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Comprehensive Approaches to Ventilator-Associated Pneumonia in Respiratory Therapy: Diagnosis, Treatment, and Prevention

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ABSTRACT

Ventilator-associated pneumonia (VAP) is a prevalent nosocomial infection in

intensive care units (ICUs), with incidence rates ranging from 10% to 40%. VAP develops when microorganisms infiltrate the lower respiratory tract, typically via aspiration of oropharyngeal organisms. Risk factors for VAP include patient characteristics, mechanical ventilation equipment, and treatment-related factors. VAP diagnosis relies on clinical and radiological suspicion supported by bacteriological evidence, with diagnostic strategies including invasive, clinical, and intermediate approaches. Treatment should commence promptly upon strong suspicion of infection, with initial empiric antibiotic therapy based on risk factors for multidrug-resistant pathogens and local microbial environment. Antibiotic regimens should be reassessed by day two or three and optimized based on pharmacokinetic and pharmacodynamic principles. Treatment duration varies, with shorter courses (≤1 week) as effective as longer courses (≥2 weeks) for VAP caused by pathogens other than nonfermenting gram-negative bacilli. Preventive strategies encompass general measures such as hand hygiene and specific interventions targeting risk exposure minimization, aspiration reduction, and bacterial colonization limitation. Comprehensive prevention programs have achieved significant reductions in VAP incidence. ICU mortality rates for VAP patients range from 20% to 65%, with attributable mortality estimated at approximately 5%. VAP prolongs mechanical ventilation duration and ICU stays. Emerging challenges include the rise of multidrug-resistant and nearly resistant strains, necessitating judicious antibiotic use and ongoing research into alternative strategies.

Keywords: Ventilator-Associated Pneumonia, VAP, Respiratory Therapy

Introduction

Ventilator-associated pneumonia (VAP) is defined as a parenchymal lung infection that arises after a patient has been intubated and mechanically ventilated (MV) for at least 48 hours (Chastre & Fagon, 2002). This definition excludes infections that are present or incubating upon admission. Other forms of hospital-acquired pneumonia, such as nosocomial pneumonia occurring during noninvasive positive pressure ventilation, ventilator-associated tracheobronchitis, and aspiration pneumonia leading to ICU admission, are not addressed in this review. The article is based on an analysis of the literature obtained from the Medline database, using keywords such as ventilator-associated pneumonia, nosocomial pneumonia, and hospital-acquired pneumonia from 1990 to 2011, supplemented by the author's clinical experience. VAP is the most prevalent nosocomial infection in ICUs, with an incidence ranging between 10% and 40%, and it is associated with the highest mortality rate. Several aspects of VAP remain subjects of debate, including optimal diagnostic and therapeutic approaches, its precise impact on short-term clinical outcomes, and effective preventive strategies.

Infectious Process

The development of VAP requires microorganisms to infiltrate the otherwise sterile lower respiratory tract, where bacterial adherence to mucosal surfaces can provoke neutrophilic alveolitis. The primary route for VAP acquisition is aspiration—either gross or microaspiration—of oropharyngeal organisms into the distal airways, directly or via gastroesophageal reflux. Less commonly, VAP may result from hematogenous dissemination from distant infections (e.g., catheter-related

bloodstream infections) or environmental sources, such as healthcare workers' hands, contaminated respiratory devices, bronchoscopes, aerosols, water (e.g., Legionella), or air (e.g., viruses, Aspergillus). The pathogens responsible for VAP can originate from the patient's endogenous flora or be acquired exogenously during hospitalization. The oropharynx is the primary reservoir for bacteria implicated in VAP.

In healthy individuals, the oropharyngeal flora acts as a natural barrier against aerobic pathogens like Streptococcus pneumoniae, Haemophilus influenzae, and Staphylococcus aureus, which are typically present in low concentrations. However, hospitalized patients frequently experience a shift in their oropharyngeal flora toward enteric Gram-negative bacilli (GNB), such as Enterobacteriaceae. Additionally, pathogens like Pseudomonas aeruginosa can colonize the oropharyngeal cavity in patients with comorbid conditions. This alteration in flora is influenced by factors such as disease severity, prior hospitalization, poor nutrition, antibiotic use, and the presence of an endotracheal tube (Safdar et al., 2005). Despite the frequent colonization of the stomach by enteric GNB, this reservoir is not considered a major contributor to lower airway colonization or VAP development (Bonten et al., 1997).

