A 47-Year-Old Woman With Wheezing and Respiratory Failure Unresponsive to Conventional Ventilatory Modalities*

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(Arch Chest 2002; 121:1688–1691)

A 47-year-old woman presented to the emergency department complaining of 2 days of increasing shortness of breath despite escalating use of albuterol by metered-dose inhaler (MDI). She had a long history of bronchial asthma, including one hospital admission for status asthmaticus with respiratory failure requiring intubation and ventilatory support. That hospitalization had been complicated by a slowly resolving myopathy from paralytic agents and corticosteroids prompting tracheotomy and a prolonged period of ventilatory support. She denied fever, facial pain, nasal discharge, or other symptoms of sinusitis, and her cough was nonproductive. Medications included albuterol MDI, fluticasone MDI, and diltiazem for mild hypertension.

Physical Examination

In the emergency department, she was in severe respiratory distress, sitting in the tripod position and able to speak only in short sentences. Vital signs were as follows: pulse rate, 169 beats/min; respiratory rate, 35 breaths/min; BP, 122/69 mm Hg (pulsus paradoxus was not measured); and temperature, 37.2°C. Auscultation of the lungs revealed very poor air entry and no audible wheezing.

Laboratory Findings

Arterial blood gas (ABG) analysis on 100% oxygen via facemask demonstrated a metabolic acidosis with pH 7.28; PCO₂, 39 mm Hg; PO₂, 122 mm Hg; and calculated bicarbonate, 19 mEq/L. Chest radiography showed clear lung fields and no signs of hyperinflation.

Hospital Course

She was aggressively treated with albuterol by continuous nebulization, heliox, IV steroids, and magnesium sulfate, but exhibited progressive deterioration in ventilatory and hemodynamic status. She was induced with ketamine, intubated, and placed on mechanical ventilation in synchronized intermittent mandatory ventilation mode at a tidal volume of 500 mL. Adequate ventilation could not be established in that mode due to premature termination of breaths from excessive airway pressure. This was attributed in part to dynamic air trapping and breath stacking (auto-positive end-expiratory pressure [PEEP]), although no formal measurements were made. Changing to pressure-control ventilation (PCV) with an inspiratory pressure of 50 cm H₂O delivered a tidal volume of only 90 mL. She was then paralyzed with vecuronium and sedated with lorazepam. A pause in ventilation for 45 s in order to relieve any auto-PEEP failed to improve her hemodynamic status. It was concluded that dynamic air trapping was not the proximate cause of her hypotension, and the possibilities of pneumothorax, mucous plugging, and/or continued severe bronchoconstriction were raised.

She was transferred to the ICU, where she was tachycardic (pulse rate, 140 beats/min) and hypotensive (BP, 90/60 mm Hg). ABG analysis on fraction of inspired oxygen of 1.00 revealed the following: pH 6.80; PCO₂, 161 mm Hg; PO₂, 117 mm Hg; and calculated bicarbonate, 25 mEq/L. Due to the high ventilatory pressures required and progressive circulatory collapse, tension pneumothorax was suspected and was treated emergently and empirically. Needle decompression on the left side produced no rush of air and failed to improve her status; subsequent

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needle decompression on the right side resulted in a rush of air and improved hemodynamic status. Bilateral 24F chest tubes were inserted and placed to water seal. With the patient receiving mechanical ventilation at a tidal volume of 375 mL, there was a substantial air leak on the right lung (estimated at 150 mL per breath), indicative of a large bronchopleural fistula. Figure 1 shows the chest radiograph obtained following tube placement and demonstrates extensive atelectasis of the left lung. Repeat ABG analysis continued to demonstrate marked respiratory acidosis and hypoxemia (pH 6.85; $P_{CO_2}$, 208 mm Hg; $P_{O_2}$, 58 mm Hg; and calculated bicarbonate, 37 mEq/L.)

