The effect of different oral hygiene treatments on the occurrence of ventilator associated pneumonia (VAP) in ventilated patients

Journal of Infection Prevention
2015, Vol. 16(2) 76–81
DOI: 10.1177/1757177414560252
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Abstract

Background: We compared the incidence of ventilator associated pneumonia (VAP) among patients treated with comprehensive oral care to those treated with conventional methods of oral care.

Methods: We conducted a prospective, controlled study in an intensive care unit of 90 ventilated patients. Patients in the study group received a comprehensive oral hygiene treatment regimen that involved tooth brushing, suctioning, sodium bicarbonate, rinsing with an antiseptic solution containing 1.5% hydrogen peroxide and a mouth moisturiser. Patients in the control group received a more conventional treatment that included cleaning with a sponge and atraumatic clamp, and rinsing with a 0.2% solution of chlorhexidine gluconate.

Results: Among the 90 patients admitted to the ICU, 8.9% of the study group developed VAP compared with 33.3% of the control group ($p < 0.004$). The development of VAP per 1,000 ventilation days was 10.2 in the study group, and 29.5 in the control group ($p < 0.06$). The mean number of ventilation days and the mean number of hospitalisation days were also lower in the study group.

Conclusions: In patients who are ventilated, a comprehensive oral hygiene treatment regimen that includes tooth brushing, suctioning and rinsing with an antiseptic is more effective in preventing VAP than more conventional protocols.

Keywords

Chlorhexidine gluconate, comprehensive oral hygiene, nosocomial infection, tooth brushing, VAP, ventilator associated pneumonia

Date received: 19 May 2014; accepted: 19 October 2014

Introduction

Ventilator associated pneumonia (VAP) is pneumonia that appears in an intubated patient 48 or more hours from the onset of ventilation or up to one week after ventilation is discontinued (American Thoracic Society and Infectious Diseases Society of America, 2005; Fields, 2008). The signs and symptoms of VAP are similar to those of other pneumonias and include the following:

1. A change in body temperature to above 38 degrees C or below 36 degrees C
2. The appearance of new infiltrate on chest x-ray
3. A white blood cell count of less than 4,000 or greater than 12,000

4. The appearance of or change in phlegm (purulence) (American Thoracic Society and Infectious Diseases Society of America, 2005).

Mouth-related risk factors for VAP include the formation of bacterial colonies in the mouth, the accumulation of pathogenic bacteria on the surface of the teeth,

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development of plaque, and aspiration of secretions from the oral cavity (Rello et al, 2002; Schleder, 2003). Studies have shown that, within 24 hours of admission to an intensive care unit (ICU), patients can become colonised with pathogenic bacteria such as *Pseudomonas*, *Acinetobacter*, and methicillin-resistant *Staphylococcus aureus* (MRSA) (Sole et al, 2002; El-Solh et al, 2004; Garcia et al, 2004; Rello, 2005; Fields, 2008).

Among mechanically ventilated patients, VAP is the most common nosocomial infection (Luyt et al, 2005). The reported incidence of VAP varies because of overlap with other lower respiratory infections, surveillance strategy, case definition, and diagnostic procedures. In its High Impact Intervention guideline, the United Kingdom Department of Health mentions that VAP is the most frequently occurring infection in patients having been admitted to the ICU (Vincent et al, 2006; United Kingdom Department of Health, 2011). This National Health Service (NHS) guideline also says that, in addition to an increased mortality rate associated with VAP (Melson et al, 2009; United Kingdom Department of Health, 2011), this nosocomial pneumonia is associated with increased duration of ventilation, ICU and total hospital length of stay, and healthcare expenses (Safdar et al, 2005; United Kingdom Department of Health, 2011). Preventing this type of infection, therefore, is feasible using cost-effective bundles.

