defect if mismatched defects were not excluded. For example, if a PE were in the apical segmental branch of the lower lobe artery, it could cause a mismatched perfusion defect in the middle zone. If a triple-matched defect occurred in the lower zone of the same lung and was not caused by PE, this nonembolic triple-matched defect would erroneously be attributed to PE because the lower lobe artery showed PE. In our study, lungs with mismatched perfusion defects were excluded, as well as lungs with pleural effusions. It was reasonable to assume, therefore, that any PE shown on the pulmonary angiogram was the cause of the triple-matched defect. We believe, therefore, that triple-matched defects in our data relate to the PE found on the pulmonary angiogram.

Our data, in general, support the observations of Worsley et al. (*1*). We observed, as did they, that triple-matched defects in the lower zone should be assessed as intermediate probability (indeterminate probability) for PE. We also observed, as they observed, that PE is uncommon with triple-matched defects in the upper or middle zones. A trend in our data suggested that triple-matched defects in the upper zone or middle zone satisfy the criteria for a very low probability interpretation [<10% positive predictive value (*8*)], rather than low probability [10–19% positive predictive value (*9*)].

In contrast to Worsley et al. (*1*), we showed that the size of the triple-matched defect relates to the positive predictive value for PE. Pulmonary embolism was more frequent in patients with triple matches that involved 25–50% of a zone than either larger or smaller triple-matched defects. Triple-matched defects that involved <25% of a zone tended to represent a linear opacity, whereas triple-matched defects >50% tended to be large areas of consolidation. The 25–50% of a zone category usually represents a segmental appearance.

CONCLUSION

Refinement of the PIOPED data by elimination of nonrandomized patients, elimination of lungs with mismatched perfusion defects and elimination of lungs with a pleural effusion indicates that PE with triple-matched defects (radiographic pulmonary infarcts) is infrequent in the upper and middle zones of the lung, but PE commonly occurs with such defects in the lower zone. When a triple-matched defect results from PE, it is most likely to be 25–50% of a zone (1 to 2 segments).

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