

# Essential Practices

A clinical decision-making resource for the respiratory care professional



## Advisory Board

**Janet Boehm** EdD, MS, RRT  
Director, Clinical Education  
Youngstown State University  
Youngstown, OH

**Richard Branson** MS, RRT, FAARC  
Associate Professor of Surgery  
University of Cincinnati College of Medicine  
Cincinnati, OH

**Richard Kallet** MSc, RRT, FAARC  
Clinical Projects Manager  
University of California  
Cardiovascular Research Institute  
San Francisco, CA

**Donna Hamel** RRT, FAARC  
Clinical Research Coordinator  
Duke University Health Systems  
Raleigh-Durham, NC

**Neil MacIntyre** MD, FAARC  
Medical Director of Respiratory Services  
Duke University Medical Center  
Durham, NC

**Tim Myers** BS, RRT-NPS  
Pediatric Respiratory Care  
Rainbow Babies and Children's Hospital  
Cleveland, OH

**Tim Op't Holt** EdD, RRT, AEC, FAARC  
Professor, Department of Respiratory Care  
and Cardiopulmonary Sciences  
University of Southern Alabama  
Mobile, AL

**Ruth Krueger Parkinson** MS, RRT  
Protocol/PI Coordinator  
Sioux Valley Hospital  
Sioux Valley, SD

**Helen Sorenson** MA, RRT, FAARC  
Assistant Professor, Dept. of Respiratory Care  
University of Texas Health Sciences Center  
San Antonio, TX

## Prevention of Ventilator-Associated Pneumonia

by Teresa A. Volsko, MHHS, RRT, FAARC

According to the Centers for Disease Control and Prevention (CDC), pneumonia accounts for approximately 15% of all hospital-associated infections, including 27% of all infections acquired in intensive-care units and 24% of those in coronary care units. Of the many risk factors for acquiring hospital-associated bacterial pneumonia, mechanical ventilation (and associated endotracheal intubation) is the most common.

The CDC's National Nosocomial Infection Surveillance System (NNIS) reported that in 2002, the median rate of ventilator-associated pneumonia (VAP) in NNIS hospitals ranged from 2.2 per 1000 ventilator-days in pediatric ICUs to 14.7 per 1000 ventilator-days in trauma ICUs. Other investigators report that patients receiving continuous mechanical ventilation have 6 to 21 times the risk of developing hospital-associated pneumonia compared with patients who are not receiving mechanical ventilation.<sup>1</sup> Because of this high risk, most of the research on hospital-associated pneumonia over the past 20 years has been focused on VAP.

The bacteria responsible for VAP are mostly *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and Enterobacteriaceae, but infectious agents differ widely depending on the patients in the ICU, duration of hospital stay, and prior antimicrobial therapy. VAP is associated with a significant mortality risk. According to one review, the mortality rate for VAP, defined as pneumonia occurring more than 48 hours after endotracheal intubation and initiation of MV, ranges from 24% to 50% and can reach 76% in some settings or when lung infection is caused by high-risk pathogens.<sup>2</sup> Although appropriate antimicrobial treatment of patients with VAP can significantly improve outcomes, the optimal strategy is to prevent infection in the first place, especially in an era of antibiotic-resistant bacteria.

## Putting VAP Guidelines into Practice: Roundtable Discussion

Moderator: Dean Hess PhD, RRT, FAARC

Patient safety and quality of care have received increasing scrutiny in recent years. There is no dispute that patient care errors result in bad outcomes and increased costs. In the near future, such errors will likely impact reimbursement. Starting in 2009, Medicare will not cover the costs of preventable conditions, mistakes, and infections resulting from a hospital stay. From the perspective of the respiratory therapist, conditions such as nosocomial pneumonia -- specifically (VAP) -- likely will fall into the category of preventable conditions. Thus, it is imperative that the respiratory therapist implement practices to prevent VAP, as this will be increasingly scrutinized from the perspectives of quality, cost, and reimbursement. In this roundtable discussion, 3 respiratory therapists present their thoughts on implementation of VAP guidelines.

# Prevention of Ventilator-Associated Pneumonia

By Teresa A. Volsko, MHHS, RRT, FAARC

**V**entilator-associated pneumonia (VAP) is among the most common causes of hospital-acquired infections among patients admitted to intensive care units and often develops in intubated patients supported by mechanical ventilation for >48 hours as a result of bacterial contamination. Colonized microorganisms in the lower airway may result from a multitude of sources. Differences in study methodology and patient case mix can influence the reported incidence of VAP. Recognition of potential risk factors for VAP are important for the development and implementation of comprehensive prevention strategies. Reducing bacterial contamination from upper airway and gastrointestinal reservoirs minimizes the risk of aspirated colonized secretions. Barriers to reduce transmission from contaminated equipment and direct care providers are also required.

## **Incidence, Morbidity, and Mortality**

Nosocomial infections typically affect patients with compromised immunity due to age, presence of underlying disease, or medical intervention. Also, increasingly aggressive medical and therapeutic interventions have created a cohort of particularly vulnerable patients. Nosocomial infection rates are highest among individuals treated in intensive care units (ICU) and are often associated with poor patient and financial outcomes in terms of increased morbidity and mortality.<sup>1</sup>

The lower respiratory tract is the most common site for hospital acquired infections, which occur at a rate of 300,000 in acute care facilities across the United States annually.<sup>2</sup> Intubated patients receiving mechanical ventilation are at particular risk for acquired infections of the lower respiratory tract. Ventilator-associated pneumonia can develop in intubated patients supported for >48 hours by mechanical ventilation due to bacterial contamination from a variety sources, ranging from medical equipment and health care providers, to aspiration of bacterially colonized secretions.<sup>3</sup> A diagnosis of VAP is indicated when the following clinical findings are present: fever >38.3°C, worsening of gas exchange, aspiration of purulent tracheo-bronchial secretions, leukocytosis, and radiological evidence of pulmonary infiltrates with microbiological evidence of pulmonary pathogens.<sup>4</sup> The incidence of VAP reported in the literature varies. Disparities are attributed to differences in patients, variations in diagnostic criteria, and sensitivity and specificity

## The lower respiratory tract is the most common site for hospital acquired infections.

discrepancies in microbiological testing. The National Nosocomial Infections Surveillance Systems Report reports a median infection rate of 2.2 to 14.7 cases per 1000 ventilator days among adult ICU patients, accounting for up to 47% of all hospital acquired infections for this population.<sup>5</sup> Health care delivery costs associated with the diagnosis and treatment of VAP are significant and are commonly a result of poor outcomes, such as prolonged duration of mechanical ventilation, and increased ICU and hospital length of stay. In addition, VAP is associated with higher crude mortality rates, ranging from 20 - 70%.<sup>6</sup> Evidence-based strategies aimed at preventing VAP should be multi-dimensional and should combine measures to reduce the risk of aspirating colonized secretions with approaches aimed at minimizing transmission of pathogens from direct care givers and medical devices.

