

Course Objectives

The goal of this program is to provide nurses with information about ventilator-associated pneumonia (VAP): its prevalence, pathogenesis, risk factors, diagnosis, management, and prevention. After studying the information presented here, you will be able to:

- Describe the pathogenesis of VAP.
 - List the risk factors for VAP.
 - Discuss strategies for preventing VAP.
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Code blue ICU! Code blue ICU! Mr. Thompson, 76, arrives in the telemetry unit with COPD and uncontrolled atrial fibrillation. He develops acute respiratory distress and is transferred to the ICU, where he suffers a respiratory arrest. A CRNA orally intubates him with an 8.0 French (Fr) endotracheal tube with a dorsal lumen and places him on a ventilator. The port of the dorsal lumen of the ETT is attached to continuous suction. His nurse elevates the head of the bed to 45 degrees, initiates an oral care protocol every four hours, and inserts a nasogastric tube for decompression.

Is this patient at risk for developing ventilator-associated pneumonia, and if so, what can a nurse do to prevent it?

VAP is a bacterial infection of the lungs that occurs 48 hours or more after intubation and mechanical ventilation. Nearly 47% of ventilated patients develop VAP, which increases morbidity and mortality in this compromised population.¹ The mortality rate of patients with VAP varies between patient populations, but can be as high as 50%.¹ VAP also increases the ICU length of stay by an average of 4.3 days² and has a treatment cost of \$12,000 or more.¹ Nurses as frontline caregivers can help prevent VAP by being well informed about evidence-based practices.

Anatomy lesson

The [upper airway](#) consists of the nasopharynx, oropharynx, larynx, and trachea. The epiglottis is a cartilage that covers the glottis (part of the larynx) during swallowing and prevents the passage of foreign material into the trachea and lungs. Endotracheal intubation prevents the epiglottis from closing. Consequently, oral and gastric secretions can be aspirated into the lungs and can lead to VAP.

An ETT is a hollow, plastic tube with a diameter ranging from 2.0 Fr for neonates to 9.5 Fr for adults.³ An inflatable cuff is located at the distal end. Leading away from the cuff is a small tube with a pilot balloon at its proximal end. The balloon indicates whether the cuff is inflated or deflated. Above the pilot balloon is a port. A syringe is attached to the port and used for inflating and deflating the cuff. The inflated cuff provides a leak-resistant fit between the tube and trachea. It reduces the risk of aspiration and allows positive pressure ventilation of the lungs.³

The ETT is inserted through the nasopharynx or oropharynx and passed through the vocal cords until the cuff disappears behind the vocal cords or until the tip of the ETT protrudes 2 cm to 3 cm into the trachea. Using a 10 mL syringe, the cuff is inflated with approximately 4 mL to 6 mL of air until leakage around it stops.³ The respiratory therapist measures and records the cuff pressure. To prevent silent aspiration, cuff pressures should be maintained at 25 cm H₂O to 27 cm H₂O. Impaired blood flow to the tracheal mucosa can occur at 34 cm H₂O.⁴

To verify the correct placement of the ETT, the patient end of the ETT is connected to a bag-valve mask. Then, as the patient is being ventilated, the clinician auscultates the lungs for the presence of equal, bilateral breath sounds. The accuracy of this method depends on the clinician's experience. As the patient is ventilated, oxygen is delivered on inspiration, and carbon dioxide is released on expiration. End-tidal CO₂ can be measured with a sensor on the end of the ETT. The presence of CO₂ indicates the ETT is positioned in the trachea. A chest X-ray confirms the position. The ETT is then secured with a commercial holder or adhesive tape.

How VAP happens

Following intubation and mechanical ventilation, the oropharynx is overgrown with bacteria.⁵ A leading hypothesis for the pathogenesis of VAP is the microaspiration of bacteria-containing oral secretions.^{1,5} Pooling of secretions above the ETT cuff increases pulmonary aspiration. The secretions pass around the ETT cuff and into the lungs.

VAP bacteria may vary between and within hospitals. [Staphylococcus aureus](#) and [Pseudomonas aeruginosa](#) cause most cases of VAP (50% to 70%).¹ [Methicillin-resistant S. aureus](#) as a cause of VAP has become a problem in many ICUs. Patients with MRSA VAP tend to be older with higher organ dysfunction studies and are ventilated for longer periods before infection.¹ Other organisms reported to cause VAP include *Escherichia coli*, *Enterobacter*, *Klebsiella pneumoniae*, *Stenotrophomonas maltophilia*, *Proteus mirabilis*,

Aspergillus, and Candida.¹

Another etiology of VAP involves the bacterial colonization of the GI tract, with backward movement of bacteria up into the oropharynx.⁵ This bacteria is aspirated into the lungs. An additional source of VAP is entry of bacteria into the lungs through the aerosol route, such as contaminated ventilator circuitry or cross-contamination by staff.⁵

