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A M E R I C A N C O L L E G E O F



P H Y S I C I A N S[®]

Radiologic Diagnosis of Ventilator-Associated Pneumonia*

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Abbreviations: IMV = intermittent mechanical ventilation; VAP = ventilator-associated pneumonia

Despite the pivotal role of abnormal chest radiographic findings in alerting clinicians to the possibility of ventilator-associated pneumonia (VAP), the accuracy of radiographic interpretation has received little research interest. Autopsy and clinical data have documented many other causes of abnormal findings, adversely affecting specificity.^{8,18,83}

In addition, sensitivity may be overestimated. Studies of *Pneumocystis carinii* pneumonia in immunocompromised hosts with normal findings on radiographs have demonstrated evidence of infection. No study has investigated the possibility that this situation may occur in patients with VAP. A concomitant presence of other major clinical characteristics of pneumonia (*ie*, fever, leukocytosis, and purulent secretions) can occur in patients without radiographic changes, and the condition is often diagnosed as purulent tracheobronchitis. The autopsy study of Rouby et al⁸⁴ suggests that this may be a valid entity. Whether these cases represent pneumonia with a false-negative chest radiographic interpretation has not been studied.

The reviewed studies attempt to distinguish between a variety of disorders that mimic pneumonia in overall clinical impression, specific radiographic signs, or both. Only six studies were available for analysis (Tables 5-6).^{8-10,39,41,85}

PERFORMANCE CHARACTERISTICS

Patient Selection

All radiographic studies retrospectively identified patients for study. All but one included consecutive cases meeting case definitions.

Three studies compared the diagnosis based on radiographs to the findings at autopsy. The other three studies were in patients thought to have VAP. The latter studies induce an *a priori* selection bias, since they did not include patients whose abnormal findings on chest radiographs were thought not to be due to VAP. Autopsy studies are compromised by the fact that patients are not identified prospectively at the clinical decision time for treating VAP. In one autopsy study, the selection of chest radiographs for interpretation was based on an arbitrary time prior to death. The other two studies did not describe the selection process. Radiographs chosen from times other than when VAP is clinically suspected may not show the same findings as those chosen from the time of diagnosis. The

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radiographic appearance of the patient at the time of initial suspicion of VAP may subsequently be altered by antibiotic treatment, fluid management, and changes in ventilator therapy.

One study was limited to patients with ARDS. Two studies included patients who received ventilator assistance for < 48 h, and, therefore did not meet the definition of VAP.

Methodology

In all studies, radiographs were interpreted by clinicians who were unaware of the findings of the reference method. The methodology for both the reference standard and the radiographic interpretation were generally well described in all but one study,⁴¹ although only three studies stated specific radiographic signs or findings. Only one study overtly compared an index radiograph to previous chest radiographs, an advantage that may increase the accuracy of interpretation in clinical practice.

Three studies included multiple independent interpretations with information on interobserver variability. No study investigated intraobserver variability, a known problem in radiographic interpretation of chest radiographs for pneumoconiosis and other conditions.

Reference Standard

As with most studies of VAP diagnosis, the accuracy of the reference standard with which to compare the diagnostic tool is a problem. Autopsy histology will show the presence of VAP, but the selection of the appropriate chest radiograph for comparison is arbitrary. The most important radiographic findings are seen when VAP is first suspected, but autopsy studies have not examined the radiographic findings made at that time. Autopsy studies also have an inherent bias toward patients who are more gravely ill. Conversely, the comparison of radiographic findings to those from bronchoscopic diagnostic techniques introduces a systematic bias since these techniques themselves have an error rate.

RESULTS

Accuracy

In patients in whom pneumonia was suspected, overall clinical opinion of the chest radiographs did not further increase the likelihood of VAP.^{9,10} Specific radiologic signs had variable sensitivity and specificity, but the likelihood ratios of any sign were > 1.5 only in autopsy studies. The major problem was lack of specificity, although the high sensitivity is biased by the selection of patients in whom pneumonia was suspected. In patients with new or worsening signs on a radiograph, the condition was consistently more unlikely to be VAP.^{8,9,39,41} Conversely, the sign with the highest specificity for VAP was the radiographic impression of atelectasis (alveolar infiltrate with volume loss).⁸ Combinations of radiologic signs,⁸ previous comparison radiographs, and basic clinical information⁹ did not add to the accuracy of the interpretation.

Table 5—Radiologic Studies and Their Methodological Quality*

Study/Year	Enrollment			Methods		
	Selection	Indication	Description	Investigators Blinded to Reference Standard	Adequately Described	Quality Assessment
Andrews et al ³⁹ /1981	Retrospective, consecutive	Autopsy, single CXR	100% ARDS patients	Yes	Yes for autopsy No for CXR	Multiple specimens; standardized criteria for autopsy; single CXR interpretation
Wunderink et al ⁸ /1992	Retrospective, consecutive	Autopsy	MV > 12 h Medical/surgical	Yes	Yes for CXR No for autopsy	Specific radiologic signs defined; 3 independent interpretations
Meduri et al ⁸³ /1994	Retrospective, selected	Suggested VAP	MV > 24 h Medical/surgical	Yes	Yes	Single interpretation
Winer-Muram et al ⁹ /1993	Retrospective, consecutive	Suggested VAP	MV > 48 h Medical/surgical	Yes	Yes	3 independent interpretations, with and without radiographs and clinical data
Lefcoe et al ¹⁰ /1994	Retrospective, consecutive	Suggested VAP	MV > 48 h Medical/surgical	Yes	Yes	2 independent interpretations, definition of categories
Torres et al ⁴¹ /1994	Prospective, consecutive	Autopsy	Respiratory ICU MV > 72 h	No indication	No	Alternative causes for infiltrates found

*CXR = chest radiograph; MV = mechanical ventilation; NA = not applicable.

