Clinical Excellence (NICE) and National Patient Safety Agency (NPSA), 2008) The incidence of VAP ranges from 6% to 52% (Davis, 2006).

It is widely recognized that VAP is a complex issue with a range of possible causes, which make any prevention strategy multifactorial. The consequences of VAP include increased length of stay, increased cost by £6000–£22,000 (Wagh and Acharya, 2009), and may account for up to 51 extra ventilated days per 1000 (Joseph et al, 2010). There is evidence to suggest that while VAP care bundles have still to prove effective in the control of VAP, a range of interventions such as those elements contained within a ventilator care bundle can significantly reduce the incidence (Novack, 2009). This article will consider the nature of VAP and explore some of the latest developments in managing the condition in critical care areas.

### Extent of the problem

VAP occurs after colonization of the lower airways by pathogens in an immuno-compromised host (Swann, 2008). Prevention of ventilator-associated pneumonia

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Ventilator-associated pneumonia (VAP) is a common complication of intensive care and is defined as pneumonia developing after 48 hours or longer following intubation (National Institute for Health and Clinical Excellence/National Patient Safety Agency technical patient safety solutions). It is widely recognized that VAP is a complex issue with a range of possible causes, which make any prevention strategy multifactorial. The consequences of VAP include increased length of stay, increased cost by £6000–£22,000 (Wagh and Acharya, 2009), and may account for up to 51 extra ventilated days per 1000 (Joseph et al, 2010). There is evidence to suggest that while VAP care bundles have still to prove effective in the control of VAP, a range of interventions such as those elements contained within a ventilator care bundle can significantly reduce the incidence (Novack, 2009). This article will consider the nature of VAP and explore some of the latest developments in managing the condition in critical care areas.

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2008). The US Institute for Healthcare Improvement (IHI) describes VAP as a leading cause of death among patients with hospital-acquired infections; indeed more than central line infection or severe sepsis (IHI, 2011). Statistics on incidence, mortality and morbidity differ greatly because of the multifocal heterogeneous nature of VAP (Melsen et al, 2009). VAP is associated with high morbidity, mortality and health-care costs (Craven, 2006). The exact cost is impossible to determine due to the complexities of critically-ill patients in terms of underlying diagnoses and the severity of comorbidities (Swann, 2008; Rea-Neto et al, 2008).

VAP is a primary problem in critical care units, and causes complications in 8–28% of patients receiving mechanical ventilation. VAP accounts for approximately 25% of all intensive care unit (ICU) infections and >50% of the antibiotics prescribed in ICU (Craven, 2006).

Intensive care patients have numerous factors that increase their susceptibility to VAP (Table 1).

### Prevention is better than cure

Prevention efforts should focus on reducing bacterial colonization, and limiting aspiration, antibiotic exposure, and use of invasive devices. There is continuing debate about how best to prevent and treat VAP.

Current strategies aimed at preventing/controlling the incidence of VAP are listed in Table 2, though many still require more extensive research to confirm their potential value as an intervention (Ruffell and Adamcova, 2008).

### Ventilator care bundle

A care bundle is a grouping of evidence-based practice interventions, that when grouped together into a single protocol, will improve patient care (Fulbrook and Mooney, 2003). Gastmeier and Geffers (2007) found a 40% reduction in the incidence of VAP when a multimodal programme for prevention was used. There is some disagreement over which elements such bundles should include, this alongside a lack of graded evidence and variability between countries and hospitals may confound compliance (Rello et al, 2011).

The Department of Health (DH) ‘High impact intervention’ for ventilated patients as part of the ‘Saving Lives’ programme (DH, 2007) used a care bundle approach with a tool to enable organizations to demonstrate compliance with the Code of Practice:

- **Elevation of the head of the bed to 30–45°**
- **Sedation holding**
- **Deep vein thrombosis prophylaxis**
- **Gastric ulcer prophylaxis**
- **Appropriate humidification of inspired gas**
- **Appropriate tubing management**
- **Suctioning of respiratory secretions**
- **Routine oral hygiene**

NICE/NPSA (2008) produced a guideline for ventilator-associated pneumonia in adults. This document examined four key areas for the prevention of ventilator-associated pneumonia:

- Hand decontamination and use of gloves
- Oral/nasal hygiene
- Selective decontamination of the gastrointestinal tract
- Reduce aspiration of oropharyngeal secretions—subglottic drainage
- **Deep vein thrombosis prophylaxis**
- Stress ulcer prophylaxis
- Adequate nutritional support
- Reconsider need for nasogastric feeding tube—early jejunostomy/gastrostomy tube
- Continuous versus intermittent tube feeding
- Avoidance of gastric over distension
- Avoiding transfusion of red blood cells
- **Formal infection control programme**
- Avoiding invasive ventilation—use of CPAP & BiPAP
- Oral rather than nasal ETT
- ETT suctioning (open versus closed)
- Use of daily sedation holds/spontaneous breathing trials
- Early extubation/use of weaning protocols
- Prevention of unplanned extubation
- Continuous aspiration of subglottic secretions
- Frequency of ventilator circuit change / tube management
- Maintenance of ETT cuff pressure
- **Humidification**—Heat and moisture exchange versus heated-wire circuits
- Semi recumbent positioning 30–45°
- **Kinetic therapy**

### Solutions to the problem

The following section outlines some of the interventions within the DH (2007) care bundle and the NICE/NPSA (2008) guidance. Many of the items outlined are not specific to VAP but are enshrined in good caring practices of the ventilated critical care patient. VAP is a specific diagnosis but the care of patients at risk of developing VAP is inextricably linked to a high standard of care for any ventilated critical care patient.

### Sedation holds

Daily sedation holds/holidays allow optimization of patient sedation levels in readiness for extubation, and to allow daily assessment of readiness to extubate. Kress et al
(2000) in a randomized controlled trial of daily sedation breaks compared to routine care, demonstrated a reduced duration of ventilation and ICU stay for those patients having sedation holds. A reduction in ventilation days will reduce the risk of patients developing VAP.

**Head elevation of at least 30° unless contraindicated**

Drakulovic et al (1999) in a study of 86 patients demonstrated a significant reduction in the incidence of VAP in patients who were nursed at a 45° angle. The incidence of VAP was 8% compared to 34% in the supine group. Van Nieuwenhoven et al (2006) attempted to replicate the earlier study, however failed to show any difference in the incidence of VAP between the groups. This may have been due to a failure in the target group to achieve the required degree of head elevation, the average head of bed elevation being only 28°. The evidence surrounding head elevation is marred by methodological difficulties. However, there does appear to be a consensus that it has some effect on reducing the incidence of VAP. Therefore this simple intervention has been adopted by DH (2007) and NICE/NPSA (2008).

**DVT prophylaxis**

Unless contraindicated, patients should have deep vein thrombosis (DVT) prophylaxis. This includes use of antiembolic stockings, and subcutaneous anticoagulation. Without prophylactic measures 22–80% of ventilated patients have been reported to develop DVT or pulmonary embolism (Westwell, 2008).

**Gastrointestinal prophylaxis**

All patients ventilated for more than 48 hours are at high risk of developing stress ulcers and subsequent bleeding (Quenot et al, 2009). Stress ulcer prophylaxis and alkaline enteral tube feeds can change the gastric pH. This can result in an overgrowth of enteric Gram-negative bacteria, turning the stomach into a bacterial reservoir (Kunis and Puntillo, 2003) and further adding to the risk of VAP.

**Cuff pressures**

Endotracheal/tracheostomy cuffs require adequate inflation to prevent secretions tracking around the cuff into the lungs. At the same time they must not be excessive to avoid trachea ischaemia, ulceration and necrosis. Cuff pressure should be checked at least once per shift (Gopalan and Browning, 2005). The use of a cuff pressure manometer will ensure pressure is maintained according to manufacturer’s guidelines for the specific endotracheal tube in use.

**Subglottic secretion drainage**

The double-lumen endotracheal tube (ETT) has a second lumen integrated in the wall of the tube with an opening above the cuff, and a suction connection next to the pilot balloon. This suction connection allows for easier secretion removal, requiring only insertion of a syringe into the suction connection. A meta-analysis of five randomized controlled trials (n=900) found that subglottic secretion drainage halved the incidence of VAP (Dezfulian and Saint, 2005). A recent multicentre trial (Lacherade et al, 2010) identified that intermittent subglottic drainage reduced VAP from 25.6% (control) to 14.8% but no differences were found in duration of ventilation or mortality.

**Early extubation**

Appropriate use of sedation holds and weaning protocols should be employed to ensure optimal timing of extubation. Feldman et al (1999) found that a biofilm (a coating of bacteria on the inner lumen of the tube) had formed in the lower third of ETTs removed from all intubated patients. The colonization and biofilm formation had occurred as early as 12 hours after intubation and was most abundant after 96 hours.

A study by Rello et al (2006) found in a prospective, randomized, single blind study in four hospitals in Europe and the US that use of an ETT with an inner silver-coated lining reduced colonization on the tube and in tracheal aspirates.

**Prevention of unplanned extubation**

This can often be avoided by vigilant observation and sensitive care of a confused, restless or combative patient. Sedation may be required if the patient is at great risk of self-harm including self-extubation.

