

A systematic review on the effectiveness of nurse-led ventilator-associated pneumonia (VAP) prevention bundles and their impact on patient mortality rates in intensive care units

Navdeep Singh^{1*}, Sanya², Ritu³, Riya⁴, Saniya⁵

^{*1}*Principal, Indus College of Nursing, Khanda Kheri, Hansi, Haryana, India*

²*Clinical Instructor and Scholar, Indus College of Nursing, Khanda Kheri, Hansi, Haryana, India*

³⁻⁵*Research Scholar, Indus College of Nursing, Khanda Kheri, Hansi, Haryana, India*

DOI: 10.5281/zenodo.21393463

Abstract:

Ventilator-associated pneumonia (VAP) remains one of the most serious healthcare-associated infections affecting critically ill patients receiving invasive mechanical ventilation in intensive care units (ICUs). Despite remarkable advances in intensive care practices, VAP continues to contribute significantly to prolonged hospitalisation, increased healthcare expenditure, higher antibiotic consumption, and elevated patient mortality. The present systematic review synthesises current evidence regarding the effectiveness of nurse-led VAP prevention bundles and their influence on important clinical outcomes. The review demonstrates that structured nurse-led preventive interventions consistently reduce VAP incidence by improving compliance with evidence-based infection prevention practices. The findings indicate that high adherence to ventilator care bundles, including head-of-bed elevation, oral hygiene, maintenance of endotracheal cuff pressure, subglottic secretion drainage, sedation interruption, spontaneous breathing trials, and strict hand hygiene, significantly decreases ventilator-associated infections. Several studies included in the review reported substantial reductions in VAP incidence, shorter duration of mechanical ventilation, decreased intensive care unit length of stay, reduced hospitalisation, and improvement in overall patient recovery. Greater compliance with nurse-led protocols was also associated with lower healthcare costs and decreased exposure to broad-spectrum antimicrobial therapy. The review further highlights the pivotal role of critical care nurses in ensuring continuous surveillance, protocol adherence, patient assessment, and multidisciplinary coordination throughout the period of mechanical ventilation. The overall evidence supports nurse-led VAP prevention bundles as an effective, evidence-based strategy for improving patient safety and enhancing the quality of critical care services in intensive care units.

Keywords:

Ventilator-Associated Pneumonia, Intensive Care Unit, Critical Care Nursing, Nurse-Led Care Bundle, Mechanical Ventilation, Infection Prevention, Patient Safety, Mortality.

1. Introduction:

Mechanical ventilation has transformed the management of critically ill patients by providing life-sustaining respiratory support during severe illness. However, prolonged invasive ventilation also increases the risk of serious hospital-acquired infections, particularly ventilator-associated pneumonia (VAP). VAP develops after at least 48 hours of endotracheal intubation or tracheostomy and represents one of the most frequently encountered infections among mechanically ventilated patients. The artificial airway bypasses normal respiratory defence mechanisms, allowing microorganisms to enter the lower respiratory tract and establish pulmonary infection. As a result, patients often experience prolonged ventilatory dependence, delayed recovery, increased intensive care stay, greater healthcare expenditure, and higher mortality. (*Klompas et al., 2022*).

The development of VAP is primarily associated with microaspiration of contaminated oropharyngeal secretions, biofilm formation on endotracheal tubes, impaired mucociliary clearance, prolonged sedation, and exposure to multidrug-resistant microorganisms. The combination of these factors produces a complex infectious process that significantly complicates the management of critically ill patients. Although improvements in ventilator technology and antimicrobial therapy have reduced several complications associated with mechanical ventilation, VAP continues to remain a major clinical challenge worldwide. (Klompas et al., 2022; Mastrogiani et al., 2023).

Healthcare systems increasingly recognise that prevention is more effective than treatment for ventilator-associated pneumonia. Consequently, the concept of evidence-based care bundles has become central to infection prevention within intensive care practice. Rather than relying upon isolated preventive measures, modern critical care integrates several complementary interventions into a standardised bundle designed to interrupt multiple pathways responsible for VAP development. These bundles combine interventions such as maintaining head-of-bed elevation, regular oral hygiene, appropriate cuff pressure monitoring, minimisation of sedation, spontaneous breathing assessment, early mobilisation, and strict hand hygiene to reduce bacterial aspiration and pulmonary infection. (Munro, 2024; Klompas et al., 2022).

