Abnormalities on Ventilation/Perfusion Lung Scans Induced by Bronchoalveolar Lavage

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Studies were performed before and at varying times after lavage in 10 normal volunteers to assess whether bronchoalveolar lavage results in significant abnormalities on ventilation/perfusion lung scans and chest x-rays. Abnormal lung scans were obtained in six subjects, interpretable as intermediate (three scans), low (one scan) and very low (two scans) probability for pulmonary emboli. Defects varied from multisegmental to subsegmental in size, while chest x-rays were normal in all but one. Both the extent and frequency of defects tended to decrease with time; 24 hr after bronchoalveolar lavage only one of four subjects had a minimally abnormal scan. It is recommended that ventilation/perfusion lung scanning be delayed at least 24 hr following bronchoalveolar lavage to avoid problems in interpretation of defects which may merely be the result of the lavage.

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Bronchoscopy with bronchoalveolar lavage (BAL) has become a common diagnostic procedure in the evaluation of patients with a wide variety of pulmonary problems (*1*). Likewise, ventilation/perfusion (V/Q) lung scanning is routinely used when the question of pulmonary embolism arises. In certain clinical situations, the need to perform both procedures in close temporal proximity occurs, particularly in seriously ill and immunocompromised patients. When BAL precedes the V/Q scan, however, abnormalities caused by the lavage may interfere with proper interpretation of the scan. BAL performed for diagnostic purposes is known to cause transient hypoxemia (*2*) and temporary, localized radiographic infiltrates (*3*). Changes on radionuclide V/Q scans, however, have been poorly documented. In an effort to better define the impact of BAL on the V/Q scan, 10 normal subjects were studied. V/Q scans and chest x-rays were obtained both before and after the performance of bronchoscopy with BAL. This study was approved by an NIH committee on human research.

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METHODS

Ten normal volunteer subjects (six males, four females) were studied. The group ranged in age from 20 to 58 yr (mean = 29 yr) and were screened for evidence of cardiopulmonary disease. All were without history of significant medical problems including asthma, pneumonia, or pulmonary emboli, and only one reported having smoked in the remote past. All had normal baseline chest x-rays.

The time between pre- and post-BAL scans ranged from 1 to 3 days. V/Q scans were performed 1–2 days before and at the following time intervals after BAL: 5 hr (two subjects), 15–16 hr (four subjects) and 24 hr (four subjects). Chest x-rays were obtained immediately following the second V/Q scan in nine subjects. One subject failed to report for a follow-up chest x-ray.

Ventilation scans were performed using 15 mCi of ^{133}Xe. For the initial and follow-up perfusion studies, 2 mCi and 4 mCi of ^{99m}Tc-MAA were used, respectively. A lower dose was used for the initial study to minimize radiation exposure and to avoid any possibility of residual activity appearing on the follow-up scan, which was occasionally performed as early as 24 hr later. A minimum of 200,000 particles MAA was used for all perfusion studies.

Imaging was performed with a scintillation camera following our standard protocol for pulmonary embolism. Single breath, equilibrium and 1-min washout images were obtained posteriorly. After injection with ^{99m}Tc-MAA, a six-view perfusion study was obtained. Studies were interpreted according to PIOPED criteria for probability of pulmonary embolism (Table 1) (*4*).

Subjects underwent bronchoscopy and BAL as previously described (*5*). In brief, subjects were monitored by digital oximetry and by electrocardiography. After local anesthesia with topical lidocaine, a 4.9-mm adult pentax bronchoscope was introduced transnasally or transorally. The lateral basal segmental bronchus of the right lower lobe (RLL) was identified and the bronchoscope was wedged into it. BAL was performed with the instillation of 6 aliquots (30 ml each) of sterile normal saline. Fluid was aspirated under negative pressure into mucus traps after each instillation. Overall, approximately 50% of the instilled volume was recoverable.