The endotracheal tube is pivotal in VAP pathogenesis as it disrupts mucosal integrity and mucociliary clearance, hampers effective coughing, and often necessitates patient immobilization in a supine position. Biofilm formation on the endotracheal tube represents a further avenue for bacterial colonization. Not all patients on MV develop lung tissue infections; this outcome depends on the interplay between host defenses and the virulence and quantity of pathogens colonizing the lower respiratory tract. Although genetic predispositions have been hypothesized, the biological mechanisms underlying why certain patients develop VAP remain unclear.

Risk Factors

Numerous risk factors for VAP development have been identified and are summarized in (Giard et al., 2008). Understanding whether these factors are modifiable or nonmodifiable and whether they are patient-, MV equipment–, or treatment-related is essential for devising effective preventive measures.

Epidemiology

The lack of a definitive diagnostic gold standard for VAP results in considerable variability in epidemiologic data. Studies relying solely on clinical criteria may differ significantly in relevance compared to those based on quantitative cultures from distal airway samples. For VAP diagnosis, patients must be mechanically ventilated for at least 48 hours, a duration established primarily to standardize research comparisons. Additionally, VAP is categorized into early-onset VAP, occurring within the first 4–5 days of MV initiation, and late-onset VAP, which develops after 5 days of MV (Vallés et al., 2007).

This distinction is clinically significant for two reasons. First, early-onset VAP is typically caused by the patient's endogenous flora, whereas late-onset VAP is associated with hospital-acquired pathogens, including Gram-negative bacteria. Second, late-onset VAP correlates with longer ICU stays, greater incidence of organ dysfunction, and higher-than-expected mortality rates compared to early-onset VAP.

Incidence

The incidence of VAP among mechanically ventilated patients ranges from 8% to 28%. Early-onset VAP accounts for 20% to 60% of VAP episodes, depending on the population case mix. The cumulative risk of VAP increases with the duration of MV, peaking during the first five days with a daily hazard risk of 3% and declining to 2% by day 10 and 1% by day 15. The incidence of VAP also varies significantly by patient population, ICU type, and hospital setting. According to a recent international surveillance study, trauma, neurologic, respiratory, and neurosurgical ICUs exhibit higher rates of VAP per 1,000 ventilator-days compared to other ICU types (Rosenthal et al., 2012). VAP is particularly common in patients undergoing major cardiac surgery who remain mechanically ventilated for over 48 hours, with an incidence of 45.9%, as reported in a Spanish study (Hortal et al., 2009).

Microorganisms Responsible for VAP

Regardless of the sampling technique utilized, most studies reveal that the majority of ventilator-associated pneumonia (VAP) cases are caused by aerobic, enteric gram-negative bacilli (GNB) (25%), Staphylococcus aureus (20%), Pseudomonas aeruginosa (20%), Haemophilus influenzae (10%), and Streptococcus species. High rates of polymicrobial infections have also been observed, ranging from 13% to 58% (Combes et al., 2002). The distribution of pathogens varies geographically, and underlying diseases may predispose patients to specific bacterial infections. For instance, chronic obstructive pulmonary disease (COPD) increases the risk of P. aeruginosa infection, while younger age, coma, absence of corticosteroid use, or prior trauma are linked to nosocomial pneumonia caused by S. aureus. The relative prevalence of causative microorganisms also differs based on the duration of mechanical ventilation (MV) prior to VAP onset. Early-onset VAP, typically occurring within 4 to 7 days, is more frequently associated with H. influenzae, Streptococcus pneumoniae, methicillin-susceptible S. aureus (MSSA), or susceptible Enterobacteriaceae. In contrast, late-onset VAP is significantly associated with P. aeruginosa, Acinetobacter species, methicillin-resistant S. aureus (MRSA), and multidrug-resistant (MDR) GNB. A similar effect is noted with the duration of hospitalization before VAP onset. Prior antibiotic exposure is a major factor contributing to MDR pathogen infections. Additional risk factors for VAP caused by MDR bacteria are outlined in the American Thoracic Society (ATS)/Infectious Diseases Society of America (IDSA) guidelines, including the prevalence of antibiotic-resistant strains in healthcare settings, risk factors for healthcare-associated pneumonia, and immunocompromised status. Immunosuppressive conditions, with or without related therapy, broaden the potential pathogen spectrum to include fungi and viruses. While anaerobes have been reported in early-onset VAP, their therapeutic significance remains uncertain (Doré et al., 1996). In immunocompetent individuals, microorganisms such as Candida, coagulase-negative staphylococci, and enterococci are occasionally isolated from respiratory samples but rarely cause parenchymal lung infections. Some researchers consider these commensal organisms as potential VAP pathogens. Epidemic outbreaks of MDR strains can occur in intensive care units