Efforts to describe the global burden of VAP reflect the challenge of gathering reliable data. It is accepted that VAP is associated with prolonged periods of mechanical ventilation, extended hospitalisations, and excessive use of antimicrobial medications (Fischer et al, 2000; Coffin et al, 2008; Edwards et al, 2009; Bekaert et al, 2011; O'Grady et al, 2012). In terms of financial implications, VAP has been shown to cost an additional US\$29,000 to \$40,000 per patient (Rello et al, 2002; Schleder, 2003; Fields, 2008; Restrepo et al, 2010). Moreover, VAP is associated with higher mortality. Although some controversy surrounds the determination of mortality rates attributable to VAP (Edwards et al, 2009; Bekaert et al, 2011; O'Grady et al, 2012), the VAP mortality rate has been reported to be as high as 40% to 80% (Fagon et al, 1993; Porzecanski and Bowton, 2006; Fields, 2008).

The results of recent quality improvement studies show that proper oral care lowers the rate of VAP in acute care facilities (Coffin et al, 2008). Using an oral care protocol reduced the VAP rate from 12 to 8 per 1,000 ventilator days ($p = 0.06$) and also significantly reduced duration of ventilation, length of stay, and mortality (Garcia et al, 2009).

As oral care continues to emerge as an issue that can change the prognosis of critically ill patients, conventional methods of oral hygiene are frequently evaluated for their efficacy in reducing VAP. Evidence has shown that preventing bacterial colonisation of the oropharynx prevents the development of VAP. Several studies have proven that the removal of dental plaque is a key to removing bacteria

from the oropharynx, and the most effective way to remove the plaque is through tooth brushing and suctioning simultaneously. Others have found that tooth brushing removes plaque more effectively than the use of soft swabs or gauze (Pearson and Hutton, 2002; Schleder, 2003; Binkley et al, 2004; El-Sohl et al, 2004; Shinn, 2004; Fields, 2008; Heo et al, 2008).

We conducted a study to examine the effects of an oral hygiene treatment that includes tooth brushing, cleaning of the oral cavity, and rinsing with antiseptic. We wished to compare the incidence of VAP among patients treated with oral care combined with the brushing of teeth to those treated with conventional methods of oral care. We hypothesized that a correlation would be found between the type of oral hygiene treatment administered and the VAP incidence in ventilated patients in the ICU.

Methods

We conducted a prospective, controlled study in the hospital ICU. The ICU is a general intensive care unit that admits patients from all hospital departments, including trauma, surgery, severe infection and internal medicine patients. Our study population included all ventilated patients in the ICU between August 2007 and October 2009. Upon admission to the ICU, patients were alternately allocated to either the study group ($n=45$) or the control group ($n=45$). We excluded from our study patients who were younger than 18 years, patients with a clinical diagnosis of pneumonia at the time of intubation, immunosuppressed patients, pregnant women, and burn patients.

All patients admitted to the general intensive care unit (GICU) were allocated to either the study or control group, aside from those filling the exclusion criteria stated above. Each patient was allocated only on the basis of the time entering the GICU. Patient surveillance was performed by an independent person (infectious disease nurse) who was unaware of the patient allocation group. National Healthcare Safety Network (NHSN) criteria were used to diagnose VAP.

The study was approved by the hospital local ethics committee and written informed consent was signed by each patient or his/her legal guardian.

Data collection

Data collection included the following factors:

- The number of days in the ICU
- The number of days of hospitalisation
- The number of days of ventilation
- The use and type of antibiotics
- Mortality within 30 days of study enrolment
- Development of VAP according to definition (American Thoracic Society and Infectious Diseases Society of America, 2005).

Table 1. Patient characteristics.

	Study group	Control group
Number of patients	45	45
Sex	Male: 25 (55.5%) Female: 20 (44.4%)	Male: 24 (53.3%) Female: 21 (46.6%)
Age (years)	Range: 21–93 68.7 ± 15.6	Range: 27–88 71.8 ± 14.8

There were no statistically significant differences in demographic characteristics between the two groups ($p > 0.34$).

