CriticalCareNurse
The journal for high acuity, progressive, and critical care nursing

Preventing Ventilator-Associated Pneumonia in Children: An Evidence-Based Protocol

Virginia Bonsal Cooper and Catherine Haut

Crit Care Nurse 2013;33:21-29 doi: 10.4037/ccn2013204

Published online http://www.cconline.org

Critical Care Nurse is the official peer-reviewed clinical journal of the American Association of Critical-Care Nurses, published bi-monthly by The InnoVision Group 101 Columbia, Aliso Viejo, CA 92656. Telephone: (800) 899-1712, (949) 362-2050, ext. 532. Fax: (949) 362-2049.

AMERICAN ASSOCIATION of CRITICAL-CARE NURSES

Preventing Ventilator-Associated Pneumonia in Children: An Evidence-Based Protocol

Virginia Bonsal Cooper, RN, MS
Catherine Haut, DNP, CPNP/AC, CCRN

Ventilator-associated pneumonia, the second most common hospital-acquired infection in pediatric intensive care units, is linked to increased morbidity, mortality, and lengths of stay in the hospital and intensive care unit, adding tremendously to health care costs. Prevention is the most appropriate intervention, but little research has been done in children to identify necessary skills and strategies. Critical care nurses play an important role in identification of risk factors and prevention of ventilator-associated pneumonia. A care bundle based on factors, including evidence regarding the pathophysiology and etiology of pneumonia, mechanical ventilation, duration of ventilation, and age of the child, can offer prompts and consistent prevention strategies for providers caring for children in the pediatric intensive care unit. Following the recommendations of the Centers for Disease Control and Prevention and adapting an adult model also can support this endeavor. Ultimately, the bedside nurse directs care, using best evidence to prevent this important health care problem. (*Critical Care Nurse.* 2013;33[3]:21-30)

As a hospital-acquired infection (HAI), ventilator-associated pneumonia (VAP) is associated with additional complications for patients in the pediatric intensive care unit (PICU). Despite the volume of published information on VAP in adults, the amount of research on VAP in children is limited. Health care providers need to be aware of the risk for VAP in infants and children and should have preventive programs in place. Evidence-based protocols that outline preventive and therapeutic treatments for specific situations for adults treated with mechanical ventilation have been developed, but little has been offered for the care of children receiving mechanical ventilation.

CNE Continuing Nursing Education

This article has been designated for CNE credit. A closed-book, multiple-choice examination follows this article, which tests your knowledge of the following objectives:

1. Describe pediatric risk factors for ventilator-associated pneumonia (VAP)
2. Identify strategies to prevent pediatric VAP
3. Discuss current evidence in the prevention of VAP in children

 doi: http://dx.doi.org/10.4037/ccn2013204

In this article, we present the definition, significance, etiology, risk factors, and diagnosis of VAP in infants and children. We provide background evidence to support the use of intervention and prevention strategies, with some reliance on data from adults, and explain the rationale for use of these strategies in children. We also supply recommendations for a bundled prevention protocol for support of children treated with mechanical ventilation in the PICU, with a focus on suctioning or airway clearance, oral care, and ventilator circuit changes.

Ventilator-Associated Pneumonia

HAIs occur in approximately 12% of PICU patients,[1] and 18% to 26% of the infections are pneumonias.[2,3] VAP is defined as a hospital-acquired pneumonia that develops in patients who have been treated with mechanical ventilation for 48 hours or longer who had no signs or symptoms of lower respiratory infection before they were intubated and treatment with mechanical ventilation began.[4] A more current general definition of VAP for adults and children includes surveillance for complications resulting in deterioration in respiratory status and increased ventilator support after a period of stability or improvement.[4,5] VAP is indicated when ventilator settings have been changed because of increased oxygen requirements and the need for increased inspiratory and expiratory pressures during a 2-day or 48-hour period.[4,5] A proposed definition is based on complications associated with mechanical ventilation, with consideration given to changing the term from VAP to ventilator-associated complications (VAC), but this change has not yet been accepted or implemented.[4,5]

VAP develops when bacteria colonize the pulmonary parenchyma or lower respiratory tract of a patient receiving mechanical ventilation.[6] According to the Centers for Disease Control and Prevention (CDC),[4] increased

Case Study, Part 1

A 4-month-old, formerly preterm girl was transferred to the pediatric intensive care unit (PICU) after she had been seen by her primary care physician because of a 1-week history of upper respiratory signs, increased work of breathing, and indications of respiratory distress, including wheezing and tachypnea with the use of accessory muscles. The girl had been born at 26 weeks of gestation and had a history of pulmonary hypertension, chronic lung disease, intraventricular hemorrhage, gastroesophageal reflux disease, and retinopathy of prematurity.

