**ABSTRACT**

**Aim:** to identify the most effective suctioning technique for the prevention of ventilator-associated pneumonia. Background: ventilator-associated pneumonia is an important hospital-acquired infection associated with increased mortality and morbidity. **Method:** a rapid review included an electronic database search of articles published between January 2009 and March 2016. The quality of the seven included studies was appraised and data were subjected to tabular and narrative syntheses. **Results:** closed suction systems have no clear advantage over open suction, but may better prevent late-onset ventilator-associated pneumonia. Subglottic secretion drainage reduces ventilator-associated pneumonia incidence. **Conclusion:** open versus closed suction combined with subglottic secretion drainage requires ongoing research. Alongside this, policy guidance, education, behavioural and managerial strategies must be implemented.

**Key words:** Pneumonia, ventilator-associated ■ Suction ■ Critical care ■ Respiration, artificial ■ Intubation ■ Infection prevention and control

**Introduction and background**

Hospital-acquired infections increase mortality (World Health Organization, 2009) and cost the NHS an estimated £1 billion annually (National Institute for Health and Care Excellence (NICE), 2012). Ventilator-associated pneumonia (VAP) is a hospital-acquired pneumonia that occurs 48 hours or more after endotracheal intubation. It is the most frequent nosocomial infection in the intensive care unit (ICU) (Hunter, 2012) and its devastating impacts have resulted in VAP being proposed as an indicator of quality care and its prevention becoming a national patient safety goal (Mietto et al, 2013). Tracheal suctioning is one of the most common invasive procedures performed by nurses on ICU patients and is crucial to reducing the risk of VAP (Mietto et al, 2013). Tracheal suctioning is traditionally performed using the open suction system (OSS), which involves disconnecting the patient from the ventilator and introducing a single-use suction catheter (Subirana et al, 2007). In contrast, the closed suction system (CSS) consists of a multi-use suction catheter included within the ventilation circuit, preventing the need for disconnection and the resultant loss of airway pressure (Lorente et al, 2006). There are many suggested advantages of CSS compared with OSS, including improved oxygenation, maintenance of positive end-expiratory pressure meaning reduced risk of alveolar de-recruitment, and smaller loss of lung volume (Subirana et al, 2007; Muscedere et al, 2008). The closed design also minimises the chance of potential contamination from either the environment or the health professional, thereby reducing the risk of bacterial transmission during suctioning (Subirana et al, 2007; Åkerman et al, 2014). However, the benefits of CSS remain contentious and there is no current consensus on which device should be recommended for clinical practice (Rello et al, 2011; Åkerman et al, 2014). Meta-analyses have been unable to demonstrate the benefit of CSS over OSS in reducing contamination, preventing VAP or in reducing mortality and length of hospital stay (Jongerden et al, 2007; Peter et al, 2007; Subirana et al, 2007; Siempos et al, 2008).

As an adjunct to tracheal suctioning, subglottic secretion drainage (SSD) is recommended to prevent VAP (Institute for Healthcare Improvement, 2012; Keyt et al, 2014). This can be performed continuously or intermittently through a specifically modified endotracheal tube (ETT) equipped with a suctioning channel opening just above the inflated cuff to drain accumulated secretions (Zolfaghari and Wyncoll, 2011; Mietto et al, 2013). These secretions from the lower respiratory tract potentially contain bacterial pathogens, which are the main cause of VAP (Muscedere et al, 2011). Several meta-analyses and systematic reviews have investigated the impact of SSD on VAP; all concluded a significant reduction in VAP when SSD is used as an intervention (Wang et al, 2012; Frost et al, 2013; Caroff et al, 2016). Furthermore the US Centers for Disease Prevention and Control (CDC) recommends the use of SSD (Tablan et al, 2004). No published systematic review has compared the use of SSD with OSS, CSS or other suctioning methods. Furthermore, the last review comparing OSS and CSS was published over a decade ago (Subirana et al, 2007).