(ICUs), and the role of pulmonary nosocomial viral infections in mechanically ventilated ICU patients remains insufficiently studied and is not discussed further here.

Diagnosis

Unlike community-acquired pneumonia, diagnosing VAP is challenging due to the difficulty in distinguishing between noninfectious complications or simple respiratory tract colonization and true lower respiratory tract infection. This differentiation is crucial, as unnecessary antibiotic use can lead to adverse effects, increased costs, and selection pressure for MDR strains within the ICU (J. L. Trouillet et al., 1998). Conversely, delayed or inappropriate antibiotic treatment can adversely impact short-term patient outcomes. Autopsy findings or quantitative cultures from protected-specimen brush or bronchoalveolar lavage (BAL) samples are often used as reference standards to evaluate the accuracy of VAP diagnosis.

The Three Components of VAP Diagnosis

VAP diagnosis typically relies on clinical and radiological suspicion supported by bacteriological evidence of lower respiratory tract infection. Common warning signs include new fever, purulent endotracheal secretions, and leukocytosis. Suspected VAP may also be indicated by deteriorating hemodynamic status or oxygenation. While plain chest radiography remains essential, portable radiographs are often of poor quality, and detecting new infiltrates is challenging, particularly in cases of acute respiratory distress syndrome (ARDS) or severe pulmonary injury. Infiltrates can also have diverse causes. As these clinical and radiological signs are sensitive but not specific, collecting respiratory tract samples such as endotracheal aspirates, BAL, or protected-specimen brushes is crucial to isolate pathogens, confirm infection, and identify the etiology. Blood and pleural fluid cultures rarely contribute to the etiological diagnosis. Emerging methods, such as multiplex polymerase chain reaction (PCR) techniques, are under development.

Diagnostic Strategies in Clinical Practice

Defining an optimal diagnostic strategy remains controversial. Literature describes several approaches, with three main strategies commonly utilized. The invasive or bacteriological strategy involves fiberoptic bronchoscopy to obtain protected distal samples via BAL or protected-specimen brushes. These samples undergo systematic quantitative cultures to identify pathogens. Growth below a specific threshold suggests colonization rather than active infection or contamination.

The clinical strategy relies solely on clinical criteria and qualitative or semiquantitative cultures of endotracheal aspirates. Proponents argue that worsening status in a mechanically ventilated patient warrants empirical antibiotic therapy guided by local epidemiology and flora.

An intermediate strategy combines clinical criteria with quantitative cultures of non-fibroscopic samples, including endotracheal aspirates, blind bronchoscopic brush samples, and mini-BAL samples. Regardless of the approach, timely decision-making is critical as standard culture techniques require at least 24 hours for initial results and an additional 24 hours for sensitivity testing. Direct examination, such as Gram staining, may provide preliminary insights but is not universally available.

Pros and Cons of Each Strategy

The clinical strategy is simple, cost-effective, and minimizes the risk of untreated VAP (Niederman, 2005), but it may lead to unnecessary antibiotic use or misdiagnosis of the cause of sepsis or radiological abnormalities. The invasive strategy, on the other hand, provides reliable direct examination and quantitative culture results, potentially supporting antibiotic de-escalation. Negative cultures may prompt exploration of alternative causes for symptoms. However, despite potential benefits, only one of five studies has demonstrated clinical advantages such as reduced antibiotic exposure and organ dysfunction (Chastre et al., 2010; Combes et al., 2010).