Despite noninvasive and aggressive medical interventions, the respiratory distress continued to worsen, necessitating endotracheal intubation and mechanical ventilation. The PICU standard protocols for intubated patients were followed, including use of sedatives and paralytic agents, suctioning as needed, and elevating the head of bed to 30° to 45°. After 7 days of intubation, the patient began to have signs of pneumonia, including fever, purulent sputum, and episodes of hypoxemia. A complete blood count showed leukocytosis, and a chest radiograph indicated the presence of new infiltrates. A sputum culture was positive for *Staphylococcus aureus,* which is often a hospital-acquired respiratory organism. These findings indicated ventilator-associated pneumonia, which ultimately increased the infant's length of intubation and stay in the PICU. ■

Authors

Virginia Cooper practices as a nurse in the pediatric intensive and intermediate care units at the University of Maryland Medical Center Children's Hospital, Baltimore, Maryland.

Catherine Haut is the program director of the acute care pediatric nurse practitioner program at the University of Maryland School of Nursing and practices as a pediatric nurse practitioner in the pediatric intensive care unit at Herman and Walter Samuelson Children's Hospital at Sinai, Baltimore, Maryland.

Corresponding author: Virginia Bonsal Cooper, RN, MS, 410 W Lombard St, Apt 515, Baltimore, MD 21201 (e-mail: vbcooper8@gmail.com).

To purchase electronic or print reprints, contact The InnoVision Group, 101 Columbia, Aliso Viejo, CA 92656. Phone, (800) 899-1712 or (949) 362-2050 (ext 532); fax, (949) 362-2049; e-mail, reprints@aacn.org.

body temperature; leukopenia; new onset of purulent sputum; apnea; tachypnea; nasal flaring with retraction of the chest wall or grunting; wheezing, rales, or rhonchi; and cough indicate VAP in a young infant or child. Bacterial colonization of the normally sterile lower respiratory tract usually is due to aspiration of secretions, colonization of the aerodigestive tract, or the use of contaminated equipment.[6] The estimated rate of VAP is 1.4 to 5.8 events per 1000 intubated patients, with a downward trend since 2000.[4,5] In the PICU, 20% of nosocomial infections are VAP, with an incidence of 4 to 44 per 1000 intubated children.[7] In addition, data from the CDC National Nosocomial Infections Surveillance System has indicated a mean PICU VAP rate of 2.9 per 1000 ventilator days.[8]

Intubated patients are at risk for VAP because of their poor cough and gag reflexes and their immobility.[9] Furthermore, the risk for VAP is greater for intubated children than for intubated adults; the associated devices include uncuffed endotracheal tubes, nasally placed endotracheal tubes, open-circuit suctioning, use of physiological saline during suctioning, and developing teeth.[9] The most common pathogens associated with VAP in the PICU are *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Haemophilus influenzae*.[9,10] In adult patients, VAP is characterized according to the time of onset—early or late—and the related pathogens. Early-onset VAP is often caused by *Streptococcus pneumoniae*, *H influenzae*, or *Moraxella catarrhalis*. Late-onset VAP occurs later than 4 days after admission and is usually caused by *P aeruginosa*, *Acinetobacter* species, *Enterobacter* species, or methicillin-resistant *S aureus*.[10] Other organisms have also been isolated from adults, and incidents of polymicrobial VAP have been reported in that population, but the same has not been documented in children.[11] Thus far, little information is available on the documentation and prevention of VAP in infants and children.

Review of the Literature

Only since 2007 has published evidence indicated a need for increased awareness of VAP in children. Despite the known consequences of VAP, unlike the situation for adults, few studies have been conducted on the epidemiology, associated risk factors, prevention, and outcomes of VAP in children.[8] The application or association of data on adults to treatment of children and comparison of data on adults with data on children are important to fully comprehend the extent of the VAP issue. However, more important is the need to appreciate an opportunity to address prevention of VAP in children.

Significance

VAP is a marked health risk for hospitalized infants and children.[1] It is one of the top causes of HAI in the PICU, accounting for 18% to 26% of all HAIs in the unit and resulting in a mortality rate of about 10% to 20%.[1,12] VAP is associated with increased mortality and morbidity, increased length of hospital stay, and high health care costs.[8,12] Currently, pneumonia is the sixth leading cause of death in the United States and the leading cause of death of children worldwide.[3,13] The mortality rate for patients of all ages with VAP is approximately 33% to 50%.[1,3] Srinivasan et al[8] found that children with VAP had a median of only 6 ICU-free days, whereas patients without VAP had a median of 13 ICU-free days.

In the PICU, 20% of nosocomial infections are VAP, with an incidence of 4 to 44 per 1000 intubated children.

VAP is associated with high costs to patients and the health care system as a whole. According to estimates, 300 000 cases of VAP occur each year and cost health care systems more than $12 billion.[3] VAP also increases length of stay up to 22 days, with a cost greater than $40 000 per patient per infection.[3] The cost per hospitalization is $308 534 for an infant or child with VAP and $252 652 for patients without VAP.[8]

Etiology and Risk Factors

The risk factors for VAP differ between adults and children[4,10,11,14-18] (Table 1). The duration of mechanical ventilation is a risk for both groups, but the results of studies in children have differed somewhat from the results of studies in adults.[1,8] Risk factors for VAP in children currently include use of opiates for sedation, sustained neuromuscular blockade, use of enteral nutrition, previous antibiotic therapy, the technique used for endotracheal suctioning, reintubation, ventilator circuit changes, gastroesophageal reflux, subglottal or tracheal stenosis, young infants or age greater than 10 years, and trauma or surgical problems.[2,4,7,8,19,20] Primarily, unlike adults, children have developmental and physiological differences for a wide range of ages. Age is also a factor in immunity, so younger or preterm infants are more likely than older