Oral care

The oral care protocol of the study group was implemented three times per day with the use of the Q-Care Suction Oral System from Sage Products LLC (Toothette® Oral Care Suction Toothbrush with Alcohol-Free Mouthwash and Mouth Moisturizer) (Sage Products LLC; Cary, IL). Each patient assigned to this group underwent a daily assessment of the oral cavity (lips, tongue, oral mucosa, gums, and teeth) and sputum. A member of the treatment team completed a structured form, which included details such as body temperature, chest x-ray findings, leucocyte count, Acute Physiology and Chronic Health Evaluation (APACHE) II score, ventilation mode, and culture results. The teeth were then brushed and oral discharge removed with a soft-bristle suction toothbrush, and suction swab. Sodium bicarbonate was used on the suction toothbrush to mechanically clean, refresh, and deodorize the oral cavity. In many ICUs in Europe, regular toothbrushes are often used in conjunction with suctioning through a soft or hard catheter. We find, however, that a small-headed toothbrush that incorporates suctioning offers greater comfort, ease of control, and efficacy. The oral cavity was cleaned with Sage Perox-A-Mint (1.5% hydrogen peroxide) solution. Finally, the oral cavity and lips were moistened with 2 grams of Toothette® Oral Care Mouth Moisturiser, a water-based moisturiser containing vitamin E to promote the healing of lesions.

For the control group, oral care was also carried out three times per day. Each patient in this group underwent assessment of oral cavity and sputum with the use of the same structured form. Oral treatment was then administered using the conventional protocol as follows: Thorough cleaning of the oral cavity with a sponge and atraumatic clamp was completed, followed by spreading throughout the oral cavity of Tarodent, which contains a 0.2% solution of chlorhexidine gluconate.

Antibiotic use

Antibiotics were used to treat both the study group and the control group. The antibiotics were divided into three

groups. The first-line antibiotics included cephalosporins, quinolones, and macrolides. The second-line antibiotics included piperacillin-tazobactam. The third-line antibiotics included vancomycin, carbapenems, and anti-fungal and anti-viral drugs. Combinations of antibiotics were also used.

We use the first-line antibiotics for infections acquired outside of the hospital. The second line is used for hospital-acquired infections or for non-responders to first-line antibiotics. The third line is reserved for hospital-acquired infections or bacteria not sensitive to the first- or second-line antibiotics, or for outbreaks of viral infections, such as influenza.

Patient characteristics

Characteristics of the study population were summarized through descriptive statistics (Table 1). In the study group, 55.5% of the patients were male. The age range was 21 to 93 years; mean age was 68.7 years (SD, 15.6). In the control group, 53.3% of the patients were male. The age range was 27 to 88 years; mean age was 71.8 (SD, 14.8). Demographic characteristics did not differ significantly between the study and control groups ($p > 0.34$).

There were no statistically substantial differences in primary diagnosis between the two groups ($p > 0.65$) (Table 2). The largest differences, however, occurred with regard to patients with cardiovascular disease (22.2% in the study group; 33.3% in the control group ($p = 0.239$)), and patients who had undergone surgery/trauma (33.3% in the study group; 24.4% in the control group ($p = 0.352$)). The mean APACHE II score was 19.1 (SD, 3.2) in the study group, and 18.2 (SD, 3.5) in the control group ($p = 0.73$) (Table 2). Patient baseline characteristics were similar across groups, providing a good baseline for comparison.

The diagnosis of VAP was based upon NHSN criteria. An independent person reviewed the data and decided whether the diagnosis of VAP could be made. This person was unaware of the group allocation of the patient. Statistical analyses were performed by the hospital statistician.

Statistical analysis

The data were analyzed using SAS® 9.2 software. Categorical variables were compared using the chi-square test and Fisher exact test. Comparisons of matched subjects with respect to the number of days of first-, second-, and third-line antibiotic use were performed using the Wilcoxon rank-sum test. A p value < 0.05 was considered statistically significant.

Results

During the study period, among the 90 patients admitted to the ICU, 8.9% of the study group developed VAP compared

Table 2. Primary diagnosis and mean APACHE II score.

	Study group	Control group	p-value
Primary diagnosis*:			
• Cardiovascular disease	22.2%	33.3%	0.239
• Surgery/trauma	33.3%	24.4%	0.352
APACHE II (Mean $\pm$ SD)	19.1 $\pm$ 3.2	18.2 $\pm$ 3.5	0.73

*There were no statistically substantial differences in diagnosis between the two groups ($p > 0.65$).