## **Reducing Sources of Colonizing Bacteria**

### *Oral Hygiene*

Colonization of the oral cavity is an important precursor in the development of VAP. The Centers for Disease Control and Prevention (CDC) report that in 76% of confirmed VAP cases, the same pathogen colonized the oral cavity and the lower respiratory tract.<sup>7</sup> Routine dental and oral hygiene, including an oral chlorhexidine rinse administered twice daily, is effective in reducing the incidence of VAP.<sup>8</sup> Proper oral and dental hygiene in combination with the use of a chlorhexidine rinse provide a cost-effective measure for minimizing one of the risk factors associated with VAP.

### *Artificial Airways and Airway Care*

The oropharynx and subglottic space can function as a reservoir for secretions and a supportive environment for bacterial growth.

Saliva, sinus drainage and gastric secretions can accumulate in the subglottic space. Gastroesophageal reflux is a contributory factor to the presence and collection of gastric secretions in the posterior pharynx. The literature reports an increased incidence of gastric colonization and secretion accumulation with the use of nasogastric tubes for enteral nutrition.<sup>9</sup> It is essential to maintain adequate nutritional status in critically ill patients, especially those receiving mechanical ventilation. Monitoring residual gastric volume can help prevent gastric overdistention during enteral feedings and assist the clinician in balancing the risks.

Altered level of consciousness and impaired mucociliary clearance can contribute to the pooling of secretions in the oropharynx and compromise the body's natural defense mechanisms against aspiration. Inoculation of the lower respiratory tract may occur as the endotracheal tube passes through the contaminated region of the oropharynx during the intubation procedure. Mucosal injury also facilitates bacterial colonization of the lower respiratory tract. This trauma may result from procedures performed to establish or remove an artificial airway, or routine airway care. Mucosal trauma may occur during insertion of the endotracheal tube. Tracheal trauma may also occur once the artificial airway is established. The use of excessive cuff pressures, endotracheal tube migration, or inadvertent extubation contribute to mucosal irritation and cellular damage.<sup>10</sup> Endotracheal tube cuffs are designed to seal the airway which will prevent volume loss during mechanical ventilation and minimize the risk of aspiration. Although there are different types of cuff designs, the high volume, low pressure cuff is very popular. During inflation, the cuff conforms to the tracheal wall, rather than sealing against it. This safety feature prevents the formation of a tight seal and minimizes the pressure exerted on the tracheal walls, lowering the probability of impeding tissue perfusion and mucosal damage. Concomitant use of cuff inflation techniques such as the minimal leak technique, and minimal occluding volume further reduce the incidence of mucosal blood flow impedance and subsequent tracheal wall damage. However, techniques to protect the integrity of tracheal wall tissue increase the likelihood that pooled, bacterially colonized subglottic secretions will leak into the trachea and contaminate the lower respiratory tract.<sup>11</sup>

Meticulous attention to the tracheal seal is essential to minimize the threat of aspiration, especially with the use of cuff pressures <20 cm H<sub>2</sub>O.<sup>12</sup> Removal of pooled secretions prior to routine cuff maintenance or manipulation of the cuff and endotracheal tube may prevent a direct pathway for secretions to be aspirated into the lower airway. However, this measure has little effect on microaspiration prophylaxis. Recent developments in endotracheal tube design make it possible to intermittently or continuously aspirate

subglottic secretions. The specially designed endotracheal tubes incorporate a suction lumen along the lateral aspect of the tracheal airway. The distal end of the lumen is elliptical and terminates just above the proximal aspect of the cuff. The proximal end of the lumen allows for attachment to a vacuum system. Studies support the role of continuous aspiration of subglottic secretions in delaying the onset and overall incidence of VAP.<sup>13</sup> In addition to subglottic secretion drainage, semi-recumbent patient positioning has been recognized as a practical, cost-effective intervention. Elevating the head of the bed at a 30 to 45 degree angle, especially during enteral feedings, enhances diaphragmatic excursion, and reduces the volume of gastric secretions and the risk for aspiration.<sup>14,15</sup> Not all ICU patients are candidates for semi-recumbent positioning. Identification of appropriate candidates and adherence to the degree of back rest elevation is essential to positive outcomes.

Endotracheal suctioning is an essential component of care and instrumental to maintaining airway patency and bronchial hygiene. There are two types of suctioning techniques. The open system requires interruption of the patient-ventilator circuit in order to introduce a single-use sterile catheter into the endotracheal tube. The manual resuscitator, used to provide oxygenation prior to secretion aspiration or during patient transport, can be a potential source for bacterial contamination of the airway and for acquired infection. Routine cleaning can reduce bacterial contamination from colonized secretions retained within the device.<sup>16</sup> Capping when the device is not in use allows for protection from environmental cross-contamination.

Closed suction systems enable the removal of airway secretions without disconnecting the patient from the ventilator circuit. The suction catheter is encased in a plastic reservoir and placed in line with the ventilator circuit proximal to the endotracheal tube adaptor. Since suctioning can transpire without disconnecting the patient from the ventilator circuit, the integrity of the patient-ventilator circuit remains intact. This lowers the probability of cross-contamination. As an added benefit, closed suction systems reduce the development of hypoxemia by preserving set levels of positive end expiratory pressure (PEEP) and the patient's lung volume.<sup>17</sup>

In a systematic review of randomized trials involving the endotracheal suctioning technique, Niel-Weise and colleagues found no evidence supporting the use of either suctioning system on the incidence of VAP.<sup>18</sup> The authors attribute methodological limitations for the inconsistent results obtained through this review. Currently, there are no CDC recommendations regarding the preferential use of open or closed suction techniques or the frequency of change for closed or multi-use suction devices.