Table 1 Risk factors for ventilator-associated pneumonia: adults versus children

Group		
Adults	**Adults and children**	**Children**
Duration of intubation	Use of H_2-receptor blockers	Mechanical ventilation for more than 48 hours
Age of patient	Gastrointestinal hypomobility with microaspiration	Underlying respiratory disease
Use of inhaled β-agonists	Use of gastric tubes and feeding tubes	Genetic syndromes
Burns	Degree or severity of illness	Immunodeficiency
Diseases of the central nervous system	Trauma	Transport out of the pediatric intensive care unit
Oral health	Reintubation	Continuous enteral feedings
	Supine positioning	Use of H_2 antagonists, immunosuppressants, neuromuscular blocking agents, narcotics
	Surgery	Previous use of antibiotics
		Bloodstream infections
		Gastroesophageal reflux
		Altered level of consciousness or coma

children or adults to experience infection and to have more frequent episodes of infection.[1,8]

Diagnosis

The complex health problems of critically ill children make the diagnosis of VAP based on sputum samples, findings on chest radiographs, and the presence of fever particularly difficult. In both adults and children, the standard test for diagnosing VAP is culture of a sputum specimen.[11,21] The CDC criteria[4] for diagnosis of VAP in infants and children are evidence of a new or progressive and persistent infiltrate on 2 or more subsequent chest radiographs, with the presence of a pneumatocele in a neonate; fever or leukopenia associated with new onset of purulent sputum or an increase in sputum production; and sputum culture positive for a microorganism known to cause VAP or detection in a sputum specimen of an antigen associated with a microorganism known to cause VAP.

The distinction between early- and late-onset VAP is also important. Early-onset disease is a primary infection that occurs within the first 4 days of mechanical ventilation; VAP that occurs after the first 4 days is known as late onset.[4,22] The distinction between the 2 types is important with regard to causative factors and thus treatment.

Intervention and Prevention Strategies

Many researchers have examined the association between VAP and the presence of dental plaque and lower respiratory tract infections. Dental plaque is a known reservoir for bacteria; therefore, interventions to improve oral hygiene and remove dental plaque should decrease the risk for VAP.[3] The oropharyngeal flora of critically ill patients changes from mainly gram-positive organisms to mainly gram-negative organisms, which are much more virulent, especially within 48 hours of hospitalization.[8,14] This more virulent flora can move into the lungs, leading to hospital-acquired pneumonia. The odds of acquiring an infection due to gram-negative microorganisms are much higher in patients treated with mechanical ventilation than in patients who do not receive this therapy.[8,14]

Use of a stress ulcer prophylaxis, such as sucralfate, that does not increase gastric pH can decrease the risk for VAP but still prevent ulcer formation.[12] In adults, the incidence of VAP was lower in patients treated with sucralfate than in patients treated with H_2-receptor antagonists. In children, the incidence of VAP did not differ significantly between patients treated with sucralfate and patients treated with H_2-receptor antagonists.[12]

Much debate has surrounded the use of suctioning and instillation of physiological saline during endotracheal suctioning in infants and children. Current research suggests that endotracheal suctioning should be used only when indicated by a physical examination.[23,24] Even though use of physiological saline to thin and mobilize secretions is ineffective, younger children and infants with endotracheal tubes of smaller sizes warrant observation for potential obstruction.[23] Use of closed versus open endotracheal tube suctioning is also controversial.[12] The use of

closed suctioning systems can cause pooling of contaminated secretions in the lumen of the tube, leading to contamination of the respiratory tract with each episode of suctioning, whereas the use of closed suctioning decreases the possibility of environmental contamination. According to Foglia et al,[12] the frequency of airway contamination was significantly higher in patients when a closed suction system was used, but the frequency of nosocomial pneumonia was not increased. Because of the unclear data on the use of closed versus open suctioning, the CDC does not currently make any recommendations for a preferred suctioning system.[5,25]

Ventilator circuit changes may also contribute to the development of VAP via accidental movement of contaminated tubing condensation and bacteria into the trachea and lungs.[25] Although most research has been conducted in adults, in a recent study[26] in children, minimal ventilator circuit changes decreased VAP rates. Samransamruajkit et al[26] found that the VAP rate was 13.9 cases per 1000 ventilator days for circuit changes every 3 days and 11.5 cases per 1000 days for circuit changes every 7 days, suggesting that a switch from a 3-day to a 7-day ventilator circuit change policy could save a PICU $22 000 annually in medical supplies and labor costs. In addition, a 7-day circuit change tended to decrease PICU length of stay and mortality rate.

