

A Strategy for the Control of
Antimicrobial Resistance in Ireland

SARI



**Guidelines for the prevention of
ventilator-associated pneumonia
in adults in Ireland**

SARI Working Group

Health Protection Surveillance Centre
February 2011

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Foreword

The Strategy for the Control of Antimicrobial Resistance in Ireland (SARI) national committee established a working group to produce national guidelines on the prevention of ventilator-associated pneumonia. Nominations were invited from relevant professional bodies. Membership of the working group is listed in Appendix 1. The committee first met in January 2009 and agreed terms of reference. A draft document was sent for consultation in June 2010 to a range of professional groups (Appendix 2).

Several international evidence-based guidelines for prevention of nosocomial pneumonia have been published (BTS, ATS, Canadian, IDSA/SHEA). The terms of reference of the working group were to review these existing guidelines, update where new evidence was available and produce a single guideline for prevention of VAP in adults for use by Irish healthcare professionals working primarily in the acute care sector. However, most of the recommendations for prevention of VAP are applicable to mechanically ventilated patients based in the community.

This document represents the expert opinion of the working group following a literature review and consultative process. It should be acknowledged that no attempt was made to grade the quality of the evidence that was used to develop these recommendations.

This document is aimed at healthcare professionals and we would encourage the engagement of local expertise in the application of these guidelines. While we accept that some aspects of the recommendations may be difficult to implement initially due to a lack of resources or insufficient personnel, we believe that these guidelines summarise best available evidence.

Where there are difficulties with implementation of the guidelines, these should be highlighted locally and to the Health Services Executive (HSE) and the Department of Health and Children (DoHC) so that measures are taken by the HSE and the DoHC to ensure implementation, including the provision of appropriate resources and personnel.

The working group recommends that these guidelines are reviewed and updated in 3-5 years.

Recommendations

A. General measures

1. Education

- All acute hospitals should have a programme of ongoing education in infection prevention and control for all clinical staff caring for patients undergoing mechanical ventilation. This should include information on local epidemiology in addition to evidence-based strategies to prevent ventilator-associated pneumonia (VAP).
- Mandatory induction training for all clinical staff should incorporate training in infection prevention and control, including hand hygiene and the appropriate use of personal protective equipment.

2. Clinical guidelines and care protocols

- Clinical guidelines and care protocols for prevention of VAP should be developed and implemented in the critical care setting.
- Adherence to the guidelines and protocols should be monitored regularly to ensure compliance and to address any deficits identified.

3. Infection prevention and control practice

- Implementation of standard precautions should be the primary strategy for the prevention of transmission of infectious agents among patients and healthcare workers.
- Hand hygiene, in accordance with national hand hygiene guidelines, should be part of the routine clinical care of mechanically ventilated patients. Hands should be decontaminated appropriately with soap and water or alcohol hand rub before and after every episode of direct patient contact, after any activity that potentially results in hands becoming contaminated and after removal of gloves.
- Adherence to hand hygiene should be monitored regularly to ensure compliance and results regularly fed back to healthcare staff.
- Personal protective equipment (e.g., gloves, aprons, face masks, goggles) should be worn appropriately and disposed of correctly in the appropriate healthcare waste stream.
- Transmission-based precautions (contact, droplet and airborne) should be used in addition to standard precautions when caring for patients who are known or suspected to be colonised or infected with organisms which can be transmitted via direct or indirect contact, or by droplet and airborne routes.
- The critical care environment should be cleaned regularly to reduce the possibility of transmission of organisms from the environment to the patient. Increased frequency of cleaning should be implemented in the event of an outbreak of infection where environmental contamination may contribute to the spread of infection.
- All hospitals should have in place *Legionella* control strategies, in accordance with national guidance.

4. Critical care environment

- Single patient rooms in newly-built or renovated critical care areas should have a minimum floor area of 26m² (not including ensuite sanitary facilities, if present). The design of new critical care units should take account of UK Health Building Note (HBN) 57 or equivalent international guidance documents.
- At least one airborne isolation room should be provided in newly-built critical care areas. The design of airborne isolation rooms should take account of UK Health Building Note (HBN) 4 Supplement 1 or equivalent international guidance documents.
- There should be a minimum of one clinical hand wash sink per 1-3 beds in open plan critical care areas and all single rooms should have a clinical hand wash sink close to the exit. Clinical hand wash sinks should be designed in accordance with UK Health Technical Memorandum (HTM) 64.
- Alcohol handrub should be available at each bed space in critical care areas.
- Aspergillus control measures should be implemented in association with construction or renovation activities, in accordance with national guidance.

5. Staffing

- Adequate levels of suitably qualified nursing and medical staff should be provided in critical care areas.

6. Intubation

- Orotracheal intubation should be performed in preference to nasotracheal intubation, whenever possible.
- Avoid unplanned tracheal extubation and subsequent reintubation, whenever possible.

7. Positive pressure ventilation

- Non-invasive ventilation should be used, whenever possible.
- Mechanical ventilation should not be continued unnecessarily.
- Evidence based weaning protocols which incorporate daily assessment of readiness to wean and daily interruptions of sedation, as appropriate, should be in place.

8. Pharmacological strategies

- A restrictive red cell transfusion policy should be used in mechanically ventilated patients.
- No recommendation is made regarding the use of probiotics for prevention of VAP.

B Prevention of aspiration

- An appropriately inflated cuffed endotracheal or tracheostomy tube should be used in patients who require mechanical ventilation and are at high risk of aspiration.
- The cuff inflation pressure should be adjusted until there is no audible air leak while using normal inspiratory airway pressures. An endotracheal cuff pressure of at least 20cm H₂O should be maintained.
- In patients with a tracheostomy requiring prolonged ventilatory support, cuff deflation should be considered when the patient is alert, has normal swallowing and is tolerating trials of spontaneous breathing.
- Aspiration of subglottic secretions should be considered in patients who are expected to be mechanically ventilated for more than 48 hours.
- Mechanically ventilated patients should be nursed in the semi-recumbent position (elevation of the head of the bed to 30-45°), unless contraindicated.
- The use of rotating beds may be considered in mechanically ventilated patients who cannot tolerate the semi-recumbent position.
- Gastric distension should be avoided in mechanically ventilated patients who are being fed enterally.

C. Prevention of contamination of equipment

- Items designated for 'single-use' must never be reused.
- All equipment involved in patient care should be cleaned, decontaminated and stored in accordance with local hospital policy and the manufacturer's instructions.
- Sterile water should be used to rinse reusable non invasive respiratory equipment.
- Nebulisers and resuscitation equipment should be single patient use only.
- Healthcare workers should use facial protection when disconnecting closed breathing circuits.
- The ventilator circuit should be changed only if soiled or damaged; scheduled changes of the circuit are not recommended. New ventilator circuit tubing should be provided for each patient.
- Condensate accumulating within the ventilator circuit may be contaminated and should be drained and disposed of carefully. The circuit should be managed so that condensate does not drain towards the patient.
- Humidifier systems (heated humidifier or heat-moisture exchangers) should be changed as clinically indicated and in accordance with the manufacturer's guidance. A new humidifier system should be provided for each patient. Aseptic technique must be used when filling the humidifier. Water used

for humidification must be sterile or distilled. No recommendation is made for the type of humidifier equipment used.

