

Effect of Positioning during Suctioning on Cerebral Perfusion Pressure among Patients with Traumatic Brain Injury

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Abstract Background: Traumatic Brain Injury (TBI) is a major cause of morbidity and mortality worldwide. Patients with TBI may need mechanical ventilation because they cannot clear their airway secretions due to decreased consciousness, loss of laryngeal reflexes and an inability to cough. Endotracheal suctioning is important and needed in mechanically ventilated patients for airway clearance, improvement of oxygenation and prevention of atelectasis and infection. However, endotracheal suctioning is an invasive procedure and adversely affects some physiological indicators, such as BP, PaO₂, O₂ saturation, HR, ICP and CPP. Aim: To examine the effect of positioning during endotracheal suctioning on cerebral perfusion pressure among mechanically ventilated patients with traumatic brain injury. Design: A quasi-experimental design (Study-Control) was used. Setting: The current study was conducted at the neurosurgical ICUs in Menoufia University Hospital and the teaching hospital in Shebin AL Khom. Sample: A convenient sample of 100 mechanically ventilated patients with traumatic brain injury were recruited from the neurosurgical ICUs. Tools: A Semi Structured Demographic Sheet; Physiological Measures Recording Sheet including CPP; MAP; CVP and Oxygenation as indicated by ABGs values; and Glasgow Coma Scale (GCS). Results: There was a highly statistically significant increase in CPP (84.30 ± 6.35 , 74.80 ± 8.20) in the study group compared with the control group after endotracheal suctioning and elevating head of bed (HOB) at 30 degrees respectively ($P=0.001$). Furthermore, there was a statistically significant increase in PaO₂ (88.57 ± 11.50 ; 73.57 ± 11.24) in the study group compared to the control group after suctioning respectively ($P<0.05$). Also, there was a statistically significant increase in SaO₂ (97.43 ± 2.88 , 88.67 ± 1.72) in the study group compared to the control group after suctioning respectively ($P<0.05$). Recommendations: Initiate the development of clinical practice guidelines for critical care nurses to use head of bed elevation of 30 degrees as routine care during endotracheal suctioning to improve cerebral pressure perfusion and oxygenation for patients with traumatic brain injury.

Keywords: cerebral pressure perfusion, oxygenation, endotracheal suctioning, traumatic brain injury

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1. Background

Traumatic Brain Injury (TBI) is a major cause of morbidity and mortality around the world. It is a critical global public health challenge [1,2]. Traumatic brain injury remains a leading cause of death and disability among trauma patients [3]. Intracranial hypertension is the most frequent cause of death and disability in brain-injured people. According to the Center for Disease Control and Prevention (CDC), over 1.7 million individuals sustain TBI annually, resulting in over 53,000 deaths and 500,000 patients developing permanent neurologic damage [4,5]. In Egypt, the overall incidence of Traumatic Brain Injury was 2,124 patients in 2016. Sixty-two percent of the patients had a mild head injury,

17.5% had moderate head injury and 20.3% had severe head injury [6].

After head trauma the homeostatic mechanisms are often lost (cerebral vascular resistance is usually increased), and the brain becomes susceptible to changes in blood pressure [7]. Those areas of the brain that are ischaemic or at risk of ischaemia are critically dependent on adequate cerebral blood flow, and therefore Cerebral Perfusion Pressure (CPP). After a brain injury, and especially in patients with multiple injuries, cerebral blood flow may be lowered to the ischaemic threshold [8].

Cerebral Perfusion Pressure (CPP) is the blood pressure gradient across the brain. CPP is important to maintain Intracranial Pressure (ICP) and cerebral perfusion pressure within normal ranges to reduce the risk of secondary brain injury in neurosurgical patients [8]. When the CPP is greater than 100mm Hg, there is a potential for

hyperperfusion and increased ICP. Low CPP, less than 60 mm Hg, result in inadequate blood supply to the brain, cerebral hypoxia and cell death may occur [9]. The autoregulation system for maintenance of constant blood flow does not function at pressures less than 40 mm Hg. Because an acutely injured brain requires a higher CPP than a normal brain, a minimum CPP of 70 mm Hg is required for maintenance of adequate cerebral perfusion and potentially improved outcomes in patients with brain injuries. The cardiovascular system responds when CPP decreases by increasing systemic pressure [10,11].