VAP Prevention Guidelines

Guidelines for VAP prevention have been published by the American Association of Critical-Care Nurses (AACN)[27] and by many other organizations, including the CDC,[4] the Institution for Healthcare Improvement (IHI),[15] and the Association for Professionals in Infection Control and Epidemiology.[11] However, because of the lack of research in infants and children, the majority of the guidelines focus on VAP prevention in adults. In 2008, the AACN[27] published evidence that led to prevention interventions known as the VAP Practice Alerts. The alerts are intended to be succinct, dynamic directives supported by authoritative evidence to ensure excellence in practice and a safe and humane work environment. These interventions include elevating the head of the bed 30° to 45° to prevent aspiration and minimal changes of the ventilator circuit. The AACN also recommends using an endotracheal tube with a dorsal lumen above the endotracheal cuff to allow continuous suctioning of tracheal secretions in the subglottic area. Currently, only minimal evidence supports continuous aspiration of subglottic secretions in infants and children; most studies have been done in animals. Changing ventilator circuits on an as-needed basis, only when the circuits are visibly soiled or malfunctioning, rather than routinely is also an AACN recommendation.

Several national organizations in the United States have outlined criteria for the prevention of VAP; the first CDC document was published in 1981.[11] The guidelines[25] of the CDC and the Healthcare Infection Control Practices Advisory Committee include strategies to combat the 3 most common mechanisms of VAP—aspiration of secretions, colonization of the aerodigestive tract, and use of contaminated equipment—as well as general strategies. In addition, the new CDC guidelines for surveillance of VAP events offer algorithms for monitoring and documenting VAP in any inpatient unit.[4] For all patients, surveillance strategies include viewing "device days" and "ventilator days" by using a pneumonia flow diagram to document occurrences according to age and the presence of underlying respiratory disease.[2] Surveillance should be used in all inpatient intensive or long-term care units, including both neonatal ICUs and PICUs. Criteria for children are separated on the basis of age (infants ≤1 year old and children from >1 to ≤12 years old) and include worsening gas exchange, fever or unstable body temperature, leukopenia, new onset of purulent sputum, and overall worsening of respiratory signs.[4] The VAP rate is calculated by dividing the number of VAP episodes by the number of ventilator days and multiplying the result by 1000. Table 2 provides a comparison of evidence-based CDC prevention strategies and recommendations from Coffin et al[6] and the Association for Professionals in Infection Control and Epidemiology.[11] The IHI has also developed a list of VAP prevention measures,[15] which include elevating the head of the bed, daily "sedation vacations," assessment of readiness for weaning from mechanical ventilation, peptic ulcer prophylaxis, deep vein thrombosis prophylaxis, and daily oral care with chlorhexidine. The IHI maintains that implementation of all of the interventions together rather than individually can lead to significantly better outcomes for patients. All the recommendations in Table 2 are similar and do not

Surveillance should be part of VAP prevention in all inpatient intensive or long-term care units.

Table 2 Evidence-based general strategies for prevention of ventilator-associated pneumonia (VAP)

Prevention strategy		
CDC and HICPAC[25]	**Coffin et al[6]**	**APIC[11]**
Active surveillance for VAP	Active surveillance for VAP	Active risk assessments for VAP
Education of health care staff	Education of health care staff	Hand hygiene
Hand hygiene, gloving, and gowning protocols to prevent transmission of causative organisms	Regular antiseptic oral care	Daily interruption of sedation and assessment of readiness for weaning from mechanical ventilation
Sterilization or disinfection and maintenance of equipment and devices	No routine changes of ventilator circuit or tubing	Regular, antiseptic oral care
Administration of immunomodulators	Daily sedation interruption and assessment of readiness for weaning from mechanical ventilation	Semirecumbent positioning
Precautions to prevent aspiration	Use of noninvasive ventilation when possible	
Elevation of the head of the bed	Semirecumbent positioning	
Noninvasive ventilation	Use of endotracheal tube with inline and subglottic suctioning for eligible patients	
Oropharyngeal cleansing		
Prevention of postoperative pneumonia		

Abbreviations: APIC, Association for Professionals in Infection Control and Epidemiology; CDC, Centers for Disease Control and Prevention; HICPAC, Healthcare Infection Control Practices Advisory Committee.

Case Study, Part 2

The infant required 3 additional weeks of mechanical ventilation with much higher settings once the diagnosis of pneumonia was made and indications of pulmonary hypertension recurred. Coupled with underlying lung disease, these complications represented major obstacles in attempts to extubate the patient after this setback. The infant spent a total of 6 weeks in the PICU and many more days on the pediatric unit. Because the mean daily cost for just the bed space was $2000, the pneumonia contributed markedly to the overall cost of hospitalization for the patient. The estimated total bill was $500 000 more than it would have been if she had not had this complication. She did eventually return home, but she now is at risk for further respiratory disease and asthma because of the prolonged mechanical ventilation to already compromised lungs. Prevention of a single complication could have prevented this cascade of problems for the infant now and in the future. ■

include practices such as using sucralfate, H_2-receptor antagonists, or antacids for prophylaxis for bleeding stress ulcers. In addition, immunotherapies other than vaccines are not recommended routinely because the evidence to support their use is inadequate.