Secretions in the artificial airway may adhere to the inner lumen of the endotra-

cheal tube creating a supportive environment for bacterial growth and biofilm formation. Biofilm-encased bacteria are typically resistant to normal cellular defenses. The bacteria can easily become dislodged during routine airway care, such as suctioning, leading to contamination of the lower respiratory tract. Prophylactic measures, such as the use of antibacterial agents to coat the internal surfaces of tracheal tubes are currently under investigation. This protective measure is aimed at reducing the onset and severity of bacterial colonization. The use of a silver-sulfadiazine coating has been instrumental in reducing secretion accumulation, bacterial growth and VAP in animal models.<sup>19,20</sup>

### Minimizing Risk of Cross-Contamination

#### *Ventilator circuit maintenance and humidifier selection*

Disposable, single-use circuits or reusable circuits are commercially available for use with mechanically ventilated patients. A heated wire may be incorporated into the circuit to reduce condensate formation, lowering the risk of colonization and subsequent spread throughout an ICU.<sup>21</sup> The choice of circuit is usually based on institutional preference. A number of randomized controlled trials and observational studies are available with regard to the frequency of ventilator circuit changes and risk of VAP, and the topic is a subject of much debate. Several studies support a longer circuit change interval, on the basis that it can reduce the cost of equipment

and staff time. Although there are no reported harmful effects associated with the practice, studies fail to report significant reductions in VAP rates.<sup>22</sup> Similarly, the American Association for Respiratory Care evidence-based guidelines on the care of the ventilator circuit do not recommend routine ventilator circuit changes for infection control purposes.<sup>23</sup> However, the maximum duration of time ventilator circuits can be safely used was not established.

Manipulation or breaks in the ventilator circuit may inherently occur during the course of routine care of the mechanically ventilated patient. The administration of medicated aerosol therapy, for example, may necessitate interruption of the ventilator circuit integrity on several occasions. If a passive humidification device is used, the circuit would be broken to remove the humidification device prior to the delivery of aerosolized medications by small volume nebulizer or metered dose inhaler to prevent filtering of aerosolized particles and reduced aerosol delivery to the patient.<sup>24</sup> Similarly, the integrity of the ventilator circuit would be compromised after the completion of therapy to replace the humidification device. Even if active humidification is used, the ventilator circuit may be interrupted, simply to place the medicated aerosol device inline with the ventilator circuit.

However, products are currently available which are marketed to reduce ventilator circuit breaks. To minimize the circuit interruptions in association with medicated aerosol therapy, manufacturers have developed



Figure 1. Spring loaded MDI Cannister (Courtesy Teleflex Medical)



Figure 2. Small Volume Nebulizer (Courtesy of Teleflex Medical)



Figure 3. Aerosolized particles redirected through center of device (Gibeck® Humid-Flo®, Teleflex Medical)



Figure 4. Aerosolized particles redirected through a separate piece of tubing (CircuVent® Smiths Medical)

products that can be permanently integrated into the ventilator circuit, such as collapsible spacers and aerosol tee's with a spring loaded valves. The use of one-way or spring loaded valves allow MDI canisters and small volume nebulizers can be directly connected to or removed from the ventilator circuit without interrupting circuit integrity (Figures 1 and 2). Manufacturers have incorporated bypass valves into the design of passive humidification devices. The valves are controlled by the caregiver and allow aerosolized particles to be redirected away from the hygroscopic media, either through the center of the device (Figure 3) or through a separate piece of tubing (Figure 4). There is a theoretical basis to support interest in such products in terms of a reduced risk of mean airway pressure, fluctuations in FIO<sub>2</sub> and loss of tidal volume with ventilator circuit interruptions.<sup>25</sup> However, further study is needed to determine if they can effectively prevent ventilator-associated pneumonia.

Warming and humidifying of inspired gases are integral components of care for mechanically ventilated patients. Artificial humidification can be accomplished with active or passive systems. Active humidifiers warm and moisturize inspired gas as it passes across or over a heated water bath. The use of heated wire circuits to decrease condensate and minimize interruptions or breaks in the patient ventilator circuit are instrumental in reducing the incidence of VAP.<sup>26</sup> Passive humidifiers, also known as heat and moisture exchangers (HMEs), employ a hygroscopic or hydrophobic material to trap heat and humidity from the patient's exhaled gas, which are then delivered back to the patient on the following inhalation. Device selection is dependent upon the length of ventilatory support, the presence and severity of pulmonary pathology, and the viscosity and characteristics of tracheobronchial secretions.

With respect to VAP prevention, several factors must be considered when selecting humidification devices. A systematic review of the literature reported that the incidence of VAP is not affected by the type of HME or the duration of use. In fact, prolonging the use of an HME further reduces the risk of cross-contamination and results in considerable cost savings.<sup>27</sup>

### Hand Hygiene

Decontamination of hands before and after patient contact is crucial for reducing person to person transmission of bacteria. Soap and water should be used when the caregiver's hands are visibly soiled with body fluids. Alcohol-based antiseptic agents, however, are acceptable alternatives, but do not negate the use of soap and water. It is important for healthcare providers to follow manufacturers' recommendations for the maximum frequency of use of these waterless cleansing agents. Compliance with routine hand washing after contact with mucus membranes, respiratory

secretions, or objects contaminated with respiratory secretions is important for the prevention of VAP, along with the use of protective barriers such as gloves.<sup>28</sup> Staff education and surveillance of hand washing compliance are instrumental in obtaining and maintaining positive preventive outcomes measures.

### Conclusions

Ventilator associated pneumonia is a frequent complication for patients receiving mechanical ventilation. This nosocomial infection is associated with increased healthcare costs and significant morbidity and mortality. Accurate clinical diagnosis of VAP can be problematic, but is an essential component of care. Interventions must begin with an understanding of the many factors contributing to the pathogenesis of this disease. Comprehensive preventive strategies must address the reservoirs and sources of bacterial colonization in addition to minimizing the routes of bacterial transmission. Useful prophylactic measures include upper and lower airway care, patient positioning, adherence to evidence-based guidelines for the manipulation and decontamination of respiratory equipment and adherence to hand hygiene.