RESULTS

Bronchoscopy with BAL was well tolerated by all subjects and no episodes of hypoxemia occurred. Several

TABLE 1
PIOPED Criteria for V/Q Scans*

High probability
≥2 large segmental (>75% of a segment) perfusion defects without corresponding ventilation or x-ray abnormalities or substantially larger than matching ventilation or chest x-ray abnormalities
≥2 moderate segmental (≥25% and ≤75% of a segment) perfusion defects without matching ventilation or chest x-ray abnormalities and 1 large mismatched segmental defect
≥4 moderate segmental perfusion defects without ventilation or chest x-ray abnormalities
Intermediate probability (indeterminate)
Not falling into other categories
Borderline high or low
Difficult to categorize as low or high
Low probability
Nonsegmental perfusion defects
Single moderate mismatched segmental perfusion defect with normal chest x-ray
Any perfusion defect with a substantially larger chest x-ray abnormality
Large or moderate segmental perfusion defects involving ≤4 segments in 1 lung and ≤3 segments in 1 lung region with matching or larger ventilation defects and chest x-ray either normal or with abnormalities substantially smaller than perfusion defects
>3 small (<25% of a segment) segmental perfusion defects with a normal chest x-ray
Very low probability
≤3 small segmental perfusion defects with a normal chest x-ray
Normal
No perfusion defects
Perfusion exactly outlines the shape of the lungs as seen on the chest x-ray

*Adapted from Ref. 4

subjects experienced a transient, mild cough following the procedure. There were no reports of post-BAL fever.

Baseline chest x-rays were normal in all subjects. Eight had normal baseline V/Q scans. Two subjects had minor abnormalities which were not suggestive of pulmonary embolism and which remained unchanged on follow-up. These consisted of a slightly heterogenous perfusion pattern in both cases. Additionally, one subject (#10) had minimal ^{133}Xe retention in the apices associated with mild decreased perfusion of the right apex. A history of smoking in the distant past (>10 yr) was elicited in this patient, and subsequent pulmonary function tests revealed no evidence of significant restrictive or obstructive lung disease. Abnormal perfusion scans in normal subjects have been reported previously (*6*), and in neither of our cases did preexisting abnormalities impair assessment for BAL-induced findings, or affect scan interpretation with respect to probability of pulmonary embolism.

The results and timing of follow-up V/Q scans and chest x-rays are included in Table 2. Following BAL, new abnormalities appeared in the lavaged lung field in six of the 10 subjects, while a new chest x-ray infiltrate was found in only one. Ventilatory defects were best appreciated on washout images, but were also evident during the single-breath and equilibrium phases in patients with sizable abnormalities. Two subjects were studied 5 hr after BAL and both developed significant new V/Q defects on scintigraphy which were not confined to the lavaged right lateral basal segment. In the first patient (#1), matched ventilation and perfusion defects involved three segments of the RLL and corresponded roughly in size to new infiltrates seen radiographically (Fig. 1). This study was interpreted as intermediate probability for pulmonary embolism. In Patient 2, matched abnormalities also involved three segments of the RLL while the chest x-ray remained clear, resulting in classification as a low probability scan. This subject was also noted to have early, minimal retention of ^{133}Xe in the left medial lung and mild increased prominence of both hila on his post-BAL scan. The cause of these latter findings is unclear.

Of the four subjects studied 15–16 hr after BAL, three demonstrated new defects in the RLL. Ventilatory defects were greater than, less than and equal in size to the perfusion defects in one case each. Perfusion abnormalities in these subjects ranged from small subsegmental (<25%) to multiple segmental areas of decreased or absent activity despite normal chest x-rays in all patients. Patient 3 was most impressive with matching decreased ventilation and absent perfusion involving almost the entire RLL (Fig. 2). This study was interpreted as having intermediate probability for pulmonary embolism. Of the three other follow-up scans in this group, one each was interpreted as intermediate probability, very low probability and normal for pulmonary embolism.

Four subjects were studied 24 hr after BAL. Three had normal follow-up V/Q scans and chest x-rays. The remaining subject had a new, small, subsegmental perfusion defect in the right lateral basal segment which was normal on ventilation and chest x-ray. This was scored as a very low probability scan.

