Effect of Open versus Closed Suction System on Cardiorespiratory Parameters and Suction Duration among Critically Ill Mechanically Ventilated Patients

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Abstract

Background: Tracheal suction is a procedure that is used to remove secretions and keep the airways clear, however it has a number of side effects. Blood pressure, heart rate, respiratory rate, and oxygen saturation variations are some of the first problems of suctioning. **This study** was aimed to compare the effects of open versus closed suction system on cardiorespiratory parameters and suction duration among critically ill mechanically ventilated patients. **comparative quasi-experimental research design** was carried out to meet the aim of this study. **A purposive sample** included 60 critically ill adult patients undergoing mechanical ventilation taken from general intensive care in Aswan University Hospital. **Patient assessment sheet** was used for collecting data, which included two parts: bio-demographic data and an assessment sheet to monitor cardiorespiratory parameters as oxygen saturation, heart rate, mean arterial blood pressure and respiratory rates. **Results:** The mean duration of ICU stay and duration of suction for critically ill adult patients in open and closed suctioning was 12.39 ± 11.74 and 5.10 ± 2.29, respectively (P <0.031*), 15.41 ± 2.37 and 7.50 ± 2.50 seconds, respectively. The mean arterial blood pressure of critically ill adult patients undergoing mechanical ventilation in open and closed suction system methods. No significant differences were observed in the four consecutive measurements. The closed suction system group have a higher mean Oxygen saturation than those in the open group during suction and immediately after suction measurements (85.53 ± 8.94 vs. 94.03 ± 3.85 and 93.91 ± 5.78 vs. 97.67 ± 2.04 respectively). **Conclusion:** The implementation of the closed suction system leads to decrease instabilities in the cardiorespiratory parameters compared to open suction system among critical ill adult patients under mechanical ventilation. **Recommendation:** More research can be replicated on larger sample, and Suction methods can be compared with acquired infection in ICU.

Keywords: close, open suction, cardiorespiratory Parameters, critically ill patients, suction duration and intensive care unit.

Introduction:

Endotracheal tube (ETT) suctioning is an essential procedure in patients undergoing mechanical ventilation (MV) with intubation to keeping the airways open through removal of accumulated pulmonary secretions **(**Vijai**, et al., 2016).**

the critically ill patients who are unable to cough, ineffective mucociliary movement function, impaired function of irregular glottic, and insufficient humidification, nurses have used suctioning on multiple occasions as a normal care **(Chegondi, et al., 2018).**

Mechanical ventilation is utilized as a life-saving strategy in treating acute and chronic respiratory failure, especially in reversible situations, in critically ill patients in the intensive care unit (ICU) for a variety of physiological and therapeutic reasons. Reduces dyspnea and inspiratory effort while effectively improving gas exchange. However, besides ineffective the spontaneous elimination of airway secretions in critical patients, and coughing is less effective or impossible **(Schettino, et al., 2016).**

ETT suctioning is performed in two ways: closed suction system (CSS) and open suction system (OSS). The OSS approach necessitates the participation of two nurses and may result in a momentary interruption of ventilation and oxygen supply due to the patient's disconnection from the ventilation device during suctioning. Hypoxia is the most significant risk factor in this method. **(Sarkar, et al., 2017).**

In the CSS approach, however, endotracheal suctioning can be performed through connections in a closed suction set while the patient is ventilated without separating the patient from the ventilator. This manoeuvre, prevent patient deprivation from oxygen supply and significant decrease life-threatening effects **(Liu XW r, et al., 2019).**

Tissue hypoxia, hypoxemia, significant fluctuations in heart beats or mean arterial blood pressure, occurrence of cardiovascular variability, raised intracranial pressure, and tracheal mucosa damage are the sequences of endotracheal suction. Patients have described the suctioning technique as unpleasant and painful. Additional sequences include bronchial tissue trauma, bronchospasm or bronchoconstriction, pulmonary bleeding, infection, elevated intracranial pressure and interruption of mechanical ventilation **(Elmansoury, et al., 2017).**

As a result, the purpose of this study investigates effects of open versus closed suction system on cardiorespiratory parameters and suction duration among critically ill mechanically ventilated patients.