In mechanically ventilated patients, endotracheal suctioning is needed to avoid accumulation of secretions into the lung and its associated complications. However, endotracheal suctioning is an invasive procedure and is not free from hazards and fatal adverse events. In particular, endotracheal suctioning can have adverse effects on cerebral hemodynamics, especially when the self-regulating mechanisms are already compromised by brain tissue damage. Insertion of a catheter into the endotracheal tube can stimulate the tracheal and laryngeal afferent nerves causing the patient to cough. The stimulation of the cough reflex results in the Valsalva's maneuver that may lead to a transient increase in intrathoracic and intra-abdominal pressure and, concurrently, an increase in ICP and a decrease in CPP [12,13]. In TBI patients, endotracheal suctioning (ETS) is a potentially dangerous procedure because it can increase intracranial pressure (ICP) [14].

Therapeutic positioning of the head of bed elevation has been proposed as a simple and effective way of preventing secondary brain injury in traumatic brain injury patients. Therapeutic head positioning has beneficial effects on brain physiology in severe TBI [15]. In neurosurgical critical care units, the head of bed (HOB) is elevated to reduce ICP and maintain sufficient CPP [16,17,18,19,20,21].

A head of bed elevation of 30 degrees is a routine nursing practice in neurosurgical intensive care units for patients with traumatic brain injury. This practice is important because it increases the cerebral perfusion pressure by reducing the Mean Arterial Blood Pressure (MAP) and maintains the Cerebral Blood Flow (CBF) [22].

1.1. Significance of the Study

Maintaining an adequate cerebral perfusion pressure (CPP) is crucial in patients with a traumatic brain injury. Several studies examined the effects of different head of bed elevations and body positions on ICP and CPP [16,17,19,21]. The beneficial effect of head of bed elevation at 30° in patients with traumatic brain injury has been well established. However, it is not known whether this position can have the same beneficial effect during the endotracheal suctioning procedure in this population. Critical care nurses must be aware of the patient's CPP and the effect of various nursing interventions on this parameter. Knowledge about the patient's CPP, and which interventions affect these pressures, enables the critical care nurse to plan care that is best suited to that individual patient. Also, it enables critical care nurses to modify any interventions that might compromise CPP to reduce the danger to the patient's cerebrovascular status. Identifying

the most optimal body position during suction that enhances adequate Cerebral Blood Flow with controlling ICP, CPP and cerebral oxygenation is an important component of nursing practice. Identifying the appropriate positions during suctioning is important for patient safety among the traumatic brain injury population.

1.2. Aim of the Study

The aim of the current study was to examine the effect of positioning during endotracheal suctioning on cerebral perfusion pressure among mechanically ventilated patients with traumatic brain injury.

2. Hypotheses

1. There is an improvement of cerebral perfusion pressure in patients with TBI who are receiving head of bed elevation at 30 degrees during endotracheal suctioning compared with patients who are not receiving the head of bed elevation with the 30-degree intervention.
2. Patients with TBI who are receiving head of bed elevation at 30 degrees during endotracheal suctioning are more likely to have improvement of oxygenation compared to patients who are not receiving the head of bed elevation with the 30-degree intervention.

3. Definition of Variables

Cerebral Perfusion Pressure (CPP) is theoretically defined as "the net pressure gradient that drives oxygen delivery to cerebral tissue. It is the difference between the Mean Arterial Pressure (MAP) and the Intracranial Pressure (ICP) or Central Venous Pressure (CVP) (as an estimate of tissue pressure) [23]. In the present study, CPP was operationally defined as the calculated individual score of CPP based on the following formula: Cerebral Perfusion Pressure (CPP) = MAP - CVP [8]. MAP is reported in mmHg. Normal CPP ranges from 70 to 130 mm Hg. Mean Arterial Pressure (MAP) is a measure indicating the systolic and diastolic blood pressures in the aorta and major arteries during any given cardiac cycle as calculated by the following formula: two times the diastolic blood pressure plus the systolic blood pressure, divided by three. MAP is reported in mm Hg. Normal range from 70 to 105 mm Hg.

Oxygenation: is theoretically defined as "a process of oxygen diffusing passively from the alveolus and the pulmonary capillary to neural cells, where it binds to hemoglobin in red blood cells or dissolves into the plasma [24]. In the present study, oxygenation was operationally defined as the recorded individual score of Arterial Blood Gases Values (Sao₂, Pao₂, Paco₂) [25].