### References

- Fridkin SK, Welbel SF, Weinstein RA. Magnitude and prevention of nosocomial infections in the intensive care unit. *Infect Dis Clin of North Am* 1997;11:479-96.
- McEachern R, Campbell GD. Hospital-acquired pneumonia: epidemiology, etiology and treatment. *Infect Dis Clin of North Am* 1998;12:761-779.
- Estes RJ, Meduri GU. The pathogenesis of ventilator-associated pneumonia: I. Mechanisms of bacterial transcolonization and airway inoculation. *Intensive Care Med* 1995;21:365-383.
- Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definition for nosocomial infections. *Am J Infect Control* 1988;16:128-140.
- Centers for Disease Control and Prevention. CDC National Nosocomial Infections Surveillance (NNIS) System Report, data summary form January 1992 through June 1994, issued October 1994. *Am J Infect Control* 2004;32:470-485.
- Craven DE. Preventing ventilator-associated pneumonia in adults; sowing seed of change. *Chest* 2006;130:251-260.
- Tabiab OC, Anderson LJ, Besser R, Bridges C, Hajjeh R, et al. Guidelines for preventing health-care-associated pneumonia, 2003: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee. *MMWR Recomm Rep* 2004;53:1-36.
- Genuit T, Bochicchio G, Napolitano LM, McCarter RJ, Roghman MC. *Surg Infect (Larchmt)* 2001;2:5-18.
- Ibabez J, Penafiel A, Raurich JM, Marse P, Jorda R, Mata F. Gastroesophageal reflux in intubated patients receiving enteral nutrition: effect of supine and semirecumbent positions. *J Parenter Enteral Nutr* 1992;16:419-422.
- Craven DE, Steger KA. Epidemiology of nosocomial pneumonia: new perspectives on an old disease. *Chest* 1995;108(suppl):1S-16S.
- Young PJ, Rollinson M, Downward G, Henderson S. Leakage of fluid past the tracheal tube cuff in a bench top model. *Br J Anaesth* 1997;78:557-562.
- Rello J, Sonora R, Jubert P, Artigas A, Rue M, Valles J. Pneumonia in intubated patients: role of respiratory airway care. *Am J Respir Crit Care Med* 1996;154:111-115.

- Kollef MH, Skubas NJ, Sundt TM. A randomized clinical trial of continuous aspiration of subglottic secretions in cardiac surgery patients. *Chest* 1999;116:1339-1346.
- Drakulovic MB, Torres A, Bauer TT, Nicolas JM, Norgue S, Ferrer M. Supine body position as a risk factor for nosocomial pneumonia in mechanically ventilated patients; a randomized trial. *Lancet* 1999;354:1851-1858.
- Kollef MH. Prevention of hospital associated pneumonia and ventilator associated pneumonia. *Crit Care Med* 2004;32:1396-1405.
- Weber DJ, Wilson M, Rutala WA, Thomann CA. Manual ventilation bags as a source for bacterial colonization of intubated patients. *Rev Respir Dis* 1990; 142: 892-894.
- Cordero L, Samanes M, Ayers LW. Comparison of a closed (Trach Care MAC) with an open endotracheal suction system in small premature infants. *J Perinatol* 2000;20:151-6.
- Niel-Weise BS, Snoeren RL, van den Brock PJ. Policies for endotracheal suctioning of patients receiving mechanical ventilation: a systematic review of randomized controlled trials. *Infect Control Hosp Epidemiol* 2007;28:531-536.
- Berra L., Curto F, Li Bassi G, Laquerriere P, Baccarelli A, Kolobow T. Antibacterial-coated tracheal tubes cleaned with emucus Shaver: a novel method to retain long-term bactericidal activity of coated tracheal tubes. *Intensive Care Med* 2006;32:888-893.
- Olson ME, Harmon BG, Kollef MH. Silver-coated endotracheal tubes associated with reduced bacterial burden in the lungs of mechanically ventilated dogs. *Chest* 2002;121:863-870.
- Craven DE, Kunches LM, Kilinsky V, Lichtenberg DA, Make BJ, McCabe WR. Risk factors for pneumonia and fatality in patients receiving continuous mechanical ventilation. *Am Rev Respir Dis* 1986;133:792-796.
- Fink JB, Krause SA, Barrett L, Schaaf D, Alex CG. Extending ventilator circuit changes in patients in intensive care unit. *Am J Infect Control* 1997;25:177-120.
- Hess DR, Kallstrom TJ, Mottram CD, Myers TR, Sorenson HM, Vines DL. American Association for Respiratory Care Evidence-Based Clinical Practice Guidelines: Care of the ventilator circuit and its relation to ventilator associated pneumonia. *Respir Care* 2003;48:869-879.
- Holtan J, Webb AR. An evaluation of the microbial retention performance of three ventilator-circuit filters. *Intensive Care Med* 1994;20:233-237.
- Choong K, Chatrkaw P, Frndova H, Cox PN. Comparison of loss in lung volume with open versus in-line catheter endotracheal suctioning. *Pediatr Crit Care Med* 2003;4:69 - 71.
- Lorente L, Lecuona M, Jimenez A, Mora ML, Sierra A. Ventilator-associated pneumonia using a heated humidifier or a heat and moisture exchanger: a randomized controlled trial. *Crit Care* 2006;10:R116.
- Dobek P, Keenan S, Cook D, et al. Evidence-Based Clinical Practice Guideline for the Prevention of Ventilator-Associated Pneumonia. *Ann Intern Med* 2004;141:305-314.
- Won SP, Chou HC, Hsieh WS, et al. Handwashing program for the prevention of nosocomial infections in a neonatal intensive care unit. *Infect Control Hosp Epidemiol* 2004;24:742-746.

**Teresa Ann Volsko, MHHS**, is Director of Clinical Education, BS in Respiratory Care & Polysomnography Programs, and Assistant Professor in the Department of Health Professions, The Bionte College of Health and Human Services, Youngstown State University, Youngstown, Ohio. Teresa is the author or coauthor of more than 50 articles, book chapters, and abstracts in respiratory care, and has given many presentations and lectures on the topic at conferences and symposia across the country. She lives in Canfield, Ohio.