- The type of endotracheal suctioning system has no effect on the incidence of VAP. The use of closed systems is recommended in patients with copious tracheal secretions, and those suspected or known to be infected with organisms that are transmitted via the airborne route.
- Endotracheal suctioning systems should be changed only if soiled or damaged; scheduled changes of the system are not recommended. A new suctioning system should be provided for each patient.

D. Prevention of colonisation of the aerodigestive tract

- Histamine (2) receptor antagonists or proton pump inhibitors should be used in mechanically ventilated patients at high risk of developing upper gastrointestinal bleeding. Sucralfate may be considered in patients at low to moderate risk of bleeding.
- Regular oral hygiene should be carried out in all mechanically ventilated patients. A soft toothbrush should be used to clean the oral mucosa at least 12-hourly, except where contraindicated (e.g., increased risk of bleeding, thrombocytopenia).
- The topical application of chlorhexidine gluconate (0.12%- 2%) should be considered in such an oral care programme. Povidone-iodine (10%) may be considered for use in patients with severe head injury.
- No recommendation is made for selective decontamination of the digestive tract.

E. Implementation of VAP care bundle

- A VAP care bundle should be implemented in all critical care areas caring for mechanically ventilated patients. An example of a VAP care bundle is provided in Appendix 3.
- Compliance with the care bundle should be regularly audited and fed back to critical care staff (see Appendix 5).

F. Surveillance of ventilator-associated pneumonia

- Surveillance of VAP should be carried out in all critical care units caring for mechanically ventilated patients.
- Healthcare managers must support surveillance activities, including VAP surveillance.
- A local multidisciplinary steering committee should be established with relevant representatives including intensivists, ICU nursing, ICU audit, microbiology, infectious diseases, infection prevention and control, surveillance staff and healthcare facility management. This committee should lead the surveillance project, encourage compliance, circulate the results of surveillance data and monitor the effectiveness of preventative programmes.
- Where critical care information systems are in place, they should be used as much as is possible to collect VAP surveillance data.
- VAP rates should be fed back to the ICU staff and healthcare facility management on a regular basis; ideally monthly, but at least quarterly.
- VAP protocols and case definitions should be standardised and adhere to other international frameworks to allow comparative analysis of VAP incidence rates. To enable European comparisons of VAP surveillance data, HELICS case definitions and protocols (ideally Level 2) are recommended. A suggested VAP surveillance dataset is provided in Appendix 7 and a sample VAP surveillance form in Appendix 8.
- VAP rates for each unit should be expressed as the number of VAP per 1000 ventilator days.

G. Implementation of recommendations

- Prevention of healthcare-associated infection, including VAP, should be prioritised by the Department of Health and Children, the Health Service Executive and all healthcare staff.
- Ring-fenced funding may be required to assist healthcare facilities to implement these recommendations, in particular to fill gaps in surveillance infrastructure (e.g., IT personnel, surveillance coordinators and administrative support).

- The following infrastructural requirements are recommended for the prevention of VAP: -
 - Adequate levels of suitably qualified nursing and medical staff in all critical care areas caring for mechanically ventilated patients
 - An infection prevention and control programme adequately staffed and resourced to provide appropriate education and training, assist with the implementation of measures to prevent VAP, coordinate surveillance of VAP and conduct appropriate audit
 - Information technology capable of collecting and calculating mechanical ventilator days as a denominator for VAP rates
 - Adequate laboratory support for timely processing of specimens and reporting of results

Background

1. Ventilator-associated pneumonia

Ventilator-associated pneumonia (VAP) is the most common nosocomial infection in intensive care units.¹ A systematic review found that VAP occurs in 10-20% of all patients mechanically ventilated for more than 48 hours.² Crude mortality rates in patients with VAP range from 24-50%, increasing to 76% if infection is caused by multi-resistant organisms.³ Patients who develop VAP are twice as likely to die as those without VAP.² VAP is also associated with prolonged length of ICU stay^{4,5} and increased healthcare costs.^{2,6} Therefore, prevention of VAP is desirable to improve patient outcomes and to improve healthcare efficiency.

Several evidence-based guidelines for the prevention of VAP have been published in recent years.⁷⁻¹⁰

2. General preventative measures

The systematic application of educational interventions has been shown to decrease rates of healthcare-associated infection (HCAI).¹¹ Staff education programmes specifically addressing VAP have significantly reduced the incidence of VAP.^{12,13}

Implementation of optimal infection prevention and control practices is crucial in the prevention of HCAI. Improved compliance with hand hygiene is associated with a reduction in rates of HCAI.¹⁴ Although there is little good quality evidence upon which to base guidance related to the maintenance of environmental hygiene, a body of clinical evidence suggests an association between poor environmental hygiene and the transmission of organisms that cause HCAI.¹⁵ As VAP may result from exogenous nosocomial colonisation with organisms present in the environment, attention to high standards of environmental decontamination will reduce the potential for transmission of infection.¹⁶

Outbreaks of VAP due to *Legionella pneumophila* that are linked to aspiration of contaminated water have been described;¹⁷ therefore, *Legionella* control strategies in line with national guidance should be in place in all hospitals.¹⁸

The environment in which healthcare is delivered can influence the risk of transmission of HCAI. Design factors that can prevent transmission of infection include the provision of adequate space around beds, minimising the number of multiple-bedded ward areas and increasing the proportion of single rooms. Irish national guidelines advocate that single patient rooms in critical care areas should have a minimum floor area of 26m² and that at least one airborne isolation room be provided in each newly built critical care unit.¹⁹ Design of critical care areas should take account of UK Health Building Note 57, or equivalent international guidance. Critical care areas should have a minimum of one clinical hand wash sink per 1-3 beds and alcohol handrub should be available at every bed space.²⁰

Outbreaks of nosocomial aspergillosis have occurred in intensive care units during hospital construction or renovation activity.^{21, 22} Ventilated patients are at increased risk of developing invasive aspergillosis and appropriate protective precautions should be instituted during any construction or renovation activity.²³

Studies have demonstrated that reduced levels of nurse staffing are associated with higher rates of HCAI.²⁴ In critical care settings, maintenance of a higher nurse to patient ratio was associated with a reduction in incidence of HCAI²⁵ and with a decreased risk of late-onset VAP.²⁶ A systematic review of physician staffing in intensive care units found that high-intensity staffing was associated with reduced hospital and ICU mortality and shorter lengths of stay.²⁷

A Cochrane review of the use of non-invasive ventilation (NIV) in patients with chronic obstructive airways disease (COAD) concluded that NIV was a beneficial first-line intervention in this patient group and was associated with a reduction in the need for intubation.²⁸ A systematic review of the use of NIV during weaning from invasive ventilation was associated with a reduction in mortality and in VAP in COPD patients. Further research is warranted to assess the net clinical benefits, particularly the impact of re-intubation after failed extubation.²⁹

A randomised trial comparing orotracheal and nasotracheal intubation found a trend towards a reduction in VAP using the orotracheal route.³⁰ Subsequent studies demonstrated a higher incidence of sinusitis in patients who had been intubated via the nasotracheal route and that the incidence of VAP was lower in patients who did not develop sinusitis.³¹⁻³⁴

Re-intubation is associated with an increased risk of VAP;³⁵ therefore, unplanned extubation should be avoided where possible.