VAP Prevention in Infants and Children

Little evidence is available on VAP prevention in infants and children, and no official guidelines have been published. Through proper staff education on the epidemiology, risk factors, and patients' outcomes associated with VAP, as well as the implementation of a thorough prevention protocol or bundle, hospitals should be able to effectively decrease the rates of VAP.[6] Bigham et al[2] determined that the use of a prevention bundle to lower the incidence of VAP in the PICU resulted in decreased occurrences of VAP. The bundle included methods to reduce bacterial colonization of the oropharynx, stomach, and sinuses and methods to prevent aspiration of contaminated secretions (Table 3). VAP rates decreased from 5.6 to 0.3 infections per 1000 ventilator days once the bundle was implemented during the course of a year. VAP prevention bundles that include hand hygiene, oral hygiene, endotracheal suctioning, minimal ventilator circuit changes, elevation of the head of the bed, and use of H_2-receptor blockers are recommended for both neonatal

Table 3 Bundle to prevent ventilator-associated pneumonia in children[a]

Goal	Intervention
Prevent bacterial colonization	Change ventilator circuits and in-line suction catheters only when they are visibly soiled or malfunctioning Drain condensation from ventilator circuit every 2-4 hours Store oral suction devices in nonsealed plastic bag at the bedside when not in use Rinse devices after use Perform hand hygiene before and after contact with ventilator circuit Wear a gown before providing care to patient when soiling from respiratory secretions is expected Follow unit's mouth care policy every 2-4 hours
Prevent aspiration	Elevate the head of the bed 30°-45° Always drain ventilator circuit before repositioning patient Use endotracheal tube with dorsal lumen above endotracheal cuff to help suction secretions above the cuff for children more than 12 years old

[a] Based on data from Bigham et al.[2]

Table 4 Oral hygiene protocol for intubated children[a]

Age group	Intervention
Neonates and infants with no teeth	Every 2 hours: moisten mouth with swabs soaked in clean water or physiological saline Every 2 hours and as needed: coat lips with petroleum jelly
Infants and children <6 years with teeth	Every 12 hours: brush teeth with small, soft toothbrush and fluoride toothpaste; suction out excess toothpaste, but do not rinse out mouth Every 2 hours: moisten mouth with swabs soaked in clean water or physiological saline Every 2 hours and as needed: coat lips with petroleum jelly
Children ≥6 years with teeth	Every 12 hours: Brush teeth with small, soft toothbrush and fluoride toothpaste; suction out excess toothpaste, but do not rinse out mouth Rinse mouth with 0.1% chlorhexidine: irrigate with a syringe or wipe oral mucosa with a swab; suction excess solution, but do not rinse out mouth with water; use at least 30 minutes after brushing teeth Every 2 hours: moisten mouth with swabs soaked in clean water or physiological saline Every 2 hours and as needed: coat lips with petroleum jelly

[a] Based on data from Johnstone et al.[9]

ICUs and PICUs.[12] Of particular interest is the recommendation for endotracheal suctioning, an intervention that was once controversial.

Oral Hygiene

Because of the adverse effects associated with poor oral hygiene, the AACN recommends that critical care patients have their teeth brushed at least twice daily, have mouth moisturizer applied every 2 to 4 hours, and have their oral cavity and pharynx suctioned frequently.[3] The CDC[3,25] suggests that a comprehensive oral hygiene regimen be implemented for all patients at risk for VAP and other health care–associated pneumonias. Johnstone et al[9] have published practice recommendations for oral hygiene in intubated children in the PICU (Table 4). The recommendations include protocols for 3 separate age groups: neonates and infants with no teeth, infants and children less than 6 years old with teeth, and children 6 years or older with teeth). With proper staff education and implementation, use of an oral care protocol, as a part of a larger VAP prevention bundle, may lead to lower rates of VAP in children.

Endotracheal Suctioning

Endotracheal suctioning should not be a routine intervention, but it should be performed when obstructive

secretions are indicated by clinical assessment of a patient's respiratory status. Indications of a need for suctioning include audible or visible secretions in the endotracheal tubing, coarse breath sounds, coughing, increased work of breathing, arterial desaturation, and/or bradycardia due to secretions. Suctioning should also be performed after chest physiotherapy. The instillation of physiological saline should not be a routine part of endotracheal suctioning. Instead of using physiological saline, health care providers should control pulmonary secretions via hydration, adequate humidification of inspired gas, mucolytic agents, and effective mobilization of secretions.[24]

Circuit Changes

Circuit changes should be minimal in infants and children and should be done only when the tubing is visibly internally soiled or is malfunctioning.[27] Minimal manipulation of patients and tubing may lead to decreases in contamination and subsequent pneumonia.[27]

Practice Recommendations

Bundles used to implement evidence-based clinical best-practice guidelines are effective when implemented on a nursing unit.[28] The IHI has advocated use of a ventilator bundle for adults,[28] which consists of 4 practices performed together that collectively are designed to improve patients' outcomes. Bundles specifically for infants and children have not been generally available. The bundle we propose (Table 5) provides a straightforward list of nursing interventions to be followed when caring for children receiving mechanical ventilation. Implementation of the enhanced prevention bundle can lead to decreased mortality, improved patient outcomes, decreased length of stay, and decreased hospital costs.[28,29]

The CDC criteria for diagnosis of VAP in infants and children are evidence of new or progressive infiltrate, fever or leukopenia with new onset of purulent sputum, and increased sputum production.

