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Effects of Open and Closed Tracheal Suction Systems on the Incidence of Ventilator Associated Events. A Systematic Review

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Abstract

Background: *Intubation is the placement of a flexible tube into a patient's trachea to maintain an open airway and assist with ventilation and oxygenation. The presence of the tube causes increased secretions hence the need for endotracheal suctioning. This is performed by open or closed tracheal suction systems. Various complications occur due to this procedure. These include ventilator associated events (VAE), decreased oxygenation and hemodynamic disturbances.*

Aim: *To compare the effects of open and closed endotracheal suctioning systems on ventilator associated events incidences in adult patients receiving mechanical ventilation.*

Method: *A systematic literature search was done from PUBMED, MEDLINE, CINAHL, EMBASE and Cochrane library databases. This was to identify randomized controlled trials comparing open and closed endotracheal suction systems effects on incidence of VAE. The search was from studies conducted between 2000 and 2017.*

Results: *The search yielded 34 articles of which 10 articles were incorporated into this study. The results showed that there was no significant difference in the incidence of VAE between open and closed suction systems.*

Conclusion: *Although there was no difference in the incidences of VAE, more studies should be conducted on the various aspects of suctioning complications. These will assist the healthcare professionals on selection of the best system to use.*

1. Introduction

1.1. Background Information

Mechanical ventilation is an essential, life-saving therapy for patients with critical illness and respiratory failure in the critical care unit (CCU). Studies have estimated that more than 300,000 patients receive mechanical ventilation in the United States each year (CDC, 2018). Surveillance for ventilator-associated events in the National Healthcare Safety Network (NHSN) prior to 2013 was limited to VAP.

In 2011, CDC convened a Working Group that composed of members of several stakeholder organizations that proposed a new approach to surveillance for Ventilator-Associated Events (VAE) for NHSN. The organizations that were represented in the Working Group included: the Critical Care Societies Collaborative (American Association of Critical-Care Nurses, American College of Chest Physicians, American Thoracic Society, and Society for Critical Care Medicine); the American Association for Respiratory Care; the Association of Professionals in Infection Control and Epidemiology; the Council of State and Territorial Epidemiologists; the Healthcare Infection Control Practices Advisory Committee's Surveillance Working Group; the Infectious Diseases Society of America; and the Society for Healthcare Epidemiology of America(CDC,2017; CDC, 2018).

The VAE surveillance definition algorithm that was developed by the Working Group was

implemented in the NHSN in January 2013. Ventilator associated events (VAEs) are identified by using a combination of objective criteria being deterioration in respiratory status after a period of stability or improvement on the ventilator, evidence of infection or inflammation and laboratory evidence of respiratory infection (CDC, 2018).

Almost 8 to 28% of critically ill patients admitted to the CCU suffer from VAE which increases morbidity, mortality and health system costs. Suctioning of respiratory secretions is a necessary procedure in patients with artificial airways (endotracheal intubation or tracheostomy) to remove respiratory secretions and to maintain permeability of the airway.

Existence of an endotracheal tube causes tissue irritation and increased secretions. Intubated patients experience inadequate effort in coughing out sputum/secretions from the trachea hence they are retained blocking the airway (Finucane&Santora, 2007). Accumulation of secretions is inevitable in intubated patients due to altered defense mechanisms of the upper airways and impaired cough reflex. Clearance of airway secretions is a normal physiological process needed for the preservation of airway patency and the prevention of respiratory tract infections (Jelic S et al, 2008).

Mechanical ventilation and maneuvers such as endotracheal suctioning are contributing risk factors for VAEs. Ventilator associated event is a common complication in ventilated patients that increases the cost of care, length of hospital stay and is associated with high morbidity and mortality rates. Any strategy to reduce its occurrence is worth considering. VAE is a common nosocomial infection in the CCUs with an incidence ranging from 6.8 to 44% (CDC, 2017; CDC, 2018; Jongerden I et al, 2007).

1.2. Endotracheal Suctioning

Maintaining airway patency is the primary goal of nursing care to patients intubated and mechanically ventilated as accumulation of secretions is inevitable in intubated patients. Endotracheal suctioning is one of the most common procedures performed in critically ill patients. It is performed 8 to 17 times a day on the patients admitted in the critical care unit. It is an intervention requiring specific knowledge based on valid scientific evidence and technique (AARC, 2010; Pedersen M et al, 2009).

