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Suction System Flushing with Chlorhexidine and Prevention of Ventilator Associated Pneumonia: Current Evidence

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1.ABSTRACT

Ventilator associated pneumonia is a problematic issue in intensive care unitsall over the world as it prolongs the duration of mechanical ventilation, increases patients' length of stay in intensive care unit, and health care costs. Ventilator associated pneumonia is reported to affect 5% –40% of mechanically ventilated patients. The estimated attributable mortality of ventilator associated pneumonia is around 10%, with higher mortality rates among patientsin surgical intensive care units. This literature review aims to present an overview summary of ventilator associated pneumonia and its care bundleas well as general preventive measuresthat have been investigated in many studies, highlight the integration of chlorhexidine in the care of critically ill patients and its effect on ventilator associated pneumonia occurrence, discussendotracheal suctioning procedure and its role in the pathogenesisof ventilator associated pneumonia, andfinally illustrate the role of the critical care nurse in prevention of ventilator associated pneumonia via suctioning.

Keywords: *Ventilator Associated Pneumonia, Chlorhexidine, Endotracheal Suctioning, Suction Circuit Flushing.*

2.Introduction:

Literature Searching Strategy

The authors searched electronic medicaland health care databases, including Google Scholar, ScienceDirect, PubMed, Cochrane library, Clinical key, Pro Quest, andMedline, to find appropriate relevant literature on this subject. As keywords, the following search phrases were used: "Intensive Care Unit," "Hospital Acquired Infection," "Ventilator Associated Pneumonia," "Chlorhexidine," "Endotracheal Suctioning," "Suction Circuit Flushing," "Suctioning," "Endotracheal Tube," and "VAP Bundle,".

Literature Review

This review will cover the following sections:

- Section I: Ventilator Associated Pneumonia: Overview and Preventive Measures
- Section II: Endotracheal Suctioning
- Section III: Nursing Role in Prevention of VAP via Suctioning

Section I: Ventilator Associated Pneumonia: Overview and Preventive Measures

Definition and Incidence

Ventilator associated pneumonia as defined by **theUnited States (US) Centre for Disease Control and Prevention (CDC, 2018)** "it is pneumonia that develops 48 hours or more after the initiation of mechanical ventilation (MV)". Also, it means hospitalized patients, intubated for 48 hours after which develop signs of lung infection, including new or progressive radiographic infiltrates, new onset fever, purulent tracheobronchial secretions, leukocytosis and decreased oxygenation **(Koenig & Truwit, 2006; Morton & Fontaine, 2017)**.

To rely on a more objective data, another proposed definition for VAP surveillance delineated a worsening oxygenation after a period of stability or improvement for at least two days. In which, worsening oxygenation can be recognized by increased daily FiO_2 or minimum positive end expiratory pressure (PEEP) **(Klompas, 2013)**.

In Egypt, a recent study initiated with 222 patients in intensive care unit (ICU) reported that 125 patients were intubated because of MV need, and 48 (38.4%) of 125 patients fulfilled the criteria of VAP **(Elkolalya, Bahra, El-Shafeya, Basuonib, & Elberc, 2019)**. Another study done at Mansoura University Hospitals showed that the incidence of VAP was about 22.6% **(Abdelkader, 2002; as cited in Fathy, Abdelhafeez, EL-Gilany, & Elhafez, 2013)**.In addition, a clinical investigation carried out in Zagazig University Hospitals reported VAP incidence of 48.8 incidences/1000 ventilator days **(Azzab, El-Sokkary, Tawfeek, & Gebriel, 2016)**. Despite differences in age, causative organisms, risk factors, as well as duration of ventilation and ICU stay between the above-mentioned studies populations, it clarifies the high incidence of VAP in Egypt.

Pathogenesis of VAP

Nurses should be aware of the pathophysiology of VAP in order to understand and follow VAP prevention strategies. The pathophysiology of VAP starts with bacterial colonization of oropharynx and then the microaspiration of secretions to the tracheobronchial tree, where bacteria multiplies and cause invasive lung disease **(Osti, Wosti, Pandey, & Zhao, 2017)**.

Regarding colonization of the oropharynx, it occurs due to multiple factors such as lack of oral care, prolonged intubation, patients inability to clear secretions, and the presence of ventilator tubing which can become contaminated with secretions and act as a reservoir for bacterial growth and subsequently promote upper airway colonization **(Morton & Fontaine, 2017)**. The realization that VAP begins with oropharynx colonization promoted the introduction of oral decontamination measures for mechanically ventilated patients (MVPs), which is now a standard care **(Marino & Galvagno, 2017)**.

Concerning microaspiration, there are two routes for that process. An endogenous route caused by accumulation of oropharyngeal contaminated secretions and leakage around endotracheal tube (ETT) cuff or biofilm formation inside the ETT. whereas, the other route is exogenous and caused by contamination during endotracheal suctioning (ETS) or ventilator circuit disconnection for aerosols performance or even patient transport **(Rouzé, Martin-Loeches, & Nseir, 2018)**. Aspiration around inflated ETT cuff promoted the introduction of subglottic suctioning. In addition, suctioning should not be performed as a routine maneuver to reduce contamination **(Marino & Galvagno, 2017)**.

Due to the presence of bacteria in the lower airway, the body's ability to filter and humidify air will decrease. In addition, because of the presence of ETT, the cough reflex is frequently decreased. Subsequently, colonization of organisms will be formed inside the lungs which will invade lung parenchyma leading to infection**(Morehead& Pinto, 2000)**. VAP prevention has a key focus of decreasing microaspiration and reduce microorganisms introduction into the lower airways from contaminated equipment **(Aitken, Marshall, & Chaboyer, 2019)**. Therefore,understanding VAP pathogenesis as shown in figure 1 is crucial for critical care nurses (CCNs).