Significance of the study:

Suction tube is a maneuver to eliminate secretions and maintain the airways clear and causes several complications. Primary complications of the suctioning comprise alteration in blood pressure, heart rate, respiratory rate and oxygen saturation **(Alizadeh, 2008).** One of the methods to maintain the airway open is endotracheal tube suctioning the in mechanically ventilated patients. A suitable suction method can be designated to prevent several complications **(Afshari, et al., 2014).** Therefore; it is necessary to assess vital signs during endotracheal suctioning to control the most serious complications **(Phipps, et al., 2003).** The common of ICUs at Aswan University Hospital used the open suction method and rarely used the closed one, so the researcher emphasis in this study to compare the effect of two approaches on cardiopulmonary parameters and recommended for its used.

Aims of the study:

The present study aimed to compere the effects of open and closed suction systems on the cardiorespiratory parameters, duration of ICU stays and suction duration in critically ill mechanically ventilated patient.

Hypotheses:

Closed suction method has positive effect on the cardiorespiratory parameters and suction duration rather than open system among critically ill mechanically ventilated patients.

Subjects and methods:

Research design:

Comparative quasi-experimental research design.

Study variables:

Independent variables: Open and closed suction methods.

Dependent variables: Cardio pulmonary parameters.

Setting:

This study was conducted at general ICU in Aswan University Hospital from the beginning of March 2018 until the end of August 2018.

Sampling:

A purposive sample included 60 adult critically ill patients included patients aged older than18, connected to a mechanical ventilation, underwent open or closed ES, They were not re-operated for revision, they were not given inotropes or vasoactive medications, and they were taken out of the general critical care unit for six months.

The total sample was randomly divided into 2 groups (each group containing 30 patients) Patients were separated into two groups:

- **Control group:**

Included mechanically ventilated patients admitted to intensive care unit during the with open suction system (OSS).

- **Study group:**

Included mechanically ventilated patients admitted to intensive care unit with closed suction system (CSS).

Tool for data collection:

The patient's assessment sheet (English form) was used to collect the data of this study (developed by the researchers), which included two parts as follows:

Part 1: Bio-demographic data of critically ill adult patients as gender, age, current diagnosis, duration of ICU stay and suction duration**.**

Part 2: **A Cardiorespiratory parameters of the mechanically ventilated patient sheet** were adopted from **Jansson et al.,(2013) & Keykha., (2016),** to monitor critically ill adult patient's cardiorespiratory parameters as oxygen saturation, heart rate, main arterial pressure and respiratory rate.

A pilot study was conducted on 4 patients to test the applicability of the tool; (two patients undergoing an open endotracheal suction system and two patients undergoing a closed endotracheal suction system) and included in the study results.

Validity: The validity of the tool was tested by measuring its contents validity index by 5 experts in critical nursing field and it equaled 91% .

Reliability: The reliability of the tool was calculated statistically by alpha crombach test (r=0.82).

Methods for data collection:

- Administrative approval was attained from the responsible persons (directors of Aswan University Hospital and head of general intensive care unit).
- Written agreements were taken from the patients of the hospitalized patients after presenting ourselves to them and explanation the purpose of the study.
- At the general intensive care unit, the researchers presented themselves and informed the nurses about the nature of the study.
- In 6 months length period study enrolled 60 adult critically ill mechanical ventilated patients, divided into 30 patients for open suctioning methods (group 1) and 30 patients for closed suctioning methods (group 2).
- The patients of the bio-demographic data were collected from the patient's record.
- All patients supply with 100% oxygen concentration for 2 minutes before suction and 2 minutes after the suction immediately.
- In the open suction group, the endotracheal tube was disconnected from the ventilator. An equipment including an ambo bag, glove, and a suitable size of the disposable suction catheter were passed down to the endotracheal tube and stretched until resistance was met and 0.5 cm was withdrawn.