Table 6—Results of Radiologic Studies*

Study/Year	No. of Patients	No. of Patients with Pneumonia	Reference Standard	Radiologic Criteria	Sensitivity, %	Specificity, %	Likelihood Ratio
Andrews et al ³⁹ /1981	24	14	Autopsy histology	Asymmetrical infiltrate	57.1 (NC)	70.0 (NC)	1.90
Wunderink et al ⁸ /1992	69	24	Autopsy histology	Alveolar infiltrate	87.5 (NC)	25.6 (NC)	1.17
				Air bronchogram	83.3 (NC)	57.8 (NC)	1.97
				Silhouette sign	79.2 (NC)	33.3 (NC)	1.19
				Atelectasis	29.2 (NC)	62.8 (NC)	0.78
				New localized	44.4 (NC)	50.0 (NC)	0.88
Meduri et al ⁸³ /1992	22	9	PSB $\geq 10^3$ Protected BAL $\geq 10^{4\dagger}$	New/worse	77.8 (NC)	16.7 (NC)	0.93
				All patients [‡]			
Winer-Muram et al ⁹ /1993	40	17	PSB $\geq 10^3$ or BAL $\geq 10^{4\dagger}$	Alveolar infiltrates	94.1 (NC)	26.1 (NC)	1.27
				Air bronchograms	70.2 (NC)	39.1 (NC)	1.15
				New/worse infiltrates	52.9 (NC)	30.9 (NC)	0.77
				Patients without ARDS			
				Alveolar infiltrate	100 (NC)	27.3 (NC)	1.38
				Air bronchograms	58.3 (NC)	45.5 (NC)	1.07
				New/worse infiltrates	50.0 (NC)	36.4 (NC)	0.78
Lefcoe et al ¹⁰ /1994	66	25	PSB $\geq 10^3$	"Suggestive" or "compatible"	64–66 (same)	27–29 (same)	0.87–0.93
Torres et al ⁴¹ /1994	30	18	Autopsy histology	Infiltrate	CC (78)	CC (42)	1.34

*NC = not calculated; CC = couldn't calculate; PSB = protected-specimen brush technique.

[†]Histology in 9 of 22 patients.

[‡]Area under receiver operating curve: single CXR, 0.57; comparison CXRs, 0.53; and with clinical information, 0.30.

Reliability

The two studies that provided information on the reliability of interpretation found high interobserver variability. Between two radiologists, interobserver variability for the diagnosis of VAP has a κ statistic of only 0.27, indicating marginal reproducibility between the two readers.¹¹ (The κ statistic is the potential agreement beyond chance divided by the actual agreement beyond chance.) Disagreement regarding the presence or absence of a radiographic sign occurs in 12 to 39% of cases.^{84,86} Intraobserver variability has not been studied.

Additional uncontrolled factors in these studies are the ventilator settings and radiographic technique used.⁸⁷ The single-view, portable technique required for ventilator-assisted patients compromises interpretation. In nonintubated patients who had upper abdominal surgery, Beydon et al⁸⁶ documented that the sensitivity of portable chest radiographs, when compared to CT scans, was as low as 33% for alveolar infiltrates in the lung bases.

While the effect of radiographic technique is well documented, the effect of ventilator settings only recently has been studied. Ely et al⁸⁷ found that exposing the film during a pressure-support breath rather than during an intermittent mechanical ventilation (IMV) breath significantly influenced the degree of lung inflation and the amount of airspace disease. Of 29 patients with moderate airspace disease that was evident on pressure support breaths, 8 (28%) were thought to have normal or mild airspace disease when IMV breaths were taken within 5 min of each other. Of 28 patients with moderate airspace disease evident on IMV ventilation, 4 (14%) improved on pressure support.

RISKS

Discussion of the potential risk of misdiagnosis using the chest radiograph is based on theoretical and clinical impressions, as no study has specifically addressed this

topic. When chest radiographs are used to diagnose pneumonia in the intubated patient, the risks relate mainly to complications of overdiagnosis and overtreatment. Falsely attributing radiographic infiltrates to pneumonia may prevent the clinician from searching for other causes that may be responsive to nonantibiotic treatment. These causes include pulmonary embolus with infarction, recurrent aspiration, or, possibly, fibroproliferative ARDS. Antibiotic therapy for these noninfectious problems results in the colonization of highly resistant organisms.

If the findings from the radiograph are incorrectly interpreted as being normal, the treatment of pneumonia is delayed. In the autopsy study of Rouby et al,⁸⁴ purulent bronchiolitis often was associated with histologic signs of pneumonia, a finding that the authors suggest may precede clinical signs of pneumonia. This concept suggests that if pneumonia is not seen radiographically, and therefore is not immediately diagnosed and treated, radiographic infiltrates will ultimately appear. This has not been confirmed in clinical studies.

CONCLUSIONS

The focus of radiologic studies of VAP has been an abnormal chest radiograph. The incidence of pneumonia in patients with normal chest radiograph findings is unknown.

Several specific radiographic signs have been studied, and the sensitivities have ranged from 87 to 100% for alveolar infiltrates, 58 to 83% for air bronchogram signs, and 50 to 78% for new or worsening infiltrates.

Specificity is also unknown, since the number of patients without pneumonia and with a normal finding on a chest radiograph is unknown.

Because ventilator-assisted patients have other potential causes or radiographic abnormalities, the likelihood of VAP is not increased by any specific radiographic sign.

The reliability of chest radiographic interpretation is low.

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