The use of weaning protocols and the regular assessment of sedation requirements are effective in reducing the duration of mechanical ventilation and the incidence of VAP.³⁶⁻³⁹

A lower mortality rate was demonstrated in critical care patients randomised to a restrictive red cell transfusion policy compared to those receiving liberal transfusions.⁴⁰ Transfusion of blood products is associated with an increased incidence of VAP,^{41,42} so unnecessary transfusion of packed red blood cells should be avoided.

A meta-analysis of five randomised control trials investigating the role of probiotics in the prevention of VAP concluded that administration of probiotics to mechanically ventilated patients was associated with a lower incidence of VAP. However, no significant reduction in all-cause mortality or duration of mechanical ventilation was demonstrated in the patients receiving probiotics compared to controls.⁴³ Further investigation is required in this area before a recommendation can be made.

3. Prevention of aspiration

Aspiration of oropharyngeal secretions into the bronchial tree is a major factor in the development of VAP;¹⁷ therefore, strategies to prevent aspiration are important in the prevention of VAP.

Semi-recumbent positioning of the patient has been shown to be associated with less aspiration into the lower airway^{44, 45} and a lower incidence of VAP than supine positioning.⁴⁶ A subsequent randomised study in which no treatment effect was observed found that the targeted semi-recumbent position of 45° was not achieved consistently.⁴⁷

The pressure of the endotracheal tube cuff should be sufficiently high to minimise the leakage of bacterial pathogens around the cuff into the lower respiratory tract. Failure to maintain an adequate cuff pressure (i.e., greater than 20cm H₂O) was found to be an independent risk factor for the development of VAP.⁴⁸

Mechanically ventilated patients receiving enteral feeding may have substantial gastric volume, which can predispose them to gastroesophageal reflux, aspiration and VAP. The rate and volume of enteral feeding should be adjusted to avoid gastric distension and so reduce the risk of aspiration.⁷

Oropharyngeal secretions can accumulate above the endotracheal cuff and contribute to the risk of aspiration. A meta-analysis found that establishing subglottic drainage of oropharyngeal secretions using a specialised endotracheal tube was effective in reducing early-onset VAP in patients expected to be ventilated for more than 72 hours.⁴⁹

Prolonged immobilisation in mechanically ventilated patients may lead to atelectasis and impaired clearance of bronchopulmonary secretions, thereby potentially increasing the risk for VAP. Rotational therapy involves continuous rotational movement of the patient on specialised beds to improve the drainage of respiratory secretions. Specific designs include kinetic therapy and continuous lateral rotation therapy. Three meta-analyses found that rotational therapy reduced the incidence of VAP, but had no effect on duration of mechanical ventilation or mortality. From the studies reviewed, it was unclear which patients would be most suited to this therapy.⁵⁰⁻⁵² A subsequent randomised study of rotational therapy in medical intensive care patients in one hospital showed a significant reduction in VAP, duration of mechanical ventilation and length of hospital stay, but no mortality benefit.⁵³ Rotational therapy may be considered in patients at high risk of VAP, but feasibility, safety and cost concerns may be a barrier to implementation.

4. Prevention of contamination of equipment

A systematic review found that changing the ventilator circuit every 24 hours did not reduce the risk of VAP. Circuits were changed if they were soiled or damaged.⁵⁴ The maximum length of time between ventilator tubing changes has not been established.

Three systematic reviews comparing open and closed endotracheal suctioning systems found no difference in the incidence of VAP.⁵⁵⁻⁵⁷ Although there is no evidence to support the use of closed suctioning for the prevention of VAP, it may be of value in reducing the exposure of healthcare workers to aerosolised respiratory secretions.⁷ A systematic review found that daily changes of suctioning equipment had no effect on the incidence of VAP compared to less frequent changes.⁵⁴

Two recent meta-analyses comparing heated humidifiers with heat and moisture exchangers found that the method of humidification used had no impact on the incidence of VAP.^{58, 59} There is no evidence to support the routine changing of humidifier systems.⁷

Outbreaks of nosocomial pneumonia due to contaminated respiratory devices, including nebulisers, have been reported.¹⁷ All reusable patient care equipment should be appropriately decontaminated between each patient use to prevent cross-infection. Nebulisers should be single patient use and should be disinfected and rinsed with sterile water between each use.⁷ Items designated for "single use" must never be reused.

Condensate collecting in the ventilator circuit can become contaminated from patient secretions and may potentially increase the risk of VAP so care should be taken that condensate does not drain towards the patient.⁶⁰

5. Prevention of colonisation of the aerodigestive tract

Gastric colonisation by potentially pathogenic organisms increases with lower gastric acidity.⁶¹ Medications that alter the gastric pH may increase the number of organisms present and so increase the risk for VAP. Stress ulcer prophylaxis with any agent is associated with an increased risk of VAP.⁶²

A systematic review that considered seven meta-analyses found that four of these reported a significantly decreased incidence of VAP with sucralfate compared with histamine (2) receptor antagonists, and that the other three found similar, but non-significant, trends in reduction of rates of VAP in patients treated with sucralfate.⁶³ However, sucralfate is associated with a significantly higher risk of clinically important gastrointestinal bleeding in mechanically ventilated patients compared with histamine (2) receptor antagonists.⁶⁴

Few studies have addressed the risk of VAP associated with proton pump inhibitors; one small randomised trial found a significantly higher risk of clinically important gastrointestinal bleeding with ranitidine compared to omeprazole, and no significant difference in the incidence of VAP.⁶⁵

Poor oral hygiene in mechanically ventilated patients can lead to bacterial colonisation of the oropharynx. There is a strong correlation between the bacteria colonising the oropharynx and those causing VAP.⁶⁶ Provision of a single oral care procedure was shown to reduce the numbers of potentially pathogenic bacteria in the oral cavity.⁶⁷ The use of toothbrushes has been found to be superior in plaque removal compared to the use of sponge sticks.⁶⁸ Delivery of oral care (tooth brushing and povidone-iodine solution) to mechanically ventilated patients was associated with a significant decrease in the incidence of VAP when compared to patients who received no oral care.⁶⁷

The use of topical chlorhexidine to prevent VAP has been studied. Two meta-analyses have been reported. The first found the topical application of chlorhexidine to be beneficial in preventing VAP, with the most marked benefit being seen in cardiac surgery patients, who comprised more than half of all patients studied.⁶⁹ The second concluded that topical chlorhexidine was associated with a significant reduction of early-onset VAP.⁷⁰ The most effective concentration has not yet been determined.

A single controlled trial demonstrated a decrease in VAP in patients with severe head injury who had oral hygiene carried out with 10% povidone-iodine.⁷¹ No effect on rates of VAP was found when topical iseganan was used.⁷²

Modulation of oropharyngeal colonisation by selective digestive decontamination (SDD) using a combination of topical application of oral antibiotics along with systemic administration of antibiotics has been studied. Eight meta-analyses have reported a significant reduction in the risk of VAP with the use of SDD, with five also reporting a significant reduction in mortality.⁷³⁻⁸⁰ However, a review which evaluated the influence of methodological quality on the effectiveness of SDD found an inverse relationship between methodological quality and the benefit of SDD on the incidence of pneumonia,⁸¹ which raises questions about the validity of the meta-analyses.

