Chapter 30

VENTILATION FOR TRACHEAL DISRUPTION AND BRONCHOPLEURAL FISTULA

JEFFREY A. MIKITA, MD,* AND DOUGLAS POWELL, MD†

Lieutenant Colonel, Medical Corps, US Army; Program Director, Critical Care Medicine Fellowship; Chief, Department of Simulation, Walter Reed National Military Medical Center, 8901 Wisconsin Avenue, Bethesda, Maryland 20889

†Major, Medical Corps, US Army; Intensive Care Unit Director, Womack Army Medical Center, Building 4-2817, Reilly Road, Fort Bragg, North Carolina 28307

INTRODUCTION

Tracheal disruption (TD) and bronchopleural fistula (BPF) are rare but serious complications of both blunt and penetrating thoracic trauma. The incidence of TD and BPF in thoracic trauma is between 0.5% to 2%, respectively.[1] In most cases of traumatic BPF, the injury is unilateral, with the majority occurring at the proximal right bronchus, within 2 cm of the carina.[2,3] The most common tracheal injury is a tear near the carina. In both cases, the injury pattern is likely due to the role of shear forces on the airways near the relatively fixed carina. Nontraumatic etiologies of TD include complications of endotrachial, thoracostomy, or tracheostomy tube placement and central venous catheter placement. BPF can be caused by ventilator-induced barotrauma in illnesses such as acute respiratory distress syndrome.[4,5]

DIAGNOSIS

Though anatomically different injuries, TD and BPF share some attributes of diagnosis and management. During initial stabilization, TD or BPF must be suspected in patients with blunt or penetrating chest trauma who deoxygenate, become difficult to manually ventilate, or have absent lung sounds despite placement of needle or tube thoracostomy. In the trauma team's assessment, suspicion for BPF should be increased in patients with respiratory signs and symptoms who display thoracic, cervical, and facial subcutaneous emphysema, pneumothoraces not reduced with chest tube drainage, ventilation that worsens with chest tube suction, or persistent air leak with chest tube drainage.[6–11] When BPF is suspected, fiberoptic bronchoscopy is the initial diagnostic modality of choice because it both permits evaluation of the cervically immobilized trauma patient and facilitates their intubation.[1,7–9,11] Intubating a patient with TD or BPF requires care that the endotracheal tube (ETT) is placed distal to the disruption to avoid the risk of rapid tension pneumothorax and death. For more proximal TD, this may be accomplished with a standard ETT. For distal TD, double-lumen intubation is necessary to protect both lungs from bleeding distal to the injury. In BPF, either one-lung (with a long ETT) or two-lung (with a double-lumen ETT) intubation is required.

Early diagnosis and surgical repair is critical for preserving lung function.[6,7] Late repair after months or years is feasible, with good operative outcomes reported, but usually at the expense of a significant loss of lung function distal to the lesion due to atelectasis, scarring, or infection.[10,12]

VENTILATION CONSIDERATIONS

If the airway is adequately protected with a single or dual-lumen ETT distal to the injury, there are no special ventilation considerations for tracheal disruption unless repair of a distal defect requires one-lung ventilation. In this case, the ventilation strategy will be similar to that for BPF. For patients with a standard ETT, providers must be vigilant for signs of hypoxia, subcutaneous emphysema of the neck and chest, and discordance between inspiratory and expiratory pressures, indicating that the ETT may have moved proximal to the lesion or that the wound has extended distal to the end of the ETT.

Ventilation for BPF and TD requiring one-lung ventilation for surgical approach is broken down into two phases: (1) acute intraoperative management and (2) postoperative care. To care for combat casualties with this injury, an understanding of the modes and risks of transport ventilation is also important. ETT selection and placement is intimately connected with the ventilatory management of patients with BPF. The goals of acute operative airway management are: (*a*) prevent damage to the uninjured lung by secretions from the injured lung, (*b*) ensure adequate ventilation of the patient through the operative procedure, and (*c*) facilitate the surgical repair of the affected bronchus.