Value of Bacteriological Samples in Patients Already Receiving Antibiotics

Two distinct scenarios must be considered regarding bacteriological sampling in patients receiving antibiotics. The first involves patients who develop clinical symptoms of VAP while undergoing antibiotic therapy for more than 72 hours for any reason. In such cases, the results of respiratory secretion cultures are usually not affected when VAP arises as a superinfection, as the responsible bacteria are resistant to previously administered antibiotics. Consequently, collecting new samples is crucial and yields valid results.

Conversely, performing microbiologic cultures of pulmonary secretions for diagnostic purposes after initiating new antibiotic therapy in suspected VAP cases can lead to a high incidence of false-negative results, regardless of the method of obtaining these secretions. Therefore, it is essential to collect bacterial samples from various sites, including pulmonary secretions and blood, before initiating or altering antibiotic therapy.

Biochemical Markers and Scores for the Diagnosis of VAP

Recent years have seen the emergence of several biochemical markers as potential tools for diagnosing VAP, such as C-reactive protein, procalcitonin, soluble triggering receptor expressed on myeloid cells-1, and endotoxin. However, none of these markers has proven superior to the clinical or invasive strategies traditionally employed. Some markers may be more useful in refining prognostic assessments and tailoring antimicrobial therapy to individual patients.

Among diagnostic scores, the Clinical Pulmonary Infection Score is the most widely recognized. This composite score evaluates seven variables: temperature, blood leukocyte count, volume and purulence of endotracheal secretions, oxygenation, pulmonary radiography, and semiquantitative culture of endotracheal aspirates, with each variable assigned 0, 1, or 2 points. Despite its popularity, the system is challenging to apply in clinical settings, and its utility in identifying VAP is questionable. For instance, one study using a recommended threshold value of six on day three found a sensitivity of 89% but a specificity of only 47%, leading to potentially unnecessary treatment in 53% of patients without VAP as confirmed by bronchoscopy (Luyt et al., 2004).

Treatment

When to Treat

Given the potential severity of VAP, treatment should commence promptly when there is strong suspicion of infection, even before receiving bacterial culture results. Studies have consistently demonstrated the prognostic benefit of early and appropriate antibiotic therapy (Luna et al., 2006). Regardless of the diagnostic algorithm adopted, diagnostic and therapeutic approaches should be pre-established through written protocols agreed upon and followed by the entire medical team.

Initial Empiric Antibiotic Therapy

Guidelines from scientific societies and experts recommend initial antibiotic therapy based on risk factors for MDR pathogens, as outlined in the ATS/IDSA guidelines. Therapy selection also depends on the local microbial environment and population characteristics. Additionally, therapeutic regimens should consider prior respiratory sample results. If a patient has recently received antibiotics, it is advisable to use a different antibiotic class.

Adaptation and Optimization of Antibiotic Treatment

By day two or three, the initial antibiotic regimen should be reassessed. If VAP is not confirmed, treatment should be discontinued, or the antibiotic spectrum narrowed through a de-escalation strategy. Optimizing antimicrobial therapy involves adhering to pharmacokinetic and pharmacodynamic principles, ensuring appropriate dosing, correct administration routes, adequate penetration at the infection site, and dose adjustments for renal or hepatic dysfunction.

Monotherapy or Combination Therapy

Using a combination of antibiotics may broaden the spectrum of initial empirical therapy, achieve synergistic effects against certain bacteria such as Pseudomonas aeruginosa, and prevent resistance development during treatment. However, when the causative microorganism is identified and its susceptibility determined, the benefits of combination therapy are unclear, especially in non-neutropenic patients.

In critically ill patients, initial empirical combination therapy is logical for late-onset VAP cases at high risk of infections caused by difficult-to-treat GNB or in patients colonized by MDR strains. Canadian trials have shown that combination therapy is safe and associated with improved microbiological and clinical outcomes in such scenarios. This approach typically involves agents from different antibiotic classes to avoid antagonistic effects. For GNB, combination regimens may include β-lactams, quinolones, or aminoglycosides. When aminoglycosides are employed, their use should be limited to three days or fewer.