# Putting VAP Guidelines into Practice: Roundtable Discussion

**Moderator:** Dean Hess, PhD, RRT, FAARC

**Panelists:** Richard Kallet, MSc, RRT, FAARC

Mike Gentile, RRT, RCP, FAARC

David Vines, MHS, RRT

**Hess:** Patient safety and quality of care have received increasing scrutiny in recent years. There is no dispute that patient care errors result in bad outcomes and increased costs. In the near future, such errors will likely impact reimbursement. Starting in 2009, Medicare will not cover the costs of preventable conditions, mistakes, and infections resulting from a hospital stay. From the perspective of the respiratory therapist, conditions such as nosocomial pneumonia—specifically ventilator-associated pneumonia (VAP)—likely will fall into the category of preventable conditions. Thus, it is imperative that the respiratory therapist implement practices to prevent VAP, as this will be increasingly scrutinized from the perspectives of quality, cost, and reimbursement. In this roundtable discussion, 3 respiratory therapists present their thoughts on implementation of VAP guidelines.

*Do you think that an invasive procedure like a bronchoscopy or mini-BAL with quantitative cultures is necessary for the diagnosis of VAP; or is a tracheal aspirate sufficient? Should a standard diagnostic protocol be developed? Do respiratory therapists in your hospital perform mini-BAL?*

**Gentile:** The diagnosis of VAP is a fiercely debated topic among 2 separate groups. One group uses a clinical strategy which includes tracheal aspirates, and the other group employs a bacteriologic strategy that uses lower respiratory secretions. A lower respiratory tract specimen obtained via bronchoscope or mini-BAL can identify the specific causative organism of pneumonia. The mini-BAL can assist in the quantitative diagnosis of VAP and improve specificity. For the most part, my institution uses the bacteriologic strategy in order to properly guide antibiotic therapy.

A universal and standard protocol should be developed for the diagnosis of VAP, especially in light of the probable reductions we will see in Medicare payments for hospital-acquired infections. Many institutions are performing a mini-BAL procedure at the time of patient

A universal and standard protocol should be developed for the diagnosis of VAP, especially in light of the probable reductions we will see in Medicare payments for hospital-acquired infections.

admission or intubation to evaluate possible pneumonia. Respiratory therapists routinely perform mini-BAL procedures in my hospital with great proficiency. This was originally performed by physicians only, but was quickly transferred to the respiratory therapists.

**Kallet:** Tracheal aspirates are probably sufficient for a diagnosis, but the problem is that reliance upon tracheal aspirates and nonquantitative cultures probably leads to overdiagnosis of VAP and excessive antibiotic usage. Although a recent major randomized controlled trial showed no difference either in outcomes or targeted therapy,<sup>1</sup> they excluded two major categories of patients—those with suspected *Pseudomonas* species and MRSA infections—so I think we need to be cautious in how we apply those results to our own patient populations. Both MRSA and *Pseudomonas* pulmonary infections are common at our hospitals.

At this juncture we use tracheal aspirates for diagnosis. Although our critical care divisions would like to adopt mini-BAL and quantitative cultures as the standard of care, we are meeting stiff resistance from the laboratory medicine people who are not convinced that the evidence justifies the huge in-

crease in workload. Given the dire economic constraints placed upon our public hospitals, this is a legitimate concern. I absolutely support standardized diagnostic protocols for VAP, and respiratory therapists should play an integral role. Select members of our respiratory therapy staff perform mini-BAL, but at this juncture, it is only as part of a research protocol.

**Vines:** I think that tracheal aspirate is sufficient for diagnosing VAP. At the University of Texas Hospital, we follow the Centers for Disease Control (CDC) guidelines for diagnosing ventilator associated pneumonia.<sup>2</sup> In most cases the clinical criteria of fever, purulent sputum production, and new infiltrate or progression of a pulmonary infiltrate will be enough to start treatment. The tracheal aspirate is sent for a semiquantitative analysis that detects mild, moderate, or heavy growth. Some physicians use bronchoscopic techniques to obtain samples for a quantitative culture. This is preferred by the infection control department.

I can certainly see the benefit of a standardized diagnostic protocol for VAP, especially for understanding prevalence and application of research findings. The complexity of diagnosis and controversy around diagnostic procedures for VAP would significantly hinder the development of this protocol.

*What strategies do you use to minimize microaspiration? Also, do respiratory therapists at your hospital regularly monitor cuff pressures?*

**Gentile:** Patients at our institution undergo specific oral care and decontamination to minimize micro-aspiration. We evaluated devices that promote subglottic aspiration of secretions and found no clinical benefit or measurable outcome improvement, and they significantly increased cost. Furthermore, patients intubated at outside facilities and transferred to our institution required removal of the standard endotracheal tube and reintubation with a subglottic aspiration device. This procedure is not without inherent risks and was deferred in most cases. We use the minimum leak technique to monitor endotracheal cuff pressure. This practice is also part of our infection control process which includes not transporting cuff monitoring devices from patient to patient.

**Kallet:** Our strategies to minimize microaspiration include maintaining HOB at 30° C or more in all patients, with the exception of those in shock or those who have other contraindications, such as spinal fractures. We do use continuous lateral rotational therapy in these patients. We don't use the special endotracheal tubes that allow for subglottic secretion drainage (SSD). When we piloted

these tubes, we found that the suction ports became routinely clogged. The tubes are expensive and are quite labor intensive. Although my understanding is that the design and functioning of the SSD tubes have improved, we have not re-examined them. We do not routinely monitor endotracheal tube (ETT) cuff pressures as we found the procedure often leads to inadvertent aspiration of secretions. This is because the additional tubing volume of the manometer system caused volume to leak from the cuff. We use Pressure-Easy, a spring-loaded valved system which maintains cuff pressure at 25 cm H<sub>2</sub>O. This obviates the need to manually check cuff pressures, and reduces the risk of inadvertent aspiration that is inherent in the manual manometer systems.

**Vines:** At the University of Texas Hospital, we use the Institute for Healthcare Improvement's Ventilator Bundle to prevent VAP. The bundle has four components: (1) elevation of the head of the bed (HOB) by 30 and 45 degrees, (2) interruption of sedation to assess readiness for extubation, (3) prophylaxis for deep vein thrombosis, and (4) prophylaxis for peptic ulcer disease. In addition to these interventions, we also provide oral care, we monitor cuff pressures and change circuits when they malfunction or become visibly soiled. Of these strategies to prevent VAP, maintaining the HOB at 30° to 45° C and routinely monitoring cuff pressure should help minimize micro-aspiration.