Table 3. Development of ventilator associated pneumonia (VAP).

	Study group	Control group	p value
Percentage of patients that developed VAP	8.9	33.3	< 0.004
Development of VAP per 1,000 ventilation days	10.2	29.5	< 0.06

with 33.3% of patients in the control group ($p < 0.004$). The development of VAP per 1,000 ventilation days was 10.2 in the study group, and 29.5 in the control group ($p < 0.06$) (Table 3).

Hospital mortality did not differ significantly between the study and control groups (26.7% vs. 28.9%, respectively ($p < 0.46$)). However, patients in the study group spent a mean of 11.09 days in the ICU; those in the control group spent 14.98 days ($p < 0.151$). The mean number of days on a ventilator was 8.39 in the study group vs. 12.69 in the control group ($p < 0.044$). The mean number of days of hospitalisation was 25.38 in the study group, and 31.71 in the control group ($p < 0.02$). The study group patients had a mean of 7.2 treatment days with antibiotics compared with 9.7 in the control group ($p < 0.413$). The study group had a mean of 5.76 treatment days with first-line antibiotics compared with 8.97 in the control group ($p = 0.0267$), 5.58 treatment days with second-line antibiotics compared with 7.42 in the control group ($p = 0.1820$), and 7.93 treatment days with third-line antibiotics compared with 9.92 in the control group ($p = 0.2255$).

Discussion

Dental plaque and other components of the oral cavity serve as perfect breeding grounds for pathogenic bacteria (Garcia et al, 2004; Fields, 2008). In patients who are ventilated, a comprehensive oral hygiene treatment regimen that involves tooth brushing, suctioning, rinsing with an antiseptic, and moisturising is more effective in preventing VAP than more conventional protocols.

Fields (2008) conducted a randomised, controlled trial in a 24-bed ICU with stroke patients randomised to usual VAP prevention measures plus timed tooth brushing vs. the usual VAP prevention measures. This study demonstrated

that a regimen including comprehensive oral care decreased the occurrence of VAP. The VAP rate dropped to zero within one week of beginning the every-eight-hours suction tooth-brushing regimen in the intervention group. The study was amended after six months, dropping the control group, because VAP rates decreased so dramatically. From then on, all intubated patients' teeth were brushed every eight hours, maintaining a zero rate until the study was completed (Fields, 2008).

These and other studies have prompted various government and medical organisations to include comprehensive oral care as part of their guidelines for preventing VAP. The American Association of Critical-Care Nurses (AACN), the Institute for Healthcare Improvement (IHI), the Centers for Disease Control and Prevention (CDC), and the International Nosocomial Infection Control Consortium (INICC) refer to the importance of including daily and comprehensive oral care in controlling pneumonia (Tablan et al, 2004; Al-Tawfiq and Abed, 2010; Lynn-McHale Wiegand, 2011; Rosenthal et al, 2012).

While the overall patient characteristics in our study did not differ significantly, the study group contained proportionately more surgery/trauma patients than the control group (33.3% vs. 24.4%, $p = 0.352$), as well as more infected patients (17.8% vs. 11.1%, $p = 0.368$) and fewer patients with cardiovascular disease (22.2% vs. 33.3%, $p = 0.239$). These patient characteristics demonstrate that the patients were well matched for their primary diagnosis, yet it appears that the study group contained proportionately more high-risk patients. Thus, our results are not confounded by underlying disease state.

The oral care regimen administered to our study group included use of an antiseptic containing 1.5% hydrogen peroxide compared with that of the control group, which contained 0.2% chlorhexidine gluconate. Our intent is not

to press any antiseptic preference. We actually believe that chlorhexidine gluconate is a potent and very effective oral antiseptic and probably our top choice for a VAP prevention protocol as also was endorsed by the British Association of Critical Care Nurses (BACCN), though at lower concentrations such as 0.12% in order to avoid chlorhexidine gluconate potential side effects. Our approach indeed aims to highlight that a good antiseptic needs to be part of an integrated and comprehensive oral care protocol.

Furthermore, the efficacy of any oral antiseptic could be compromised if dental plaque is not consistently removed, underscoring the importance of tooth brushing.