Treatment Duration

There is no definitive consensus on the optimal duration of treatment for ventilator-associated pneumonia (VAP). Epidemiological studies have demonstrated that some pathogens, including H. influenzae, S. pneumoniae, and Moraxella catarrhalis, can be eradicated quickly, whereas others, such as Enterobacteriaceae, S.

aureus, and P. aeruginosa, may persist even when antibiotics exhibit in vitro efficacy (Pugh et al., 2015). Recent randomized trials have indicated that shorter treatment courses (≤1 week) are as effective as longer courses (≥2 weeks) for VAP caused by pathogens other than nonfermenting gram-negative bacilli (e.g., P. aeruginosa or A. baumannii), with reduced antibiotic usage observed in the shorter-duration group. Prolonged antibiotic therapy is associated with increased adverse events and a higher likelihood of colonization with antibiotic-resistant bacteria, potentially leading to recurrent VAP episodes.

In clinical settings, the treatment duration can be predetermined. For instance, Singh et al. utilized a modified Clinical Pulmonary Infection Score to identify low-risk VAP patients (score ≤6), who could be effectively treated with a three-day antibiotic regimen, in contrast to the conventional 10–21 days of therapy. Patients in the shorter treatment group demonstrated improved clinical outcomes compared to those receiving prolonged therapy.

Prevention

Nonspecific Measures

General preventive strategies, such as adherence to hand hygiene protocols using hydroalcoholic solutions, are part of broader programs targeting nosocomial infections and healthcare-associated infections (Lorente et al., 2007). These measures encompass architectural considerations, quality of materials, sufficient and well-trained nursing staff, surveillance of ICU infections, proper maintenance of ventilatory equipment, adherence to care protocols, and antibiotic stewardship. A restrictive transfusion policy is recommended due to the observed statistical correlation between the volume of transfused blood products and the incidence of infection. Additionally, avoiding overly aggressive mechanical ventilation (MV), such as using excessively high tidal volumes, is crucial.

Specific Measures

Targeted preventive interventions are detailed with three primary objectives: minimizing the duration of exposure risk (e.g., liberating patients from MV promptly), reducing aspiration frequency, and limiting bacterial colonization of the oropharynx. Variations in guideline recommendations persist (Bekaert et al., 2011).

Combining sedation and MV weaning protocols has demonstrated a reduction in MV duration and, in a recent study, a decrease in VAP incidence. The ATS/IDSA guidelines advocate for the avoidance of intubation and reintubation. Noninvasive MV is recommended when feasible; however, early tracheostomy did not reduce VAP incidence in at least two randomized trials (J.-L. Trouillet et al., 2011). The ATS/IDSA also recommend positioning patients semi-recumbently to reduce aspiration risk. While maintaining a daily 45° angle is challenging, the effect of this positioning remains uncertain (Niël-Weise et al., 2011).

Notably, significant reductions in VAP incidence were observed in over six randomized trials employing continuous subglottic secretion drainage with specialized endotracheal tubes. In contrast, post-pyloric feeding tubes showed no clear benefits.

The properties of endotracheal tube cuffs (e.g., polyurethane vs. polyvinyl chloride, tapered vs. cylindrical) and the use of modest positive end-expiratory pressure may decrease microinhalation risk, though evidence is insufficient to recommend their widespread adoption. Devices enabling continuous intracuff pressure monitoring may mitigate microaspiration, but their impact on VAP incidence remains unproven.

Strategies to minimize oropharyngeal colonization include preferring orotracheal over nasotracheal intubation and employing oropharyngeal decontamination with antiseptics like chlorhexidine, though results are inconsistent. Selective digestive decontamination using nonabsorbable antibiotics has been shown to decrease bacterial colonization, VAP incidence, and, in a recent multicenter randomized trial, mortality by 3% (de Smet et al., 2009). However, the ATS/IDSA guidelines do not support routine selective digestive decontamination in settings with a high prevalence of multidrug-resistant (MDR) strains.

In a randomized trial, Kollef et al. demonstrated that silver-coated endotracheal tubes reduced VAP incidence without impacting MV duration or hospital length of stay. Other interventions, such as routine ventilator circuit changes, various humidification systems, closed vs. open endotracheal suction systems, and kinetic or rotational beds, did not show substantial benefits in terms of VAP incidence, MV duration, or ICU stay.