Numerous risk factors are associated with VAP, including male gender, age over 60, COPD, cardiac disease, emergency surgery (particularly chest or abdominal), trauma, and serious burns.¹ Risk factors after ICU admission include mechanical ventilation for 48 hours or more, reintubation, daily ventilator circuit changes, continuous sedation, decreased level of consciousness, and the presence of oral or nasal gastric tubes/enteral nutrition.¹

VAP is often clinically diagnosed. The following signs may be diagnostic of VAP: a temperature of 38.5 C (101.3 F) or greater or a temperature of 36.5 C (97.7 F) or less, purulent tracheal secretions, evidence of pulmonary infiltrates on chest X-ray, a WBC of 10,000 or greater or of 4,000 or less, and a reduction in the PaO₂/FiO₂ (P/F) ratio of 15% or more over the preceding 48 hours.¹ The P/F ratio is the difference between the partial pressure of oxygen in arterial blood (PaO₂), measured by an arterial blood gas, and the fraction of inspired oxygen (FiO₂), the amount of oxygen delivered to the patient. If a patient's PaO₂ is 120 mm Hg and the FiO₂ is 0.80, the P/F ratio is 150 (120/0.80). A P/F ratio of 200 mm Hg or less is indicative of acute respiratory distress syndrome (ARDS).¹

The most reliable diagnostic technique is a bronchoscopic bronchial alveolar lavage (BAL),¹ in which a bronchoscope is passed through the mouth or ETT into different areas of the lungs. Sterile water or saline is injected into a segment of the lung and recollected for examination. BAL is often used to diagnose infections in patients with a compromised immune system, VAP, and some lung cancers. BAL culture results have a sensitivity of about 90% and specificity of over 90% for VAP.¹ About 60% of BAL cultures rule out VAP and permit early discontinuation of empiric antibiotics,¹ those used to treat an infection before the suspected organism is known. Typically, these antibiotics are broad-spectrum (treating a wide range of microorganisms).

Individual ICUs should use empirical antibiotics that target known pathogens in their patient populations.¹ In most ICUs, empirical antibiotic therapy should target *S. aureus* and *P. aeruginosa*. Empirical antibiotic therapy with antipseudomonal penicillins and B-lactamase inhibitors, e.g., piperacillin-tazobactam (Zosyn), reduces in-hospital mortality.¹ In patients with MRSA VAP, linezolid (Zyvox) therapy has been associated with improved survival rates.^{1,5} Generally eight days of antibiotic therapy may be sufficient and have been shown to be as effective as a 15-day regimen.¹ A shorter regimen may also prevent the development of multiresistant organisms.¹ Antibiotic rotation has been associated with a reduction in the VAP rate^{1,5} and decreased mortality.⁵ When microbiology results that list antibiotics the microorganism is sensitive to become available, patients should receive the appropriate antibiotic.¹

An ounce of prevention

Prevention is the best strategy against VAP. [Evidence-based guidelines](#) describe how to prevent VAP and its morbidity, mortality, and high financial cost. If possible, health care providers should avoid intubation of the patient and use noninvasive ventilation, such as continuous positive airway pressure and bilevel positive airway pressure.^{1,6} CPAP delivers a preset pressure throughout the respiratory cycle, and BiPAP alternates between two pressure levels: higher pressure during inspiration and lower pressure during expiration. These methods are delivered by a nasal or facial mask. Noninvasive ventilation reduces the need for intubation and mortality in cardiogenic pulmonary edema.⁷ If intubation becomes necessary, the following interventions can help prevent VAP from developing:

Managing the airway: Oral intubation should be the first choice.⁶ Orotracheal intubation is associated with a lower incidence of sinus infections.² Since the ETT prevents the epiglottis from closing, oropharyngeal secretions accumulate above the tube cuff and can leak into the lungs, causing VAP. A securely inflated cuff reduces the risk of aspiration of secretions. The RN or respiratory therapist should routinely assess the patient for a cuff leak. The nurse or respiratory therapist places the bell of the stethoscope over the larynx and listens for air movement around the cuff. If a leak is detected, air should be injected through the port until the leak stops.³ The cuff pressure should always be measured after adding air. Excessive cuff pressure can lead to tracheal ulceration and necrosis as a result of reduced blood supply to the mucosa.³

If possible, the patient should be intubated with a dorsal lumen ETT to allow continuous aspiration of subglottic secretions.⁶ The dorsal lumen is above the ETT cuff, and the dorsal lumen port is connected to continuous or intermittent suction. This allows drainage of tracheal secretions that accumulate above the endotracheal cuff in the patient's subglottic area. If a dorsal lumen ETT is not used, every effort should be made to clear secretions from the oropharynx. Closed suction catheters, which don't have to be changed every day, should be used to prevent VAP.^{1,8}