Criteria for closed suction system

Application the close suction system :
1. Wash hands according to unit protocol Wash your hands according to your unit protocol: Wear examination gloves and face protection when working with Trach Care. Other safety precautions may be required depending on your unit's policy.
2. Determining the correct catheter sizing and configuration: Multiply the ET diameter by 2, then use the next smallest size of catheter to get the suitable French size for your TrachCare72. Multiply by 2 if you're using an 8 mm ET tube, and you'll get 16. Then utilize the smallest catheter size available. There are 14 French in this case. Using a catheter that is too big can cause Auto-PEEP by interfering with the ventilator's function.
3.Removal of Trach Care from its platform and linking of the flex tube Open the packaging and connect the flex tubing to the Trach Care Double Swivel Elbow's 15mm port. Take off the Trach Care's red wedge plug.
4) Attachment of the day change sticker The next Trach Care change is due on the day indicated by the day change sticker. On a Tuesday, for example, you would place the Friday sticker on the valve, which indicates when the catheter has to be changed. This sticker makes it simple for your coworkers to check the date of the modification.
5) Connection of the wall suction line to the Trach Care and setting the vacuum level Connect the Trach care suction valve's suction connecting tubing to the negative pressure manometer and collecting jar. Depress the suction valve entirely and adjust the manometer to a negative pressure of 15.9 kPa or 120 mm Hg for an adult patient with the suction valve unlocked. ,
6) Insert Trach Care into ventilation circuit (humidified or HME) with gloved hands and masks: Remove the old elbow connector and flex tubing. If this is too difficult, use the red wedge plug to pry them apart. Connect the Trach Care flex tubing to the ventilator's Y-piece and the 15 mm endotracheal tube to the double swivel elbow.
7) Observation of ventilator parameters and assessing the patient's need of suctioning
8) Full suctioning procedure (7 steps) 1. To unlock the thumb valve, lift up the cap, then depress and hold the valve while adjusting the vacuum regulator to the correct setting. To attain the required pressure, fully depress the valve and adjust the manometer reading. We recommend a pressure range of 80 to 120 mm Hg (10.6 -15.9 kPa) for adult patients. 2. To flush the system clean automatically, remove the cover from the irrigation port and attach a saline vial. 3. To suction, stabilize the manifold and ET tube with one hand, then advance the catheter down the ET tube to the required depth using the thumb and forefinger of the other hand. Shortly, we'll go into measured depth suctioning in greater detail. 4. Suctioning must be administered for two seconds before the catheter can be withdrawn. Depress and maintain the thumb valve while carefully withdrawing the catheter. It should not be depressed on a regular basis. It is not essential or advantageous to twist the catheter when it is withdrawn. 5. Suctioning must be administered for two seconds before the catheter can be withdrawn. Depress and maintain the thumb valve while carefully withdrawing the catheter. It should not be depressed on a regular basis. It is not essential or advantageous to twist the catheter when it is withdrawn. 6. When the suction procedure is finished, utilize the irrigation port to clean and rinse the catheter. Make sure the black marking ring in the sleeve is visible. Simultaneously depress the thumb control valve and the catheter will be cleaned dynamically. Continue irrigating until the catheter is free of debris. 7. To lock the valve, lift up the thumb valve cover and turn it.
9) Suction tubing is repositioned. Remove the suction tube from the support and replace it out of the way.
10) Check the ventilator and keep an eye on the patient. Assess the patient's vital signs, breathing sounds, and oxygen saturation at this point.
11) Wash hands and dispose of gloves Once the suctioning procedure is finished, take gloves off and dispose of them, and wash hands.

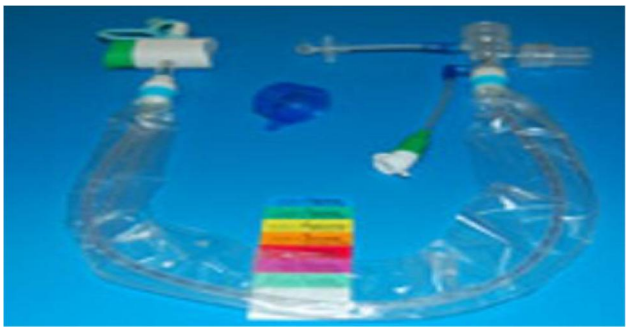

Figure 1. Set of closed tracheal suction system.

Measurements:

Cardio-respiratory parameters [heart rate (beats per minute), respiratory rate (c/min), mean arterial blood pressure, and oxygen saturation (percent)] were measured and recorded at five intervals [before suction (baseline), during suction (0 min), post suctioning 5th minute, and post suctioning 15th minute]. - Oxygen saturation, heart rate, and blood pressure were obtained using monitor while the respiratory rate was obtained from the mechanical ventilator.

