Persistent Bronchopleural Air Leak during Mechanical Ventilation*

A Review of 39 Cases

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Bronchopleural fistula (BPF), or bronchopleural air leak, is regarded as an ominous complication of ventilator management in acute respiratory failure, but data on its natural course and prognosis are lacking. We reviewed all instances of mechanical ventilation at a major trauma center during a four-year period, and found that 39 of the 1,700 mechanically-ventilated patients developed BPF lasting at least 24 hrs. Overall mortality in these 39 patients was 67 percent, and this was higher when BPF developed late in the illness (16 of 17, or 94 percent, when mean onset was hospital day 13), than when it occurred within 24 hours of admission (ten of 22, or 45 percent, p = 0.002). Survival in patients with chest trauma (12 of 27, 44 percent), most of whom had air leaks on or just after admission, was better than in those with other primary diagnoses (one of 12, 8 percent, p<0.005). All eight patients whose maximum air leak exceeded 500 ml per breath died, whereas 13 of 30 with smaller maximum leaks survived (p<0.05). Despite leaks as large as 900 ml per breath, however, conventional ventilator adjustments permitted avoidance of severe respiratory acidosis (pH less than 7.30) in all but two patients. We conclude that the occurrence of BPF during mechanical ventilation identifies patients with high mortality, but that unmanageable respiratory acidosis from this complication is rare.

Persistent bronchopleural air leak or bronchopleural fistula (BPF) during mechanical ventilation is regarded as a serious complication of ventilator therapy.13 It can lead to persistent pneumothorax, poor lung expansion due to loss of a large fraction of each breath from the ventilator, mismatching of ventilation and perfusion, direct extension of airway infection to the pleural space, inability to maintain positive end-expiratory pressure (PEEP), and failure to maintain adequate alveolar ventilation resulting in respiratory acidosis. Three types of processes can produce bronchial or alveolar disruption leading to BPF: direct blunt or penetrating trauma; accidental lung puncture or laceration during thoracostomy, insertion of a thoracostomy tube, or central intravenous catheter placement; and alveolar rupture occurring either spontaneously, or as a result of ventilator management in the adult respiratory distress syndrome (ARDS). Patients developing BPF in this last circumstance often develop multiple leaks because of their severe underlying parenchymal damage, perhaps aggravated by high minute ventilation demands and requirement for high levels of PEEP. Published reports on BPF4,5 have focused mainly on devices or maneuvers to reduce the volume of the leak, and include little information on the natural history or prognosis of the lesion. In many instances, therapeutic approaches have been offered despite lack of evidence that the leak was physiologically compromising the patient, or that the therapeutic intervention affected outcome. Specifically, no study has examined the prognostic significance of the leak itself or whether therapeutic interventions have any impact on the patient's clinical course. In order to establish a data base on the incidence, severity, and natural history of BPF, we have reviewed a large consecutive series of patients ventilated at a major trauma center.

Materials and Methods

 Patients with BPF were identified by reviewing respiratory therapy records of 1,700 consecutive patients who received mechanical ventilation at Harborview Medical Center from January, 1977 through December, 1980. This institution functions as both county hospital and regional trauma and burn center, treating large numbers of patients with acute respiratory failure. Virtually all patients are adults. All ventilated patients are managed in the surgical, medical, coronary, or burn intensive care units.

 Patients with BPF were identified from respiratory therapy records, discharge codes, and records of thoracostomy tube insertion. Patients ventilated after cardiac or pulmonary resectional surgery were excluded. We defined BPF as an air leak, bubbling in the collection device, that continued for more than 24 hrs following insertion of a thoracostomy tube. Presence and size of the leak was confirmed with nurses' notes, physicians' notes, and respiratory therapy narrative records. Leak size was determined by subtraction of expired from inspired tidal volumes at the endotracheal tube.

Charts of patients meeting these criteria were then reviewed for age; known history of chronic obstructive pulmonary disease; presence of pneumonia, ARDS, pleural space infection; and eventual outcome. Pneumonia was defined as localized infiltrate(s) on chest radiographic examination associated with sputum purulence,
fever, elevated blood leukocyte count, or the clinical syndrome of sepsis. ARDS was considered present if the patient had the clinical syndrome of diffuse pulmonary infiltrates evident on chest radiograph without sign of cardiac failure (pulmonary capillary wedge pressure less than 15 mm Hg, if known), hypoxemia (PaO₂ less than 75 mm Hg on FIO₂ 0.50 or greater), and a known associated risk factor.¹³ Pleural space infection was diagnosed by drainage of grossly purulent material from thoracotomy tube or by positive cultures from pleural fluid. Other data included time of leak onset with respect to hospital admission, delivered tidal volume, delivered minute ventilation, and maximum air leak per breath. Clinically significant alveolar hypoventilation during mechanical ventilation was defined by PaCO₂ greater than 45 mm Hg, or an increase of at least 5 mm Hg, associated with an arterial pH below 7.30.¹⁹ Statistical comparisons were done using Fisher's exact test.