What is the next step in managing this patient’s respiratory failure?
Answer: Independent lung ventilation

**Discussion**

Independent lung ventilation should be considered when the pathophysiologic properties of each lung are so radically different that the usual method of ventilating both lungs in parallel fails to maintain adequate gas exchange or presents an unacceptable risk of complications. Such instances include treatment of bronchopleural fistula using conventional ventilators on each side or a jet or high-frequency ventilator on the side exhibiting the bronchopleural fistula, severe unilateral lung disease with conventional ventilators on each side or separate high-frequency oscillatory ventilators, and massive hemoptysis where contralateral spread of blood can result in asphyxiation. Our patient exhibited a bronchopleural fistula and contralateral total lung atelectasis complicating status asthmaticus, a result of barotrauma and mucous plugging, respectively. It was believed that conventional ventilation would be ineffective at resolving her life-threatening respiratory acidosis, since settings capable of ventilating her left lung would simply increase the air leak on the right lung, and settings minimizing her right-sided air leak could not ventilate the left lung. A logical approach was to separate the lungs with a dual-lumen endotracheal tube and tailor the ventilatory strategies to the differing pathologies of each lung. The right lung could receive PCV without PEEP in order to minimize the air leak and allow the bronchopleural fistula to heal, while the left lung could receive PEEP and inverse inspiratory/expiratory (I:E) ratio in an attempt to reverse atelectasis and improve ventilation/perfusion matching. Unsynchronized independent lung ventilation would reduce the complexity of the necessary equipment, and although less physiologic, there is no evidence that synchronization provides any concrete advantage.

Management of bronchopleural fistula has long consisted of minimizing the airflow through the fistulous tract in order to allow healing. Although this has never been subjected to prospective study, a retrospective analysis of 39 cases supports the contention that patients with the smallest air leak have the best prognosis. In addition to using the lowest possible thoracostomy tube suction pressure (or a water seal alone), mean airway pressure should be reduced as much as possible. This includes using minimal or no PEEP, low peak airway pressures, reducing the proportion of minute ventilation provided by the ventilator (intermittent mandatory ventilation modes with low machine tidal volumes and respiratory rates), and shorter inspiratory times.

However, ventilator management for mucous plugging and atelectasis is based on higher levels of sustained airway pressure that may allow recruitment of atelectatic lung units. In our patient, this could be achieved with pressure-controlled inverse ratio ventilation and moderate levels of PEEP, although we acknowledge that the use of PEEP in airway obstruction is controversial.

The patient was extubated and reintubated with a double-lumen endotracheal tube (Broncho-Cath; Mallinckrodt Medical; St. Louis, MO), with placement confirmed bronchoscopically. Individual standard ventilators (Puritan Bennett Models 7200 and 840; Mallinckrodt Medical) were used to ventilate each lung separately, without interventilator synchronization. The right lung ventilator was set to PCV of 50 cm H2O; rate, 16/min; I:E of 1:2; and no PEEP. The left lung ventilator was set to PCV of 30 cm H2O; rate, 10/min; I:E of 2:1; and PEEP of 10 cm H2O. Her BP normalized within minutes of instituting independent lung ventilation, with improvement of her ABG analysis at 6 h to pH 7.36; PCO2, 55 mm Hg; PO2, 185 mm Hg; and calculated bicarbonate, 32 mEq/L. She continued to receive aerosolized albuterol via both ventilator circuits and IV corticosteroids. Two days later, she was converted to a conventional single-lumen endotracheal tube, and 4 days later was extubated uneventfully. Four weeks after discharge, receiving maintenance therapy with fluticasone, salmeterol, and albuterol MDIs, she appeared well and spirometry findings were normal.

The investment of time and resources was substantial. Intensive utilization was seen at all levels: nursing, respiratory care, equipment, and physician staffing. Two ventilators were maintained in the same room, a total of three bronchoscopies with a pediatric bronchoscope were necessary to confirm tube placement when the patient’s respiratory status changed, and the patient required pharmacologic paralysis for several days. However, the rapid improvement in the patient’s clinical status immediately following independent lung ventilation clearly demonstrated the efficacy of this strategy.

**Clinical Pearls**

1. Consider independent lung ventilation when radically different pathology exists in each lung and conventional mechanical ventilation fails.

2. Asynchronous independent lung ventilation is as effective as synchronous independent lung ventilation in adults, and is well tolerated. Conventional ventilators using settings tailored to the individual pathology of each lung may be used, or different...
ventilators (eg, high frequency ventilation on one side, conventional ventilation on the other side) may be employed.

3. Double-lumen endotracheal intubation increases the risk of laryngeal trauma, and carries the additional risk of trauma, ischemia, or even rupture of a mainstem bronchus. Careful choice of endotracheal tube size, placement by a skilled operator, and verification of position (usually by fiberoptic bronchoscopy) are essential.

SUGGESTED READINGS


Tuxen DV. Detrimental effects of positive end-expiratory pressure during controlled mechanical ventilation of patients with severe airflow obstruction. Am Rev Respir Dis 1989; 140:5–9