Pediatric critical care nurses play a vital role in applying VAP prevention strategies and in identifying recommendations for improvement. After collecting data in the PICU, nursing staff can establish a VAP prevention bundle for children that is based on Table 5. Monthly documentation of HAIs in collaboration with the infection control department within the PICU and pediatric inpatient unit can keep the entire nursing staff abreast of concerns and potential areas for improvement. Initiating the use of a VAP prevention bundle provides evidence-based alerts to adapt nursing care to prevention whenever a patient being treated with mechanical ventilation is admitted to or a current patient is intubated in the PICU. Nurses can also be involved in designing studies that truly document the effectiveness of bedside protocols. Maintaining data collection over time with the use of the VAP bundle will supply critical information on the effectiveness of these nursing and respiratory interventions in changing the incidence of VAP in a particular setting. CCN

Table 5 Proposed bundle for prevention of ventilator-associated pneumonia in infants and children

- Elevate the head of the bed 35°-45°
- Perform hand hygiene before and after contact with the patient or the ventilator
- Provide oral care according to the patient's age
  - Neonates and infants with no teeth
    - Every 2 hours: moisten mouth with swabs soaked in clean water or physiologica saline
    - Every 2 hours and as needed: coat lips with petroleum jelly
  - Infants and children <6 years old with teeth
    - Every 12 hours: brush teeth with small, soft toothbrush and fluoride toothpaste; suction out excess toothpaste, but do not rinse out mouth
    - Every 2 hours: moisten mouth with swabs soaked in clean water or physiological saline
    - Every 2 hours and as needed: coat lips with petroleum jelly
  - Children ≥6 years old with teeth
    - Every 12 hours:
      - Brush teeth with small, soft toothbrush and fluoride toothpaste; suction out excess toothpaste, but do not rinse out mouth
      - Rinse mouth with 1% chlorhexidine: irrigate with a syringe or wipe oral mucosa with a swab; suction excess solution, but do not rinse out mouth with water; use at least 30 minutes after brushing teeth
    - Every 2 hours: Moisten mouth with swabs soaked in clean water or physiological saline
    - Every 2 hours and as needed: coat lips with petroleum jelly
- Change ventilator circuit every 7 days or when circuit is visibly soiled or malfunctioning
- Suction endotracheal tube only when indicated by a clinical examination; do not instill physiological saline for suctioning
- Drain condensation from ventilator circuit every 2-4 hours and before repositioning the patient

Financial Disclosures
None reported.

eLetters

Now that you've read the article, create or contribute to an online discussion about this topic using eLetters. Just visit www.ccnonline.org and click "Submit a response" in either the full-text or PDF view of the article.

dotmore

To learn more about caring for patients with ventilator-associated pneumonia, read "Diagnosing Ventilator-Associated Pneumonia in Critically Ill Patients With Sepsis" by Sun et al in the *American Journal of Critical Care*, November 2012;21:e110-e119. Available at **www.ajcconline.org**.