Nurses should ensure that secretions are removed from above the cuff before deflating the cuff in preparation for removing the tube or changing the position of the tube (e.g., from one side of the mouth to the other). Clinicians should remove the patient's ETT as soon as possible and make every effort to avoid repeat intubation.⁶

Positioning the patient: Supine positioning increases pulmonary aspiration. The head of the patient's bed should be elevated between 30 and 45 degrees at all times to prevent aspiration, unless medically contraindicated.⁶ One study found that VAP was more likely to develop in severely ill patients with backrest elevations lower than 30 degrees during the first 24 hours after intubation.⁹ Elevating the

head of the bed is crucial for ventilated patients receiving enteral nutrition because of the added risk of aspiration of feeding formula.

Patients on mechanical ventilation should have early nutritional support. Enteral nutrition is preferred over parenteral nutrition in patients with a functioning GI tract because of a lower incidence of infectious and noninfectious complications and reduced costs and lengths of stay.¹⁰ If a feeding tube (gastric or small bowel) is used, correct placement should be verified by an X-ray before administering feedings or medications.¹¹ After confirmation of correct tube placement, the nurse marks and documents the tube's exit site from the mouth or nose.^{11,12} If the length of the external tubing increases, the tube has been displaced upward. Subsequent chest and abdominal X-ray reports should include the position of the feeding tube.

Other bedside measures to confirm correct tube placement include assessing the volume of aspirate, color of aspirate, and pH of aspirate. Gastric aspirates can be greater than 50 mL, and small bowel aspirates usually measure 10 mL.^{11,12} Gastric aspirates are usually green or clear (fasting) or white with unchanged feeding formula. Small bowel aspirates usually contain bile, ranging in color from light yellow to golden yellow or brownish-green.^{11,12} The gastric pH is lower (5 or less) than in the small bowel (6 or greater). But formulas may increase the pH in both the stomach and small bowel,¹¹ and assessing volume, color, and pH of gastric and small bowel aspirates may be difficult. It may be difficult to obtain a sample aspirate because of the small diameter of the feeding tube. Using a 60 mL syringe and injecting 30 mL of air into the tube before aspiration may help in obtaining residual volume.^{11,12} Flushing the tube with 30 mL of water or normal saline (if indicated for patients with hyponatremia, or low sodium) after residual measurements prevents the tube from occluding.¹¹ Since small bowel feeding tubes can be displaced upward into the stomach and gastric tubes can be displaced into the esophagus, the nurse should routinely assess for an increase in the external portion of the tubing and the volume, color, and pH of aspirates to prevent aspiration.

The auscultatory method to determine tube placement should be avoided. In one study, it was found to have a sensitivity of only 34% in differentiating between gastric and enteral tube placement in 85 acutely ill adults.¹¹

Providing oral care: Bacterial colonization of the oropharynx and dental plaque has been associated with VAP, so an oral care protocol should be implemented.^{1,6} This includes assessing the oropharynx daily, brushing the teeth to remove plaque, brushing the tongue, maintaining the integrity of the mucosa through oral cleansing, and suctioning the mouth and pharynx regularly to minimize the risk of aspiration of secretions. Commercial oral care kits contain suction toothbrushes, swabs, and rinses. Although no recommendations have been made for the use of an oral chlorhexidine rinse, an antiseptic rinse, for the prevention of VAP in all postoperative and critically ill patients, use of an oral chlorhexidine gluconate (0.12%) rinse has been recommended during the perioperative period on adult patients undergoing cardiac surgery.⁶

Ventilator tubing, exhalation valves, and humidifiers should not be routinely changed unless soiled or malfunctioning.^{6,8}

Avoiding cross-contamination: Nurses should wear gloves when in contact with the ventilator and secretions. Tubing should be emptied of any condensate, being careful not to drain condensate toward the patient. All clinicians should clean their hands with soap and water (if visibly soiled) or with an alcohol-based hand rub after performing the above procedure and after contact with mucous membranes, respiratory secretions, or objects contaminated with respiratory secretions. Clinicians should change gloves and wash hands before coming in contact with another patient. When soiling with respiratory secretions is anticipated, wear a gown and change it after soiling occurs and before contact with another patient.⁶

Administering immune modulators: RNs should vaccinate patients at high risk for severe pneumococcal infections with the 23-valent pneumococcal polysaccharide vaccine, as ordered. This includes patients 65 or older; patients 5 to 64 with chronic cardiovascular disease, chronic pulmonary disease, diabetes, alcoholism, chronic liver disease, or cerebrospinal fluid leaks; patients living in special environments or social settings, e.g., assisted living or long-term care; and immunocompromized patients 5 or older with HIV, leukemia, lymphoma, Hodgkin's disease, multiple myeloma, generalized malignancy, chronic renal failure, nephrotic syndrome, or other conditions associated with immunosuppression.⁶

Bundling up

The Institute for Healthcare Improvement has devised a series of "bundles," collections of [evidence-based practices](#) to care for patients undergoing treatments with inherent risks.¹³ The "ventilator bundle" to prevent VAP consists of four basic practices: elevation of the head of the bed, as discussed; a daily "sedation vacation" and assessment of readiness to wean; peptic ulcer disease prophylaxis; and deep vein thrombosis (DVT) prophylaxis.¹³ Institutions may individualize the ventilator bundle (e.g., adding oral care and glycemic control).