A small number of studies have addressed the development of antimicrobial resistance and have generally shown no increase in resistant organisms using SDD over a short interval of follow up in units with low baseline bacterial resistance. In longer follow up and where there are higher rates of MRSA or VRE, SDD has been associated with increased resistance, particularly in Gram-positive organisms.^{82, 83}

A recent trial showed that both SDD and selective oral decontamination (SOD), which consists of oropharyngeal application of antimicrobials, reduced mortality in intensive care patients compared to standard treatment.⁸⁴ This result suggests that SOD may be comparable to SDD and would be preferable in view of cost and potential antibiotic resistance. The investigators also studied the effect of SDD and SOD on the bacterial ecology of the participating units. All patients were included, regardless of whether or not they had received the decontamination regimens. The prevalence of resistant organisms was significantly higher after periods of SDD and SOD.⁸⁵ Therefore, no recommendation is made regarding the use of selective decontamination in prevention of VAP in Ireland.

6. Implementation of VAP care bundle

A care bundle is a collection of interventions (usually three to five) that are applied to the management of a particular condition. All the individual elements of a bundle are evidence-based practices, which benefit patient care; however, when applied together they result in significantly better outcomes than when implemented individually. In routine clinical practice, individual elements of a care bundle may not always all be done in the same way, leading to variation in the delivery of patient care. The aim of the care bundle is to tie them together into a cohesive unit that should be performed for every patient. All the tasks are necessary and must all occur in a specified period and place. Compliance with the bundle should be audited regularly (see Appendix 5).

The systematic implementation of VAP care bundles in the intensive care unit has been shown to reduce the incidence of VAP.^{86, 87}

A suggested VAP care bundle, and sample exclusions are outlined in Appendices 3 and 4.

7. Surveillance of VAP

Surveillance of healthcare-associated infection (HCAI) is a key requirement of SARI and of the European Commission decision 2119/98/. Without surveillance, the true burden of HCAI is unknown. Development of a high quality surveillance system is essential to monitor HCAI, including VAP, and to identify areas for improvement, thereby optimising the quality and safety of patient care.

The definition of VAP is often subjective; even where common definitions are employed, significant inter-observer variability has been noted.^{88, 89} Differences in surveillance strategy, diagnostic techniques, and microbiology laboratory procedures may account for some of the differences in VAP rates between different institutions.

Nevertheless, for comparative analysis of VAP incidence rates, VAP protocols and case definitions must be standardised and adhere to other international frameworks. A number of internationally comparable protocols exist including CDC and HELICS. HELICS VAP surveillance is used in many European

countries. The HELICS case definition of pneumonia incorporates a combination of radiological, clinical and laboratory criteria and five categories of pneumonia are defined according to the type of positive microbiology available (see Appendix 6). There are two levels of surveillance within the HELICS ICU surveillance system:

- **Level 1** is a unit-based surveillance system. The denominator is collected at the level of the unit and consists of the number of patient days for patients staying longer than 2 days in the ICU. Indicators issued by level 1 are suited for the follow-up of trends for pathogen-specific infection rates within the same unit and at the regional, national and international level. They offer limited inter-unit comparability due to the lack of risk stratification data.
- **Level 2** is a patient-based surveillance system. This is intended for advanced risk-adjusted comparison of infection rates between ICUs (benchmarking), as a measure of quality of care in terms of infection control. Risk factors are collected for every patient staying more than 2 days in the ICU, whether infected or not.

While Level 2 surveillance permits risk-adjusted rates for comparison of infection rates between ICUs, it is resource intensive. Level 1 surveillance is less resource intensive and allows collection of ICU-acquired pathogen-specific incidence rates over time. Many critical care units collect data locally that could be used to support VAP surveillance, although this is usually collected for different purposes. Adjustments may be necessary to accommodate HCAI surveillance. It is recommended that current critical care information systems should be used as much as is possible to collect VAP surveillance data. To enable European comparisons of VAP surveillance data, it is recommended that the HELICS case definitions and protocols (ideally Level 2) are used for surveillance of VAP in Ireland. A suggested VAP surveillance dataset is provided in Appendix 7 and a sample VAP surveillance form in Appendix 8.

Appendix 1: Membership of working group

Dr. Karen Burns

(Irish Society of Clinical Microbiologists)

Dr. Edmund Carton

(Intensive Care Society of Ireland)

Dr. Susan FitzGerald (Chair)

(Irish Society of Clinical Microbiologists)

Dr. Fidelma Fitzpatrick

(Health Protection Surveillance Centre)

Ms. Cathryn Lee

(Irish Association of Critical Care Nurses)

Dr. Anthony O'Regan

(Irish Thoracic Society)

Mr. Brendan O'Reilly

(Surveillance Scientists Association)

Mr. John Walsh

(Infection Prevention Society)

Appendix 2: Consultation process

The draft document was placed on the HSE and HPSC websites for general consultation in June 2010. The document was also sent to the following groups for consultation:

College of Anaesthetists of Ireland
National Director of Quality and Clinical Care, HSE
HSE HCAI Governance Group
Infectious Diseases Society of Ireland
Infection Prevention Society
Intensive Care Society of Ireland
Irish Antimicrobial Pharmacists Group
Irish Association of Critical Care Nurses
Irish Patients Association
Irish Society of Clinical Microbiologists
Irish Thoracic Society
Joint Faculty of Intensive Care Medicine of Ireland
Royal College of Physicians in Ireland (RCPI)
RCPI Faculty of Pathology
SARI National Committee
SARI Regional Committees
Surveillance Scientists Association of Ireland

Appendix 3: Sample VAP care bundle

1	Sedation reviewed and, if appropriate, stopped each day.
2	Patient assessed for weaning and extubation each day.
3	Avoid supine position. Aim to have the head of bed elevated to at least 30°.
4	Use chlorhexidine as part of daily oral care (0.12-2.0% applied 6-hourly).
5	Use subglottic secretion drainage in patients likely to be ventilated for more than 48 hours.

Adapted from Scottish Intensive Care Society Audit Group/NHS National Services Scotland VAP Prevention Bundle

Appendix 4: Sample exclusions from individual components of VAP care bundle

1. Sedation reviewed and, if appropriate, stopped each day.

Exclusions: -

- Paralysed patient
- Patient with brain injury, sedated with possible ICP problem
- Patient who is difficult to ventilate – coughing, asynchrony
- Patient who is difficult to oxygenate ($FiO_2 > 0.7$ or $PEEP \geq 10$)
- Patient receiving therapeutic hypothermia
- Patient receiving palliative/terminal care

2. Patient assessed for weaning and extubation each day.

Exclusions: -

- Paralysed patient
- Patient with brain injury, sedated with possible ICP problem
- Patient who is difficult to ventilate – coughing, asynchrony
- Patient who is difficult to oxygenate ($FiO_2 > 0.7$ or $PEEP \geq 10$)
- Patient receiving therapeutic hypothermia
- Patient receiving palliative/terminal care

3. Avoid supine position. Aim to have the head of bed elevated to at least 30°.

Exclusions: -

- Unstable, shocked patient e.g., requiring fluid challenges, high dose inotropes
- Unstable pelvic or spinal injury (it may be possible to tilt the whole bed)

4. Use chlorhexidine as part of daily oral care (0.12-2.0% applied 6-hourly).

Exclusions: -

- Oro-pharyngeal trauma or surgery
- Known hypersensitivity to chlorhexidine

5. Use subglottic secretion drainage in patients likely to be ventilated for more than 48 hours.

Exclusions: -

- Intubated prior to ICU admission
- Endotracheal tube with subglottic drainage port not available in hospital

Adapted from Scottish Intensive Care Society Audit Group/NHS National Services Scotland VAP Prevention Bundle

Appendix 5: Measuring compliance with VAP care bundle

Compliance with the VAP care bundle is defined as the percentage of mechanically ventilated patients for whom all five components of the bundle are documented on the daily record or elsewhere in the medical record. Compliance with the bundle is an 'all or nothing' measure; a case is not in compliance unless all elements of the care bundle have been documented.