References

1. Casado RJ, de Mello MJ, de Aragão RC, et al. Incidence and risk factors for health care-associated pneumonia in a pediatric intensive care unit. *Crit Care Med.* 2011;39(8):1968-1973.
2. Bigham MT, Amato R, Bondurrant P, et al. Ventilator-associated pneumonia in the pediatric intensive care unit: characterizing the problem and implementing a sustainable solution. *J Pediatr.* 2009;154(4):582-587.
3. Seckel M. Implementing evidence-based practice guidelines to minimize ventilator-associated pneumonia. *AACN News.* 2007;24(1):8-10
4. Centers for Disease Control and Prevention. Ventilator-associated pneumonia (VAP) event. *Device Assoc Events.* January 2012:6:1-6:13. http://www.cdc.gov/nhsn/pdfs/pscmanual/6pscvapcurrent.pdf. Accessed February 27, 2013.
5. Klompas M. Is a ventilator-associated pneumonia rate of zero really possible? *Curr Opin Infect Dis.* 2012;25(2):176-182.
6. Coffin SE, Klompas M, Classen D, et al. Strategies to prevent ventilator-associated pneumonia in acute care hospitals. *Infect Control Hosp Epidemiol.* 2008;29:S31-S40.
7. Morinec J, Iacaboni J, McNett M. Risk factors and interventions for ventilator-associated pneumonia in pediatric patients. *Pediatr Nurs.* 2012;27(5):435-442.
8. Srinivasan R, Asselin J, Gildengorin G, et al. A prospective study of ventilator-associated pneumonia in children. *Pediatrics.* 2009;123(4):1108-1115.
9. Johnstone L, Spence D, Koziol-McClain J. Oral hygiene care in the pediatric intensive care unit: practice recommendations. *Pediatr Nurs.* 2010;36(2):85-97.
10. Venkatachalam V, Hendley O, Willson DF. The diagnostic dilemma of ventilator-associated pneumonia in critically ill children. *Pediatr Crit Care Med.* 2011;12(3);286-296.
11. Green LR, Sposato K. A guide to the elimination of ventilator-associated pneumonia. Association for Professionals in Infection Control and Epidemiology Web site. http://www.apic.org/Resource_/EliminationGuideForm/18e326ad-b484-471c-9c35-6822a53ee4a2/File/VAP_09.pdf. Published 2009. Accessed February 27, 2013.
12. Foglia E, Meier MD, Elward A. Ventilator-associated pneumonia in neonatal and pediatric intensive care unit patients. *Clin Microbiol Rev.* 2007;20(3):409-425.
13. World Health Organization Media Centre. Pneumonia. Fact sheet 331. http://www.who.int/mediacentre/factsheets/fs331/en/index.html. Published November 2012. Accessed March 12, 2013.
14. Murila F, Frances JV, Bland A, et al. Interpreting positive cultures of endotracheal aspirates: factors associated with treatment decisions in ventilated neonates. *J Pediatr Child Health.* 2012;47(10):728-733.
15. Institute for Healthcare Improvement. Implement the IHI ventilator bundle. http://www.ihi.org/knowledge/Pages/Changes/ImplementtheVentilatorBundle.aspx. Modified August 2, 2011. Accessed February 28, 2013.
16. Grap MJ. Not-so-trivial pursuit: mechanical ventilation risk reduction. *Am J Crit Care.* 2009;18(3):198.
17. Jaillette E, Nseir S. Relationship between inhaled b2-agonists and ventilator-associated pneumonia: a cohort study. *Crit Care Med.* 2011;39(4):725-730.
18. Cook A, Norwood S, Berne J. Ventilator-associated pneumonia is more common and of less consequence in trauma patients compared with other critically ill patients. *J Trauma.* 2010;69(5):1083-1091.
19. Abdel-Gawad TA, El-Hodhod MA, Ibrahim HM, Michael YW. Gastroesophageal reflux in mechanically ventilated pediatric patients and its relation to ventilator associated pneumonia. *Crit Care Med.* 2010;13(5):R164.
20. Hsieh TC, Hsia SH, Wu CT, Lin TY, Chang CC, Wong KS. Frequency of ventilator-associated pneumonia with 3-day versus 7-day ventilator circuit changes. *Pediatr Neonatol.* 2010;51(1):37-43.
21. Turton P. Ventilator-associated pneumonia in pediatric intensive care: a literature review. *Nurs Crit Care.* 2008;13(5):241-248.
22. Hunter JD. Ventilator associated pneumonia. *Postgrad Med J.* 2006;82(965):172-178.
23. Morrow BM, Argent AC. A comprehensive review of pediatric endotracheal suctioning: effects, indications, and clinical practice. *Pediatr Crit Care Med.* 2008;9(5):465-477.
24. Halm MA, Krisko-Hagel K. Instilling normal saline with suctioning: beneficial technique or potentially harmful sacred cow? *Am J Crit Care.* 2008;17(5):469-472.
25. Tablan OC, Anderson LJ, Besser R, Bridges C, Hajjeh R; CDC and Healthcare Infection Control Practices Advisory Committee. Guidelines for preventing health-care—associated pneumonia, 2003: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee. *MMWR Recomm Rep.* 2004;53(RR-3):1-36.
26. Samransamruajkit R, Jirapaiboonsuk S, Siritantiwat S, et al. Effect of frequency of ventilator circuit changes (3 vs 7 days) on the rate of ventilator-associated pneumonia in PICU. *J Crit Care.* 2010;25(1):56-61.
27. American Association of Critical-Care Nurses. Ventilator-associated pneumonia (VAP). http://www.aacn.org/wd/practice/content/vap-practice-alert.pcms?menu=practice. Published January 2008. Accessed February 28, 2013.
28. Wip C Napolitano L. Bundles to prevent ventilator-associated pneumonia: how valuable are they? *Curr Opin Infect Dis.* 2009;22:159-166.
29. Zilberberg MD, Shorr AF, Kollef MH. Implementing quality improvements in the intensive care unit: ventilator bundle as an example. *Crit Care Med.* 2009;37(1):305-309.

CNE Test **Test ID C133: Preventing Ventilator-Associated Pneumonia in Children: An Evidence-Based Protocol**

Learning objectives: 1. Describe pediatric risk factors for ventilator-associated pneumonia (VAP) 2. Identify strategies to prevent pediatric VAP 3. Discuss current evidence in the prevention of VAP in children

1. Which of the following is an effective strategy to prevent ventilator-associated pneumonia (VAP) in pediatric patients?
a. Hourly oral hygiene
b. Changing the in-line suction catheter only when visibly soiled
c. Changing ventilator circuits daily
d. Rinsing the mouth with 0.1% chlorhexidine every shift

2. Which of the following is one of the most common causative organisms in pediatric VAP?
a. *Streptococcus pneumoniae*
b. *Acinetobacter* species
c. Methicillin-resistant *Staphylococcus aureus*
d. *Haemophilus influenzae*

3. Risk factors for VAP specific to intubated children include which of the following?
a. Developing teeth
b. Poor cough and gag reflex
c. Use of oral endotracheal tubes
d. Greater exposure to polymicrobes