Patients receiving a continuous infusion of a sedative agent should have a daily "sedation vacation" to reduce the time of mechanical ventilation.¹³ The sedation is discontinued for a time so the patient may awaken. Clinicians can perform a neurological assessment and determine readiness for weaning from mechanical ventilation.

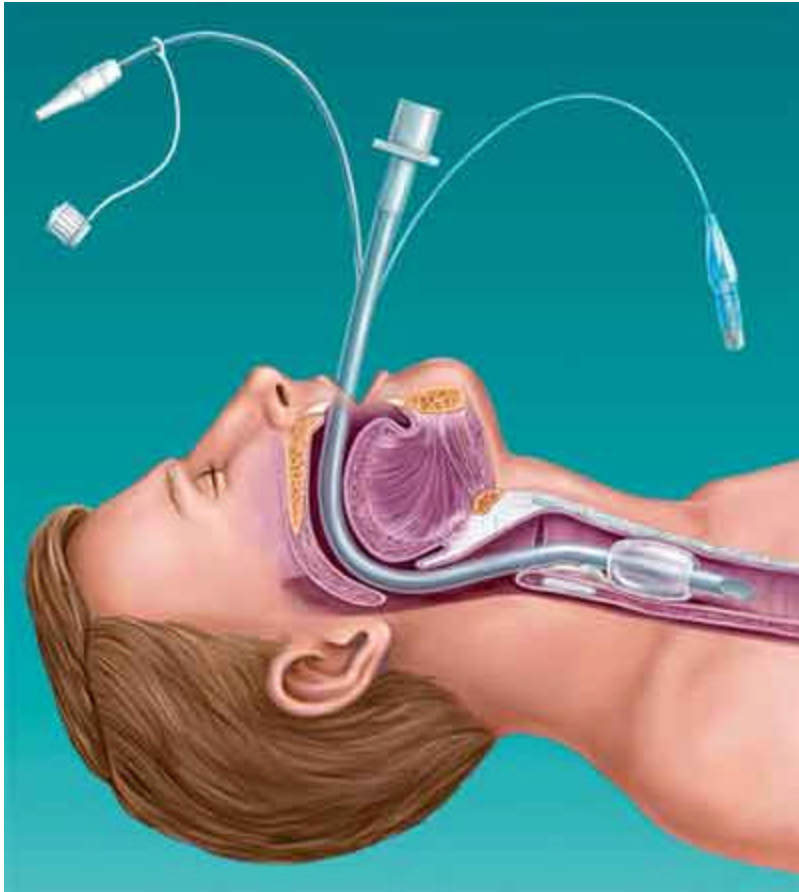
Critically ill patients can develop stress ulcers and should receive H2 receptor blockers, e.g., ranitidine (Zantac) or famotidine (Pepcid). H2 receptor blockers are preferred over sucralfate, which increases the incidence of VAP.¹ Proton pump inhibitors, such as omeprazole (Prilosec), may be efficacious, but they have not been fully studied in this population. In case of aspiration, an increased gastric pH has reduced the pulmonary inflammatory response.¹³

DVT prophylaxis (pharmacological or mechanical) helps prevent VAP when used in combination with the other three interventions. The mechanism of action in preventing VAP is uncertain, however.¹³

Nurses working interdependently with physicians can provide evidence-based care to prevent VAP. Evidence-based nursing practices have contributed to the reduction in VAP and positive clinical outcomes.

What happened to Mr. Thompson?

Mr. Thompson's heart rate was controlled with cardizem (Diltiazem), and he was extubated 96 hours after admission to the ICU. He remained afebrile, secretions were clear, and a chest X-ray showed no signs of pulmonary infiltrates. He went home the next day, after receiving the pneumococcal vaccine and instructions to follow up with his physician.



(SOURCE: Reprinted with permission of Nellcor Puritan Bennett Inc., Pleasanton, Calif.) The patient is orally intubated with a dorsal lumen ETT (a Hi-Lo Evac ETT). The cuff is inflated in the larynx. The small tube on the right contains the pilot balloon and cuff inflation port. The tube on the left extends from the dorsal lumen above the cuff. The port will be connected to suction for continuous aspiration of subglottic secretions.

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