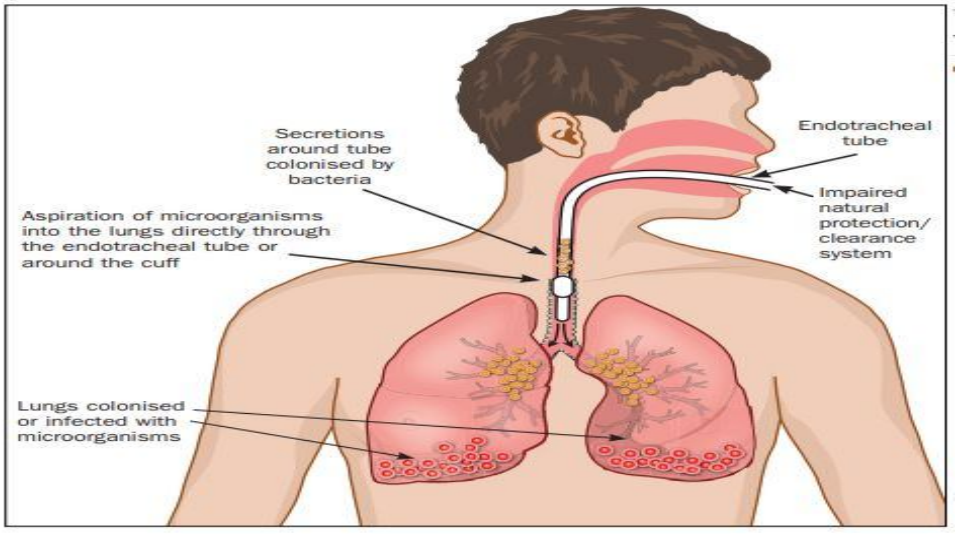

Figure 1. **Pathogenesis of VAP**

Adopted from "Does oral care with chlorhexidine reduce ventilator-associated pneumonia in mechanically ventilated adults?" byL. Jackson, &M. Owens, (2019)**.***British Journal of Nursing*, *28*(11), P. 683.

Causative Organisms of VAP

Early onset VAP (E-VAP) results from aspiration and usually have a better prognosis. It is most often caused by pathogens similar to community-acquired pneumonia causative organisms including Streptococcus pneumonia, Methicillin-sensitive Staphylococcus aureus, Escherichia coli, Hemophilus influenza, Klebsiella pneumonia, and Proteus species**(Kabak et al., 2019)**. Whereas late onset VAP (L-VAP), is often caused by microbes from the hospital environment including multidrug-resistant pathogens including Oxacillin resistant staph. aureus, Pseudomonas aeruginosa, Acinetobacter baumannii, and Methicillin-resistant S. aureus**(Aitken et al., 2019; American Thoracic Society [ATS],& Infectious Diseases Society of America [IDSA], 2005)**.

It is claimed that, E-VAP is usually caused by community acquired pathogens, whereas L-VAP involves hospital flora **(Ramsamy & Muckart, 2017)**. The most common causative organisms of VAP are gram negative bacteria which have high resistance to commonly used antibiotics in ICU. Therefore, awareness of causative organisms of VAP will help targeting it with appropriate antibiotics to reduce VAP occurrence **(Khoshfetrat, Keykha, Sedaghatkia, Farahmandrad, & Behnampour, 2020)**.The accurate and timely administration of antibiotics directly impacts the patient's outcomes. In critically ill patients, the first antibiotics dose should be administered within an hour of VAP diagnosis **(Aitken et al., 2019)**. Therefore, awareness of VAP causative organisms is compulsory for VAP management and essential knowledge for CCNs.

Risk Factors of VAP

Ventilator associated pneumonia can prolong the patient's length of hospital stay and ventilator weaning difficulties, which represents a considerable financial burden to patients. Therefore, it is very important to clarify VAP risk factors for further knowledge and better prevention and control **(D. Wu, Wu, Zhang, & Zhong, 2019)**.

Risk factors can be differentiated into modifiable and non-modifiable risk factors. Modifiable risk factors have a greater value in the nursing field because they have a potential opportunity for intervention. It includes conditions which enhancing aspiration of secretions from gastrointestinal tract to the lower respiratory tract such as enteral feeding, supine position, and tracheal intubation**(ATS & IDSA, 2005)**. Therefore, interventions such as elevating the head of the bed to 45° have been proposed as a preventive VAP strategy.

Additionally, non-modifiable risk factors include patient or treatment related. Patient-related non-modifiable factors include sex, extremes of age, altered level of consciousness, malnutrition, and immunosuppression. While, treatment-related non-modifiable risk factors involve reintubation, nasogastric tube insertion, and transportation out of the ICU **(Morton & Fontaine, 2017)**. Although these are uncontrolled factors, we believe that awareness of CCNs for such elements will be reflected on a more cautious nursing interventions and adherence to evidence-based practice when caring for MVPs.

Diagnosis of VAP

Ventilator associated pneumonia can be difficult to diagnose, as clinical features can be non-specific and other conditions may cause infiltrates on chest X-rays. Additionally, ambiguity in the definition of VAP has led to inconsistencies in interpretation and application of the definition **(Aitken et al., 2019)**. Traditionally, VAP diagnosis is defined by the concomitant presence of the three following criteria: clinical suspicion, positive lower respiratory tract culture result, and new or progressive radiographic infiltrates**(Kalil et al., 2016; Torres et al., 2017)**.

Scores have been proposed for improving the diagnostic accuracy. The most used one is the clinical pulmonary infection score (CPIS) that was developed by **Pugin et al. (1991)**. The original description of CPIS was based upon six variables including the temperature, white blood cells count, the volume and quality of tracheal secretions, chest radiographic infiltrates, oxygenation, and semiquantitative cultures of tracheal aspirates with gram stain for diagnosis of VAP. Patients with a total score more than 6 were considered having VAP **(Singh, Rogers, Atwood, Wagener, & Yu, 2000)**.