TABLE 2
Patient Data

Patient case no.	Age/sex	BAL-VQ2* (hr)	V/Q-1 pre-BAL	CXR-1	V/Q-2 post-BAL	CXR-2	V2:Q2† (size)	PIOPED
1	52/F	5	V: NL Q: NL	NL	V: retention R base + mid-lung Q: decr. R LB, AB, + SU (m)	Infiltrate = Q	V = Q	I
2	27/M	5	V: NL Q: NL	NL	V: retention RLL + L medial lung Q: absent R LB, AB (m) decr. PB; prominent hila	NL	V = Q	L
3	23/M	15	V: NL Q: NL	NL	V: retention RLL Q: absent R LB, AB, PB (m), SU (m)	NL	V = Q	I
4	20/F	16	V: NL Q: NL	NL	V: retention RLL Q: decr. R LB (s)	—	V > Q	VL
5	26/M	16	V: NL Q: NL	NL	V: min. retention R base Q: decr. R LB	NL	V < Q	I
6	24/M	16	V: NL Q: NL	NL	V: NL Q: NL	NL	—	NL
7	42/F	24	V: NL Q: hetero	NL	V: NL Q: No change	NL	—	NL
8	20/M	24	V: NL Q: NL	NL	V: NL Q: NL	NL	—	NL
9	26/M	24	V: NL Q: NL	NL	V: NL Q: NL	NL	—	NL
10	58/F	24	V: apical retention Q: hetero; decr. R apex	NL	V: No change Q: decr. R LB (s); no change elsewhere	NL	V < Q	VL

*Time between BAL + V/Q2
†Relative sizes of V/Q defects.
Abbreviations: hetero = diffuse heterogeneity; LL = lower lobe; LB = lateral basal segment; AB = anterior basal segment; PB = posterior basal segment; SU = superior segment of lower lobe; (m) = moderate size, ≥25 and ≤75% segment; (s) = small <25% segment; I = intermediate probability; L = low probability; and VL = very low probability.

DISCUSSION

Scintigraphic and radiographic studies in animals (*7*) and patients (*8,9*) undergoing lobar lavage with relatively large volumes of fluid have previously demonstrated changes in oxygenation, ventilation and perfusion. Lavage leads to decreased ventilation as alveoli become filled with fluid, and decreased perfusion is likely caused by increased hydrostatic pressure within alveoli (*10*) and physiologic shunting of pulmonary blood flow away from regional hypoxia (*8,11*). Francoz et al. (*7*) performed serial V/Q scans and chest x-rays in dogs following lobar lavage with 1850 ml of saline. After initial early decreases in both ventilation and perfusion in the lavaged lobe, follow-up studies showed rapid improvement with 80% of scans returning to normal by 6–8 hr. Likewise, localized chest x-ray infiltrates resolved completely in 56% or were markedly decreased in 44% of dogs after 4–10 hr. These authors concluded that the majority of lavage-induced changes on V/Q scans and chest x-rays should resolve within 6 hr.

In a study of the effects of diagnostic BAL using small volumes of lavage fluid, Brach et al. (*2*) found that V/Q scans performed 10–15 min after BAL showed either no change or improvement over baseline (presumably due to removal of mucus and other secretions as occurs in therapeutic lavage of patients with alveolar proteinosis (*8,9*)) in 15 of 16 patients. Only one patient developed new abnormalities. This patient had been lavaged with 250 ml of saline as opposed to the 30–50 ml used in the others. In current clinical practice, 100–200 ml is the usual volume used for diagnostic BAL (*12*).

In contrast to these studies, the results reported here demonstrate that diagnostic BAL using relatively small amounts of lavage fluid results in V/Q scan abnormalities that are more extensive and more frequent than previously reported, occurring in 60% of the normal volunteers studied. Subjects studied early after BAL tended to have more extensive defects compared to those studied at 24 hr. Major multisegmental changes were seen as late as 15–16 hr after lavage. In addition, despite the fact that lavage was limited to a single segment of the RLL, scintigraphic abnormalities frequently involved adjacent lung segments as well, probably due to spillage into neighboring segmental bronchi during BAL or redistribution of residual lavage fluid after the procedure. Abnormal findings in the con-