Before, during, immediately after, and 15 minutes after suctioning, the heart rate, respiratory rate, and oxygen saturation were compared in open and closed suctioning procedures.

Field of the study:

The data was collected over a six-month period, from the beginning of March 2018 until the end of August 2018.

This was accomplished during the hospital's morning and afternoon shifts. The assessment sheet takes around 15-20 minutes to complete; each week, about 1-2 critically ill adult patients on mechanical ventilation were gathered.

Ethical consideration:

Each patient gave their written consent to take part in the trial. Participants have the ethical right to accept or decline participation. The researchers assured them that the information they acquired would be kept private and utilized only for research purposes.

Statistical analysis:

SPSS version 19 was used for data entry and analysis (Statistical Package for Social Science). The data was presented in the form of a mean and a standard deviation. To compare qualitative variables, Chi-square and Fisher Exact tests were used. In the case of non-parametric data, the Mann-Whitney test was utilized to compare quantitative variables. P-values of less than 0.05 were considered statistically significant.

Results:

In **table 1,** the mean ±SD for the age of patients in open and closed suction was 44.72 ± 13.88, 46.20 ± 12.81 years respectively. In open suction method, more half of patient (53.0%) were males and less than half were females (46.0%) while Most patients were non-smoker in both of the open and close groups and respiratory disease, smoking and current diagnosis were statistically non-significant.

Table 2 illustrates the mean duration of ICU stay and duration of suction for critically ill adult patients undergoing mechanical ventilation in open and closed suctioning. This study revealed that the mean duration of hospital stay was 12.39 ± 11.74 and 5.10 ± 2.29, respectively (P <0.031*). Mean suction duration in open and closed suction methods was 15.41 ± 2.37 and 7.50 ± 2.50 seconds, respectively.

Table 3 represents that mean heart rate was increase during suction and 15-min after suction in closed suction than in open suction (104.92 ± 12.92 vs. 98.06 ± 16.18 and96.67 ± 15.30 vs. 91.93 ± 13.94 respectively) but there were no significant differences observed between the open and close suction methods in all repeated measurements.

Table 4 represents the mean ±SD of respiratory rate among studied critical ill patients in open and closed suction, as revealed in this table before suction and 5-min after suction, there was no statistical significant differences between the two suction methods, but respiratory rate differences between the open and close suction system methods, During suction, immediately after suction, and 15-min after suction there was statistically significant improved with P- value (0.026, 0.015, 0.023) respectively.

Table 5 reveals the mean arterial blood pressure of critically ill adult patients undergoing mechanical ventilation in open and closed suction system methods. As shown in this table, no significant differences were observed between the two suction methods in terms of mean arterial blood pressure in the four consecutive measurements. While Significantly Increase the mean arterial blood pressure during suction in open and close suction system methods 101.83 ± 15.33 vs. 92.75 ± 12.59 respectively (p-value 0.020*).

Table 6 shows that in the closed suction system group have a higher mean Oxygen saturation than those in the open group in the during suction and immediately after suction measurements (85.53 ± 8.94 vs. 94.03 ± 3.85 and 93.91 ± 5.78 vs. 97.67 ± 2.04 respectively). There were highly statistical significant differences between the two suction methods during suction and immediately after suction the P value was (0.001*, 0.003* respectively.

Table 1: Percentage distribution of the studied group according to their bio-demographic characteristics:

Personal data	Open suction (n= 30)	Closed suction (n= 30)	P-value
	Mean ± SD	Mean ± SD	
Age (years)	44.72 ± 13.88	46.20 ± 12.81	0.676
Sex:			
Male	16 (53.3%)	18 (60.0%)	0.602
Female	14 (46.7%)	12 (40.0%)	
Diagnosis: [N (%)]			
Respiratory disease	13 (43.3%)	9 (30.0%)	0.166
Respiratory disease with other	7 (23.3%)	14 (46.7%)	
Other	10 (33.3%)	7 (23.3%)	
Smoking [N (%)]			
Smoker	6 (20.0%)	9 (30.0%)	0.371
Non-smoker	24 (80.0%)	21 (70.0%)	

Table 2: Mean and standard deviations of duration of suctioning and ICU stay among studied critically ill adult in open and closed suction (n=30)