The CPIS combines the clinical, physiological, microbiologic, and radiographic data into a single numerical finding, each worth 0-2 points. When the CPIS result becomes more than 6 points, it is associated with a sensitivity of 72% and

a specificity of 85% for tendency of pneumonia **(Divatia, Pulinilkunnathil, & Myatra, 2020)**. Ambiguities in the CPIS scoring system or missing required data to calculate the CPIS could result in large inter-observer variability. Another drawback of the CPIS is its association with a delay of 24-48 hours for the results of tracheal aspirate cultures**(Moustafa, Tantawey, El-Soussi, & Ramadan, 2016)**.

Therefore, **Singh et al. (2000)** proposed the modified CPIS that includes only five clinical elements, using diagnostic criteria of radiographic infiltrates and at least two of the three following clinical features of VAP: fever greater than 38° C; leukopenia or leukocytosis; decreased saturation, and purulent tracheal secretions. The use of these criteria resulted in a 69% sensitivity and a 75% specificity for VAP**(Koenig & Truwit, 2006)**.

General Preventive Measures of VAP

Prevention of VAP is a key emphasis in the care of MVPs. There are a growing number of evidence-based strategies for VAP prevention, which if applied in practice, can reduce the occurrence of this serious nosocomial infection**(Aitken et al., 2019; Muscedere et al., 2008)**.The risk of VAP occurrence is 3% per day during the first five days of MV, 2% per day for days 6-10, and 1% per day for the rest of the days. Therefore, VAP prevention strategies are best achieved by preventing or minimizing the MV duration **(Torres et al., 2017)**. Various strategies have been described to minimize VAP,these include hand washing, ETT modifications, ventilator circuit change, MVPs' position, subglottic suctioning, the use of probiotics, and the administration of prophylactic antibiotics.

Hand Washing

Hand washing before and after any contact with the patient or related devices has an extremely important role in reducing the incidence of nosocomial infection. In a recent multicenter study, hand hygiene resulted in decreasing all respiratory tract infections by 36.3 infections/1,000 device days **(Finco et al., 2018)**. Hand washing using soap and water is the best way to kill organisms in many situations. If soap and water are not available, it is recommended to utilize an alcohol based hand sanitizer which contains at minimum 60% alcohol **(CDC, 2021a)**.

Gloves are not a substitute for hand hygiene, it is recommended to perform hand hygiene prior to donning gloves, before touching the patient or his/her environment **(CDC, 2021b)**. The importance of hand washing as well as donning gloves prior to suctioning procedure and contact patient's secretions has been recommended to reduce health care infection. However, pathogens may gain access to the caregivers' hands via small defects in the gloves or by hands contamination during the removal of gloves. Therefore, hand washing is recommended after glove removal **(World Health Organization [WHO], 2009)**.

Endotracheal Tube modifications

The presence of ETT is considered the most responsible factor for VAP development. Pathogens are migrated through it directly to the trachea, and defense mechanism of host such as cough reflex and tracheal cilia movement are blunted due to the intubation process**(Pneumatikos, Dragoumanis, Bouros, Warner, & Warner, 2009)**.In critically ill patients the presence of ETT is usually unavoidable. Therefore, VAP prevention is based on the limitation of ETT associated medical treatment complications **(Coppadoro, Bellani, & Foti, 2019)**.

A large randomized controlled trial (RCT) investigated 2003 patients' reported that ETTs coated with silver were effective in preventing VAP occurrence **(Kollef et al., 2008)**. In addition, another trial noted reduced ETT colonization and thinner biofilm layer utilizing silver sulfadiazine coated ETTs **(Berra et al., 2008)**.

A recent systematic review and metanalysis of RCTs investigated the effect of ETT with tapered cuff in the prevention of VAP and reported no significant difference between study groups**(Maertens, K. Blot, & Blot, 2018)**. Theoretically, the conical cuff as shown in figure 2, allows the elimination of a full lower circumference of the trachea/cuff contact zone. But, the outer diameter of the cuff still playing a significant sealing efficacy role, because the sealing zone is achieved when the diameter of cuff approximates the internal diameter of trachea **(Bassi, Senussi, & Xiol, 2017)**.

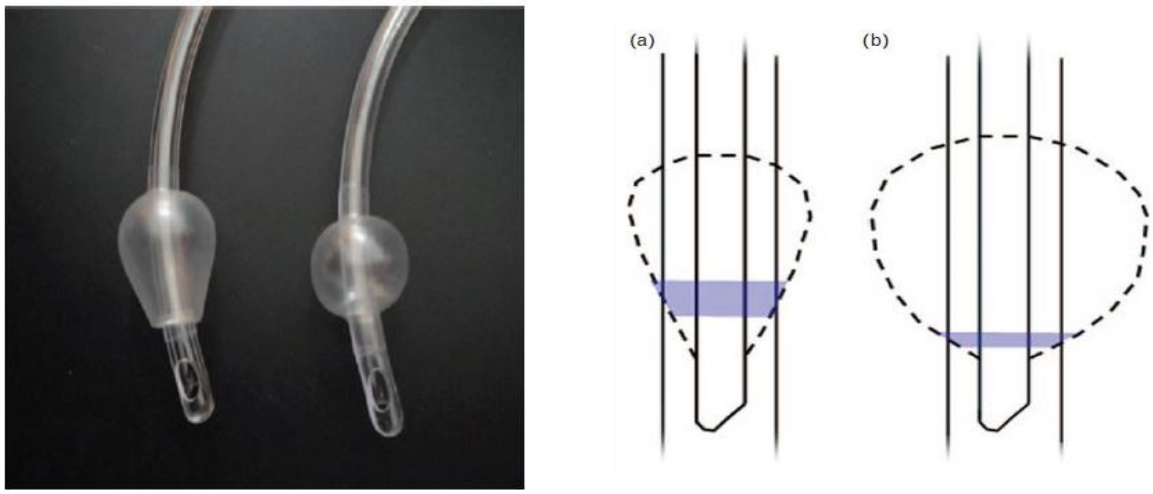

Figure 2. **(A) Conical Shaped ETT Cuff. (B) Standard Spherical Shaped ETT Cuff.**

Adopted from "Prevention of ventilator-associated pneumonia" by G. Bassi, T. Senussi, &E. Xiol, (2017). *Current Opinion in Infectious Diseases*, 30(2), P. 216.