4. When should suctioning be performed on an intubated child?
a. Routinely every 4 hours
b. Before chest physiotherapy
c. When coarse breath sounds and increased work of breathing are noted
d. When administering mucolytic agents and physiologic saline

5. Appropriate methods to control pulmonary secretions include which of the following?
a. Frequent suctioning
b. Routine instillation of physiologic saline
c. Chest physiotherapy every shift
d. Hydration and humidification of inspired gas

6. Which of the following is true regarding pediatric VAP?
a. Children with VAP have a median of 8 intensive care unit–free days
b. Length of stay is increased by 7 days
c. Mortality is approximately 33% to 50%
d. VAP accounts for 18% to 26% of hospital-acquired infections in the pediatric intensive care unit (PICU)

7. Per the Centers for Disease Control and Prevention (CDC), which of the following is an indicator of VAP in a child?
a. Fever, leukopenia, and new purulent sputum
b. Wheezes, rales, and tachycardia
c. Fever, apnea, tachypnea, and tachycardia
d. Nasal flaring with chest wall retraction and hypotension

8. Late-onset VAP is defined as which of the following?
a. Develops after the first 4 days in the PICU
b. Develops after the first 4 days of mechanical ventilation
c. The development of a secondary infection while in the PICU
d. Develops very rarely in the pediatric population

9. Conclusions from Bigham PICU VAP study state which of the following?
a. Ventilator circuit changes should be performed every 7 days
b. VAP bundle use is more effective in the neonatal ICU than in the PICU
c. Endotracheal suctioning remains controversial
d. Use of prevention bundles resulted in decreased occurrence of VAP

10. Recommendations in an oral hygiene protocol for intubated children include which of the following?
a. Rinse the mouth with 0.1% chlorhexidine every 8 hours
b. Brush the teeth with a fluoride toothpaste every shift
c. Use of petroleum jelly on the lips every 2 hours and as needed
d. Moisten the mouth with swabs soaked in water every 4 hours

11. Which of the following describes why prevention of VAP in pediatrics is challenging?
a. Bundles are difficult to implement
b. Children are exposed to different organisms than adults
c. Children are much sicker than adults
d. There is a limited amount of research on pediatric VAP

12. Which of the following is one of the 3 most common mechanisms of VAP and the focus of CDC and Healthcare Infection Control Practices Advisory Committee VAP prevention guidelines?
a. Use of contaminated equipment
b. Number of ventilator days
c. Length of time in the PICU
d. Exposure to polymicrobes

Test answers: Mark only one box for your answer to each question. You may photocopy this form.

1. ❑**a**	**2.** ❑**a**	**3.** ❑**a**	**4.** ❑**a**	**5.** ❑**a**	**6.** ❑**a**	**7.** ❑**a**	**8.** ❑**a**	**9.** ❑**a**	**10.** ❑**a**	**11.** ❑**a**	**12.** ❑**a**
❑**b**	❑**b**	❑**b**	❑**b**	❑**b**	❑**b**	❑**b**	❑**b**	❑**b**	❑**b**	❑**b**	❑**b**
❑**c**	❑**c**	❑**c**	❑**c**	❑**c**	❑**c**	❑**c**	❑**c**	❑**c**	❑**c**	❑**c**	❑**c**
❑**d**	❑**d**	❑**d**	❑**d**	❑**d**	❑**d**	❑**d**	❑**d**	❑**d**	❑**d**	❑**d**	❑**d**

Test ID: C133 Form expires: June 1, 2016 Contact hours: 1.0 Pharma hours: 0.0 Fee: AACN members, $0; nonmembers, $10 Passing score: 9 correct (75%)
Synergy CERP Category A Test writer: Patricia Kelly Rosier, MS, RN, ACNS-BC

AMERICAN ASSOCIATION of CRITICAL-CARE NURSES

For faster processing, take this CNE test online at www.ccnonline.org
or mail this entire page to:
AACN, 101 Columbia
Aliso Viejo, CA 92656.

Program evaluation

	Yes	No
Objective 1 was met	❑	❑
Objective 2 was met	❑	❑
Objective 3 was met	❑	❑
Content was relevant to my nursing practice	❑	❑
My expectations were met	❑	❑
This method of CNE is effective for this content	❑	❑

The level of difficulty of this test was:
❑ easy ❑ medium ❑ difficult
To complete this program, it took me _____ hours/minutes.

Name _____ Member # _____
Address _____
City _____ State ____ ZIP _____
Country _____ Phone _____
E-mail _____
RN Lic. 1/St _____ RN Lic. 2/St _____
Payment by: ❑ Visa ❑ M/C ❑ AMEX ❑ Discover ❑ Check
Card # _____ Expiration Date _____
Signature _____

The American Association of Critical-Care Nurses is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center's Commission on Accreditation.
AACN has been approved as a provider of continuing education in nursing by the State Boards of Nursing of Alabama (#ABNP0062), California (#01036), and Louisiana (#ABN12). AACN programming meets the standards for most other states requiring mandatory continuing education credit for relicensure.