**Methods**

The aim of this rapid review (Grant and Booth, 2009) was to determine which suctioning method is most effective in preventing VAP. Using terms identified from an amended version of the population, intervention, comparison and outcome (PICO) framework (Richardson et al, 1995) (*Table 1*), studies of relevance were retrieved using a systematic search of three electronic databases (Cumulative Index to Nursing and Allied Health Literature (CINAHL), MEDLINE and EMBASE) for articles published between January 2009 and March 2016. This was supplemented by applying inclusion and exclusion criteria (*Table 2*), screening the reference lists of identified papers and a forward citation search via Google Scholar (*Figure 1*).

**[Figure 3] - Literature Search Process**

Total manuscripts identified by backward citation searching

**n = 1**

Total manuscripts identified by forward citation searching

**n = 0**

Total number of papers included in the review from complete search

**n = 7**

Total citations identified by database search

**n = 117**

Abstracts screened

**n = 28**

Full text papers

**n = 24**

Included in review from database search

**n = 6**

Excluded at title

**n = 89**

Excluded at abstract

**n = 4**

Excluded at full paper

**n = 18**

**[Table 1] - Search Terms**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Population** **(Search a)**  |  | **Intervention** **(Search b)**  |  | **Outcome** **(Search c)** |
| Intensive care unit**OR** |  | Tracheal suction**OR** |  | Ventilator acquired pneumonia**OR** |
| ITU**OR** | **AND** | Closed system suction\***OR** | **AND** | Ventilator associated pneumonia**OR** |
| ICU**OR** |  | Open system suction\***OR** |  | VAP |
| Critical Care**OR**Ventilated |  | Closed tracheal suction\***OR** |  |  |
|  |  | Open tracheal suction\***OR** |  |  |
|  |  | Open suction\***OR** |  |  |
|  |  | Closed suction\***OR** |  |  |
|  |  | Closed-suction system**OR** |  |  |
|  |  | Open-suction system**OR** |  |  |
|  |  | Subglottic secretion drainage**OR** |  |  |
|  |  | Subglottic drainage**OR** |  |  |
|  |  | Subglottic suction\* |  |  |

\* = Wildcard

**[Table 2] - Inclusion and Exclusion Criteria**

|  |  |
| --- | --- |
| **Inclusion Criteria** | **Exclusion Criteria** |
| Intubated adults (18 years old +)  | Non-invasive ventilation  |
| Quantitative data | Secondary data, abstracts, letters to editor, opinion based papers, reviews |
| English language literature published 2009 to present |
| VAP as an outcome |
| Any form of respiratory suction |

VAP = Ventilator Associated Pneumonia

The seven studies included in the review (*Table 3*) were quality appraised using the Critical Appraisal Skills Programme (CASP) (2013) tools.

**[Table 3] – Included Studies**

|  |  |  |
| --- | --- | --- |
| **Authors** | **Study design** | **Interventions** |
| Lacherade *et al*., (2010) | RCT  | SSD |
| David *et al*., (2011) | RCT  | OSS vs CSS |
| Juneja *et al.,* (2011) | Retrospective cohort study  | OSS, CSS, SSD, and SSD with CSS |
| Speroni *et al.,* (2011) | Cohort study  | SSD |
| Åkerman *et al*., (2013) | Cohort study  | OSS vs CSS |
| Lorente *et al.*, (2014) | Cohort study  | OSS vs SSD with cuff pressure control |
| Damas *et al*., (2015)  | RCT  | SSD |

RCT = Randomised Controlled Trial

SSD = Subglottic Secretion Drainage

OSS = Open Suction System

CSS = Closed Suction System

Data analysis

The only common form of reported statistical data was p-values; thus a meta-analysis was not possible. Following the advice of a statistician, p-values were collated into table form, with p<0.05 deemed to be statistically significant and an additional narrative synthesis of the findings undertaken.

**Findings**

Six of the seven studies reported p-values (*Table 4*).