Critical care nurses are responsible for ETT care including appropriate cuff pressure monitoring and preventing its slippage or migration. Therefore, its crucial for CCNs to have sufficient knowledge and skills concerning ETT care.

Ventilator Circuit Change

Another location for bacterial colonization is the ventilator circuit itself. A recent study reported that bacterial colonization inside the ventilator circuit itself is a significant cause in the development of VAP **(Pen et al., 2021)**. Therefore, research studies have been conducted to investigate the appropriate interval for changing the ventilator circuit and the development of VAP.

Generally, it is recommended that ventilator circuits should not be changed routinely, but only when the equipment is visibly soiled or malfunctioned **(CDC,2003)**. In addition, an observational cohort study reported that changing the circuit within two days versus a week interval is not associated with decreasing the risk of VAP **(Chu et al., 2015)**. Moreover, a single center retrospective study investigated daily versus a weekly interval and also showed no change in VAP rates **(Sharma, Rawat,Vijhani, &Thakur, 2018)**.

In pediatrics, a prospective RCT investigated three days versus a week interval and reported no association with decreasing VAP occurrence **(Samransamruajkit et al., 2010)**. In addition, a recent systematic review and meta-analysis in neonates and children reported that extending the interval of ventilator circuit changes to "once weekly" may not increase the incidence of VAP**(Abiramalatha, Ramaswamy, Thanigainathan, Pullattayil, & Kirubakaran, 2021)**.

Additionally, a prospective RCT compared the effect of disposable and non-disposable ventilator circuit on VAP incidence and showed that the type of ventilator circuit is not likely to affect the VAP incidence and mortality in children **(Srisan & Meechaijaroenying, 2017)**. Moreover, another study reported that both the reused and disposable ventilator systems had a high bacterial contamination rate after one week of use **(Li et al., 2018)**.

Critical care nurses are responsible for ventilator circuit change. Therefore, it is mandatory for nurses to be oriented with recent findings concerning the appropriate interval for circuit change to minimize VAP occurrence as well as the health care cost.

Positions for MVPs

The preferable position for MVPs is usually a semi-sitting position (30 degrees) to prevent vomiting and subsequently reduce the leak of gastric contents within the patient's airways. A Cochrane review confirmed that the semi-sitting/recumbent position is better than the supine position (0 degree) for VAP prevention **(Wang et al., 2016)**.

The lateral, and Trendelenburg positions were investigated as alternative positionsfor VAP prevention. When the level of patient's head is lower than the level of the airways, vomiting does not result in leakage of gastric material into the airways and clearance of tracheal secretions is

improved **(Coppadoro et al., 2019)**. Additionally, a recent RCT reported a reduced VAP incidence in the lateral-Trendelenburg group; however, that trial was prematurely stopped due to lower overall incidence of VAP in both groups and increasedadverse events in the treatment group **(Bassi et al., 2017)**. Therefore, current evidence does not support any position for MVPs other than the semi-sitting/recumbent position.

Subglottic Suctioning

Secretions hailing from the oropharynx tend to accumulate in the glottis just above the ETT cuff. When the cuff seal is not properly inflated, secretions can leak into the trachea leading to transport of pathogens inside the lung **(Aitken et al., 2019; Urden, Stacy, & Lough, 2019)**. Concerns about aspiration around inflated cuffs promoted the introduction of specialized ETT equipped with a suction port just above the cough **(Marino & Galvagno, 2017)**.

Subglottic suctioning as seen in figure 3, requires specialized tubes to allow continuous subglottic secretions removal, which is connectd to a continuous (-20 to -30 cmH_2O) suction. These tubes are recommended for patients who require intubation for more than 48 – 72 hours **(Urden et al., 2019)**. In addition, a recent evidence suggests that subglottic secretions contains mucin which impairs the activity of neutrophil against bacteria, exposing patients to increased infectionrisk **(Powell et al., 2018)**.In a smaller study, the drainage system of subglottic secretions either alone or combined with cuff pressure frequent monitoring or utilizing a tapered cuff shape was associated with low VAP occurrence **(Mahmoodpoor et al., 2017)**.

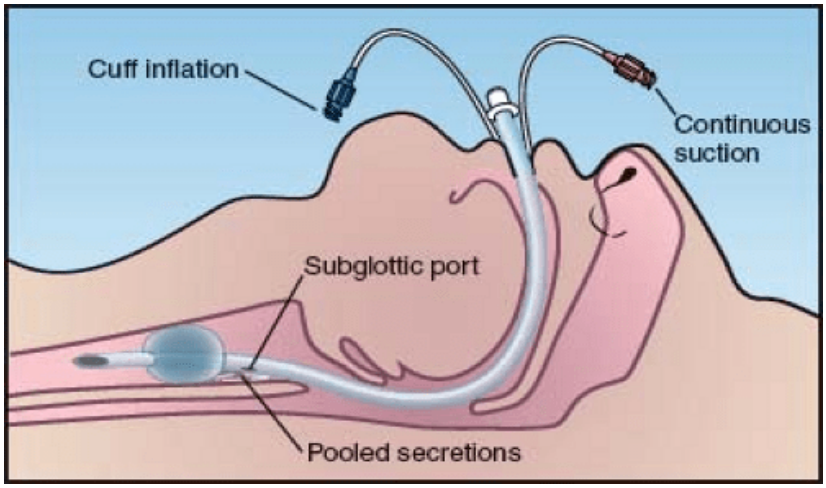

Figure 3. **Subglottic Suctioning System**

Adopted from "Marino's the little ICU book, 2nd ed." byP. Marino, &S. Galvagno, (2017). Philadelphia: Wolters Kluwer, p. 297.