**RESULTS**

Of the 1,700 patients who were mechanically ventilated during the four-year period reviewed, 39 (two percent) had bronchopleural air leak for more than 24 hrs. Of these patients, 27 of 39 (69 percent) were admitted because of trauma, 22 with chest trauma and five with trauma excluding the chest. There were four incidences of nontraumatic surgical illness (two intraabdominal catastrophes and two burns) and eight patients with medical illnesses (pneumonia in four; and tuberculosis, pancreatitis, near drowning, and sepsis in one each). Overall in-hospital mortality in these patients was 67 percent (26 of 39).

Onset of air leak occurred in the first 24 hrs following admission in 56 percent (22 of 39 patients). Of these early-onset air leaks, all but one (a near-drowning victim) had chest trauma. Late air leak, first appearing more than 24 hrs following admission, developed in 44 percent (17 of 39 patients), at a mean of 13 days following admission (range, three to 47 days). Mortality in patients developing late air leak was 94 percent (16 of 17 patients), compared with a mortality of 45 percent (ten of 22 patients) in those with early-onset BPF (p = 0.002). Mortality among patients with trauma was 56 percent (15 of 27 patients) as compared with 92 percent (11 of 12 patients) in those with other diagnoses. This difference in survival was due entirely to the patients with chest trauma, whose mortality was 45 percent (ten of 22 patients) as compared with 100 percent (five of five patients) in those with purely extrathoracic trauma. Patients with chest trauma had a significantly better survival rate than all other patients (p<0.005).

Maximum air leak per breath was recorded in 38 of the 39 patients (Fig 1). Of patients with maximum leak less than 500 ml per breath, mortality was 57 percent (17 of 30 patients), as compared to 100 percent (eight of eight patients) among those whose leaks exceeded 500 ml per breath at any time (p<0.05).

Patients with pleural space infections did significantly less well (87 percent mortality, 13 of 15 patients) than did those without infected pleural spaces (54 percent mortality, 13 of 24 patients) (p<0.05). Mortality tended to be higher in patients with BPF who also had ARDS (17 of 21, 81 percent, vs nine of 18, 50 percent, without ARDS), and also in the presence of pneumonia, known pre-existing obstructive lung disease, and age over 60 years, but these trends were not statistically significant (p>0.05).

Ventilatory mode was assist-control in 33 of the 39 patients and intermittent mandatory ventilation in six. Delivered (inspiratory) tidal volumes while BPF was present averaged 14.6 ml/kg (range, 11.2 to 18.9 ml/kg). Transient hypoventilation occurred at some time in the course of 34 of the 39 patients. However, in only two patients was persistent acidemia (pH less than 7.30) secondary to inability to maintain adequate alveolar ventilation despite maximal output of the mechanical ventilator (35 L/min in each instance). Both of these patients died.

**DISCUSSION**

In this retrospective review of 1,700 mechanically-ventilated adults, there were 39 patients with a bronchopleural air leak persisting for more than 24 hrs. Air leaks appearing within 24 hours of admission were almost exclusively the result of chest trauma and were present on admission; in this setting, BPF identified patients with a relatively good prognosis (45 percent in-hospital mortality). Conversely, patients developing BPF later in the course of their illness had an extremely poor prognosis, with 94 percent succumbing. This high mortality group included patients with nonthoracic trauma and other medical and surgical illnesses. Other major prognostic factors were the size of the air leak, with 100 percent mortality if the leak exceeded 500 ml/breath, and the presence of pleural space infection.

Only two (five percent) of the patients had acute...
respiratory acidosis (pH<7.30) that could not be corrected with adjustments of the ventilator settings. In these patients, alveolar hypoventilation associated with BPF may well have caused or at least contributed to the fatal outcome.16 However, based on observations of similar patients at our institution,16 the other patients in this series are more likely to have died of their underlying injury, or of sepsis or other complications, than from BPF. While this study was not designed to assess the effects of BPF on mortality or morbidity, which would have required a control group of individuals with comparable diagnosis, illness severity, and management but no BPF, the presence of this lesion clearly identifies a population with high mortality, particularly in the case of late-onset leaks. Thus, while BPF may not have led directly to a fatal outcome in our patients with ARDS, their mortality rate (81 percent) exceeded that reported from our institution17 and others18 among patients with similar clinical features and severity of respiratory dysfunction. In the setting of ARDS, BPF is thus an important marker of illness severity and prognosis, whether or not it affects those features directly.

Our data do allow us to comment, however, on the management of this condition based upon our observations of its physiologic effects. Therapy in these patients consisted primarily of conventional ventilator adjustments,1 although in some instances briefly, usually unsuccessful attempts were made to apply PEEP to the chest tubes2,4,5 or to occlude them during a portion of the ventilator cycle.2,6 Possible benefits of high-frequency jet ventilation7,10 or of several other anecdotally-reported experimental techniques11-13 in decreasing the size of the leak cannot be assessed from this study. The fact that only two of our 39 patients developed respiratory acidosis that could not be reversed by conventional ventilator manipulations indicates that most cases of BPF do not require special techniques, apparatus, or other extraordinary measures, at least from the physiologic standpoint. No information is presently available about the effects of ventilator adjustments or other therapy on the duration or healing of the air leak.

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