Compliance should be audited regularly, for example, weekly. On the day of audit, all patients who are being mechanically ventilated are assessed for compliance with the bundle. If an element is contraindicated in a particular patient and this has been documented in the daily record or in the medical record, then the patient can be regarded as compliant with that intervention. Only those patients with all five elements of the bundle documented to be in place are considered compliant. For example, if there are seven ventilated patients and six have all five elements of the bundle completed, then the compliance is 86% (6 divided by 7). However, if all seven were missing even a single component, then the compliance is zero percent (0 divided by 7).

Appendix 6: HELICS case definition of pneumonia

Positive radiology

Two or more serial chest X-rays or CT scans with a suggestive image of pneumonia for patients with underlying cardiac or pulmonary disease. In patients without underlying cardiac or pulmonary disease one definitive chest X-ray or CT-scan is sufficient.

- Fever > 38 °C with no other causes
- Leukopenia (<4000 WBC/mm³) or leucocytosis (≥ 12 000 WBC/mm³)

and at least one of the following

(or at least two if clinical pneumonia only = PN 4 and PN 5)

- New onset of purulent sputum, or change in character of sputum (colour, odour, quantity, consistency)
- Cough or dyspnoea or tachypnoea
- Suggestive auscultation (rales or bronchial breath sounds), rhonchi, wheezing
- Worsening gas exchange (e.g., O₂ desaturation or increased oxygen requirements or increased ventilation demand)

and, according to the diagnostic method used

a – Bacteriologic diagnostic performed by:	
Positive quantitative culture from minimally contaminated LRT ¹ specimen <ul style="list-style-type: none"> • Broncho-alveolar lavage (BAL) with a threshold of ≥ 10⁴ cfu/mL or ≥ 5 % of BAL obtained cells contains intracellular bacteria on direct microscopic exam (classified on diagnostic category BAL). • Protected brush (PB Wimberley) with a threshold of ≥ 10³ cfu/mL • Distal protected aspirate (DPA) with a threshold of ≥ 10³ cfu/mL 	PN1
Positive quantitative culture from possibly contaminated LRT specimen Quantitative culture of LRT specimen (e.g., endotracheal aspirate) with a threshold of 10 ⁶ cfu/mL	PN2
b- Alternative microbiology methods <ul style="list-style-type: none"> • Positive blood culture not related to another source of infection • Positive growth in culture of pleural fluid • Pleural or pulmonary exam shows evidence of pneumonia • Positive exams for pneumonia with virus or particular germs (<i>Legionella</i>, <i>Aspergillus</i>, mycobacteria, <i>Mycoplasma</i>, <i>Pneumocystis carinii</i>) <ul style="list-style-type: none"> • Positive detection of viral antigen or antibody from respiratory secretions (e.g., EIA, FAMA, shell vial assay, PCR) • Positive direct exam or positive culture from bronchial secretions or tissue • Seroconversion (ex: influenza viruses, <i>Legionella</i>, <i>Chlamydia</i>) • Detection of antigens in urine (<i>Legionella</i>) 	PN3
c-Others	
Positive sputum culture or non-quantitative LRT specimen culture	PN4
No positive microbiology	PN5

Notes:

PN1 and PN2 criteria were validated without previous antimicrobial therapy

¹LRT = lower respiratory tract

² cfu = colony forming unit

VAP: A pneumonia is defined as ventilator-associated if an invasive respiratory device was present (even intermittently) in the 48 hours preceding the onset of infection.

ICU-acquired: An infection is considered to be ICU-acquired if it occurs later than 48 hours after admission to ICU

Second episode VAP: The combination of new signs and symptoms and radiographic evidence for pneumonia or other diagnostic testing is required.

Appendix 7: Suggested VAP surveillance dataset

Level of data	Data item	One record for...	Options
Hospital	Hospital code	Each hospital	Use existing MRSA protocol codes
	Hospital size	Each hospital	Use HELICS bands
	Hospital type	Each hospital	Use HELICS
ICU	ICU code	Each ICU	Use existing MRSA protocol codes
	ICU size	Each ICU	Use local data
	ICU type	Each ICU	Use local data
Patient	Patient ID	Each Patient	Use local data
	Date of ICU admission	Each Patient	Use local data
	Date of ICU discharge	Each Patient	Use local data
	Discharge status	Each Patient	Use local data
	Sex	Each Patient	M, F, U
	Age	Each Patient	Age in years
	Patient origin	Each Patient	Ward, other ICU, community, long term care
	Date of hospital admission	Each Patient	Use local data
	SAPS II	Each Patient	Use local data
APACHE II	Each Patient	Use local data	
Infection	Infection date	Each infection episode after 2 days ventilation	Use microbiology data
	Infection site	Each infection episode after 2 days ventilation	PN1 to PN5
	Organism	Each infection episode after 2 days ventilation	Use standard codes (WHOCARE)
	Resistance	Each infection episode after 2 days ventilation	Compile list of appropriate resistant pathogens
	Organism	Each infection episode after 2 days ventilation	Use standard codes (WHOCARE)
	Resistance	Each infection episode after 2 days ventilation	Compile list of appropriate resistant pathogens
	Organism	Each infection episode after 2 days ventilation	Use standard codes (WHOCARE)
	Resistance	Each infection episode after 2 days ventilation	Compile list of appropriate resistant pathogens
	Invasive device used	Each infection episode after 2 days ventilation	Always yes
	Antimicrobial treatment	Each infection episode after 2 days ventilation	Yes or No (for this infection)
	Validated infection	Each infection episode after 2 days ventilation	Checked against definition
Each ventilated day	Date of ventilation	Each ventilated day	Use local data
	ICU exposure	Each ventilated day	Use local data
	Elevation of bed*	Each ventilated day	Generate bands of angles
	Sedation check*	Each ventilated day	Use local data
	DVT prophylaxis*	Each ventilated day	Use local data
	Gastric ulcer prophylaxis*	Each ventilated day	Use local data
Antibiotic	Antimicrobial code	Each antibiotic	Use local data

* From "Implementing a ventilator care bundle in an adult intensive care unit" Westwell, 2008

Appendix 8: Sample VAP surveillance form

 	Ventilator associated pneumonia surveillance VAP episode surveillance	Version 0.2 Active from dd/mm/yyyy
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Please fill out one form per VAP episode

Unit information :

Hospital Code ICU Code

Patient information .