Among all healthcare professionals involved in intensive care management, nurses occupy the most important position in implementing these preventive interventions. Critical care nurses remain continuously at the patient's bedside and perform regular assessment, airway management, positioning, oral care, ventilator monitoring, documentation, and infection surveillance throughout every shift. Their continuous presence enables early identification of risk factors, immediate implementation of preventive measures, and consistent monitoring of compliance with established protocols. Nurse-led prevention bundles therefore represent a transition from physician-dependent intervention towards proactive nursing practice based upon evidence-based clinical guidelines. (Klompas et al., 2022).

The effectiveness of these nurse-led interventions extends beyond infection prevention alone. High compliance with ventilator bundles has been associated with shorter duration of mechanical ventilation, reduced intensive care unit stay, lower antibiotic utilisation, decreased healthcare costs, improved patient survival, and enhanced quality of care. Continuous education, structured nursing protocols, routine compliance audits, multidisciplinary collaboration, and institutional support further strengthen successful implementation of these preventive strategies. As a result, nurse-led VAP prevention bundles have become one of the most cost-effective approaches for improving outcomes among mechanically ventilated patients.

1.1. Ventilator-associated pneumonia: definition and classification:

Ventilator-associated pneumonia (VAP) is one of the most significant healthcare-associated infections encountered in modern intensive care medicine and remains a major cause of morbidity and mortality among critically ill patients requiring invasive mechanical ventilation. It is defined as a **nosocomial lower respiratory tract infection that develops at least 48–72 hours after endotracheal intubation or tracheostomy**, provided there is no evidence that the infection was present or incubating before initiation of mechanical ventilation (Klompas et al., 2022; Kalil et al., 2016). The requirement for invasive mechanical ventilation fundamentally alters normal respiratory defence mechanisms by bypassing the protective functions of the upper airway, allowing pathogenic microorganisms direct access to the lower respiratory tract. Consequently, VAP represents not merely a complication of mechanical ventilation but a multifactorial infectious process resulting from interactions between host susceptibility, microbial virulence, invasive medical devices, and healthcare-associated environmental factors.

VAP constitutes an important subgroup within the broader category of **hospital-acquired pneumonia (HAP)**. While HAP refers to pneumonia developing 48 hours or more after hospital admission in patients who are not mechanically ventilated, VAP specifically occurs in patients receiving invasive ventilatory support. This distinction is clinically important because mechanically ventilated patients possess unique risk factors, different microbial flora, and higher rates of multidrug-resistant organisms than patients with non-ventilator-associated hospital-acquired pneumonia (Kalil et al., 2016).

From a microbiological perspective, VAP is characterised by progressive colonisation of the oropharynx, endotracheal tube, and lower respiratory tract with pathogenic microorganisms that ultimately overwhelm local pulmonary immune defences. Unlike community-acquired pneumonia, where pathogens are generally acquired before hospitalisation, VAP typically develops from microorganisms colonising the patient's own upper airway or from cross-transmission within the intensive care environment. The disease therefore represents the culmination of several sequential pathological processes including bacterial colonisation, biofilm formation, secretion pooling, microaspiration, inflammatory activation, and alveolar infection (Klompas et al., 2022).

Historically, VAP has been classified into **early-onset** and **late-onset** disease according to the duration of invasive mechanical ventilation prior to infection onset. This temporal classification serves as an important predictor of likely causative microorganisms and guides empirical antimicrobial therapy (Torres et al., 2021). **Early-onset VAP** develops during the first **96 hours** of mechanical ventilation and is generally associated with community-acquired or antibiotic-sensitive microorganisms that colonise the patient's upper respiratory tract before or shortly after hospital admission. Common pathogens include *Streptococcus pneumoniae*, *Haemophilus influenzae*, Methicillin-Susceptible *Staphylococcus aureus* (MSSA), and other relatively susceptible Gram-positive and Gram-negative bacteria. Patients with early-onset disease usually have lower exposure to broad-spectrum antibiotics and consequently demonstrate a lower prevalence of multidrug-resistant organisms. Clinical outcomes are generally more favourable because empirical antibiotic therapy is more likely to provide appropriate microbial coverage (Vincent et al., 2020).

In contrast, **late-onset VAP** develops after **96 hours** of continuous invasive ventilation and reflects prolonged exposure to the intensive care environment. During extended ICU admission, patients become progressively colonised with healthcare-associated pathogens that frequently exhibit multidrug resistance. Common organisms include *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, extended-spectrum beta-lactamase (ESBL)-producing Enterobacterales, carbapenem-resistant Gram-negative bacilli, and Methicillin-Resistant *Staphylococcus aureus* (MRSA). Late-onset VAP is associated with prolonged antibiotic therapy, increased healthcare costs, higher rates of treatment failure, longer ICU stay, and significantly greater mortality than early-onset disease (Vincent et al., 2020).

