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# Prevention of Ventilator-Associated Pneumonia (VAP): Current evidence and recent developments

**[1]Sangameshwara and [2]Dr. Suresh Patil**

[1, 2] Professor, Government College of Nursing, BIMS, Belagavi, Karnataka, India

**Corresponding Author:** Sangameshwara

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**Abstract**

Ventilator-associated pneumonia (VAP) is a major healthcare-associated infection among mechanically ventilated patients, associated with increased morbidity, mortality, length of stay and costs. Prevention of VAP has therefore become a key quality indicator in intensive care practice. Over the last decade, surveillance concepts have shifted from VAP to the broader ventilator-associated events (VAE) framework, and prevention strategies have evolved from isolated measures to structured VAP prevention bundles. This review summarizes the pathogenesis and risk factors for VAP, outlines evidence-based bundle components, and highlights recent developments, including updated international guidelines, new data on subglottic secretion drainage, evolving evidence on oral chlorhexidine, and technology-enabled interventions. Implications for nursing practice, especially in resource-limited settings, are discussed.

**Keywords:** VAP, ventilator-associated pneumonia, ventilator-associated events, prevention bundle, subglottic secretion drainage, oral care, nursing interventions, intensive care

## Introduction

Ventilator-associated pneumonia (VAP) is a type of hospital-acquired pneumonia that occurs in patients receiving invasive mechanical ventilation, typically after ≥ 48 hours of intubation. CDC It is one of the most frequent ICU-acquired infections and is associated with higher duration of ventilation, ICU and hospital length of stay, antibiotic use, and healthcare costs.

Because traditional VAP definitions were criticized for poor reliability and subjectivity, the U.S. CDC introduced the ventilator-associated events (VAE) framework in 2013. This classification includes Ventilator-Associated Condition (VAC), Infection-Related Ventilator-Associated Complication (IVAC), and possible VAP (PVAP), using objective changes in $FiO_2$ and PEEP along with evidence of infection. While surveillance has moved toward VAEs, prevention strategies remain focused on reducing microaspiration, colonization, and complications of mechanical ventilation.

For nurses and medical-surgical/critical care teams, VAP prevention is a central patient safety priority. Updated guidelines emphasize bundle-based care, staff education, and high compliance as the most effective strategies.

## Pathogenesis and Risk Factors

VAP typically results from microaspiration of contaminated secretions around the endotracheal tube (ETT) cuff, biofilm formation on airway devices, and impaired host defences.

**Major mechanisms include**

- Pooling of oropharyngeal and gastric secretions above the ETT cuff, leading to microaspiration.
- Biofilm on the ETT which harbours pathogens and seeds the lower respiratory tract.
- Impaired cough and mucociliary clearance due to sedation, muscle weakness, and underlying disease.
- Colonization from healthcare environment and devices, especially with multidrug-resistant organisms.

Recognized risk factors include prolonged mechanical ventilation, reintubation, supine positioning, deep or prolonged sedation, frequent ventilator circuit disconnections, poor oral hygiene, and inadequate infection prevention practices (e.g., hand hygiene, glove use).

## Evidence-based strategies for VAP prevention (Core Bundle)

Most contemporary guidelines recommend a **VAP prevention bundle**, a group of simple, low-cost interventions implemented together. Key elements include:

### Head of Bed Elevation (30-45°)

- Reduces risk of aspiration of gastric and oropharyngeal contents.
- Nursing responsibilities: ensure semi-recumbent position unless contraindicated; document and audit compliance.

**Daily sedation interruption and assessment of readiness to extubate**

- Minimizing sedation and combining daily Spontaneous Awakening Trials (SAT) and spontaneous breathing trials (SBT) reduces ventilator days and VAEs.
- Nursing role, Sedation score monitoring, coordinating SAT/SBT with physicians and respiratory therapists, monitoring for agitation or instability.

**Oral Care and Oropharyngeal Hygiene**

- Regular tooth-brushing and oral suction to reduce oropharyngeal colonization.
- Historically, chlorhexidine (CHX) mouth care was widely recommended; however, evidence has become more nuanced (see "Recent Developments").

**Subglottic Secretion Drainage (SSD)**

- Using ETTs with a dorsal lumen for continuous or intermittent suction of subglottic secretions reduces early-onset VAP and may decrease mortality.
- Nursing role: correct positioning of SSD tubes, maintaining suction pressures, monitoring for airway injury or blockage.