The data on endotracheal and tracheostomy tubes for subglottic aspiration of secretions is not convincing enough to justify the expense. I would recommend that the institution first develop a comprehensive program to prevent VAP as recently described in an article by Murray and Goodyear-Bruch.<sup>3</sup> Then add the endotracheal tube with subglottic aspiration to determine if they reduce the occurrence of VAP in your ICU setting. If they do, great! If not, discontinue their use.

As for your question concerning the monitoring of cuff pressures, our respiratory therapist monitors cuff pressures at least every 12 hours. The cuff pressure is maintained at 20 to 25 cm H<sub>2</sub>O.

**Do you use inline suction catheters on a routine basis?**

**Gentile:** We have used inline suction catheters on all mechanically ventilated patients since their introduction. In addition to our VAP prevention strategy, the use of inline suction catheters avoids the need to disconnect the patient from the mechanical ventilator, thus preserving mean airway pressure and recruited lung volume.

## I do believe that not breaking the circuit on a routine basis plays a role in preventing VAP.

- Vines -

**Kallet:** Yes, inline suction catheters are a standard of care at our institution. This is done primarily as part of our VAP bundle, but it has the added benefit of reducing the risk of derecruitment and arterial oxygen desaturation during suctioning in patients on high levels of PEEP and FiO<sub>2</sub>. As we care for a patient population at extraordinarily high risk for tuberculosis, inline suction catheters provide a further benefit in reducing environmental risks to the clinicians.

**Vines:** We use inline suction catheters on a routine basis to avoid breaking the circuit. The infection control department recommends the use of inline suction catheters but it is not required. I do believe that not breaking the circuit on a routine basis plays a role in preventing VAP. Every time a healthcare provider breaks the circuit, they create an opportunity to contaminate the circuit. There is one randomized trial that reported no significant difference in VAP rate between no routine changes and daily changes of the in-line suction catheter.

**Is elevation of the head of the bed (HOB) a useful strategy to prevent VAP? What can be done to improve compliance?**

**Gentile:** As we've discussed, elevation of the head of the bed is a fundamental part of VAP prevention and is a component of the widely accepted Institute for Healthcare Improvement's "Ventilator Bundle". Elevation of the head of the bed at 30 to 45 degrees has been associated with significant VAP reduction.

**Kallet:** I agree. Elevated HOB strategy has been shown to be a very simple and effective strategy to reduce VAP.<sup>4</sup> It works by limiting gastric regurgitation and thereby decreasing the ease with which gastric secretions can reach the hypopharynx. There is convincing evidence that elevated HOB reduces the presence of gastric secretions in the lower respiratory tract by more than 50%.<sup>5,6</sup> It is worth emphasizing that the overwhelming source of VAP is the gastrointestinal tract.

**Vines:** Everyone is correct about the value of elevating HOB, but maintaining staff compliance is the main difficulty with this recommendation. Reminders on the nursing flow sheet and in the room may be helpful. Even a line on the wall behind the bed to indicate that the HOB is too low may serve as an additional reminder. Staff and family education on the need for the HOB to remain elevated is also beneficial in improving compliance.

**Would an antimicrobial coating on endotracheal tubes be useful for preventing and mitigating VAP? What do you see as advantages and disadvantages of this approach?**

**Gentile:** Coating endotracheal tubes with an agent such as chlorhexidine or silver has great potential to decrease the incidence of VAP. This technology is now being evaluated in large, multicenter, randomized controlled trials. The prospective advantages include reduction in biofilm accumulation, decreased bacterial colonization in the ventilator circuit, lungs, and endotracheal tube, and ultimately a reduction in VAP. The possible disadvantage may be a significantly increased cost for endotracheal tubes.

**Kallet:** I think incorporating an antimicrobial coating into ETT or tracheal tubes would be helpful in reducing the contributions of biofilm to the development of VAP. That being said, however, I really think the emphasis should be on better cuff design and perfecting the design of tubes that provide SSD by improving the suction capabilities and perhaps by facilitating instillation of chlorhexidine into the area above the cuff. The major disadvantage of the silver coating (and SSD tubes) is economic. Is it really justified using these expensive devices? For example, SSD tubes cost about 15 times as much as a standard ETT in most mechanically ventilated patients when the average duration of mechanical ventilation is often less than 4 days.<sup>7</sup> It is often difficult to predict who is going to require a prolonged course of mechanical ventilation. Also, it is not feasible to change over to a special ETT in patients who do require prolonged mechanical ventilation because the act of changing the artificial airway itself markedly increases the risk of VAP.

**Vines:** In my opinion, the use of antimicrobial coated endotracheal tubes to eliminate biofilm has not been effective in reducing VAP. In theory, the advantage of eliminating the biofilm is the prevention of organisms becoming dislodged during suctioning and contaminating the lungs. The disadvantage may be the development of antibiotic resistant organisms that may result in multiresistant microorganism VAP.

I think the single most  
important thing we can do as  
clinicians  
is to ensure that we maintain  
an elevated HOB position  
whenever possible.

*What is the single most important strategy that respiratory therapists can use to prevent VAP?*

**Gentile:** Oddly enough, respiratory therapists can help prevent the risk of VAP by avoiding endotracheal intubation of a patient, if safely possible. Noninvasive positive pressure ventilation (NPPV) may be an effective alternative to endotracheal intubation and is growing in acceptance and popularity. If a patient requires intubation, then weaning, daily assessment of readiness to extubate, and mechanical ventilator discontinuation should occur as soon as it is medically safe for the patient to be without an artificial airway. Also imperative for the prevention of VAP is infection control practices and universal precautions.

**Kallet:** I think the single most important thing we can do as clinicians is to ensure that we maintain an elevated HOB position whenever possible. Although I think there are other techniques that may be helpful in preventing VAP, at this juncture, the clinical evidence is fairly ambiguous. In contrast, the evidence from studies of patient positioning are the most persuasive and unambiguous.