4. Methods

Design: A quasi-experimental design (Study-Control) was used.

Setting: The current study was conducted at the neurosurgical ICUs in the University and the Teaching Hospitals of Menoufia University, Shebin EL-Kome, Menoufia Governrat, Egypt.

Sample: A convenient sample of 100 critically ill adult patients recruited from the neurosurgical ICUs at Menoufia University Hospital, Shebin EL-Kome.

4.1. Sample Size Calculation

The sample size was calculated based on the difference between mean pre and post positioning (30° HOB elevation) in a previous study by [17] in 46 patients undergoing external ventricular drainage. Thirty patients were enrolled to explore the difference ICP averages between positions (power of 80% and an alpha of 0.05). The average sample size varies between 10 and 38 in most of the studies in patients with TBI. However, the findings of these studies were limited in generalization because of the small sample size. Also, considering the high mortality rate and accordingly the high percentage of attrition rate, it has been decided to increase the sample size to 100 (50 patients in each group).

Patients were recruited if they met the study inclusion criteria which included: a) adult patients from 19 to 60 years of age; b) hospitalized < 48 hours; c) GCS<8; and d) receiving mechanical ventilation on pressure controlled mode with endotracheal tube. Patients were excluded from the study if: a) they were below 16 years of age or more than 65 years because the study focuses on adults; b) diagnosed with brain death; c) patients with fever (Temperature >38°C) because fever affects patient cerebral perfusion pressure.

Patients who met the study inclusion criteria were divided alternatively and randomly into equal groups (50 patients each). The study group received head of bed elevation of 30 degrees during endotracheal suctioning. The control group received the routine hospital care during endotracheal suctioning.

4.2. Tools of Data Collection

I- A Semi Structured Demographic Sheet: including data about age, gender and medical diagnosis. Data was extracted from the patients' medical record by the researcher at the initial data collection point.

II- Physiological Measures Recording Sheet: including a) Cerebral Perfusion Pressure; b) Mean Arterial Pressure; c) Central Venous Pressure and d) Oxygenation as indicated by Arterial Blood Gases (ABGs) values.

Cerebral Perfusion Pressure (CPP) was calculated as the difference between the Mean Arterial Pressure (MAP) and the Central Venous Pressure (CVP) [8,23]. Mean Arterial Pressure (MAP) was calculated via the following formula:

$$\text{MAP} = \frac{\text{Systolic Blood Pressure} + 2 \text{ Diastolic Blood Pressure}}{3}$$
 Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), and Mean Arterial Pressure (MAP) were obtained from the bed side monitor (NIHON KOHDEN, life scope, BSM 3000 series, Tokyo, Japan). Blood pressure was measured via arterial catheter placed in the radial artery. The correct position of an arterial pressure transducer was adjusted after each head of bed

elevation. Central Venous Pressure (CVP) was measured manually. The reliability of the bed side monitor (NIHON KOHDEN, life scope, BSM 3000 series) was tested by Cronbach's Co efficiency Alpha = 0.87. Oxygenation was measured through Arterial Blood Gases values (SaO₂, PaO₂ and PaCo₂) via RAPID Point 500 Blood Gas analyzer which was equipped with a fully automated calibration mechanism and was calibrated every 2 hours. The reliability of Rapid Point 500 (®) was reported in a sample of one hundred sixty-five adult hospitalized patients in ICU. The Intra- and inter-assay coefficients was higher than 0.91. The validity of Rapid Point 500 (®) was assessed through two types of evaluation. The first was an analysis of paired-sample measurements on 114 randomly selected patient blood samples using the Rapid Point 500 (®) and standard analyzer. The second analysis consisted of using standard reference material to assess reproducibility (precision) of the analyzer over a 20-day period. In the paired-sample analysis, the correlation coefficient for the values determined by the two systems showed a significant relationship (r = 0.96 for pH, r = 0.99 for PaCO₂), and r = 0.98 for PaO₂). Rapid Point 500 (®) has adequate accuracy and precision for use in the clinical area.

III- Glasgow Coma Scale (GCS): It is a neurological scale developed by [26] and used to give a reliable and objective way to assess or record the conscious level for patients with traumatic brain injury. It is composed of three parameters: Best Eye Response, Best Verbal Response, and Best Motor Response. The total GCS is scored between 3 and 15. The maximum score of 15 indicates the awake or alert person. A minimum score of 3 indicates complete lack of responsiveness. A total score of 13 or higher correlates with a mild brain injury; a score of 9 to 12 indicates moderate injury and a score of 8 or less indicates a severe brain injury.