**[Table 4] - Combined *p*-values for VAP Reduction**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Comparison | Lacherade *et al.,* 2010 | David *et al*., 2011 | Juneja *et al.,* 2011 | Åkerman *et al*., 2013 | Lorente *et al*., 2014  | Damas *et al*., 2015 |
| CSS versus OSS: Early onset VAP  |  | *p*=0.067  |  | NS |  |  |
| CSS versus OSS: Late onset VAP  |  | *p*=0.03\*  |  | NS |  |  |
| SSD versus no SSD: Early onset VAP  | *p*=0.02\* |  |  |  |  |  |
| SSD versus no SSD: Late onset VAP | *p*=0.01\* |  |  |  |  |  |
| SSD versus no SSD |  |  | \**p*-value not reported |  |  | *p*=0.016\* |
| CSS with/without SSD  |  |  | NS |  |  |  |
| SSD with/without continuous control of cuff pressure  |  |  |  |  | *p*=0.008\* |  |

\* = Statistically significant

NS = Not Significant

CSS = Closed Suction System

OSS = Open Suction System

SSD = Subglottic Secretion Drainage

VAP = Ventilator Associated Pneumonia

CSS versus OSS

Two studies compared CSS with OSS. Neither study was able to demonstrate that CSS was preferable to OSS for reducing early-onset VAP and only one supported CSS for preventing the development of late-onset VAP.

Åkerman et al (2014) conducted a cohort study with 126 ICU patients recruited during two consecutive study periods (one with OSS and one with CSS). There was no statistically significant difference in VAP rates between groups; however, the use of CSS during the non-sampling period to train staff may have induced a user bias. The cohort design and the absence of confidence intervals further undermine the validity of these results.

David et al (2011) conducted a randomised controlled trial (RCT) of 200 ICU patients. Results showed a significant reduction in late, but not early-onset VAP with CSS compared with OSS. The sample size was based on an 80% power calculation. However, as with the other studies included within this review, blinding was not possible due to the visible presence of OSS and CSS, which may have increased the risk of bias. The external validity of the study may also be reduced as it was conducted in India, so findings may not be applicable to the UK.

The use of SSD and other adjuncts

Five studies assessed the impact of SSD. Together, these studies support that the use of SSD reduces VAP incidence. They further suggest that SSD combined with other interventions may be of benefit.

Speroni et al (2011) conducted a cohort study investigating the use of SSD in 154 patients, the first 77 of whom received SSD. No cases of VAP were reported in the SSD group compared with one case in the standard group. In conjunction with cost analysis, this led the authors to recommend the use of SSD. This study has several limitations, perhaps the most important of which is that conclusions were based on finding one VAP case in the control group, which may have been due to chance. Furthermore the type of tracheal suction used in either group was not stated.

A multi-centre RCT by Lacherade et al (2010) investigated SSD in 333 patients in four ICUs. The authors reported a significant reduction in both early onset and late onset VAP in the intervention group (SSD) compared with the control. The large sample size based on an 80% power calculation, the multi-centre nature of the study, its methodological rigour and its European focus increase the external validity of the results. However, the authors did not state whether the intervention or control groups used OSS or CSS, therefore conclusions cannot be drawn as to any combination of suction techniques.

A Belgian RCT by Damas et al (2015) also investigated SSD on 352 adult patients in five ICUs within the same hospital. Study findings were consistent with Lacherade et al (2010), with a statistically significant reduction in VAP rates with SSD. The sample size was based on an 80% power calculation and confidence intervals and odds ratios were reported. However, the study was monocentric, minimising its external validity.

Juneja et al (2011) conducted a retrospective cohort study on 311 ventilated patients who received OSS, CSS, SSD with OSS, or SSD with CSS. A statistically significant reduction in VAP was found with SSD, although no significant differences between SSD used with OSS or CSS were reported. The results of this monocentric cohort study may not lend themselves to generalisation, particularly as it was conducted in India, with neither confidence intervals, odds ratios, nor power calculations reported.

Lorente et al’s (2014) single-centre cohort study compared the use of OSS and SSD with or without continuous control of cuff pressure in 656 patients. A statistically significant reduction in ventilator-associated respiratory infections, including VAP, was reported with the use of continuous cuff-pressure control This study had the largest sample size of all articles included in the review, however, there was no evidence that this was based on a power calculation and no confidence intervals were reported, making it hard to assess the clinical significance of results. Furthermore the monocentric study design reduces its external validity.