Patient ID Age (years) Sex (M/F/U)

Origin : Ward Other ICU Community Long term care

Hospital admission date Ventilation date

ICU admission date ICU discharge date

APACHE II score SAPS score

Discharge status : RIP Ward Other

Infection information

Infection date Infection site

Period of intubation (hours)

Diagnosis of VAP Microbiology and clinical Clinical alone

Antimicrobial treatment Yes No

Antibiotic 1 Antibiotic 2 Antibiotic 3

Antibiotic 4 Antibiotic 4 Antibiotic 5

Organism information

Organism 1 Notable resistance

Organism 2 Notable resistance

Organism 3 Notable resistance

Appendix 9 Abbreviations list

ATS	American Thoracic Society
BTS	British Thoracic Society
COAD	Chronic obstructive airways disease
DOHC	Department of Health and Children
HBN	Health Building Note
HCAI	Healthcare associated infection
HELICS	Hospital in Europe Link for Infection Control through Surveillance
HSE	Health Service Executive
HTM	Health Technical Memorandum
ICP	Intracranial pressure
ICU	Intensive care unit
IDSA	Infectious Diseases Society of America
MRSA	Meticillin resistant <i>Staphylococcus aureus</i>
NHS	National Health Service
SARI	Strategy for the Control of Antimicrobial Resistance in Ireland
SDD	Selective digestive decontamination
SHEA	Society for Healthcare Epidemiology of America
SOD	Selective oral decontamination
UK	United Kingdom
VAP	Ventilator-associated pneumonia
VRE	Vancomycin resistant enterococci

References

1. Richards MJ, Edwards JR, Culver DH, Gaynes RP. Nosocomial infections in combined medical-surgical intensive care units in the United States. *Infect Control Hosp Epidemiol* 2000; 8: 510-515.
2. Safdar N, Dezfulian C, Collard HR, Saint S. Clinical and economic consequences of ventilator-associated pneumonia: a systematic review. *Crit Care Med* 2005; 33: 2184-2193.
3. Chastre J, Fagon JY. Ventilator-associated pneumonia. *Am J Respir Crit Care Med* 2002; 165: 867-903.
4. Bercault N, Boulain T. Mortality rate attributable to ventilator-associated nosocomial pneumonia in an adult intensive care unit: A prospective case-control study. *Crit Care Med* 2001; 29: 2303-2309.
5. Heyland DK, Cook DJ, Griffith L, Keenan SP, Brun-Buisson C. The attributable morbidity and mortality of ventilator-associated pneumonia in the critically ill patient. *Am J Respir Crit Care Med* 1999; 159: 1249-1256.
6. Muscedere JG, Martin CM, Heyland DK. The impact of ventilator-associated pneumonia on the Canadian health care system. *J Crit Care* 2008; 23: 5-10.
7. Masterton RG, Galloway A, French G, Street M, Armstrong J, Brown E et al. Guidelines for the management of hospital-acquired pneumonia in the UK: Report of the Working Party on Hospital-acquired Pneumonia of the British Society for Antimicrobial Chemotherapy. *J Antimicrob Chemother* 2008; 62: 5-34.
8. American Thoracic Society; Infectious Diseases Society of America. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. *Am J Respir Crit Care Med* 2005; 171: 388-416.
9. Muscedere J, Dodek P, Keenan S, Fowler R, Cook D, Heyland D; VAP Guidelines Committee and the Canadian Critical Care Trials Group. Comprehensive evidence-based clinical practice guidelines for ventilator-associated pneumonia: prevention. *J Crit Care* 2008; 23: 126-137.
10. Coffin SE, Klompas M, Classen D, Arias KM, Podgorny K, Anderson DJ et al. Strategies to prevent ventilator-associated pneumonia in acute care hospitals. *Infect Control Hosp Epidemiol* 2008; 29 (Suppl 1): S31-40.
11. Safdar N, Abad C. Educational interventions for prevention of healthcare-associated infection: a systematic review. *Crit Care Med* 2008; 36: 933-940.
12. Salahuddin N, Zafar A, Sukhyani L, Rahim S, Noor MF, Hussain K et al. Reducing ventilator-associated pneumonia rates through a staff education programme. *J Hosp Infect* 2004; 57: 223-227.
13. Babcock HM, Zack JE, Garrison T, Trovillion E, Jones M, Fraser VJ, et al. An educational intervention to reduce ventilator-associated pneumonia in an integrated health system: a comparison of effects. *Chest* 2004; 125: 2224-2231.
14. Pittet D, Allegranzi B, Sax H, Dharan S, Pessoa-Silva CL, Donaldson L et al. Evidence-based model for hand transmission during patient care and the role of improved practices. *Lancet Infect Dis* 2006; 6: 641-652.
15. Pratt RJ, Pellowe CM, Wilson JA, Loveday HP, Harper PJ, Jones SR et al. epic2: National evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. *J Hosp Infect* 2007; 65 (Suppl 1): 1-64.
16. Crnich CJ, Safdar N, Maki DG. The role of the intensive care unit environment in the pathogenesis and prevention of ventilator-associated pneumonia. *Respir Care* 2005; 50: 813-836.
17. Safdar N, Crnich CJ, Maki DG. The pathogenesis of ventilator-associated pneumonia: its relevance to developing effective strategies for prevention. *Respir Care* 2005; 50: 725-739.
18. HPSC. National guidelines for the control of legionellosis in Ireland. 2009.
19. SARI. Infection prevention and control building guidelines for acute hospitals in Ireland. 2009.
20. SARI. Guidelines for hand hygiene in Irish health care settings. 2005.
21. Humphreys H, Johnson EM, Warnock DW, Willatts SM, Winter RJ, Speller DCE. An outbreak of aspergillosis in a general ITU. *J Hosp Infect* 1991; 18:167-177.
22. Flynn PM, Williams BG, Hetherington SV, Williams BF, Giannini MA, Pearson TA. *Aspergillus terreus* during hospital renovation. *Infect Control Hosp Epidemiol* 1993; 14: 363-365.
23. NDSC. National guidelines for the prevention of nosocomial invasive aspergillosis during construction / renovation activities. 2002.
24. Stone PW, Pogorzelska M, Kunches L, Hirschhorn LR. Hospital staffing and health care-associated infections: a systematic review of the literature. *Clin Infect Dis* 2008; 47: 937-944.