Clinical data	Open suction (n= 30)	Closed suction (n= 30)	P-value
Duration of ICU stay: (days)			0.031*
Mean ± SD	12.39 ± 11.74	5.10 ± 2.29	
Median (Range)	7 (3.0-60.0)	5.0 (2.0-8.0)	
Duration of suctioning: (seconds)			0.002*
Mean ± SD	15.41 ± 2.37	7.50 ± 2.50	
Median (Range)	15.0 (11.0-20.0)	7.0 (5.0-14.0)	

Table 3: Mean and standard deviations of heart rate among studied critically ill adult patients in open and closed suction (n=30)

Heart rate	Open suction (n= 30)	Closed suction (n= 30)	P-value
	Mean ± SD	Mean ± SD	
Before suctioning	94.76 ± 14.23	97.32 ± 16.12	0.525
During suctioning	104.92 ± 12.92	98.06 ± 16.18	0.085
Immediately after suctioning	86.42 ± 17.57	88.71 ± 10.59	0.554
5-min after suctioning	94.06 ± 15.65	96.76 ± 15.21	0.516
15-min after suctioning	96.67 ± 15.30	91.93 ± 13.94	0.228

Table 4: Mean and standard deviations of respiratory rate among studied groups in open and closed suction (n=30)

Respiratory rate	Open suction (n= 30)	Closed suction (n= 30)	P-value
	Mean ± SD	Mean ± SD	
Before suctioning	18.16 ± 4.58	19.11 ± 8.72	0.608
During suctioning	22.30 ± 9.70	18.67 ± 3.97	0.026*
Immediately after suctioning	20.82 ± 7.52	16.60 ± 4.53	0.015*
5-min after suctioning	18.26 ± 4.98	17.04 ± 3.01	0.268
15-min after suctioning	21.30 ± 9.98	16.50 ± 3.97	0.023*

Table 5: Mean and standard deviations of mean arterial blood pressure among studied group in open and closed suction system methods (n=30)

Mean arterial blood pressure	Open suction (n= 30)	Closed suction (n= 30)	P-value
	Mean ± SD	Mean ± SD	
Before suctioning	91.20 ± 15.35	92.41 ± 12.26	0.743
During suctioning	101.83 ± 15.33	92.75 ± 12.59	0.020*
Immediately after suctioning	94.08 ± 15.33	91.75 ± 11.75	0.521
5-min after suctioning	90.24 ± 13.31	91.26 ± 11.56	0.758
15-min after suctioning	92.42 ± 21.67	94.95 ± 20.50	0.651

Table 6: Mean and standard deviations of Oxygen saturation (%) among studied group in open and closed suction (n=30)

Oxygen saturation (%)	Open suction (n= 30)	Closed suction (n= 30)	P-value
	Mean ± SD	Mean ± SD	
Before suctioning	98.54 ± 1.33	98.41 ± 0.87	0.663
During suctioning	85.53 ± 8.94	94.03 ± 3.85	0.001*
Immediately after suctioning	93.91 ± 5.78	97.67 ± 2.04	0.003*
5-min after suctioning	98.43 ± 1.45	98.56 ± 0.82	0.678
15-min after suctioning	98.30 ± 1.44	98.52 ± 0.77	0.474

Discussion:

One of the greatest common nursing procedures utilized in critical care setting is an endotracheal suctioning. The two ways for endotracheal suctioning are open and closed suction, although neither of them outperformed the other in the intensive care unit (**Evans et al., 2014**).

In critically ill patients, endotracheal suctioning has side effects such as arterial blood oxygen desaturation, erratic respiratory rate, bradycardia, and transient elevations in arterial blood pressure. The use of the endotracheal suctioning procedure on a regular basis is linked to a reduced heart rate and oxygen saturation **(Chegondi, et al., 2018).**

Hence the present study was conducted to investigate effects of open and closed suction systems on the cardiorespiratory parameters in critically ill mechanically ventilated patient

This study was done on 60 critically ill adult patients who were mechanically ventilated from the starting of March 2018 to the end of August 2018 at general intensive care unit in Aswan University Hospital. Patients sample were randomized separated into 2 groups, group one with open suction system (OSS) and group two with closed suction system (CSS).