In the United Kingdom, controlling VAP presents a challenge similar to that of other European countries. Data published by the European Centre for Disease Prevention and Control (ECDC) based on National Health Service trusts' reporting show a mean VAP rate of 13.5 per 1,000 ventilator days in ICU patients (European Centre for Disease Prevention and Control, 2011). Additionally, in its latest annual epidemiological report, which was published in December 2013, the ECDC identifies *Klebsiella* spp., MRSA, *Escherichia coli*, and *Enterobacter* spp. as some of the most common pathogens causing ICU-acquired pneumonia in the United Kingdom (European Centre for Disease Prevention and Control, 2013).

To address these issues, the *Critical Care Manual of Clinical Procedures and Competencies*, endorsed by the BACCN and published in 2013, mentions key components that should be included in oral care protocols to prevent pneumonias:

- Tooth brushing (at least twice a day)
- Completely removing toothpaste from the oral cavity to prevent it from drying there
- Using an antiseptic solution (in this manual, 0.12% chlorhexidine gluconate)
- Implementing a small-headed toothbrush that allows for better manoeuvring inside the mouth of the intubated patient (Mallett et al, 2013)

The research performed in our facility sought to address the same types of VAP-related challenges facing British and European acute care facilities, and demonstrated in a statistically successful manner that these components are indeed important elements in any bundle targeting the control of pneumonia-associated pathogens.

We know that hospital costs increase substantially with additional ventilation and hospitalisation days. Acquired pneumonia in ventilated patients contributes to the economic burden because of the need for more ventilation and hospitalisation days. We found a statistically significant reduction in the mean number of ventilation days and in the mean number of hospitalisation days between the study and control groups. Although our study did not show a difference in mortality rates between the study and control groups, a reduction in the factors contributing to economic

burden is enough to justify promotion of an oral hygiene treatment regimen that is comprehensive and proven to reduce VAP rate in ICU patients.

Study limitations

We conducted a prospective, controlled study that was unblinded. Patients were alternately allocated to either the study or control group. The unblinded nature of the study has the potential to introduce bias. Patients received varying antibiotic regimens, which could have affected VAP rates. Finally, providers of oral care could have varying skill in the application of the protocol, introducing the possibility of operator bias.

Recommendations

We propose the following recommendations with regard to oral hygiene treatments in ventilated patients:

1. The continued tracking of the development of VAP in ICU patients
2. Ongoing awareness of VAP prevention through continued education of the team – emphasizing the importance of timely and proper mouth cleaning
3. Inclusion of suction tooth brushing two to three times a day as part of the oral hygiene protocol of the ICU
4. A continuation of the discussion of additional ways to reduce VAP in ventilated patients
5. A standardization of oral hygiene treatment protocols among ICU medical teams
6. Implementation of oral hygiene treatment protocols in other hospital facilities treating ventilated patients.

Acknowledgements

The authors would like to thank Nava Teitler, Infection Control Coordinator, Emek Medical Center, Afula, Israel; and Susan J. Antonini Affinito, for assisting with the writing of this manuscript.

Declaration of conflicting interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Funding

Sage Products LLC provided funding to support the preparation of this manuscript.

Peer review statement

Not commissioned, blind peer-reviewed.

References

- Al-Tawfiq JA and Abed MS (2010) Decreasing ventilator-associated pneumonia in adult intensive care units using the Institute for Healthcare