25. Hugonnet S, Chevolet JC, Pittet D. The effect of workload on infection risk in critically ill patients. *Crit Care Med* 2007; 35: 76-81.
26. Hugonnet S, Uçkay I, Pittet D. Staffing level: a determinant of late-onset ventilator-associated pneumonia. *Crit Care* 2007; 11: R80.
27. Pronovost PJ, Angus DC, Dorman T, Robinson KA, Dremsizov TT, Young TL. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. *JAMA* 2008; 288: 2151-2162.
28. Ram FS, Picot J, Lightowler J, Wedzicha JA. Non-invasive positive pressure ventilation for treatment of respiratory failure due to exacerbations of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2004; CD004104.
29. Burns KE, Adhikari NK, Keenan SP, Meade M. Use of non-invasive ventilation to wean critically ill adults off invasive ventilation: meta-analysis and systematic review. *BMJ* 2009; 338: b1574.
30. Holzapfel L, Chevret S, Madinier G, Ohen F, Demingeon G, Coupry A et al. Influence of long-term oro- or nasotracheal intubation on nosocomial maxillary sinusitis and pneumonia: results of a prospective, randomised, clinical trial. *Crit Care Med* 1993; 21: 1132-1138.
31. Salord F, Gaussorgues P, Marti-Flich J, Sirodot M, Allimant C, Lyonnet D et al. Nosocomial maxillary sinusitis during mechanical ventilation: a prospective comparison of orotracheal versus the nasotracheal route for intubation. *Intensive Care Med* 1990; 16: 390-393.
32. Michelson A, Kamp HD, Schuster B. Sinusitis in long-term intubated, intensive care patients: nasal versus oral intubation. *Anaesthetist* 1991; 40: 100-104.
33. Bach A, Boehrer H, Schmidt H, Geiss HK. Nosocomial sinusitis in ventilated patients. Nasotracheal versus orotracheal intubation. *Anaesthesia* 1992; 47: 335-339.
34. Rouby JJ, Laurent P, Gosnach M, Cambau E, Lamas G, Zouaoui A et al. Risk factors and clinical relevance of nosocomial maxillary sinusitis in the critically ill. *Am J Respir Crit Care Med* 1994; 150: 776-783.
35. Torres A, Gatell JM, Aznar E, el-Ebiary M, Puig de la Bellacasa J, González J et al. Re-intubation increases the risk of nosocomial pneumonia in patients needing mechanical ventilation. *Am J Respir Crit Care Med* 1995; 152: 137-141.
36. Kollef MH, Shapiro SD, Silver P, St John RE, Prentice D, Sauer S et al. A randomised, controlled trial of protocol-directed versus physician-directed weaning from mechanical ventilation. *Crit Care Med* 1997; 25: 567-574.
37. Marelich GP, Murin S, Battistella F, Inciardi J, Vierra T, Roby M. Protocol weaning of mechanical ventilation in medical and surgical patients by respiratory care practitioners and nurses: effect on weaning time and incidence of ventilator-associated pneumonia. *Chest* 2000; 118: 459-467.
38. Brook AD, Ahrens TS, Schaiff R, Prentice D, Sherman G, Shannon W et al. Effect of a nursing-implemented sedation protocol on the duration of mechanical ventilation. *Crit Care Med* 1999; 27: 2609-2615.
39. Quenot JP, Ladoire S, Devoucoux F, Doise JM, Cailliod R, Cunin N et al. Effect of a nurse-implemented sedation protocol on the incidence of ventilator-associated pneumonia. *Crit Care Med* 2007; 35: 2031-2036.
40. Hébert PC, Wells G, Blajchman MA, Marshall J, Martin C, Pagliarello G et al. A multicenter, randomized, controlled clinical trial of transfusion requirements in critical care. Transfusion Requirements in Critical Care Investigators, Canadian Critical Care Trials Group. *N Engl J Med* 1999; 340: 409-417.
41. Shorr AF, Duh MS, Kelly KM, Kollef MH. Red blood cell transfusion and ventilator-associated pneumonia: A potential link? *Crit Care Med* 2004; 32: 666-674.
42. Bochicchio GV, Napolitano L, Joshi M, Bochicchio K, Shih D, Meyer W et al. Blood product transfusion and ventilator-associated pneumonia in trauma patients. *Surg Infect (Larchmt)* 2008; 9: 415-422.
43. Siempos II, Ntaidou TK, Falagas ME. Impact of the administration of probiotics on the incidence of ventilator-associated pneumonia: a meta-analysis of randomised control trials. *Crit Care Med* 2010; 38: 954-962.
44. Torres A, Serra-Batlles J, Ros E, Piera C, Puig de la Bellacasa J, Cobos A et al. Pulmonary aspiration of gastric contents in patients receiving mechanical ventilation: the effect of body position. *Ann Intern Med* 1992; 116: 540-543. 111-115.

45. Orozco-Levi M, Torres A, Ferrer M, Piera C, el-Ebiary M, de la Bellacasa JP *et al.* Semirecumbent position protects from pulmonary aspiration but not completely from gastroesophageal reflux in mechanically ventilated patients. *Am J Respir Crit Care Med* 1995; 152: 1387-1390.
46. Drakulovic MB, Torres A, Bauer TT, Nicolas JM, Nogué S, Ferrer M. Supine body position as a risk factor for nosocomial pneumonia in mechanically ventilated patients: a randomised trial. *Lancet* 1999; 354: 1851-1858.
47. van Nieuwenhoven CA, Vandenbroucke-Grauls C, van Tiel FH, Joore HC, van Schijndel RJ, van der Tweel I *et al.* Feasibility and effects of the semirecumbent position to prevent ventilator-associated pneumonia: a randomized study. *Crit Care Med* 2006; 34: 396-402.
48. Rello J, Soñora R, Jubert P, Artigas A, Rué M, Vallés J. Pneumonia in intubated patients: role of respiratory airway care. *Am J Respir Crit Care Med* 1996; 154:
49. Dezfulian C, Shojania K, Collard HR, Kim HM, Matthay MA, Saint S. Subglottic secretion drainage for preventing ventilator-associated pneumonia: a meta-analysis. *Am J Med* 2005; 118: 11-18.
50. Hess DR. Patient positioning and ventilator-associated pneumonia. *Respir Care* 2005; 50: 892-898.
51. Delaney A, Gray H, Laupland K, Zuege D. Kinetic bed therapy to prevent nosocomial pneumonia in mechanically ventilated patients: a systematic review and meta-analysis. *Crit Care* 2006; 10: R70.
52. Goldhill DR, Imhoff M, McLean B, Waldmann C. Rotational bed therapy to prevent and treat respiratory complications: a review and meta-analysis. *Am J Crit Care* 2007; 16: 50-61.
53. Staudinger T, Bojic A, Holzinger U, Meyer B, Rohwer M, Mallner F *et al.* Continuous lateral rotation therapy to prevent ventilator-associated pneumonia. *Crit Care Med* 2010; 38: 486-490.
54. Hess DR, Kallstrom TJ, Mottram CD, Myers TR, Sorenson HM, Vines DL. Care of the ventilator circuit and its relation to ventilator-associated pneumonia. *Respir Care* 2003; 48: 869-879.
55. Jongerden IP, Rovers MM, Grypdonck MH, Bonten MJ. Open and closed endotracheal suction systems in mechanically ventilated intensive care patients: a meta-analysis. *Crit Care Med* 2007; 35: 2260-270.
56. Niel-Wiese BS, Snoeren RL, van der Broek PJ. Policies for endotracheal suctioning of patients receiving mechanical ventilation: a systematic review of randomised controlled trials. *Infect Control Hosp Epidemiol* 2007; 28: 531-536.
57. Subirana M, Sola I, Benito S. Closed tracheal suction systems versus open tracheal suction systems for mechanically ventilated adult patients. *Cochrane Database Syst Rev* 2007: CD004581.
58. Niël-Weise BS, Wille JC, van den Broek PJ. Humidification policies for mechanically ventilated intensive care patients and prevention of ventilator-associated pneumonia: a systematic review of randomized controlled trials. *J Hosp Infect* 2007; 65: 285-291.
59. Siempos II, Vardakas KZ, Kopterides P, Falagas ME. Impact of passive humidification on clinical outcomes of mechanically ventilated patients: a meta-analysis of randomized controlled trials. *Crit Care Med* 2007; 35: 2843-2851.
60. Craven DE, Goularte TA, Make BJ. Contaminated condensate in mechanical ventilator circuits. A risk factor for nosocomial pneumonia? *Am Rev Respir Dis* 1984; 129: 625-628.
61. Donowitz LG, Page MC, Mileur BL, Guenther SH. Alteration of normal gastric flora in critical care patients receiving antacid and cimetidine therapy. *Infect Control* 1986; 7: 23-26.
62. Cook DJ, Reeve BK, Guyatt GH, Heyland DK, Griffith LE, Buckingham L *et al.* Stress ulcer prophylaxis in critically ill patients. Resolving discordant meta-analyses. *JAMA* 1996; 275: 308-314.
63. Collard HR, Saint S, Matthay M. Prevention of ventilator-associated pneumonia: an evidence-based systematic review. *Ann Intern Med* 2003; 138: 494-501.
64. Cook D, Guyatt G, Marshall J, Leasa D, Fuller H, Hall R *et al.* A comparison of sucralfate and ranitidine for the prevention of upper gastrointestinal bleeding in patients requiring mechanical ventilation. Canadian Critical Care Trials Group. *N Engl J Med* 1998; 338: 791-797.
65. Levy MJ, Seelig CB, Robinson NJ, Ranney JE. Comparison of omeprazole and ranitidine for stress ulcer prophylaxis. *Dig Dis Sci* 1997; 42: 1255-1259.