Probiotics

Probiotics are microorganisms that can be administered either as individual strains or in various combinations **(Bassi et al., 2017)**. A large meta-analysis study pooled data from 30 RCTs in 2972 patients, and a significant reduction in the incidence of VAP was found with the use of probiotics **(Manzanares, Lemieux, Langlois, & Wischmeyer, 2016)**.

A multicenter RCT that was conducted in 11 ICUs including 235 patients confirmed that 36.4% of the patients receiving the probiotics capsules developed VAP, compared to 50.4% in the control group patients **(Zeng et al., 2016)**. However, we believe that large-scale RCTs are still needed to provide definitive recommendations regarding the use of probiotics in critically ill patients.

Prophylactic Antibiotics

The use of prophylactic antibiotics either intravenous, inhalation, or oral administration with the purpose of eradicating the endogenous pathogen colonization has been investigated in multiple attempts throughout the past years for VAP ultimate prevention. However, it is recommended that any unnecessary use of antibiotics should be restricted **(Bassi et al., 2017)**.

A randomized controlled trial investigated the administration of inhaled colistin, or physiological saline including 168 patients illustrated that, VAP was developed in 16.7% of the patients in the colistin group and 29.8% of the saline group. Therefore, it has been reported that antibiotics could prevent VAP occurrence, particularly if nebulized, but, there is an increased

risk for long-term development of further antibiotic resistance **(Karvouniaris, Makris, Zygoulis, Petinaki, & Zakynthinos, 2015)**.

Care Bundle

Care bundle was originally described as a group of several evidence-based practices (usually three to five), when used in combination, achieve a greater effect on the positive outcome of patients. Care bundles provide a method for establishing the best clinical practices, which in theory will improve the clinical effectiveness of intervention**(Resar, Griffin, Haraden, & Nolan, 2012)**. Furthermore, there is a level III evidence that successful implementation of care bundle results in decreased VAP rates**(Aitken et al., 2019)**.

The VAP bundle, which is driven from the **Institute for Healthcare Improvement** (**IHI, 2012)** involves five elements including elevation of the head of the bed to 45 degrees, daily sedation vacation and assessment of readiness to extubate, stress ulcer prophylaxis (SUP), deep venous thrombosis (DVT) prophylaxis, and daily oral care with Chlorhexidine (CHX).

Elevation of the Head of the Bed to 45degrees

It is recommended that a semi-recumbent patient position is more practical and more tolerable than supine position in reducing VAP occurrence**(Allen, 2020; Wang et al., 2016)**. In addition, another study reported that head elevation by 45° degrees did not show superiority in reducing the risk of VAP than 25-30° degrees elevation**(Leng, Song, Yao, & Zhu, 2012)**. Moreover, a recent study reported that elevation less than 30° should be avoided unless medically indicated **(Güner & Kutlutürkan, 2021)**.

Elevating the head of the bed more than 30° reduces the aspiration and clinically confirmed VAP **(Wang et al., 2016)**. Furthermore, another study reported that early elevation of the head of the bed was associated with a lower rate of tracheal pepsin which is a marker for gastric secretion aspiration **(Garland, Alex, Johnston, Yan, & Werlin, 2014)**. Moreover, a recent RCT reported that elevation of 45 degrees was effective in preventing VAP. Hence, it is recommended that MVPs should be positioned 45 degrees according to their conditions **(Najafi Ghezeljeh, Kalhor, Moradi Moghadam, Lahiji Niakan, & Haghani, 2018)**.

Daily Sedation Vacation and Assessment of Readiness to Extubate

Continuous sedation infusion is required for MVPs to ameliorate symptoms of anxiety and stress associated with critical illness. Consequently, these patients are at risk of receiving excessive sedation. Additionally, they are susceptible to prolonged ventilation and VAP occurrence due to suppression of coughing reflex and the high risk for aspiration **(Urden et al., 2019)**.

Daily sedation interruption (DSI) has been proposed as one of the main components of VAP bundles for VAP prevention among MVPs. DSI is implemented through thediscontinuation of sedation medication either completely or partially at a fixed time, for a period of five hours, while ensuring a Richmond Agitation Sedation Score (RASS) value between zero and two **(Isac, Samson, & John, 2021)**.

A clinical trial investigated 80 MVPs reported that patients exposed to DSI had 0% VAP incidence on their third day of MV, compared with 15% incidence among their counterparts with the routine sedation interruption **(Shahabi, Yousefi, Yazdannik, & Alikiaii, 2016)**. In addition, a recent review reported that incorporating DSI in the care of MVPs seems beneficial to the facilitation of the weaning process **(Vagionas et al., 2019)**. However, a mini systematic review reported that the application of DSI did not appear to affect the duration of MV, the length of ICU stay, and mortality rate **(Satolia & Alefragkis, 2020)**.

Moreover, not every patient is a candidate for DSI. There are some contraindications including increased intracranial pressure, hemodynamic instability, ongoing agitation, seizures, and use of neuromuscular blocking agents **(Urden et al., 2019)**.

Stress Ulcer Prophylaxis

Upper gastrointestinal (GI) bleeding due to stress ulcers is a major contributor to increased illness severity and death among ICUs patients. MVPs face a high risk for stress ulceration, therefore SUP was included in the VAP bundle although it is not a specific VAP prevention strategy. It also prevents stress-related mucosal disease due to MV**(Toews et al., 2018)**.

The use of SUP is recommended for MVPs. Accordingly, SUP is widely used in ICU, proton-pump inhibitors and histamine-2-receptor antagonists are considered the most frequently prescribed SUP agents **(Krag et al., 2015)**. A meta-analysis study reported that proton pump inhibitors are preferred and more efficient than histamine-2 antagonistsin preventing GI bleeding events **(Alshamsi et al., 2016)**.