**Cuff Pressure Monitoring**

- Maintaining cuff pressure within the recommended range (usually 20-30 $cmH_2O$) reduces micro aspiration without compromising tracheal mucosa.
- Nurse-driven protocols and automated or volume-based systems have emerged to standardize this.

**Strict Hand Hygiene and Infection Prevention Practices**

- Alcohol-based hand rub before and after patient contact, glove use, aseptic suction technique, and appropriate personal protective equipment.

**Ventilator Circuit and Humidifier Management**

- Avoid routine circuit changes, change only when visibly soiled or malfunctioning.
- Use closed suction systems to reduce circuit disconnections and contamination.

Implementation of such bundles has consistently shown significant reductions in VAP rates and ventilator days across different ICUs.

**Recent developments and emerging evidence**

**Updated International Guidelines and VAE-Focused Prevention**

Recent guidelines from international societies emphasize bundle-based prevention, staff training, and performance monitoring. The 2025 ISID guideline highlights the importance of multimodal interventions, including elevation of the head, oral hygiene, SSD, hand hygiene, and early weaning, and shows that bundle implementation significantly reduces VAP episodes.

Parallel work on ventilator-associated events (VAEs) has shifted some focus from pneumonia alone to broader respiratory complications, emphasizing:

- Minimizing sedation
- Early mobilization
- Conservative fluid strategies
- Lung-protective ventilation.

These VAE-oriented strategies overlap considerably with VAP prevention and reinforce the need for nurse-led protocols.

**Subglottic Secretion Drainage (SSD): Optimization Rather Than "Yes or No"**

Multiple meta-analyses confirm that subglottic secretion drainage reduces VAP incidence and may reduce mortality, especially for early-onset VAP in patients ventilated >48-72 hours.

**Recent developments include**

- **Intermittent vs. continuous SSD:** A 2023 systematic review and 2024 RCTs explore optimal modes of drainage, with some suggesting volume-based, individualized drainage can improve secretion removal while limiting airway injury.
- **Airway injury concerns:** Newer observational data show SSD may be associated with more laryngotracheal mucosal injury if cuff pressures or suction are not well controlled.

**Implications for nursing practice:**

- Ensure use of SSD tubes for patients expected to need prolonged ventilation.
- Standardize suction pressures and drainage intervals (or monitor automated systems closely).
- Regularly assess for blood-tinged secretions, cuff leaks, or signs of airway trauma.

**Oral Chlorhexidine: From Standard to "Use with Caution"**

Earlier RCTs and meta-analyses suggested that oropharyngeal chlorhexidine decontamination reduced VAP risk. As a result, 0.12-0.2% CHX mouth care became routine in many ICUs.

**However, recent evidence has challenged this practice:**

- Several meta-analyses and observational studies have linked oral CHX to no clear reduction in VAP and even a possible increase in mortality and certain ICU infections.
- A 2024 systematic review concluded that CHX oral decontamination does not significantly reduce VAP or mortality in critically ill adults and routine use cannot be recommended.
- Some recent nursing-led RCTs comparing oral care protocols with vs. without CHX show mixed results, with improved oral hygiene but inconsistent impact on VAP rates.

**Current trend**

- Focus on meticulous mechanical oral care (tooth-brushing, suctioning, moisturizing) with CHX reserved for selected high-risk populations, following local policy and antimicrobial stewardship advice.

- Emphasis on standardizing frequency and technique of oral care rather than relying primarily on antiseptic solutions.

**Technology-Enabled Prevention: Smart monitoring and data-driven bundles**

Newer approaches integrate **technology and informatics** into VAP prevention:

- Automated cuff pressure controllers to maintain optimal cuff pressure and reduce micro aspiration.
- Electronic reminders and dashboards to prompt head-of-bed elevation, sedation interruption, and oral care, improving bedside compliance.
- Utilization of big datasets (e.g., MIMIC-IV) to study bundle compliance and outcomes, showing that higher adherence to all bundle elements correlates strongly with lower VAP rates.

For nursing practice, this supports the development of checklists, electronic documentation prompts, nurse-driven protocols, and real-time feedback mechanisms.

**Early mobility, sedation strategies, and VAE-focused care**

Recent VAE literature highlights mobility and sedation as modifiable factors:

- Minimizing continuous deep sedation, daily SAT/SBT, and early mobilization reduce ventilator days and VAEs, thereby indirectly reducing VAP risk.
- Conservative fluid management and lung-protective ventilation have also been linked to fewer VAEs.