Modern infection surveillance has evolved beyond this traditional classification. The Centers for Disease Control and Prevention (CDC) and the National Healthcare Safety Network (NHSN) introduced the broader concept of Ventilator-Associated Events (VAEs) to improve surveillance reliability and reduce subjectivity associated with clinical diagnosis (Centers for Disease Control and Prevention, 2024).

1.2 Need of the study:

Ventilator-associated pneumonia continues to impose a substantial burden on healthcare systems despite significant advances in critical care medicine. The disease remains one of the leading healthcare-associated infections among mechanically ventilated patients and contributes directly to prolonged intensive care admission, increased morbidity, antimicrobial resistance, higher treatment costs, and considerable mortality. Although international clinical guidelines strongly recommend evidence-based preventive interventions, adherence to these recommendations varies widely between institutions because of differences in nursing workload, staffing patterns, available resources, education, and organisational support. (Klompas et al., 2022).

The increasing emergence of multidrug-resistant organisms has further intensified the importance of preventing ventilator-associated pneumonia. Patients who develop VAP frequently require prolonged broad-spectrum antibiotic therapy, which accelerates antimicrobial resistance and increases healthcare expenditure. Preventing infection through structured nursing interventions therefore represents a safer and more sustainable strategy than relying primarily upon antimicrobial treatment after infection develops. (Mahima et al., 2025).

2. Review of literature:

Ventilator-associated pneumonia continues to be recognised as one of the most common healthcare-associated infections affecting mechanically ventilated patients in intensive care units. Current evidence consistently demonstrates that VAP develops through a multifactorial process involving bacterial colonisation, biofilm formation on endotracheal tubes, repeated micro aspiration of contaminated secretions, impaired host defence mechanisms, prolonged mechanical ventilation, and cross-transmission of microorganisms within the intensive care environment. Because multiple pathogenic mechanisms operate simultaneously, prevention requires several complementary interventions rather than reliance upon a single preventive measure. (Klompas et al., 2022).

The literature further indicates that invasive mechanical ventilation fundamentally alters the normal physiological defence mechanisms of the respiratory tract. Endotracheal intubation bypasses the filtering function of the upper airway, suppresses cough reflexes, impairs mucociliary clearance, and facilitates colonisation of pathogenic microorganisms. Biofilm formation on the inner surface of the endotracheal tube provides a protected environment where microorganisms survive despite host immune responses and antimicrobial therapy. Fragments of mature biofilm may subsequently

dislodge and enter the lower respiratory tract, initiating pulmonary infection. Continuous micro aspiration of contaminated oral and gastric secretions further accelerates this infectious process and contributes significantly to VAP development. (Hellyer et al., 2022; Timsit et al., 2025).