Deep Venous Thrombosis Prophylaxis

Neither SUP nor DVT prophylaxis has a direct relation to VAP prevention strategy, instead, they have been added to the VAP bundle to prevent other complications of MV that could increase morbidity and mortality of these patients. Since, MVPs are at higher risk for DVT, therefore DVT prophylaxis is an important component of standard care of MVPs **(Divatia et al., 2020)**.

Deep venous thrombosis prophylaxis is one of the important aspects of VAP bundle application. MVPs are usually sedated and immobile which exposes them for the risk of DVT. Therefore, the administration of DVT prophylaxis such as antithrombotic medications and antiembolism stockings are used **(Osti et al., 2017)**.

Daily Oral Care with CHX

Chlorhexidineis a well-known, widely utilized low cost product, used as an antiseptic and a disinfectant to kill microorganisms and reduce hospital‐acquired infectionsspread in ICUs **(Lewis, Schofield-Robinson, Rhodes, & Smith, 2019)**.Recent research studies have showed that intraoral application of CHX reduces VAP occurrence among MVPs **(Jackson & Owens, 2019; Pinto, Silva, Santiago-Junior, & Sales-Peres, 2021)**. A recent Cochrane systematic review reported that up to 48 hours after the initial application of CHX, it has a slow-release antibacterial activity which explains the reason why organisms that come into contact after CHX use may not be able to grow **(Lewis et al., 2019)**.Furthermore, a RCT has reported that oral decontamination with a 2% CHX concentration is more effective than oral decontamination with 0.2% concentration in preventing VAP and reducing oropharyngeal colonization**(Zand et al., 2017)**.

Chlorhexidine is associated with some side effects. After a week of using CHX, it can cause stinging, burning sensation of the tongue, reversible discoloration of the teeth and tongue, and transient disturbances of taste **(Rakel, 2018)**. Allergic reactions to CHX are relatively rare, particularly when one considers how wide- spread the use of CHX is in our living environment. Nevertheless, cases of contact allergies are consistently reported**(Koch & Wollina, 2014).**

In addition, oral care should include patient's teeth brushing using a soft toothbrush to reduce teeth plaques. To be effective, CHX should be applied to the inside of the mouth using a sponge swab applied to the teeth, tongue, and inside of the oral cavity. To have the greatest effect CHX should be applied four times daily **(Urden et al., 2019)**.

Section II: Endotracheal Suctioning

Endotracheal suctioning to clear secretions has been a standard practice in the care of MVPs **(Marino & Galvagno, 2017)**.Suctioning is a sterile procedure that is performed only when the patient needs it and not on a routine schedule. Indications for suctioning include the presence of coarse crackles over the trachea on auscultation, coughing, and presence of visible secretions in the airway **(Urden et al., 2019)**.

Suction catheter (SC) is used to remove tracheal secretions and may be either open tracheal suctioning system (OTSS) or closed tracheal suctioning system (CTSS). The OTSS method necessitates temporary disconnection of the ETT from the ventilation circuit and insertion of a single use, disposable SC into the patient **(Elmansoury & Said, 2017)**. Whereas, in CTSS, the suction technique is done through maintaining a sterile SC in an enclosed sheath attached to the inside of the ETT without disconnecting the ventilation circuit **(Urden et al., 2019)**.

Closed tracheal suctioning system as shown in figure 4, allows suctioning of secretions without patient's disconnection from MV. It is believed that disconnection of the patient from MV may result in airways contamination. Therefore, the use of CTSS might prevent the pneumonia incidence **(Urden et al., 2019)**. A meta-analysis study suggested a possible VAP preventive effect when closed systems are used, but the evidence was not strong enough to provide a definitive recommendation **(Kuriyama, Umakoshi, Fujinaga, & Takada, 2015)**.

Some research studies reported no difference between using an OTSS or a CTSS on reducing the incidence of VAP or mortality rate**(Ardehali, Fatemi, Rezaei, Forouzanfar, & Zolghadr, 2020; Elmansoury & Said, 2017)**. However, the closed suction systems offer many advantages such as the removal of secretions while PEEP is maintained, maintenance of oxygenation, protection of staff members from patients secretions, and reduction of hypoxemia related complications**(Coppadoro et al., 2019)**. Therefore, the use of CTSS appears reasonable in the critical care scenario.

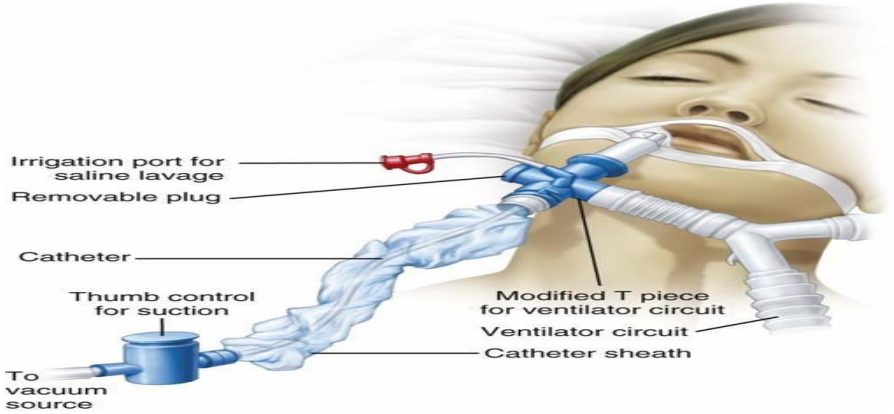

Figure 4. **Closed Tracheal Suctioning System**

Adopted from "Priorities in critical care nursing, 8th ed." by L. Urden,K. Stacy, &M. Lough, (2019). Mosby: Elsevier Health Sciences. P. 269

There are two different techniques for suctioning depending on how deeply the SC is inserted into the trachea: shallow suctioning, in which the SC is inserted to the end of the ETT or tracheostomy tube (TT), and deep suctioning in which the SC is inserted until resistant is met, the catheter is pulled back approximately 1 cm, and then suctioning is applied **(American Association for Respiratory Care [AARC]., 2010)**.