**Nurses play a pivotal role in:**

- Assessing sedation levels (e.g., RASS), titrating sedatives as per protocol, and identifying candidates for SAT/SBT.
- Coordinating early mobilization activities (passive/ active limb exercises, sitting, standing where feasible) with physiotherapists.

**Emerging/Adjunctive Strategies (Still Evolving)**

Several interventions are under investigation or remain controversial:

**Inhaled antibiotics**

- Recent reviews describe inhaled antibiotics as a potential strategy for prevention/treatment of VAP, particularly in multidrug-resistant settings, but robust evidence for routine prophylactic use is still lacking.

**Selective Digestive Decontamination (SDD) and Selective Oropharyngeal Decontamination (SOD)**

- These can reduce VAP in some settings but raise concerns about antimicrobial resistance and are not widely recommended in all regions.

**Probiotics and immunonutrition**

- Some small studies suggest a possible reduction in VAP with probiotics, but evidence is heterogeneous and not yet standard of care.

**Endotracheal tube materials (e.g., silver-coated tubes, polyurethane cuffs)**

- These may reduce biofilm formation or microaspiration but are more expensive and not universally available; evidence is mixed.

Overall, guidelines currently prioritize low-cost, high-yield measures such as bundle adherence, SSD, early weaning, and infection control over more expensive or experimental interventions.

**Nursing Implications**

Nurses are central to successful VAP prevention. Key implications include:

**Leadership in Bundle Implementation**

- Use standardized checklists and protocols for head-of-bed elevation, oral care, suctioning, cuff pressure checks, sedation assessment, and early weaning.
- Participate in quality improvement projects and audits to monitor bundle compliance and VAP/VAE rates.

**Individualized Risk Assessment**

- Identify high-risk patients (prolonged ventilation, reintubation, high aspiration risk) and ensure enhanced preventive measures such as SSD and more frequent oral care.

**Evidence-based oral care**

- Prioritize thorough mechanical oral hygiene and suctioning.
- Apply chlorhexidine cautiously, following updated institutional policies, and remain aware of emerging evidence on risks and benefits.

**Education and Interprofessional Collaboration**

- Provide ongoing education to staff and students on VAP mechanisms, bundle elements, and updated evidence.
- Collaborate with intensivists, respiratory therapists, infection control teams, and pharmacists to align practices with the latest guidelines.

**Documentation and Surveillance**

- Accurate documentation of ventilator settings, sedation levels, oral care, cuff pressures, and positioning is crucial for surveillance and continuous improvement.
- Engage with VAE/VAP surveillance data to identify gaps and target interventions.

**Challenges in Resource-Limited Settings**

In many low-and middle-income countries, limited availability of SSD tubes, automated devices, or advanced materials can be a barrier. However, studies demonstrate that even simple, low-cost measures such as strict hand hygiene, head-of-bed elevation, basic oral care, and nurse-led sedation/weaning protocols can significantly reduce VAP rates when applied consistently.

**Nursing strategies in such settings should prioritize:**

- Low-cost bundle components with strong evidence.

- Education, auditing, and feedback to improve compliance.
- Local guideline adaptation considering available resources.

## Conclusion

Prevention of ventilator-associated pneumonia remains a central goal in critical care and medical-surgical nursing practice. Contemporary evidence supports the use of multimodal VAP prevention bundles, nurse-led sedation and weaning protocols, and meticulous infection control measures. Recent developments have refined these strategies:

- Subglottic secretion drainage is confirmed as beneficial, with growing attention to optimizing drainage modes and minimizing airway injury.
- The role of oral chlorhexidine has become controversial, with newer evidence questioning routine use and shifting emphasis toward high-quality mechanical oral care.
- Technology-enabled interventions, such as automated cuff pressure monitoring and electronic bundle prompts, enhance compliance and outcomes where available.
- VAE-focused preventive strategies minimizing sedation, early mobilization, and conservative fluid management are now recognized as important in reducing both VAEs and VAP.

For nurses, the priority is consistent, evidence-based implementation of prevention bundles, continuous education, and active engagement in quality improvement. With sustained effort and attention to emerging evidence, VAP is a largely preventable complication of mechanical ventilation.

## Conflict of Interest

Not available

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