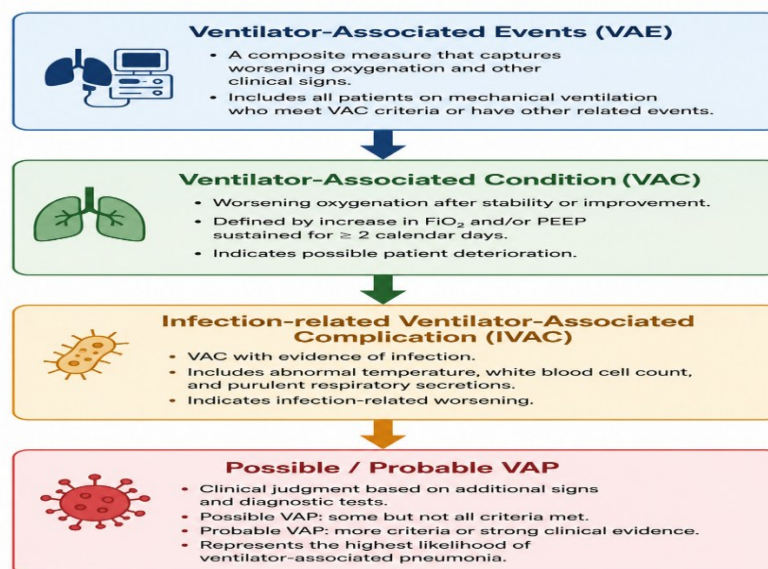


Figure 1: CDC/NHSN Ventilator-Associated Events (VAE) Surveillance Hierarchy

Critical care nurses remain central to successful implementation of these preventive strategies because they provide uninterrupted bedside care throughout the patient's intensive care admission. Unlike other healthcare professionals who perform periodic clinical assessments, nurses continuously monitor ventilator settings, patient positioning, airway management, oral hygiene, cuff pressure, sedation levels, spontaneous breathing readiness, infection surveillance, and documentation of bundle compliance. Their continuous presence allows early correction of deviations from established protocols and promotes consistent adherence to evidence-based practice. (Klompas et al., 2022). Education and competency-based training have also been identified as major determinants of successful bundle implementation. Regular educational programmes, simulation training, bedside demonstrations, competency assessments, clinical audits, and multidisciplinary feedback improve nurses' knowledge regarding infection prevention while enhancing compliance with international guidelines. Several quality improvement programmes reviewed within the literature reported substantial reductions in VAP incidence following implementation of structured educational initiatives combined with nurse-led monitoring systems. (Mahima et al., 2025).

Table 1. Multi-Dimensional Burden of Ventilator-Associated Pneumonia

Burden Dimension	Key Findings
Epidemiological Burden	VAP remains among the leading healthcare-associated infections in mechanically ventilated patients with marked variation between healthcare settings.
Patient Outcomes	Associated with prolonged ventilation, longer ICU stay, increased morbidity and higher mortality.
Healthcare Costs	Produces significant increases in hospital expenditure due to prolonged ICU admission and antimicrobial therapy.
Antimicrobial Resistance	Increased use of broad-spectrum antibiotics contributes to emergence of multidrug-resistant organisms.
Quality of Care	High compliance with nurse-led prevention bundles significantly improves patient safety and infection prevention.

3. Results / key findings:

The evidence included in this systematic review consistently demonstrates that nurse-led ventilator-associated pneumonia prevention bundles produce favourable clinical outcomes across diverse intensive care settings. Studies included in the review reported that implementation of comprehensive

ventilator bundles was associated with measurable reductions in VAP incidence when compared with conventional intensive care practices. Improved compliance with evidence-based nursing interventions contributed directly to enhanced infection prevention, reduced ventilator exposure, and better overall patient outcomes. (*Klompas et al., 2022*).

Across the reviewed literature, maintenance of head-of-bed elevation, routine oral hygiene, meticulous hand hygiene, regular cuff pressure monitoring, spontaneous awakening trials, spontaneous breathing trials, early mobilisation, and systematic assessment of ventilator readiness emerged as the most consistently applied bundle components. High adherence to these interventions interrupted multiple pathogenic mechanisms responsible for bacterial colonisation and aspiration, thereby reducing pulmonary infection among mechanically ventilated patients. (*Klompas et al., 2022; Mahima et al., 2025*).

The findings of this systematic review indicate that nurse-led Ventilator-Associated Pneumonia (VAP) prevention bundles consistently improve clinical outcomes by ensuring systematic implementation of evidence-based preventive practices throughout the period of mechanical ventilation. Unlike conventional care, where preventive interventions are often performed independently or inconsistently, nurse-led bundle implementation integrates multiple evidence-based measures into routine bedside practice. This coordinated approach strengthens infection prevention by simultaneously targeting bacterial colonisation, aspiration of contaminated secretions, prolonged ventilator exposure, inadequate oral hygiene, and inconsistent airway management. (*Klompas et al., 2022*).

One of the most consistent findings across the reviewed studies was the significant reduction in VAP incidence following implementation of structured nurse-led care bundles. Healthcare institutions maintaining high compliance with ventilator bundle components reported markedly lower infection rates than centres relying upon conventional physician-directed care alone. The literature emphasised that prevention bundles produced maximum benefit when every component was performed consistently during each nursing shift rather than selectively according to individual clinical preference. Continuous bedside surveillance by critical care nurses ensured that preventive interventions remained uninterrupted despite changing patient conditions and intensive care workload. (*Klompas et al., 2022*).

The review further demonstrated that maintaining patients in a semi-recumbent position of 30°–45° remained one of the most effective interventions for reducing aspiration of contaminated oral and gastric secretions. Consistent repositioning immediately following diagnostic procedures, hygiene care, physiotherapy, and patient transport reduced aspiration risk throughout intensive care admission. Nurses played the primary role in maintaining appropriate positioning, verifying endotracheal tube stability, reassessing cuff pressure after movement, and ensuring safe continuation of enteral feeding following positional changes. These routine bedside interventions collectively contributed to lower VAP occurrence. (*Klompas et al., 2022*).