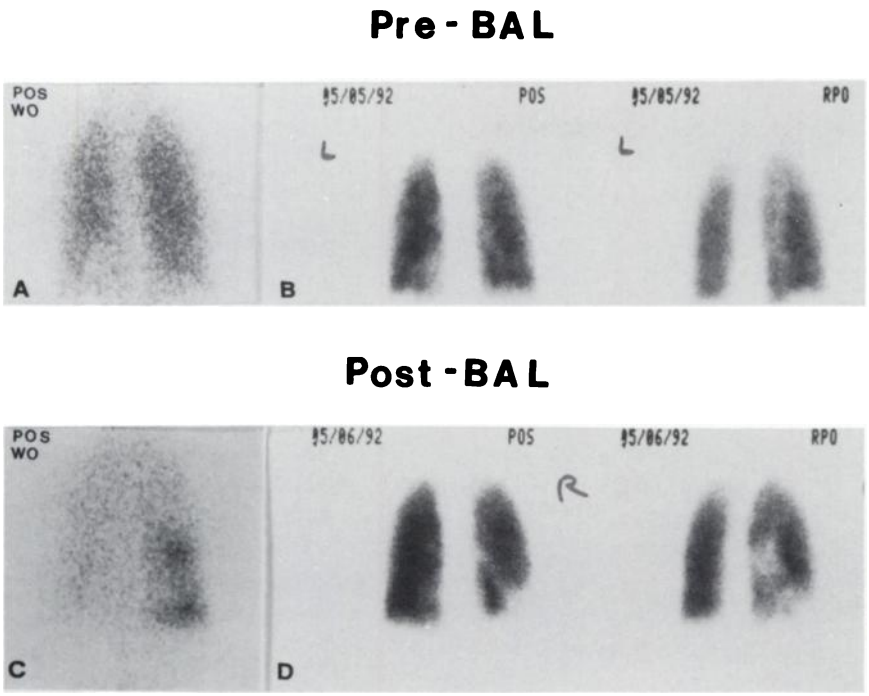

FIGURE 1. Patient 1. Paired ventilation and perfusion images obtained pre- and 5 hr post-BAL. Abnormalities appearing after BAL involve multiple segments of the RLL. The chest x-ray showed matching infiltrates. Posterior washout ventilation images (A and C); posterior and right posterior oblique perfusion images (B and D).

tralateral lung were not seen, with the exception of the changes noted in Patient #2.

In the six subjects with BAL-induced V/Q scan abnormalities, defects in perfusion were greater than ventilation in two patients, equal in three patients and smaller in one patient. More importantly, under different clinical circumstances, these scans would have been interpreted as intermediate probability for pulmonary emboli in three patients, low in one patient, and very low in two patients using PIOPED criteria. Thus, interpretation of V/Q scans can be seriously confounded if performed after BAL, so one should wait at least 24 hr after BAL before a V/Q study is performed. If performed sooner than 24 hr after BAL, caution must be used in interpreting defects seen in the lavaged region. In addition, chest x-rays cannot be used to determine when post-BAL scans can be safely performed, as they are often normal despite the presence of major scintigraphic defects. Ideally, when the need for both V/Q scanning and BAL arises in a patient, scintigraphy should be performed first.