Ultimately, only comprehensive prevention programs, designed as care bundles or multimodal approaches, encompassing measures such as patient positioning, equipment optimization, nutritional support, infection control, sedation minimization, and MV weaning, have achieved significant reductions in VAP incidence. ICU teams should implement such programs, ensuring consistent application of each measure. Regular audits and immediate feedback for medical and nursing staff can facilitate this goal.

Alternative Strategies

An emerging approach involves guiding treatment duration using biochemical markers. A recent multicenter trial involving critically ill patients, including 141 with VAP, found that repeated procalcitonin measurements allowed earlier discontinuation of antibiotic therapy without compromising patient safety or efficacy. Similar outcomes were observed in another VAP-specific study, though further research is necessary before endorsing this strategy widely.

MDR and Nearly Resistant Strains

Historically, vancomycin was the primary treatment for MRSA-related VAP, although treatment failure rates were as high as 40%. Over the past decade, the oxazolidinone antibiotic linezolid has shown efficacy against MRSA in clinical infections. Multiple studies have demonstrated its effectiveness in MRSA VAP, with one randomized trial reporting superiority over vancomycin in clinical resolution and microbial eradication.

For extended-spectrum β-lactamase–producing bacteria, carbapenems remain the most reliable therapy, often combined with amikacin, which can be nebulized to achieve high lung tissue concentrations while minimizing systemic

toxicity. Alternatives like cefepime or tazobactam are occasionally viable but require consultation with a bacteriologist. For MDR P. aeruginosa or A. baumannii, colistin, administered intravenously, nebulized, or via endotracheal instillation, may be the only effective option. The emergence of carbapenemase-producing Enterobacteriaceae, highly resistant to most β-lactams, represents a growing challenge.

Morbidity and Mortality

ICU mortality rates for patients with VAP range from 20% to 65%, varying by institution and population. Patients with suspected VAP face an increased risk of death, with relative risk estimates between 1.7 and 2.1 according to a 1996 study. However, determining mortality attributable specifically to VAP is challenging, with estimates varying from 0% to over 50%. Using advanced statistical methods, recent research from a multicenter database suggested a relatively modest attributable mortality of approximately 5%.

Short-term outcomes are negatively influenced by factors such as virulence of the causative organism (e.g., P. aeruginosa), host factors (e.g., immunocompromise), severity of organ failure, and inappropriate initial antibiotic therapy. VAP prolongs MV duration and ICU stays by approximately four days and seven to nine days, respectively, per patient.

Conclusion

Ventilator-associated pneumonia (VAP) is a complex and significant challenge in respiratory therapy, particularly in ICU settings. Its multifactorial etiology, influenced by patient-specific risk factors, pathogen characteristics, and therapeutic interventions, underscores the need for an integrative approach to management. Effective strategies for diagnosing VAP, including clinical assessments and bacteriological sampling, must balance the risks of overtreatment with the dangers of delayed therapy. Evidence supports the use of shorter antibiotic courses for selected cases, reducing the risk of adverse effects and antibiotic resistance.

Preventive measures, ranging from universal practices like hand hygiene to advanced interventions like subglottic secretion drainage, form the cornerstone of reducing VAP incidence. The adoption of care bundles integrating evidence-based practices, alongside consistent staff education and rigorous monitoring, has shown the greatest efficacy in lowering VAP rates.

Future advancements, including the potential use of biochemical markers to tailor treatment duration and emerging therapies for multidrug-resistant pathogens, offer hope for improving outcomes. As respiratory therapy continues to evolve, a multidisciplinary, patient-centered approach remains essential for managing VAP and enhancing patient recovery.