Routine oral hygiene emerged as another major determinant of infection prevention. The reviewed literature consistently reported that colonisation of dental plaque and oral mucosal surfaces by pathogenic microorganisms occurs rapidly after endotracheal intubation. Nurse-led oral care protocols involving scheduled tooth brushing, antiseptic mouth care, oral suctioning, moisturisation of oral tissues, and regular inspection of the oral cavity substantially reduced microbial colonisation. Continuous adherence to these protocols interrupted one of the principal sources of pulmonary contamination and contributed significantly to lowering ventilator-associated pneumonia incidence. (*Klompas et al., 2022*).

Strict compliance with hand hygiene also demonstrated considerable influence on infection prevention outcomes. Because nurses perform the majority of direct patient care activities within intensive care units, adherence to hand hygiene before and after every patient contact substantially reduced cross-transmission of microorganisms. Appropriate use of personal protective equipment, aseptic suctioning techniques, and meticulous cleaning of reusable equipment further strengthened infection prevention practices. Several quality improvement programmes included in the review

reported improved institutional compliance following nurse-led educational initiatives, peer observation, and continuous performance feedback. (Klompas et al., 2022).

Daily assessment of sedation requirements and readiness for ventilator weaning represented another important finding. Nurse-led spontaneous awakening trials (SATs) followed by spontaneous breathing trials (SBTs) enabled early identification of patients suitable for ventilator liberation. Earlier discontinuation of invasive mechanical ventilation shortened ventilator exposure, reduced cumulative infection risk, and improved patient recovery. The evidence consistently identified reduction in ventilator duration as one of the strongest contributors to lower VAP incidence because infection risk increases progressively with each additional day of invasive ventilation. (Mahima et al., 2025).

The review further demonstrated that standardisation of clinical practice significantly enhanced quality of care. Structured nurse-led protocols reduced variation in bedside practices by ensuring uniform implementation of oral hygiene, head-of-bed elevation, cuff pressure assessment, sedation monitoring, suctioning techniques, and ventilator weaning evaluation irrespective of staff experience or shift allocation. This consistency improved reliability of nursing care, strengthened patient safety, and minimised preventable deviations from evidence-based guidelines. (Klompas et al., 2022).

Educational interventions formed another recurring theme across the reviewed evidence. Continuous professional education, competency-based training, simulation exercises, bedside demonstrations, and regular compliance audits improved nurses' knowledge regarding VAP prevention and strengthened adherence to international infection prevention guidelines. Institutions implementing structured educational programmes reported higher bundle compliance together with measurable reductions in healthcare-associated infections. Ongoing education also encouraged critical thinking, professional accountability, multidisciplinary collaboration, and participation in quality improvement initiatives. (Mahima et al., 2025).

The integration of clinical checklists and electronic documentation systems further enhanced successful implementation of prevention bundles. Visual reminders incorporated within bedside documentation ensured regular assessment of oral hygiene, patient positioning, cuff pressure, sedation interruption, ventilator weaning readiness, and documentation of bundle compliance. Electronic monitoring enabled healthcare organisations to evaluate compliance trends, identify barriers to implementation, and introduce targeted corrective measures whenever deficiencies were detected. These structured monitoring systems reduced omissions associated with heavy clinical workload and improved communication between nursing teams during shift handovers. (Klompas et al., 2022).