**Ventilator tubing management**

Ventilator tube disconnections should be minimized to prevent contamination. A closed suction system may be helpful in avoiding disconnections. Tubing should be carefully positioned and secured to reduce the need for disconnection during patient re-positioning, dressing or bed changes. Tubing should be changed when soiled rather than routinely.
Heat and moisture exchange versus heated circuits
Ten small trials have examined the incidence of VAP in patients randomized to receiving either heat and moisture exchange or heated-wire ventilation circuits. Pooling the results of these trials together, without taking methodological differences into account, does not show statistically different VAP rates (Swann, 2008).

Mouth care/oral hygiene
Regular mouth care using toothpaste and toothbrush will reduce bacterial colonization of the mouth. An oral antiseptic (eg 2% chlorhexidine) should be included as part of the oral hygiene regime. The oral cavity should be cleared of oral secretions regularly (DH, 2007).

A meta-analysis of 11 randomized controlled trials, with a total sample of 3242 patients, using a range of antiseptic regimes including chlorhexidine 0.12–2% and povidone iodine 10% concluded that oral decontamination using antiseptics is associated with a lower risk of VAP but it did not significantly reduce mortality, duration of mechanical ventilation or duration of ICU stay (Chan et al, 2007).

A study by Berry et al (2010) suggested that the choice of solution is less important than the mechanics of brushing whereas Di Filippo et al (2011) considered the solution to be critical. Needleman et al (2011) compared the use of electric toothbrushes with the use of sponge swabs using chlorhexidine 0.2% and found no statistical difference between the groups in terms of respiratory pathogens but did find that the group receiving tooth brushing demonstrated a highly statistical difference in the formation of dental plaque.

Selective decontamination of the digestive tract
Oral pastes containing a mixture of non absorbable antibiotics have been employed in an effort to prevent colonization of the upper airways and VAP. A recent meta-analysis considered four trials with 1098 patients, concluding there was no significant difference in VAP rates and mortality (Chan et al, 2007).

Enteral feeding and control of regurgitation
Careful monitoring of feeding protocols is needed to prevent aspiration. Bowman et al (2005) instituted an evidence-based enteral feeding protocol in which 78–85% of patients reached their enteral feeding goal and aspiration pneumonia rates decreased from 6.8/1000 patient days to 3.2/1000 patient days. It is important to perform regular nasogastric tube aspiration to ensure gastric emptying, particularly prior to lowering the head of the bed for nursing care.

Kinetic beds
In a meta-analysis of 15 randomized controlled trials kinetic bed therapy, which employs the use of specialized beds that slowly and continuously rotate the patient from side to side, reduced the incidence of VAP but not mortality, duration of mechanical ventilation, duration of ICU stay, or hospital stay (DH, 2007). A more recent study (Staudinger et al, 2010) found a reduction of VAP from 23 % (control) to 11% alongside a reduction in duration of ventilation and length of stay when kinetic therapy was used.

New technology
Product developments that are being investigated to help prevent VAP include:
- High-volume, low-pressure cuffs with elongated cuff to reduce folds and extend the amount of cuff that is in contact with the tracheal wall
- Silver-coated ETT
- Cuff technology using modified polyurethane material
- Constant pressure inflation devices—regulate a constant cuff pressure
- LoTrach—A relatively new ETT on the market that includes a low-volume, low-pressure cuff, with an aspiration port above the cuff for subglottal irrigation, plus an integral bite block and a fixation device to avert accidental extubation

The role of the nurse
Critical care nurses at the bedside can do much to reduce the risk of their patient developing VAP. The use of the care bundle recommendations tailored to individual requirements or challenges will ensure VAP risk is minimized. Of course, ongoing education is a vital component in the success of any strategy, equally important are the audit and evaluation of both practice and outcomes—a continuous process to ensure we are providing the best care for our patients.

Conclusions
The research surrounding VAP prevention is abundant, often contradictory and difficult to assimilate for application to patient care (Muscedere et al, 2008). In the UK we must be guided by NICE/NPSA (2008) guidelines and current research evidence with the aim to do the very best for our patients.

This article has considered VAP, its causes and how nurses may prevent its occurrence. While it is clear that there still needs to be much more research into the various dimensions of such a complex problem, it is apparent from the literature that very basic and simple interventions such as oral hygiene and regular suctioning can have a potentially beneficial effect.
Ventilator-associated pneumonia (VAP) is a common complication of intensive care and is defined as pneumonia developing 48 hours or more after intubation.

VAP is associated with high morbidity, mortality and health-care costs.

Intensive care patients have numerous factors that increase their susceptibility to VAP.

Prevention strategies must be multifaceted, efforts should focus on reducing bacterial colonization, and limiting aspiration, antibiotic exposure, and use of invasive devices.

Use of a care bundle can reduce the incidence of VAP.