Despite endotracheal suctioning being a necessary procedure, it can lead to complications which include hypoxemia, hemodynamic changes, cardiac and respiratory arrest and respiratory tract infections. Despite the evidence based protocols and instructions, low knowledge of nurses about endotracheal tube suctioning is considered as the main cause of these complications (PagottoB et al, 2008).

1.3. Types of Tracheal Suction Systems

Endotracheal suctioning is accomplished by use of two types of suction systems, a single-use open tracheal suction system (OTSS) or a multiple-use closed tracheal suction system (CTSS). Whether CTSS reduces the incidence of ventilator-associated events (VAE) compared with the OTSS is inconclusive and studies should be conducted to make a conclusion on this aspect of patient care.

1.3.1. Open Tracheal Suction System (OTSS)

This type of suctioning is performed by disconnecting respiratory circuits and using a sterile single use suction catheter to suction sections from the patient's endotracheal or tracheal tube. This is associated with inability to maintain positive end expiratory pressure (PEEP), infections (VAE) and cardiac arrhythmias (CDC, 2018; CDC, 2017; Jongerden I et al, 2007; LasockiS et al, 2006).

Figure1. *Open tracheal suction system (OTSS)*

1.3.2. Closed Tracheal Suction System (CTSS)

This type of suction system was developed to minimize the complications of the OTSS with specific interest in VAE. This was introduced in the late 1980's to more safely suction intubated and mechanically ventilated patients as a multi-use catheter. In 2003, respiratory care society of the USA strongly recommended CTSS as one of the preventive strategies for VAE. There are studies suggesting low evidence for prevention of VAE with CTSS. Other studies have shown that CTSS should be changed every 48 hours concluding that further trials are required to

include CTSS in VAE prevention guidelines. Closed tracheal suction system (CTSS) permits the health care providers to perform suctioning several times without disconnection from ventilator thus, it decreases hypoxemia and infection rate. Primary studies have shown that CTSS could result in lowered pneumonia rates because of lower incidence of intervention in respiratory circuit (CDC, 2017; CDC, 2018; Siempos I, 2008; Jongerden I et al, 2007).

In CTSS, the catheter is part of the ventilator circuit which is a sterile, closed, in line suction catheter to the ventilator circuit allowing passage of suction catheter through the artificial airway without disconnecting the patient from the ventilator during suctioning. It is introduced into the airways through a one way valve. This system can stay for as long as 24 hours or as per the manufacturer's instructions. This type of suction system has comparatively fewer physiological disturbances and provides ease of use given that only operator is required for suctioning (Jongerden I et al, 2007; LasockiS et al, 2006; Maggiore S et al, 2003; Maggiore S, 2006).

However, regarding the selection of one of the suction system over the other is not conclusive. There are some ambiguities since each of the systems has advantages and disadvantages though there are controversial results about the superiority of one system over the other. In CTSS there are some benefits like improved oxygenation, decreased clinical signs of hypoxemia, maintenance of positive end expiratory pressures (PEEP), limited environmental and patient contamination and reduced pulmonary infections. This system is also easy to apply since it only needs one nurse to operate. There is also less possibility of aspiration compared to OTSS. Though the CTSS has some flaws such as higher cost, less efficacy to remove secretions and it causes unpredictable high level of interstice positive end-expiratory pressure (LorenteL et al, 2006).

In recent decades, the CTSS has been gaining popularity in the developed countries compared to developing ones. In the United States, the CTSS is used in approximately 58% of CCUs, but there is no evidence to support CTSS superiority over OTSS (Jongerden I et al, 2007). There is no evidence on the use of these system of endotracheal suctioning in the developing countries. The most commonly used in Africa is the OTSS, that requires at least two nurses to operate and may lead to infections, temporary disruption of ventilation and oxygen supply due to disconnection during suctioning (AlfasiriJ et al, 2014).

Studies have shown that using CTSS results in a higher rate of colonization without the incidence of VAE (Topeli A et al. 2004, Deppe S.A et al. 1990). Other studies have suggested that CTSS does not increase colonization of lower respiratory tract, yet it reduces the spread of infection in ICUs (Adams D. et al, 1997).