References

Bekaert, M., Timsit, J.-F., Vansteelandt, S., Depuydt, P., Vésin, A., Garrouste-Orgeas, M., Decruyenaere, J., Clec'h, C., Azoulay, E., Benoit, D., & Outcomerea Study Group. (2011). Attributable mortality of ventilator-associated pneumonia: A reappraisal using causal analysis. *American Journal of Respiratory and Critical Care Medicine*, *184*(10), 1133–1139. https://doi.org/10.1164/rccm.201105-0867OC

Bonten, M. J., Gaillard, C. A., de Leeuw, P. W., & Stobberingh, E. E. (1997). Role of colonization of the upper intestinal tract in the pathogenesis of ventilator-associated pneumonia. *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America*, *24*(3), 309–319. https://doi.org/10.1093/clinids/24.3.309

Chastre, J., & Fagon, J.-Y. (2002). Ventilator-associated pneumonia. *American Journal of Respiratory and Critical Care Medicine*, *165*(7), 867–903. https://doi.org/10.1164/ajrccm.165.7.2105078

Chastre, J., Trouillet, J.-L., Combes, A., & Luyt, C.-E. (2010). Diagnostic techniques and procedures for establishing the microbial etiology of ventilator-associated pneumonia for clinical trials: The pros for quantitative cultures. *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America*, *51 Suppl 1*, S88-92. https://doi.org/10.1086/653054

Combes, A., Figliolini, C., Trouillet, J.-L., Kassis, N., Wolff, M., Gibert, C., & Chastre, J. (2002). Incidence and outcome of polymicrobial ventilator-associated pneumonia. *Chest*, *121*(5), 1618–1623. https://doi.org/10.1378/chest.121.5.1618

Combes, A., Luyt, C.-E., Trouillet, J.-L., & Chastre, J. (2010). Controversies in ventilator-associated pneumonia. *Seminars in Respiratory and Critical Care Medicine*, *31*(1), 47–54. https://doi.org/10.1055/s-0029-1246288

de Smet, A. M. G. A., Kluytmans, J. a. J. W., Cooper, B. S., Mascini, E. M., Benus, R. F. J., van der Werf, T. S., van der Hoeven, J. G., Pickkers, P., Bogaers-Hofman, D., van der Meer, N. J. M., Bernards, A. T., Kuijper, E. J., Joore, J. C. A., Leverstein-van Hall, M. A., Bindels, A. J. G. H., Jansz, A. R., Wesselink, R. M. J., de Jongh, B. M., Dennesen, P. J. W., … Bonten, M. J. M. (2009). Decontamination of the digestive tract and oropharynx in ICU patients. *The New England Journal of Medicine*, *360*(1), 20–31. https://doi.org/10.1056/NEJMoa0800394

Doré, P., Robert, R., Grollier, G., Rouffineau, J., Lanquetot, H., Charrière, J. M., & Fauchère, J. L. (1996). Incidence of anaerobes in ventilator-associated pneumonia with use of a protected specimen brush. *American Journal of Respiratory and Critical Care Medicine*, *153*(4 Pt 1), 1292–1298. https://doi.org/10.1164/ajrccm.153.4.8616556

Giard, M., Lepape, A., Allaouchiche, B., Guerin, C., Lehot, J.-J., Robert, M.-O., Fournier, G., Jacques, D., Chassard, D., Gueugniaud, P.-Y., Artru, F., Petit, P., Robert, D., Mohammedi, I., Girard, R., Cêtre, J.-C., Nicolle, M.-C., Grando, J., Fabry, J., & Vanhems, P. (2008). Early- and late-onset ventilator-associated pneumonia acquired in the intensive care unit: Comparison of risk factors. *Journal of Critical Care*, *23*(1), 27–33. https://doi.org/10.1016/j.jcrc.2007.08.005

Hortal, J., Giannella, M., Pérez, M. J., Barrio, J. M., Desco, M., Bouza, E., & Muñoz, P. (2009). Incidence and risk factors for ventilator-associated pneumonia after major heart surgery. *Intensive Care Medicine*, *35*(9), 1518–1525. https://doi.org/10.1007/s00134-009-1523-3

Lorente, L., Blot, S., & Rello, J. (2007). Evidence on measures for the prevention of ventilator-associated pneumonia. *The European Respiratory Journal*, *30*(6), 1193–1207. https://doi.org/10.1183/09031936.00048507

Luna, C. M., Aruj, P., Niederman, M. S., Garzón, J., Violi, D., Prignoni, A., Ríos, F., Baquero, S., Gando, S., & Grupo Argentino de Estudio de la Neumonía Asociada al Respirador group. (2006). Appropriateness and delay to initiate therapy in ventilator-associated pneumonia. *The European Respiratory Journal*, *27*(1), 158–164. https://doi.org/10.1183/09031936.06.00049105