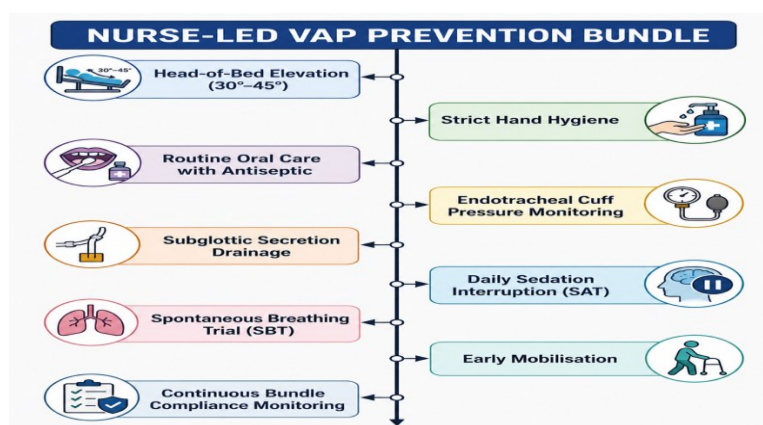


Figure 2: Core Components of the Nurse-Led VAP Prevention Bundle

The reviewed evidence also highlighted the broader organisational benefits associated with successful nurse-led bundle implementation. Hospitals demonstrating sustained compliance experienced reductions in intensive care unit length of stay, lower antibiotic utilisation, decreased healthcare expenditure, and improved utilisation of critical care resources. Prevention of ventilator-associated pneumonia also supported antimicrobial stewardship by reducing unnecessary exposure to broad-spectrum antimicrobial agents, thereby limiting selective pressure responsible for the emergence of

multidrug-resistant organisms. These findings emphasise that effective infection prevention not only improves individual patient outcomes but also contributes to long-term sustainability of intensive care services. (*Klompas et al., 2022; Mahima et al., 2025*).

Overall, the evidence synthesised in this review consistently supports nurse-led VAP prevention bundles as one of the most effective evidence-based strategies available for reducing ventilator-associated pneumonia. High compliance with structured preventive interventions improves patient safety, shortens mechanical ventilation, decreases intensive care utilisation, reduces healthcare costs, strengthens antimicrobial stewardship, and enhances survival among critically ill mechanically ventilated patients. The collective findings reinforce the central role of critical care nurses in translating evidence-based recommendations into routine bedside practice while maintaining continuous surveillance and ensuring sustained adherence to established clinical protocols.

4. Conclusion:

Ventilator-associated pneumonia remains one of the most significant healthcare-associated infections affecting critically ill patients receiving invasive mechanical ventilation in intensive care units. The evidence synthesised in this systematic review demonstrates that VAP continues to contribute substantially to prolonged mechanical ventilation, increased intensive care unit stay, greater healthcare expenditure, higher antimicrobial consumption, and increased patient mortality. Despite advances in critical care medicine, VAP remains a persistent clinical challenge because of its multifactorial pathogenesis involving bacterial colonisation, biofilm formation, micro aspiration, impaired airway defence mechanisms, prolonged ventilatory support, and healthcare-associated transmission of pathogenic microorganisms. (*Klompas et al., 2022*).

The reviewed evidence consistently indicates that nurse-led VAP prevention bundles represent one of the most effective evidence-based approaches for reducing ventilator-associated pneumonia in mechanically ventilated patients. Simultaneous implementation of evidence-based interventions, including head-of-bed elevation, strict hand hygiene, routine oral hygiene, maintenance of endotracheal cuff pressure, subglottic secretion drainage, daily sedation interruption, spontaneous breathing trials, early mobilisation, and continuous compliance monitoring, provides significantly greater protection than isolated preventive measures. These interventions collectively interrupt multiple pathogenic pathways responsible for VAP development and contribute directly to improved patient outcomes. (*Klompas et al., 2022*).

The review further highlights the indispensable role of critical care nurses in ensuring successful implementation of these preventive strategies. Continuous bedside presence enables nurses to perform uninterrupted patient assessment, maintain adherence to bundle components, identify clinical deterioration at an early stage, coordinate multidisciplinary care, and ensure consistent compliance with institutional protocols. Their contribution extends beyond routine nursing responsibilities by transforming evidence-based recommendations into standard clinical practice throughout every stage of intensive care management. (*Klompas et al., 2022; Mahima et al., 2025*).

Another important finding emerging from the review is the positive influence of structured education, competency-based training, regular compliance audits, clinical checklists, and multidisciplinary collaboration on bundle adherence. Healthcare institutions implementing comprehensive nurse-led prevention programmes consistently reported lower VAP incidence, reduced duration of mechanical ventilation, shorter intensive care unit stay, decreased antimicrobial utilisation, improved patient safety, and lower healthcare costs. These findings emphasise that sustained adherence to evidence-based nursing interventions remains fundamental to successful infection prevention within intensive care settings. (*Mahima et al., 2025*).

Overall, the available evidence strongly supports nurse-led VAP prevention bundles as an effective strategy for improving the quality and safety of intensive care services. Consistent implementation of standardised preventive interventions not only reduces ventilator-associated pneumonia but also enhances patient survival, strengthens antimicrobial stewardship, optimises utilisation of healthcare resources, and promotes high-quality critical care practice.

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