66. Garrouste-Orgeas M, Chevret S, Arlet G, Marie O, Rouveau M, Popoff N *et al.* Oropharyngeal or gastric colonization and nosocomial pneumonia in adult intensive care unit patients. A prospective study based on genomic DNA analysis. *Am J Respir Crit Care Med* 1997; 156:1647-1655.
67. Mori H, Hirasawa H, Oda S, Shiga H, Matsuda K, Nakamura M. Oral care reduces incidence of ventilator-associated pneumonia in ICU populations. *Intensive Care Med* 2006; 32: 230-236.
68. Pearson LS, Hutton JL. A controlled trial to compare the ability of foam swabs and toothbrushes to remove dental plaque. *J Adv Nurs* 2002; 39: 480-489.
69. Chlebicki MP, Safdar N. Topical chlorhexidine for prevention of ventilator-associated pneumonia. *Crit Care Med* 2007; 35: 595-602.
70. Kola A, Gastmeier P. Efficacy of oral chlorhexidine in preventing lower respiratory tract infections. Meta-analysis of randomized controlled trials. *J Hosp Infect* 2007; 66: 207-216.
71. Seguin P, Tanguy M, Laviolle B, Tirel O, Mallédant Y. Effect of oropharyngeal decontamination by povidone-iodine on ventilator-associated pneumonia in patients with head trauma. *Crit Care Med* 2006; 34: 1514-1519.
72. Kollef M, Pittet D, Sánchez García M, Chastre J, Fagon JY, Bonten M *et al.* A randomized double-blind trial of isegagan in prevention of ventilator-associated pneumonia. *Am J Respir Crit Care Med* 2006; 173: 91-97.
73. Vandembroucke-Grauls CM, Vandembroucke JP. Effect of selective decontamination of the digestive tract on respiratory tract infections and mortality in the intensive care unit. *Lancet* 1991; 338: 859-862.
74. Meta-analysis of randomised controlled trials of selective decontamination of the digestive tract. Selective Decontamination of the Digestive Tract Trialists' Collaborative Group. *BMJ* 1993; 307: 525-532.
75. Heyland DK, Cook DJ, Jaeschke R, Griffith L, Lee HN, Guyatt GH. Selective decontamination of the digestive tract. An overview. *Chest* 1994; 105: 1221-1229.
76. Kollef MH. The role of selective digestive tract decontamination on mortality and respiratory tract infections. A meta-analysis. *Chest* 1994; 105: 1101-1108.
77. Hurley JC. Prophylaxis with enteral antibiotics in ventilated patients: selective decontamination or selective cross-infection? *Antimicrob Agents Chemother* 1995; 39: 941-947.
78. D'Amico R, Pifferi S, Leonetti C, Torri V, Tinazzi A, Liberati A.. Effectiveness of antibiotic prophylaxis in critically ill adult patients: systematic review of randomised controlled trials. *BMJ* 1998; 316: 1275-1285.
79. Nathens AB, Marshall JC. Selective decontamination of the digestive tract in surgical patients: a systematic review of the evidence. *Arch Surg* 1999; 134: 170-176.
80. Liberati A, D'Amico R, Pifferi S, Torri V, Brazzi L, Parmelli E. Antibiotic prophylaxis to reduce respiratory tract infections and mortality in adults receiving intensive care. *Cochrane Database Syst Rev* 2009; CD000022.
81. van Nieuwenhoven CA, Buskens E, van Tiel FH, Bonten MJ. Relationship between methodological trial quality and the effects of selective digestive decontamination on pneumonia and mortality in critically ill patients. *JAMA*. 2001; 286: 335-340.
82. Verwaest C, Verwaest C, Verhaegen J, Ferdinande P, Schetz M, Van den Berghe G, Verbist L *et al.* Randomized, controlled trial of selective digestive decontamination in 600 mechanically ventilated patients in a multidisciplinary intensive care unit. *Crit Care Med* 1997; 25: 63-71.
83. Lingnau W, Berger J, Javorsky F, Fille M, Allerberger F, Benzer H. Changing bacterial ecology during a five-year period of selective intestinal decontamination. *J Hosp Infect* 1998; 39:195-206.
84. de Smet AM, Kluytmans JA, Cooper BS, Mascini EM, Benus RF, van der Werf TS *et al.* Decontamination of the digestive tract and oropharynx in ICU patients. *N Engl J Med* 2009; 360: 20-31.
85. Oostdijk EA, de Smet AM, Blok HE, Thieme Groen ES, van Asselt GJ, Benus RF *et al.* Ecological effects of selective decontamination on resistant Gram-negative bacterial colonization. *Am J Resp Crit Care Med* 2010; 181: 452-457.
86. Resar R, Pronovost P, Haraden C, Simmonds T, Rainey T, Nolan T. Using a bundle approach to improve ventilator care processes and reduce ventilator-associated pneumonia. *Jt Comm J Qual Patient Saf* 2005; 31: 243-248.

87. Hawe CS, Ellis KS, Cairns CJ, Longmate A. Reduction of ventilator-associated pneumonia: active versus passive guideline implementation. *Intensive Care Med* 2009; 35: 1180-1186.
88. Schurink CA, Van Nieuwenhoven CA, Jacobs JA, Rozenberg-Arska M, Joore HC, Buskens E *et al*. Clinical pulmonary infection score for ventilator-associated pneumonia: accuracy and inter-observer variability. *Intensive Care Med* 2004; 30: 217-224.
89. Klompas M, Platt R. Ventilator-associated pneumonia--the wrong quality measure for benchmarking. *Ann Intern Med* 2007; 147: 803-805.



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