The Role of Suctioning in the Occurrence of VAP

It is recognized that the inner surface of artificial airways becomes colonized with biofilms containing pathogenic organisms as seen in figure 5, and passing a SC through it can dislodge these biofilms inside the SC, resulting in the inoculation of pathogenic organisms into the lungs, causing VAP**(Marino & Galvagno, 2017)**.Therefore, it is recommended that routine suctioning should be avoided **(AARC, 2010)**.

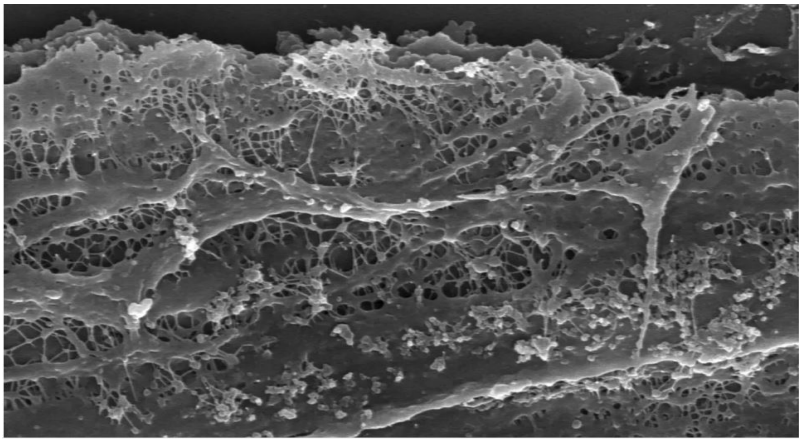

Figure 5. **Electron Micrograph Showing a Biofilm on the ETT Inner Surface**

Adopted from "Implications of endotracheal tube biofilm in ventilator-associated pneumonia response: A state of concept" by S. Gil-Perotin, P. Ramirez, V. Marti, J. Sahuquillo, E. Gonzalez, I. Calleja, ... &J. Bonastre, (2012). *Critical Care*, 16(3), P. 5.

In addition, a 5–10 ml bolus of *sterile* normal saline (NS) solution is commonly instilled into the ETT or tracheostomy before suctioning, *but* this act does not liquify or reduce the viscosity of secretions. Instead, it can lead to the accumulation of viscous secretions and bacterial colonization that increases the risk of VAP **(Marino, & Galvagno, 2017)**. One study showed that a 5-mL saline instillation dislodged up to 310,000 viable bacterial colonies **(Hagler & Traver, 1994)**. Moreover, research studies reported that saline instillation reduces oxygen saturation**(Schults, Mitchell, Cooke, & Schibler, 2018)**.Therefore, saline instillation is no longer recommended act in the care of MVPs **(AARC, 2010)**.

Section III: Nursing Role in Prevention of VAP via Suctioning

Although ETS is a necessary procedure for ICU patients, if not *performed* with correct techniques, it can result in serious complications, as infection, bleeding, hypoxia, increase intracranial pressure, atelectasis, bronchoconstriction, cardiac arrest, and sudden death **(Mwakanyanga, Masika, & Tarimo, 2018)**. Therefore, CCNs should have the necessary knowledge and skills based on valid scientific evidence in performing ETS and other interventions related to it, as presented in figure 6.

SN	GUIDELINES	RECOMMENDED
1	Frequency	ETS should be performed only when necessary
2	Suctioning catheter	Should occlude less than half of the lumen of the ETT
3	Suctioning pressure	Should be lowest as much as possible, usually 80–120 mmHg
4	Depth of suctioning	Minimum invasion to the length of the ETT only
5	Time of suctioning	Should last no longer than 15 seconds
6	Continuous vs Intermitted	Should be continuous rather than intermittent suctioning during the individual suction procedure
7	Normal Saline instillation	No routine instillation of normal saline (N/S) prior to ETS
8	Oxygenation	There should be pre-oxygenation by the delivery of 100% oxygen for at least 30 seconds prior to and after the suctioning procedure to prevent decrease in oxygen saturation
9	Hyperinflation	Hyper-oxygenation prior to suctioning should be combined with hyperinflation (20–30 cmH_2O)
10	Infection Control	Aseptic technique should be used for infection control
11	Closed vs Open suctioning	Both open and closed suction systems are recommended

Figure 6. **Endotracheal Suctioning Recommended Guidelines**

Adopted from "Intensive care nurses' knowledge and practice on endotracheal suctioning of the intubated patient: A quantitative cross-sectional observational study" by E. Mwakanyanga, G. Masika, &E. Tarimo, (2018). *PloS one*, *13*(8), P. 3.

Frequency

Endotracheal suctioning should be performed when respiratory secretions are present. This is because secretions accumulation may impair oxygenation and ventilation; leading to ETT occlusion, increased respiratory work, and atelectasis. In addition, it predisposes to pulmonary infection **(Marino & Galvagno, 2017)**.

In addition, ETS should be done only when necessary. Clinical signs of tracheal secretions includes the presence of snoring or decreased breathing sounds on auscultation **(Gonçalves, Tsuzuki, & Carvalho, 2015)**. Moreover, a pragmatic RCT reported that, as-needed ETS has more advantages in logistics, being more physiological, does not increase neither morbidity nor mortality, and also have additional economic benefits **(Lema-Zuluaga, Fernandez-Laverde, Correa-Varela, & Zuleta-Tobón, 2018)**.

Therefore, CCNs should incorporate this aspect in the care of MVPs and perform suctioning only when there are signs of secretions accumulation and not as a routine procedure.

Suction Catheter Size

Selecting the appropriate SC size is based on the SC external diameter and ETT internal diameter. As seen in figure 7, a SC/ETT ratio of 50 % is recommended and up to 70% is acceptable, to allow air to pass into the lungs during the suctioning. This is crucial to minimize the generated negative pressure within the lungs and prevent suctioning related complications, including hypoxemia **(Russian, Gonzales, & Henry, 2014)**.