Luyt, C.-E., Chastre, J., & Fagon, J.-Y. (2004). Value of the clinical pulmonary infection score for the identification and management of ventilator-associated pneumonia. *Intensive Care Medicine*, *30*(5), 844–852. https://doi.org/10.1007/s00134-003-2125-0

Niederman, M. S. (2005). The clinical diagnosis of ventilator-associated pneumonia. *Respiratory Care*, *50*(6), 788–796; discussion 807-812.

Niël-Weise, B. S., Gastmeier, P., Kola, A., Vonberg, R. P., Wille, J. C., van den Broek, P. J., & Bed Head Elevation Study Group. (2011). An evidence-based recommendation on bed head elevation for mechanically ventilated patients. *Critical Care (London, England)*, *15*(2), R111. https://doi.org/10.1186/cc10135

Pugh, R., Grant, C., Cooke, R. P. D., & Dempsey, G. (2015). Short-course versus prolonged-course antibiotic therapy for hospital-acquired pneumonia in critically ill adults. *The Cochrane Database of Systematic Reviews*, *2015*(8), CD007577. https://doi.org/10.1002/14651858.CD007577.pub3

Rosenthal, V. D., Bijie, H., Maki, D. G., Mehta, Y., Apisarnthanarak, A., Medeiros, E. A., Leblebicioglu, H., Fisher, D., Álvarez-Moreno, C., Khader, I. A., Del Rocío González Martínez, M., Cuellar, L. E., Navoa-Ng, J. A., Abouqal, R., Guanche Garcell, H., Mitrev, Z., Pirez García, M. C., Hamdi, A., Dueñas, L., … INICC members. (2012). International Nosocomial Infection Control Consortium (INICC) report, data summary of 36 countries, for 2004-2009. *American Journal of Infection Control*, *40*(5), 396–407. https://doi.org/10.1016/j.ajic.2011.05.020

Reem Ahmed Albaqshi, Wasayf Ameen Almumtin, Zainab Abbas Al Khamis, Sarah Mohammed Albagshi, Sara Abdulrahman Almukhaizeem, Zainab Taleb Alameer, Fatmh Ahmed Ibraheem Al Ali, Hadeel Sameer Ali Ajizan, Zahra Abdulkarim Alquraini, Fatimah Ahmed Alwayil, Sarah Mansour Albaqshi, Heba Abdullah AlBagshi, Essa Mohammed Abdullah Alsalem, Zainab Abdullah Alqattan, Zainab Yaseen Alnasser.

Safdar, N., Crnich, C. J., & Maki, D. G. (2005). The pathogenesis of ventilator-associated pneumonia: Its relevance to developing effective strategies for prevention. *Respiratory Care*, *50*(6), 725–739; discussion 739-741.

Trouillet, J. L., Chastre, J., Vuagnat, A., Joly-Guillou, M. L., Combaux, D., Dombret, M. C., & Gibert, C. (1998). Ventilator-associated pneumonia caused by potentially drug-resistant bacteria. *American Journal of Respiratory and Critical Care Medicine*, *157*(2), 531–539. https://doi.org/10.1164/ajrccm.157.2.9705064

Trouillet, J.-L., Luyt, C.-E., Guiguet, M., Ouattara, A., Vaissier, E., Makri, R., Nieszkowska, A., Leprince, P., Pavie, A., Chastre, J., & Combes, A. (2011). Early percutaneous tracheotomy versus prolonged intubation of mechanically ventilated patients after cardiac surgery: A randomized trial. *Annals of Internal Medicine*, *154*(6), 373–383. https://doi.org/10.7326/0003-4819-154-6-201103150-00002

Vallés, J., Pobo, A., García-Esquirol, O., Mariscal, D., Real, J., & Fernández, R. (2007). Excess ICU mortality attributable to ventilator-associated pneumonia: The role of early vs late onset. *Intensive Care Medicine*, *33*(8), 1363–1368. https://doi.org/10.1007/s00134-007-0721-0