**Discussion**

Healthcare policy and guidelines offer contradictory recommendations for clinical practice around tracheal suction methods, with some not advocating any specific method of tracheal suctioning (Berwick et al, 2006; NICE, 2012). Therefore, selection of the most appropriate method for the patient remains at the discretion of the nursing team.

This review was unable to find evidence that CSS is superior to OSS for reducing overall VAP incidence, findings correlating with those of previous studies (Jongerden et al, 2007; Peter et al, 2007; Subirana et al, 2007; Siempos et al, 2008). Results do, however, support a potential benefit for CSS over OSS for the prevention of late-onset VAP. Findings from this review suggest that SSD may reduce the incidence of VAP, a result also correlating with previous studies (Dezfulian et al, 2005; Muscedere et al, 2011; Wang et al, 2012; Frost et al, 2013) and with the recommendations of the CDC (Tablan et al, 2004). The present findings also highlight the potential added benefit of continuous control of cuff pressure.

Strengths and limitations

The systematic and transparent approach taken provides confidence in the findings of this review. Limitations are largely circumstantial and contextual. The review was conducted by a sole researcher (EL) with limited resources. Important evidence may therefore have been neglected as only studies where the full text was accessible through university-subscribed databases were included. In addition, despite identifying strict eligibility criteria, the diagnostic criteria for VAP varied between studies making direct comparisons difficult. Quantitative differences between late and early-onset VAP also varied and were not

CSS: closed suction system, OSS: open suction system, SSD: subglottic secretion drainage, VAP: ventilator-associated pneumoniaalways identified by included studies. Finally, although most studies stated the suctioning technique investigated was through an ETT as opposed to a tracheostomy, this was not always specified.

Research recommendations

Future research should investigate which combination of tracheal suction methods and adjuncts is most effective for preventing VAP. Similarly, the use of SSD with interventions such as mode of ventilation, cuff pressure control and other VAP prevention strategies, including head of bed elevation and oral care, requires further investigation. Additionally, future work should separate findings comparing intermittent and continuous SSD to increase specificity.

Future work should include cost-effectiveness analysis as part of its outcomes and should also address the growing recognition that a mixed-methods approach can enable a better understanding about why an intervention may or may not work (Aveyard, 2014).

Recommendations for practice

Nursing practice implications remain unclear. Although CSS may better prevent late-onset VAP, this is not the case for early-onset VAP. The absence of any clear benefit in preventing early-onset VAP might suggest that CSS should not be used for short intubation periods such as during surgery but it is often hard to estimate the likely duration of invasive ventilation.

The poor patient outcomes and health costs associated with VAP make its prevention a priority. The findings of this review support the introduction of SSD into standardised clinical practice; however, the technique is often not used (Muscedere et al, 2011). One potential restriction is the high cost associated with SSD, coupled with financial constraints imposed on the health service (Alp and Voss, 2006). Furthermore, implementation of evidence-based practice depends on behavioural change and requires commitment at individual, managerial and policy level (Michie et al, 2011).

All nurses caring for mechanically ventilated patients should be aware of the tracheal suction methods and adjuncts that can be employed to prevent VAP (Standing, 2014). Nurse managers also have a responsibility to provide the necessary education and training to support evidence-based practice (Care Quality Commission, 2017).

**Conclusions**

VAP is the most common nosocomial infection in ICU and one of the leading causes of ICU mortality. This review compared different tracheal suction methods and adjuncts on the incidence of VAP. Findings identify the potential benefit of CSS over OSS for the prevention of late onset VAP and support SSD as an effective adjunct to reduce VAP. However, there is insufficient evidence available to recommend the standardised use of OSS or CSS. The combination of SSD with other interventions is an area that requires ongoing research. Additionally, policy guidance, effective training, education, and behavioural and managerial strategies for nurses must be implemented focused on VAP prevention.

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