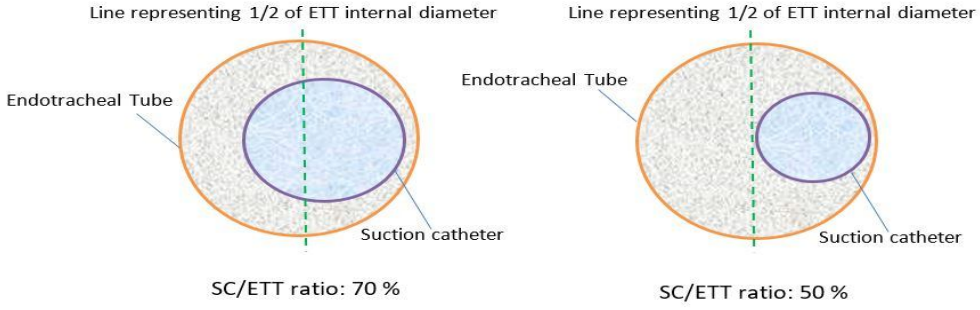

Figure 7. **Ratio of SC Outer Diameter to ETT Inner Diameter. A: 70%. B: 50%**

Adapted from"Suction catheter size: An assessment and comparison of 3 different calculation methods" by C. Russian, J. Gonzales, & N. Henry, (2014). *Respiratory Care*, *59*(1), P. 36

Other numerical methods for selecting SC size including formulas. The first formula calculated through SC size (Fr) = [ETT size (mm) - 2] then multiply by 2. For example, for a size 8 mm ETT: Using the first formula, (8 – 2) then multiply by 2 = 12 Fr **(Pedersen, Rosendahl-Nielsen, Hjermind, & Egerod, 2009).** Another formula calculated through 3 Fr = 1 mm diameter. For example, for a size 8 mm ETT: half the diameter of 8 mm = 4 mm. Then multiply this number by 3 = size 12 Fr **(Salih, 2018)**.

A cross sectional study investigated Nurses' knowledge and practices about ETS, reported that 64% of nurses correctly identified the size of SC **(Majeed, 2017)**. Selecting the appropriate SC size is one of the most professional skills that CCNs should be aware of. Therefore, CCNs should be familiar with different calculations for selecting the appropriate SC before suctioning.

Suction Catheter Depth

Critical care nurses should determine the appropriate depth for SC insertion to decrease catheter-related tissue damage. The use of shallow suctioning is recommended, rather than deep, with suctioning duration of less than 15 seconds **(AARC, 2010)**. A recent Egyptian study recommended the use of centimeter markings on the ETT and SC. The catheter tip will be within 0.5–1 cm from the ETT end when it has been advanced so that the number on the SC is lined up with the same number on the ETT. Therefore, nurses should avoid inserting the SC more than 0.5–1 cm beyond the ETT end **(Elmansoury & Said, 2017)**.

The SC should be inserted to a pre-determined length and should not be advanced beyond the ETT tip, usually the length of the ETT plus the adapter. Deep suction can cause mucosal damage, possible tracheal/bronchial perforation, hemorrhage, bradycardia, and hypotension **(Vincent, Abraham, Kochanek, Moore, & Fink, 2017)**.

Suctioning Pressure

Suctioning of mucus is done under pressure, which is distinguished by age. For adults the pressure is usually settled between 100-140 mmHg, for children 95-100 mmHg and infants 50-95 mmHg with a duration of 10-15 seconds. Selecting the appropriate suctioning pressure and duration should be done to minimize the desaturation of oxygen **(Timby, 2009)**.

A quasi experimental study compared the effect of two different suctioning levels reported that 140 mmHg suctioning pressure is more effective compared to 130 mmHg suctioning pressure in increasing oxygen saturation among MV patients **(Muhaji, Santoso, & Putrono, 2017)**. Therefore, CCNs should have the sufficient knowledge and skills to adjust the suctioning pressure level for MVPs.

Intermittent Vs Continuous Suctioning

A single center RCT investigated the effect of continuous vs intermittent subglottic suctioning on the occurrence of VAP and reported no significant difference in VAP occurrence. However, the continuous system reduced the duration of MV and ICU stay when compared to intermittent suctioning technique **(Fujimoto et al., 2018)**.

Continuous subglottic secretions aspiration devices were associated with low VAP occurrence, especially when anticipating prolonged tracheal intubation. However, two cases of tracheal injury were reported to be attributable to the use of these devices **(Harvey, Miller, Lee, Bowton, & MacGregor, 2007)**.

Critical care nurses should be aware of different types and techniques of suctioning in order to maximizing MVPs' outcomes and minimizing side effects.

Hyperoxygenation and Hyperventilation

Pre-oxygenation involves the administration of a higher concentration of oxygen to the patient before undergoing suctioning maneuver using different ways such as oxygen mask, oxygen tent, or a mechanical ventilator for 1-2 minutes depending on the patient's clinical condition and saturation level **(Tavangar, Javadi, Sobhanian, & Jahromi, 2016)**.It is recommended that pre-oxygenation must be ensured by nursing staff through the delivery of 100% oxygen for at least 30 seconds before and after the suctioning maneuver to prevent oxygen level desaturation **(Mwakanyanga et al., 2018)**.

Manual hyperinflation (MHI) and ventilator hyperinflation (VHI) are interventions that are commonly performed to improve oxygenation, and facilitate clearance of secretions**(Anderson, Alexanders, Sinani, Hayes, & Fogarty, 2015; Dennis, Jacob, &Budgeon, 2012)**. MHI involves MV disconnection to deliver large tidal volumes

through a manual resuscitation bag, while VHI is adjusted through mechanical ventilators**(Linnane et al., 2019; Paulus, Binnekade, Vroom, & Schultz, 2012)**.Hyperinflation has also been applied to open collapsed lung units not associated with airway secretion obstruction **(Tucci, Nakamura, Carvalho, & Volpe, 2019)**.

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