**Vines:** VAP is a complex disease and requires a holistic team approach to prevent its occurrence. It is important for everyone to participate in maintaining the elevated HOB and good hand washing procedures. Respiratory therapists also need to avoid breaking the circuit for routine infection control changes. The therapist should prevent the accumulation of water and secretions in the circuit from draining back down the endotracheal tube. Maintaining cuff pressure between 20 and 25 cm H<sub>2</sub>O and good humidity and bronchial hygiene are other factors the therapist should pay special attention to. Daily assessment of the patient's readiness for the discontinuation of mechanical ventilation can help avoid the development of VAP. Respiratory

therapists should pay attention to the little details; they can make a big difference.

### Summary

In this discussion, Richard Kallet, Mike Gentile, and David Vines have provided important and useful insights related to the prevention and diagnosis of VAP. Their responses to these important questions are a model for all respiratory therapists as we develop strategies in our own hospitals to prevent VAP. As respiratory therapists, we will be increasingly held accountable for patient safety within our sphere of clinical responsibility including prevention of VAP. I think Rich, Mike, and David did a very nice job addressing the questions that we posed to them.

1. Canadian Critical Care Trials Group. A randomized trial of diagnostic techniques for ventilator associated pneumonia. *N Engl J Med.* 2006; 355:2619-2630.
2. Centers for Disease Control and Prevention. "Guidelines for preventing health-care-associated pneumonia, 2003: Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC)." 2004. available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5303a1.htm>. Accessed: October 5, 2007.
3. Murray T, Goodyear-Bruch C. Ventilator-associated Pneumonia Improvement Program. *AACN Advanced Critical Care* 2007;18:190-199.
4. Drakulovic MB, Torres A, Bauer TT, Nicolas JM, Nogue S, Ferrer M. Supine body position as a risk factor for nosocomial pneumonia in mechanically ventilated patients: A randomised trial. *Lancet.* 1999;354:1851-1858.
5. Ibanez J, Penafiel A, Raurich JM, et al. Gastroesophageal reflux in intubated patients receiving enteric nutrition: effect of supine and semirecumbent positions. *J Parenter Enteral Nutr.* 1992;16:419-422.
6. Torres A, Serra-Batllés J, Ros E, et al. Pulmonary aspiration of gastric contents in patients receiving mechanical ventilation: the effects of body position. *Ann Intern Med.* 1992;116:540-543.
7. Diaz E, Rodriguez AH, Rello J. Ventilator-associated pneumonia: issues related to the artificial airway. *Respir Care* 2005; 50(7):900-906.

**Michael A. Gentile** is a Registered Respiratory Therapist and Research Associate in the Divisions of Pulmonary Medicine and Pediatric Critical Care, Duke University Medical Center, Durham. He serves on the American Association for Respiratory Care's Clinical Practice Guidelines Steering Committee and Program Steering Committee and is Program Co-director of Optimizing Mechanical Ventilation for Infant and Children. Michael is the author or coauthor of over 50 publications and abstracts in the area of respiratory care. He lives in Durham, North Carolina.

**Dean Hess**, PhD RRT, is Assistant Director of Respiratory Care, Massachusetts General Hospital, and Associate Professor of Anesthesia, Harvard Medical School, Boston, MA. He has over 30 years of experience in respiratory care, which includes clinical, research, teaching, and administrative responsibilities. He is an Associate Editor of Respiratory Care journal and serves on the Editorial Boards of the Journal of Aerosol Medicine, International Anesthesiology Clinics, and Critical Care Alert. His research interests include aerosol delivery techniques, adult mechanical ventilation, and critical care monitoring. He is a Fellow of the American Association for Respiratory Care and the American College of Chest Physicians. He has published nearly 200 papers and 7 books.

**Richard Kallet**, MS, RRT, FAARC, is Clinical Projects Manager at the University of California at San Francisco's Cardiovascular Research Institute and Supervisor of Research and Education at its Department of Anesthesia, Respiratory Care Services. Chairman, Respiratory Care Section, of the Society of Critical Care Medicine, he has been a registered respiratory therapist since 1980. He is also a certified respiratory care practitioner.

A fellow of the American Association for Respiratory Care, he received the Dr. Allen DeVilbiss Technology Paper Award presented by the American Respiratory Care Foundation. He was also a research citations finalist at the 2005 Critical Care Congress of the Society of Critical Care Medicine. He is the author or co-author of over 80 studies and papers published in journals such as *Critical Care Medicine Journal*, *American Journal of Respiratory and Critical Care Medicine*, and *Respiratory Care Journal* where he is a member of the editorial board.

**David L. Vines** is a Registered Respiratory Therapist and program director at the University of Texas Health Science Center at San Antonio, Department of Respiratory Care, San Antonio, Texas. His main research interests in the area of mechanical ventilation are the theory and application of modes of ventilation, positive end expiratory pressure (PEEP), and ventilator graphics. He has taught many courses at the undergraduate level and developed curricula in management, advanced airway support, pediatric and neonatal respiratory care, and basic respiratory care equipment. David is the author of over 30 articles, abstracts, book chapters, and reviews, and has been invited to speak on respiratory care topics at facilities in Texas and across the country. He lives in San Antonio, Texas.

*Clinical Foundations* is a serial education program distributed free-of-charge to health professionals. *Clinical Foundations* is published by Saxe Healthcare Communications and is funded through an education grant from Teleflex Medical Incorporated. The goal of *Clinical Foundations: A Patient-Focused Education Program for Respiratory Care Professionals* is to present clinically- and evidence-based practices to assist the clinician in making an informed decision on what is best for his/her patient. The opinions expressed in *Clinical Foundations* are those of the authors only. Neither Saxe Healthcare Communications nor Teleflex Incorporated make any warranty or representations about the accuracy or reliability of those opinions or their applicability to a particular clinical situation. Review of these materials is not a substitute for a practitioner's independent research and medical opinion. Saxe Healthcare Communications and Teleflex Incorporated disclaim any responsibility or liability for such material. They shall not be liable for any direct, special, indirect, incidental, or consequential damages of any kind arising from the use of this publication or the materials contained therein.