In the current study, patients with a closed suction system spent a shorter time in the ICU than patients with an open suction system, and during this study, there was a statistically significant difference between the two suction methods in terms of the average stay time in the ICU. This corresponds to research, **Elmansoury and Said (2017),** who found that patients in group B with the suction system turned off spent less time in the hospital than patients in group A with the suction system turned on.

In the current study, the average puff duration/sec showed that the average puff duration of closed puffs was shorter than that of open puffs. According to **Morrow and Argent (2008) and the American Association of Respiratory Care (AARC) (2010),** the suction time should be as short as possible. Some authors mention 15 seconds or less than 10 seconds. According to the researchers, these results could be because the fact that in an open suction system, patients are disconnected from the ventilator and the suction catheter is attached to the endotracheal tube, whereas in a closed suction (CS) system, the nurse connects the catheter to the ventilator circuit and it becomes part of the mechanical ventilators device and stays in contact with the patient for longer than in an open suction system. According to the company, CS procedures save

time because the nurse does not need to install or unhook the catheter or prepare the equipment during each suction process.

The current study revealed that the mean of respiratory rates was lower in closed suctioning than in open suctioning during suction, before suction and 5-min after suction, and increased during suction, immediately after suction, and 15-min after suction with highly statistical significant differences between the two suction methods. This finding was opposed to another study by **Cardoso et al., (2015)** which reported that, there was an increase in respiratory rate only with the use of open suction without significant differences. While, This was in line with the study by **Futter et al., (2014)** which illustrated that there was a significant elevation in RR after ES resulting from suction producing suffering pain and restless.

The current study's results demonstrate that the closed suction method's mean oxygen saturation was higher than the open method's, with a highly statistically significant difference between the two approaches during and immediately after suctioning. This was in line with a study by **Taheri et al., (2012),** who found that during suctioning and shortly after suction, the arterial blood oxygen saturation ratio declined significantly in the open approach compared to the closed method. **Pirr et al., (2014)** also agreed that the mean minimum SpO2 was significantly greater during closed suction compared to open suction.

According to the findings of this study, closed suction had a lower mean heart rate in consecutive measures than open suction, but there were no significant differences. This study is congruent with the findings of **Yazdannik et al., (2013),** who found no significant variation in heart rate between closed and open suction systems. According to **Keykha et al. et al., (2014),** the closed suction had a significantly lower pulse rate than the open suction (p0.05).

From the researchers' point of view, these findings could be related to the fact that with the open suction approach, the suction tube disconnects from the mechanical ventilator, resulting in decreased oxygenation and hypoxia. As a compensatory response to the lack of blood oxygen saturation, hypoxia stimulates the adrenergic nerve system, which controls cardiovascular and hemodynamic responses such as tachycardia.

The open suction system groups showed a substantial increase in mean arterial blood pressure during suction in the current study. This finding is consistent with previous research, which found a statistically significant difference in mean arterial blood pressure during suction. In a study of patients undergoing coronary artery bypass grafting**, Favretto et al., (2012) and Adib et al., (2014)**, discovered that oxygenation before endotracheal suction resulted in higher variability in mean arterial blood pressure measurements. In a study conducted by **Cereda et al., (2016)** examining the effects of open and closed suction procedures on lung volume in 10 patients, their findings were similar to present study.

From the researchers' point of view, the catheter is a part of a ventilator circuit in a close endotracheal suction system, eliminating the need to disconnect the ventilator and thus improving oxygenation; significantly reducing signs of hypoxemia, desaturation, as a result, hemodynamic parameters such as heart rate, mean arterial blood pressure.

Conclusion:

According to the findings of this study, the study concluded that:

The application of the closed suction system leads to fewer disturbances in the cardiorespiratory parameters especially, in respiratory rate, oxygen saturation, heart rate, mean arterial blood pressures compared to open suction system in mechanically ventilated critically ill adult patients for the reason that it does not deprive them of mechanical ventilation and oxygen supply. Therefore, the close suction system is the best method of suction for critically ill patients within the general intensive care units.

Recommendations:

Based on the results of the present study, the current study recommended that:

1- All health organizations must be apply the procedure of closed suction as a high nursing care standard.

2- Critical care nurses in all intensive care units should be inspire and trained to implementation of closed suction system procedure.

3- More research can be replicated on larger sample.

4- Suction methods can be compared with acquired infection in ICU.

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