- Improvement bundle. *American Journal of Infection Control* 38(7): 552–6.
- American Thoracic Society, Infectious Diseases Society of America (2005) Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. *American Journal of Respiratory Critical Care Medicine* 171(4): 388–416.
- Bekaert M, Timsit JF, Vansteelandt S, Depuydt P, Vesin A, Garrouste-Orgeas M, Decruyenaere J, Clec'h C, Azoulay E and Benoit D (2011) Attributable mortality of ventilator-associated pneumonia: a reappraisal using causal analysis. *American Journal of Respiratory Critical Care Medicine* 184(10): 1133–9.
- Binkley C, Furr LA, Carrico R and McCurren C (2004) Survey of oral care practices in US intensive care units. *American Journal of Infection Control* 32(3): 161–9.
- Coffin SE, Klompas M, Classen D, Arias KM, Podgorny K, Anderson DJ, Burstin H, Calfee DP, Dubberke ER, Fraser V, Gerding DN, Griffin FA, Gross P, Kaye KS, Lo E, Marschall J, Mermel LA, Nicolle L, Pegues DA, Perl TM, Saint S, Salgado CD, Weinstein RA, Wise R, Yokoe DS. (2008) Strategies to prevent ventilator-associated pneumonia in acute care hospitals. *Infection Control and Hospital Epidemiology* 29(Suppl 1): S31–40.
- Edwards JR, Peterson KD, Andrus ML, Tolson JS, Goulding JS, Dudeck MA, Mincey RB, Pollock DA and Horan TC (2007) National Healthcare Safety Network (NHSN) report, data summary for 2006, issued June 2007. *American Journal of Infection Control* 35(5): 290–301.
- Edwards JR, Peterson KD, Mu Y, Banerjee S, Allen-Bridson K, Dudeck MA, Pollock DA and Horan TC. (2009) National Healthcare Safety Network (NHSN) report: data summary for 2006 through 2008, issued December 2009. *American Journal of Infection Control* 37(10): 783–805.
- El-Solh AA, Pietrantoni C, Bhat A, Okada M, Zambon J, Aquilina A and Berbary E. (2004) Colonization of dental plaques: a reservoir of respiratory pathogens for hospital-acquired pneumonia in institutionalized elders. *Chest* 126(5): 1575–82.
- European Centre for Disease Prevention and Control (2011) *Annual Epidemiological Report on Communicable Diseases in Europe, 2011*. www.ecdc.europa.eu/en/publications/Publications/1111_SUR_Annual_Epidemiological_Report_on_Communicable_Diseases_in_Europe.pdf (accessed 19 March 2014).
- European Centre for Disease Prevention and Control (2013) *Annual Epidemiological Report 2013*. <http://www.ecdc.europa.eu/en/publications/Publications/annual-epidemiological-report-2013.pdf> (accessed 19 March 2014).
- Fagon JY, Chastre J, Hance AJ, Montravers P, Novara A and Gibert C. (1993) Nosocomial pneumonia in ventilated patients: a cohort study evaluating attributable mortality and hospital stay. *The American Journal of Medicine* 94(3): 281–8.
- Fields LB (2008) Oral care intervention to reduce incidence of ventilator-associated pneumonia in the neurologic intensive care unit. *Journal of Neuroscience Nursing* 40(5): 291–8.
- Fischer JE, Allen P and Fanconi S (2000) Delay of extubation in neonates and children after cardiac surgery: impact of ventilator-associated pneumonia. *Intensive Care Medicine* 26(7): 942–9.
- Garcia R, Jendresky L and Colbert L (2004) Reduction of microbial colonization in the oropharynx and dental plaque reduces ventilator-associated pneumonia. *American Journal of Infection Control* 32(3): E101–2.
- Garcia R, Jendresky L, Colbert L, Bailey A, Zaman M and Majumder M (2009) Reducing ventilator-associated pneumonia through advanced oral-dental care: a 48-month study. *American Journal of Critical Care* 18(6): 523–32.
- Heo S, Haase E, Lesse A, Gill S and Scannapieco F (2008) Genetic relationships between respiratory pathogens isolated from dental plaque and bronchoalveolar lavage fluid from patients in the intensive care unit undergoing mechanical ventilation. *Clinical Infectious Diseases* 47(12): 1562–70.