Please direct your correspondence to:

**Saxe Healthcare Communications**  
P.O. Box 1282  
Burlington, VT 05402  
[info@saxecomunications.com](mailto:info@saxecomunications.com)  
Fax: 802.872.7558  
© Saxe Communications 2008

**Questions**

1. **What is the most effective measure used to prevent person-to-person transmission of bacteria.**
  - a. The routine use of gown and gloves
  - b. Hand washing before and after patient contact
  - c. Strict isolation measures
  - d. Protective eyewear
2. **What action is recommended to prevent microaspiration of subglottic secretions during endotracheal tube cuff maintenance?**
  - a. Deflate and inflate the cuff as needed
  - b. Hyperventilate the patient prior to cuff manipulation
  - c. Suction above the cuff prior to cuff deflation
  - d. Perform vigorous oral care before manipulating cuff pressures
3. **Which of the following best describes the rationale for the use of semi-recumbent positioning?**
  - a. Prevents decubitus formation of the lumbar region
  - b. Reduces the risk of accidental extubation
  - c. Facilitates patient orientation to time and place
  - d. Decreases the volume of gastric secretions and risk of aspiration
4. **Which of the following agents is effective in reducing the incidence of VAP when incorporated into an oral hygiene plan**
  - a. Commercially prepared mouthwashes
  - b. Chlorhexidine rinse preparations
  - c. Half-strength hydrogen peroxide and sterile water
  - d. Sterile normal saline solution
5. **Which of the following is the current CDC recommendation regarding the preferential use of suction devices?**
  - a. Closed suction systems should be used and changed every 24 hours
  - b. Open suction technique reduces the incidence of VAP
  - c. No CDC recommendations exist with regard to preferential use of suction devices.
  - d. Multi-use suction devices should be changed with the ventilator circuit
6. **Selection of an artificial humidification device is dependent upon**
  - a. Length of ventilatory support
  - b. Presence and severity of pulmonary pathology
  - c. Viscosity and characteristics of airway secretions
  - d. All of the above
7. **Endotracheal suctioning is essential in**
  - a. Maintaining airway patency and bronchial hygiene
  - b. Preventing mucosal injury from impedance of capillary blood flow
  - c. Minimizing microaspiration of pooled subglottic secretions
  - d. Reducing the formation of bacterial biofilm
8. **The most common type of endotracheal tube cuff is**
  - a. Foam
  - b. High pressure, low volume
  - c. High volume, low pressure
  - d. Tight to the shaft
9. **What is the incidence, reported by the CDC, of the same pathogen colonizing the oral cavity and lower respiratory tract?**
  - a. 26%
  - b. 49%
  - c. 65%
  - d. 76%
10. **What strategy(ies) can be used to minimize microaspiration**
  - a. Oral care
  - b. Head of bed elevated by 30 to 45 degrees
  - c. Routine monitoring of ETT cuff pressure
  - d. All of the above
11. **Inline suction catheter are used in VAP prevention strategy to:**
  - a. avoid disconnecting patient from mechanical ventilator
  - b. improve subglottic suctioning
  - c. diagnosis of VAP
  - d. none of the above
12. **Breaking the circuit can contribute to VAP by:**
  - a. preventing arterial oxygen desaturation during suctioning
  - b. increasing opportunity to contaminate the circuit
  - c. minimize interruption of sedation to assess readiness for extubation
  - d. reduce risk of inadvertent aspiration
13. **What technological change promises to reduce risk of VAP?**
  - a. lower respiratory tract specimen obtained via bronchoscope or mini BAL
  - b. endotracheal tubes that allow for subglottic secretion drainage
  - c. coating endotracheal tubes with an agent such as chlorhexidine or silver
  - d. all of the above

This test must be taken online. Go to [www.saxetesting.com/crce/](http://www.saxetesting.com/crce/) and log in. Upon successful completion, your certificate can be printed out immediately. AARC members' results are automatically forwarded to the AARC for accreditation.

This program has been approved for 1.5 contact hours of continuing education (CRCE) by the American Association for Respiratory Care (AARC). AARC is accredited as an approver of continuing education in respiratory care.

*To earn credit, do the following:*

1. Read all the articles.
2. Complete the entire post-test.
3. Mark your answers clearly with an "X" in the box next to the correct answer. You can make copies.
4. Complete the participant evaluation.
5. Go to [www.saxetesting.com/crce/](http://www.saxetesting.com/crce/) to take the test online.
6. To earn 1.5 CRCEs, you must achieve a score of 75% or more. If you do not pass the test you may take it over one more time.
7. Your results will be sent within 4-6 weeks after forms are received.
8. Answer forms must be postmarked by Jan. 13, 2017.
9. **This article is no longer sponsored. You may still take this test and receive accreditation, however there is a nominal fee (\$10.00) to cover the cost of accreditation and scoring. You may take this test 2 times at no additional charge.**

**Participant's Evaluation**

The goal of this program is to educate healthcare professionals on the management of OSA

1. **What is the highest degree you have earned? Circle one. 1. Diploma 2. Associate 3. Bachelor 4. Masters 5. Doctorate**
2. **Indicate to what degree the program met the objectives:**

**Objectives**

Upon completion of the course, the reader was able to:

1. **Define ventilator-associated pneumonia.**  
Strongly Agree      Strongly Disagree  
1    2    3    4    5    6
2. **List the factors that contribute to the pathogenesis of VAP.**  
Strongly Agree      Strongly Disagree  
1    2    3    4    5    6
3. **Discuss prophylactic measures designed to reduce contamination of the lower airway from colonized secretions.**  
Strongly Agree      Strongly Disagree  
1    2    3    4    5    6
4. **List strategies to minimize microaspirations**  
Strongly Agree      Strongly Disagree  
1    2    3    4    5    6
5. **Identify the most important strategy (ies) to prevent VAP.**  
Strongly Agree      Strongly Disagree  
1    2    3    4    5    6

Please indicate your agreement with the following statement. "The content of this course was presented without bias of any product or drug."

Strongly Agree      Strongly Disagree  
1    2    3    4    5    6

**Answers**

- |   |                            |                            |                            |                            |    |                            |                            |                            |                            |
|---|----------------------------|----------------------------|----------------------------|----------------------------|----|----------------------------|----------------------------|----------------------------|----------------------------|
| 1 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 9  | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 2 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 10 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 3 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 11 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 4 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 12 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 5 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 13 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 6 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 14 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 7 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 15 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 8 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 16 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |

*This test is no longer sponsored.*

*To cover the costs of internet and accreditation, there is a modest charge of \$10.00 for accreditation.*

*Please go to [www.saxetesting.com/crce/](http://www.saxetesting.com/crce/) to take your post-test*