Preventing Further Injury

Anatomic separation of the lungs with the ETT protects the uninjured lung from blood and secretions.[6,13] Methods most supported in the literature include bronchial intubation of the uninjured lung with a long ETT or double-lumen ETT placement with the bronchial lumen in the uninjured lung.[8,11] Intubation is ideally performed under direct bronchoscopic visualization in an awake patient or with bronchoscopic evaluation and adjustment, if needed, of an ETT placed by direct or fiberoptic laryngoscopy.[1,8,11,14] If available, a double-lumen ETT is preferred because it also permits physiologic separation of the lungs if the air leak becomes severe enough to require different ventilator modes or settings for each lung.[3,6,13]

In BPF, air leak during positive-pressure ventilation can be up to 25% of minute ventilation.[5,15,16] This physiology is worsened by ventilator maneuvers that increase the gradient from the lung across the pleural space such as higher inspiratory or positive end-expiratory pressure (PEEP), tidal volume (VT), increased inspiratory flow, and increased inspiratory time (including breath hold and inverse-ratio).[16] Subacutely, unilateral BPF can create differences in lung physiology between the injured and uninjured lung that can be great enough with large defects to require two-lung independent lung ventilation (2L-ILV), separate ventilator management of each lung to achieve adequate oxygenation and ventilation.[13,14]

Ventilator Settings

The initial approach to ventilator settings is to provide low VT (6–7 mm Hg/kg) and allow hypercapnia by maintaining P_{CO_2} below 60 mm Hg and pH at 7.3 or greater.[13,17] PEEP should be low, ideally 5 mm Hg, to minimize expiratory air leak.[16] Goal plateau pressure (Ppl) should be less than 26 mm Hg for optimal compliance and gas exchange.[13,18] If the patient cannot be ventilated at a VT that maintains Ppl at desired levels, switching to pressure-controlled mode with the same target Ppl has been shown to improve ventilation and reduce peak airway pressure.[19] In patients with refractory respiratory acidosis, persistently elevated peak airway pressure, or oxygenation difficulties, salvage modes include high-frequency ventilation (HFV) or 2L-ILV (synchronous or asynchronous).[11,13,20–22] Some studies have found that in a selected population with BPF/TD and otherwise healthy lungs, HFV improves oxygenation at lower mean airway pressures than conventional mechanical ventilation.[20,23,24] As with Ppl in conventional mechanical ventilation, the goal for mean airway pressure in HFV should be less than 26 mm Hg. With 2L-ILV, initial VT should be administered in a ratio of 55% on the right lung and 45% on the left, then adjusted to meet airway pressure and ventilation goals.[21] Outcomes with 2L-ILV are similar whether synchronous or asynchronous ventilation is used.[22,25] The former is easier to set up because it does not require specialized ventilator synchronization software or connecting cabling between the ventilators.

An advantage of HFV is that ventilation is achieved through an ETT with the cuff deflated.[6,26] This can facilitate surgical repair and healing by removing cuff ulceration as a risk to the wound, but does not provide the protection of anatomic separation of the lungs. More useful for facilitating surgical repair is a two-lung ETT or traditional long ETT cannulation of the uninjured lung, with the inflated cuff anatomically isolating that lung from contamination. Ventilation of the uninjured lung allows deflation of the injured lung to improve surgical access.[1,3,8] In large or bilateral disruption of the trachea, intraoperative cannulation of the injured lung distal to the disruption with a sterile ETT may be necessary.[8,9] Care must be taken to avoid barotrauma when ventilating a lung segment perioperatively, and the anesthesiologist may be required to manually ventilate to achieve low enough airway pressure.[9] There are case reports of cardiac bypass and extracorporeal membrane oxygenation being used in cases of severe bilateral disruption.[9,27]

Postoperative Care

The goals of postoperative ventilatory care are to reduce strain on the operative repair and prevent complications such as pneumonia and atelectasis. The optimal method for protecting the repair is extubation, since spontaneous respiration places the least strain on the airways. Nevertheless, most multisystem trauma patients must remain intubated postoperatively. Goals for postoperative ventilator management are to use the lowest VT possible, maintain Ppl under 26 mm Hg, and consider modes that encourage spontaneous respirations, such as intermittent mandatory ventilation (IMV).[20] If two-lung IMV was used perioperatively, criteria for converting to single ventilator mode are VT equalization to within 100 mL and compliance within 20%.[13] Epidural analgesia with fentanyl or bupivacaine has been found in some series to improve lung mechanics and ventilation and may encourage more spontaneous respiration.[28,29]