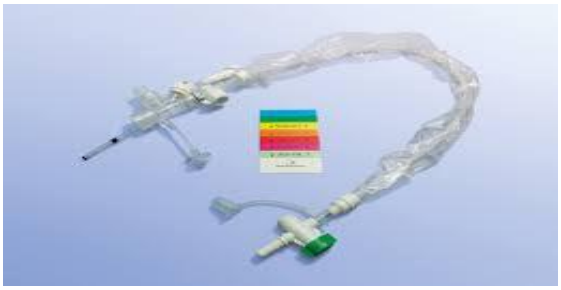

Figure2. *Closed tracheal suction system (CTSS)*

2. AIM OF THE STUDY

The aim was to assess if there was any difference between closed tracheal suction system and open tracheal suction system with respect to VAE incidences.

2.1. Method

A systemic review of electronic literature for articles published on CTSS and OTSS was done guided by recommendations of Cochrane collaboration. The search was carried out in the MEDLINE, CINAHL, EMBASE, Cochrane library databases.

The review question was based on population, intervention, comparison, outcome (PICO). The search strategy considered sets of terms related to the study population being adult intubated and mechanically ventilated patients (P), intervention evaluation being open tracheal suction systems (I), type of studies included (RCTs), exclusion of pediatric and neonatal studies, comparison being the closed tracheal suction (C) and outcome being incidences in VAE (O).

The search was carried out using the **search items**; endotracheal suctioning, tracheal suctioning, closed tracheal suction system, open tracheal system, randomized/clinical trials, ventilator associated events/ventilator associated pneumonia and gram negative bacteria.

The selection of studies was carried out for potential review of their titles that suggested

relevance to the search question. Based on the titles, abstracts studies were selected for inclusion or exclusion to the review. Abstracts were then reviewed and those pertaining to open/closed suction were retrieved and read in full articles. If abstracts were not available, full articles were selected based on their titles. Data was extracted from the selected studies using a predefined checklist and this included the general information on the study, study design, description of the participants, interventions, outcome measures and results.

Inclusion Criteria: Studies of randomized controlled trials (RCT) published in English, undertaken on adult patients (above 18 years). Only trials reporting on intubated patients who were undergoing mechanical ventilation and those that addressed incidences of VAE were included.

Exclusion Criteria: Randomized controlled trials (RCTs) performed in children or infants, non-English articles and studies with methodologies other than trials.

2.2. Hypothesis

There is no differences in ventilator associated events (VAE) in patients suctioned using closed tracheal and open tracheal suction systems.

3. Results and Discussion

Closed tracheal suction system (CTSS) is increasingly replacing the OTSS for bronchial toilet and suctioning in intubated and mechanically ventilated patients. The advent of CTSS has emerged as an alternative to the OTSS since it was believed that the open system was a facilitator in the increase of ventilator-associated events (VAEs). Whether CTSS reduces the incidence of VAE compared to the OTSS is inconclusive. This lead to the current systematic review of the randomized controlled trials (RCTs) that compared the two systems.

The results showed that there was an evidence that CTSS was responsible for the lowest occurrence of VAE compared to OTSS though it was not statistically significant.

VonbergP et al. (2006) reported in their study that there was no significant advantages for selecting either type of suction system in preventing VAE. In their study, 648 patients were selected for the OTSS group and 644 for the CTSS group. VAE occurred in 128 (20%) of the OTSS group and 120 (19%) in the CTSS group with a RR of 0.95. They concluded that there was a prevalence of VAE of 20% in CCU patients with no significant advantage for the use of either suctioning system. Hence there was no difference in the incidence of VAE in the OTSS and OTSS.

It is unknown whether CTSS as compared with OTSS prevents cross transmission of bacteria in intubated patients on mechanical ventilation. Jongerden I et al. (2012) stated that there is controversy regarding the efficacy of these systems in reducing infections. They conducted a study to determine whether CTSS as compared with the OTSS reduced the incidence of cross-transmission of Gram-negative bacteria in intensive care unit. The study was conducted on 1,110 patients (585 in the CTSS group and 525 in the OTSS). Acquisition for selected Gram-negative bacteria was 35.5 and 32.5 per 1,000 patient-days during closed suction period and open suction period respectively (95% CI, 0.9-1.4). They concluded that CTSS failed to reduce cross-transmission and acquisition rates of the most relevant Gram-negative bacteria in the critical care unit patients. The outcomes also analyzed the incidences of VAE in which there was no difference when the two systems were compared. Hence, concluding that there was no difference in VAE incidences between the two systems.