- Luyt CE, Guerin V, Combes A, Trouillet J-L, Ayed SB, Bernard M, Gilbert C and Chastre J (2005) Procalcitonin kinetics as a prognostic marker of ventilator-associated pneumonia. *American Journal of Respiratory and Critical Care Medicine* 171(1): 48–53.
- Lynn-McHale Wiegand DJ (ed.) (2011) Endotracheal tube and oral care. In: *American Association of Critical-Care Nurses Procedure Manual for Critical Care*. 6th ed. Elsevier Saunders: Philadelphia: 33–5.
- Mallett J, Albarran JW and Richardson A (eds) (2013) *Critical Care Manual of Clinical Procedures and Competencies*. Wiley Blackwell: Oxford.
- Melson WG, Rovers MM and Bonten MJM (2009) Ventilator-associated pneumonia and mortality: a systematic review of observational studies. *Critical Care Medicine* 37(10): 2709–18.
- O'Grady NP, Murray PR and Ames N (2012) Preventing ventilator-associated pneumonia: does the evidence support the practice? *Journal of the American Medical Association* 307(23): 2534–9.
- Pearson LS and Hutton JL (2002) A controlled trial to compare the ability of foam swabs and toothbrushes to remove dental plaque. *Journal of Advanced Nursing* 39(5): 480–9.
- Porzecanski I and Bowton DL (2006) Diagnosis and treatment of ventilator-associated pneumonia. *Chest* 130(2): 597–604.
- Rello J (2005) Bench-to-bedside review: therapeutic options and issues in the management of ventilator-associated bacterial pneumonia. *Critical Care* 9(3): 259–65.
- Rello J, Ollendorf DA, Oster G, Vera-Llonch M, Bellm L, Redman R and Kollef MH (2002) Epidemiology and outcomes of ventilator-associated pneumonia in a large US database. *Chest* 122(6): 2115–21.
- Restrepo MI, Anzueto A, Arroliga AC, Afessa B, Atkinson MJ, Ho NJ, Schinner R, Bracken R and Kollef M. (2010) Economic burden of ventilator-associated pneumonia based on total resource utilization. *Infection Control and Hospital Epidemiology* 31(5): 509–15.
- Rosenthal VD, Rodrigues C, Alvarez-Moreno C, Madani N, Mitrev Z, Ye G, Salomao R, Ulger F, Guanche-Garcell H, Kanj SS, Cuellar LE, Higuera F, Mapp T, Fernandez-Hidalgo R, and INICC members (2012) Effectiveness of a multidimensional approach for prevention of ventilator-associated pneumonia in adult intensive care units from 14 developing countries of four continents: findings of the International Nosocomial Infection Control Consortium. *Critical Care Medicine* 40(12): 3121–8.
- Safdar N, Dezfulian C, Collard HR and Saint S (2005) Clinical and economic consequences of ventilator-associated pneumonia: a systematic review. *Critical Care Medicine* 33(10): 2184–93.
- Sage Products LLC; Q-Care and Toothette are registered trademarks of Sage Products LLC, Cary, IL.
- Schleder BJ (2003) Taking charge of ventilator-associated pneumonia. *Nursing Management* 34(8): 27–32.
- Shinn JA (2004) Decreasing the risk of ventilator-associated pneumonia: the impact of nursing care. *Progress in Cardiovascular Nursing* 19(3): 85–6.
- Sole ML, Poalillo FE, Byers JF and Ludy JE. (2002) Bacterial growth in secretions and on suctioning equipment of orally intubated patients: a pilot study. *American Journal of Critical Care* 11(2): 141–9.
- Tablan OC, Anderson LJ, Besser R, Bridges C and Hajjeh R, CDC, Healthcare Infection Control Practices Advisory Committee. (2004) Guidelines for preventing health-care-associated pneumonia, 2003: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee. *Morbidity and Mortality Weekly Report Recommendations and Reports* 53(RR-3): 1–36.
- United Kingdom Department of Health (2011) High impact intervention care bundle to reduce ventilation-associated pneumonia. <http://webarchive.nationalarchives.gov.uk/20120118164404/http://hcai.dh.gov.uk/files/2011/03/2011-03-14-HII-Ventilator-Associated-Pneumonia-FINAL.pdf> (accessed 19 March 2014).
- Vincent JL, Sakr Y, Sprung CL, Ranieri VM, Reinhart K, Gerlach H, Moreno R, Carlet J, Le Gall JR and Payden D, Sepsis Occurrence in Acutely Ill Patients Investigators (2006) Sepsis in European intensive care units: results of the SOAP study. *Critical Care Medicine* 34(2): 344–53.