Aggressive pulmonary toilet is mandatory to reduce the risk of postobstructive pneumonia. Bedside bronchoscopy is often required to clear secretions below the anastomosis.[1,30] Patients with TD and BPF are at high risk for postoperative pneumonia and should receive prophylactic broad-spectrum antibiotics, which can be discontinued when they are extubated and clearing their own secretions.[6,11]

Aeromedical Evacuation

Air transport of patients with BPF, whether repaired or not, should be approached with great caution. Actual VT and PEEP delivered can increase greatly with altitude, posing a serious risk to an operative repair or of air leak to an unrepaired BPF or TD.[31] Delay in transport until extubation of a repaired BPF is ideal. If air evacuation must be attempted, a thorough understanding of the transport ventilator settings and fluctuations of VT and PEEP to both sustained and abrupt changes in altitude, as well as scrupulous monitoring of the patient's ventilatory status and chest tube air leak, are essential.

SUMMARY

TD and PBF are rare but serious complications of thoracic and cervical trauma. Suspicion for these injuries should be raised in patients with thoracic or neck injuries who are difficult to ventilate or have absent lung sounds despite needle or chest tube decompression, persistent air leak, or subcutaneous emphysema of the face, neck or thorax. Prompt recognition is essential for appropriate airway management and because early repair is associated with improved long-term lung function. Airway management and ventilation depend on the location of the injury. Proximal TD may be managed with the placement of a standard ETT distal to the injury. TD closer to the carina and BPF will usually require placement of a dual-lumen ETT to protect the lungs from bleeding and one-lung ventilation for surgical exposure. Postoperative ventilator management of BPF requires care to re-expand the injured lung without disrupting the surgical repair. Aeromedical evacuation of patients with BPF, whether repaired or not, is risky. It is preferable to delay evacuation until extubation after surgical repair.

REFERENCES

1. Karmy-Jones R, Wood DE. Traumatic injury to the trachea and bronchus. *Thoracic Surg Clin*. 2007;17:35–46.
2. Kiser AC, O'Brien SM, Detterbeck FC. Blunt tracheobronchial injuries: treatment and outcomes. *Ann Thorac Surg*. 2001;71:2059–2065.
3. Ramzy AI, Rodriguez A, Turney SZ. Management of major tracheobronchial ruptures in patients with multiple system trauma. *J Trauma*. 1988;28:1353–1357.
4. Gomez-Caro A, Ausin P, Moradiellos FJ, et al. Role of conservative medical management of tracheobronchial injuries. *J Trauma*. 2006; 61:1426–1435.
5. Pierson DJ, Horton CA, Bates PW. Persistent bronchopleural air leak during mechanical ventilation: a review of 39 cases. *Chest*. 1986;90:321–323.
6. Chu CP, Chen PP. Tracheobronchial injury secondary to lung chest trauma: diagnosis and management. *Anesth Intensive Care*. 2002;30(2):145–152.
7. Guest JL, Anderson JN. Major airway injury in closed chest trauma. *Chest*. 1977;72(1):63–66.
8. Kirsh MM, Orringer MB, Behrendt DM, Sloan H. Management of tracheobronchial disruption secondary to nonpenetrating trauma. *Ann Thorac Surg*. 1976;22:93–101.
9. Fabia RB, Arthur LG 3rd, Phillips A, Galantowicz ME, Caniano DA. Complete bilateral tracheobronchial disruption in a child with blunt chest trauma. *J Trauma*. 2009;66:1478–1481.
10. Kelly JP, Webb WR, Moulder PV, Everson C, Burch BH, Lindsey ES. Management of airway trauma: tracheobronchial injuries. *Ann Thorac Surg*. 1985;40:551–556.
11. Devitt JH, Boulanger BR. Lower airway injuries and anaesthesia. *Can J Anaesth*. 1996;43(2):148–159.
12. Deslauriers J, Beaulieu M, Archambault G, LaForge J, Bernier R. Diagnosis and long-term follow-up of major bronchial disruptions due to nonpenetrating trauma. *Ann Thorac Surg*. 1982;33:32–39.
13. Cheatham ML, Promes JT. Independent lung ventilation in the management of traumatic bronchopleural fistula. *Am Surg*. 2006;72(6):530–533.
14. Campos JH. Lung isolation techniques for patients with difficult airway. *Curr Opin Anaesthesiol*. 2010;23:12–17.
15. Bishop MJ, Benson MS, Pierson DJ. Carbon dioxide excretion via bronchopleural fistulas in adult respiratory distress syndrome. *Chest.* 1987;91:400–402.