Elmansoury A and Said H (2017), also conducted a study to compare the CTSS with the OTSS on the incidences of VAE. The incidence of VAE for the group under OTSS was 30.13/1000 ventilator days not statistically significant in comparison with those in the group with CTSS who had a VAE incidence of 17.48/1000 ventilator days. They concluded that there was no statistically significant difference in the incidence of VAE between the two groups.

Suctioning performed via closed system increased the incidence of colonization but not nosocomial pneumonias and eventually decreased mortality compared to the open system (Deppe et al, 2010).

Subriana M, et al (2007) conducted another study to compare the CTSS and OTSS in patients receiving mechanical ventilation for more than 24 hours. The two tracheal suction systems showed that there was no difference in the risk of VAE (RR 0.88; 95% CI 0.70 - 1.12). The CTSS produced higher bacterial colonization rates than the OTSS (RR 1.49; 95% CI 1.09 - 2.03). Hence, they concluded that

there was no statistical difference in the incidence of VAE in patients suctioned using OTSS and CTSS. They also reported that suctioning by use of either closed or open tracheal suction system did not have an effect on the risk of VAE.

In developing countries where there is resource limitations and constrain on provision of optimal bed space for critically ill patients, CTSS assumes greater importance in such settings. Deepu D, et al. (2011) conducted a study to compare CTSS with OTSS on outcome of VAE incidence. In their study two hundred (200) patients were recruited, of which 100 were selected for each suction system. The incidence of VAE was 23.5%. Closed endotracheal suction system (CTSS) was associated with reduced incidence of VAE (OR = 1.86; 95% CI, 0.91-3.83; *P* = 0.067). However, a significant benefit was observed with CTSS for late-onset VAP (*P* = 0.03). A conclusion was made to indicate that there was no difference in VAE incidences between the two suction systems.

Hamishekar H et al. (2014), conducted a study on 100 patients who were randomly allocated into two groups, CTSS and OTSS. Patients were monitored for developing VAE during the study. Among these patients, development of VAE was 20% and 12% in the OTSS and CTSS groups, respectively (P > 0.05). Use of CTSS compared with OTSS did not show statistically significant effect on VAE incidence in multivariate analysis. However, OR tended to identify OTSS as an exposure factor for the development of VAE (OR = 1.92; CI = 0.45-8.30; = 0.38) compared with the CTSS. Based on these results, the impact of suctioning is similar between CTSS and OTSS regarding the occurrence of VAP. Hence, there was no difference in the incidence of VAE between the two groups.

In another study conducted by Lorente L, et al (2005) to analyze the prevalence VAE using a CTSS vs. an OTSS, CTSS did not reduce VAE incidence. A total of 443 patients (210 with CTSS and 233 with the OTSS) were included. No significant differences were found in either the percentage of patients who developed VAE (20.47% vs. 18.02%) or in the number of VAE cases per 1000 mechanical ventilation-days (17.59 vs. 15.84). Hence, they concluded that there was no difference in the incidence of VAE among patients suctioned using either type of suction system.

In the most recent guidelines for preventing health-care-associated pneumonia published by the Centres for Disease Control and Prevention, the preferential use of either the CTSS or OTSS for VAE prevention was considered as an unresolved issue. In the year 2003, the American Association for Respiratory Care's made a recommendation of CTSS being considered part of a VAE prevention strategy (Hess D.R et al, 2003). The Canadian Critical Care Trials Group and the Canadian Critical Care Society in the year 2004 concluded that the type of TSS (closed or open) has no effect on VAP incidence but they encouraged the use of CTSS based on cost considerations (Dodek P. et al, 2004).

4. Conclusion

Ventilator associated events (VAE) is a main source of concern in critically ill patients due to its high mortality and frequency. Our study results showed that the incidence of VAE did not have any significant difference between OTSS and CTSS.

It is also concluded that closed tracheal suction system is unlikely to be inferior to the open suction system regarding VAE prevention, hence further trials at low risk of bias are recommended to confirm or refute these findings.

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