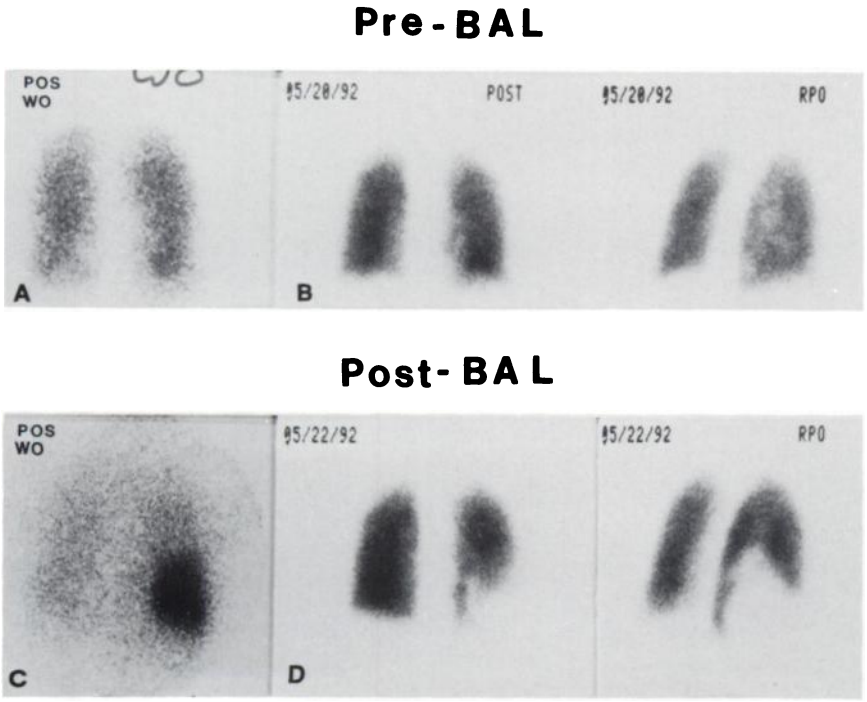

FIGURE 2. Patient 3. Paired ventilation and perfusion images obtained pre- and 15 hr post-BAL. Marked abnormalities after BAL involve multiple segments of the RLL. The chest x-ray was normal. Posterior washout ventilation images (A and C); posterior and right posterior oblique perfusion images (B and D).

REFERENCES

1. Goldstein RA, Rohatgi PK, Bergofsky EH, Block ER. Clinical role of bronchoalveolar lavage in adults with pulmonary disease. *Am Rev Respir Dis* 1990;142:481–486.
2. Brach BB, Escano GG, Harrell JH, Moser KM. Ventilation-perfusion alterations induced by fiberoptic bronchoscopy. *Chest* 1976;69:335–337.
3. Pereira W, Kovnat DM, Khan MA, Iocovino JR, Spivack ML, Snider GL. Fever and pneumonia after flexible fiberoptic bronchoscopy. *Am Rev Respir Dis* 1975;112:59–64.
4. Pioped Investigators. Value of the ventilation/perfusion scan in acute pulmonary embolism: results of the prospective investigation of pulmonary embolism diagnosis (PIOPED). *JAMA* 1990;263:2753–2759.
5. Ognibene FP, Shelhamer J, Gill V, et al. The diagnosis of pneumocystis carinii pneumonia in patients with the acquired immunodeficiency syndrome using subsegmental bronchoalveolar lavage. *Am Rev Respir Dis* 1984;129:929–932.
6. Tetalman MR, Hoffer PB, Heck LL, Kunzmann A, Gottschalk A. Perfusion lung scan in normal volunteers. *Radiology* 1973;106:593–594.
7. Francoz RA, Konopka R, Sgroi V, Moser KM. Changes in ventilation and perfusion in anesthetized dogs following lobar lavage with saline solution. *Chest* 1978;74:552–558.
8. Brach BB, Harrell JH, Moser KM. Alveolar proteinosis. Lobar lavage by fiberoptic bronchoscopic technique. *Chest* 1976;69:224–227.
9. Ramirez RJ, Kieffer RF Jr., Ball WC Jr. Bronchopulmonary lavage in man. *Ann Intern Med* 1965;63:819–828.
10. Rogers RM, Szidon JP, Shelburne J, et al. Hemodynamic response of the pulmonary circulation to bronchopulmonary lavage in man. *N Engl J Med* 1972;286:1230–1233.
11. Hughes JMB. Lung gas tensions and active regulation of ventilation/perfusion ratios in health and disease. *Br J Dis Chest* 1975;69:153–170.
12. Levine SJ, Stover DE. Bronchoscopy and related techniques. In: Shelhamer J, Pizzo PA, Parrillo JE, Masur H, eds. *Respiratory disease in the immunocompromised host, first edition*. Philadelphia: J.B. Lippincott Co; 1991:73.