16. Powner DJ, Grevnik A. Ventilatory management of life-threatening bronchopleural fistulae. *Crit Care Med*. 1981;9(1):55–58.

17. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. *N Engl J Med*. 2000;342(18):1301–1308.

18. Cinella G, Dambrosio M, Brienza N, et al. Independent lung ventilation in patients with unilateral pulmonary contusion. Monitoring with compliance and EtCO(2). *Intensive Care Med*. 2001;27:1860–1867.

19. Litmanovitch M, Joynt GM, Cooper PJ, Kraus P. Persistent bronchopleural fistula in a patient with adult respiratory distress syndrome. *Chest.* 1993;104:1901–1902.

20. Baumann MH, Sahn SA. Medical management and therapy of bronchopleural fistulas in the mechanically ventilated patient. *Chest*. 1990;97(3):721–728.

21. Rico FR, Cheng JD, Gestring ML, Piotrowski ES. Mechanical ventilation strategies in massive chest trauma. *Crit Care Clin*. 2007;23:299 – 315.

22. Ost D, Corbridge T. Independent lung ventilation. *Clin Chest Med*. 1996;17: 591–601.

23. Hoff BH, Wilson E, Smith RB, Bennett E, Philips W. Intermittent positive pressure ventilation and high frequency ventilation in dogs with experimental bronchopleural fistulae. *Crit Care Med.* 1983;11:598–602.

24. Turnbull AD, Carlon G, Howland WS, Beattie EJ. High-frequency jet ventilation in major airway or pulmonary disruption. *Ann Thorac Surg*. 1981;32:468–474.

25. Anantham D, Jagadesan R, Tiew P. Clinical review: independent lung ventilation in critical care. *Crit Care*. 2005;9:594–600.

26. Dreyfuss D, Jackson RS, Coffin LH, Deane RS, Shinozaki T. High-frequency ventilation in the management of tracheal trauma. *J Trauma*. 1986;26(3):287–289.

27. Voelckel W, Wenzel V, Rieger M, Antretter H, Padosch S, Schobersberger W. Temporary extracorporeal membrane oxygenation in the treatment of acute traumatic lung injury. *Can J Anaesth*. 1998;45:1097–1102.

28. Mackersie RC, Shackford SR, Hoyt DB, Karagianes TG. Continuous fentanyl analgesia: ventilatory function improvement with routine use in treatment of blunt chest injury. *J Trauma*. 1987;27:1207–1212.

29. Cicala RS, Voeller GR, Fox T, Fabian TC, Kudsk K, Mangiante EC. Epidural analgesia in thoracic trauma: effects of lumbar morphine and thoracic bupivacaine on pulmonary function. *Crit Care Med. 1990*;18:229–231.

30. Mulder DS, Barkun JS. Injury to the trachea, bronchus and esophagus. In: Moore EE, Mattox KL, Feliciano DV, eds. *Trauma*. 2nd ed. East Norwalk, CT: Appleton and Lange; 1991: 343–355.

31. Grissom TE, Papier KS, Lawlor D, Farmer JC, Derdak S. *Mechanical Ventilator Performance During Aeromedical Evacuation*. Paper presented at: Aeromedical Support Issues in Contingency Operations Conference; Rotterdam, The Netherlands; 29 September–1 October 1997. http://ftp.rta.nato.int/public/PubFullText/AGARD/CP/AGARD-CP-599/40SE5-34.pdf. Accessed August 21, 2013.