4.3. Data Collection Procedure

Ethical Consideration: An official permission for conducting the study was obtained from the Faculty of Nursing Research and Ethics Committee and the Menoufia University Hospital Director to carry out the study after explaining the purpose of the study. An oral consent was obtained from the patients' relatives. The researcher assured the patients' relatives about the confidentiality and anonymity of the patients' information. Data was collected by the researcher.

One hundred adult patients with traumatic brain injury connected to mechanical ventilation were randomly assigned into two equal groups (50 participants each). The random assignment of the participants to either study or control group took place by writing all names of the participants on slips of paper, placed in container, mixed well, and then drawn out one at a time and alternatively placed in one of the groups until assigning the required number of participants completed. The control group received routine endotracheal suctioning according to the usual ICU routine care.

The study group received head of bed elevation of 30 degrees during endotracheal suctioning.

The Glasgow Coma Scale (GCS) was assessed for both study and control groups before starting the intervention.

4.4. The Intervention

Head of bed elevation of 30 degrees was initiated before endotracheal suctioning. MAP and arterial blood gases were measured before starting endotracheal suctioning and then the FiO₂ was increased to 100% for one minute. A sterile catheter was inserted into the endotracheal tube and a single-pass endotracheal suctioning was performed for less than 30 seconds. After endotracheal suctioning, FiO₂ was maintained at 100% for 30 seconds, then MAP was calculated and a blood sample was drawn. Ventilator mode and IV sedation rates were not changed. Hyperinflation, head rotation, or saline instillations into the tube were avoided.

4.5. Statistical Analysis

Data was tabulated and analyzed using SPSS program; relevant statistical analysis was used to test the obtained data. Descriptive statistics were (e.g. mean, standard deviation, frequency, percentage). Also a t-test was used and the significant level was set at $p \leq 0.05$.

5. Results

Characteristics of the sample: One hundred adult patients who attended to the neurosurgical ICUs of Menoufia University and teaching Hospital, Shebin EL-Kome, Menoufia Governrat were approached over a three-month period from the end of June 2019 to the beginning of September 2019.

The mean age of the participants in the control and the study group was 36.20 ± 14.80 ; 35.25 ± 14.98 respectively. The majority of participants (88%) in the control group and in the study group (94%) were male. According to the current diagnosis, 46% of the participants in the control group and 50% of the participants in the study

group were diagnosed with subdural hemorrhage. See Table 1.

Table 1. Demographic Characteristics of the Studied Groups

Demographic Characteristics	Control Group (n=50)		Study Group (n=50)	
Age				
Mean \pm SD	36.20 \pm 14.80		35.25 \pm 14.98	
Sex	No	%	No	%
Male	44	88.0	47	94.0
Female	6	12.0	3	6.0
Diagnosis				
Subdural Hemorrhage	23	46.0	25	50.0
Subarachnoid Hemorrhage	12	24.0	14	28.0
Epidural Hemorrhage	15	30.0	11	22.0

Table 1 showed that there were no statistically significant differences between the study and the control group related to the demographic characteristics.

Table 2 showed that there was a high statistically significant increase in CPP (84.30 ± 6.35 , 74.80 ± 8.20) in the study group compared to the control group after endotracheal suctioning and elevating head of bed at 30 degrees respectively ($P = 0.001$).

Figure 1 showed that there was a statistically significant difference between the study and the control group regarding CPP after endotracheal suctioning.

Table 3 showed that there was a statistically significant difference between the study and the control group regarding oxygenation after the suctioning. There was a statistically significant increase in PaO₂ (88.57 ± 11.50 ; 73.57 ± 11.24) in the study group compared to the control group after suctioning respectively ($P < .05$). Also, there was a statistically significant increase in SaO₂ (97.43 ± 2.88 , 88.67 ± 1.72) in the study group compared to the control group after suctioning respectively ($P < .05$).

Table 2. The Effect of Head of bed Elevation of 30 degrees during Endotracheal Suctioning on Cerebral Perfusion Pressure

Variable	Control Group (n=50)	Study Group (n=50)	Student's t test	P value
Cerebral Perfusion Pressure Mean \pm SD	74.80 \pm 8.20	84.30 \pm 6.35	2.59	0.001 HS

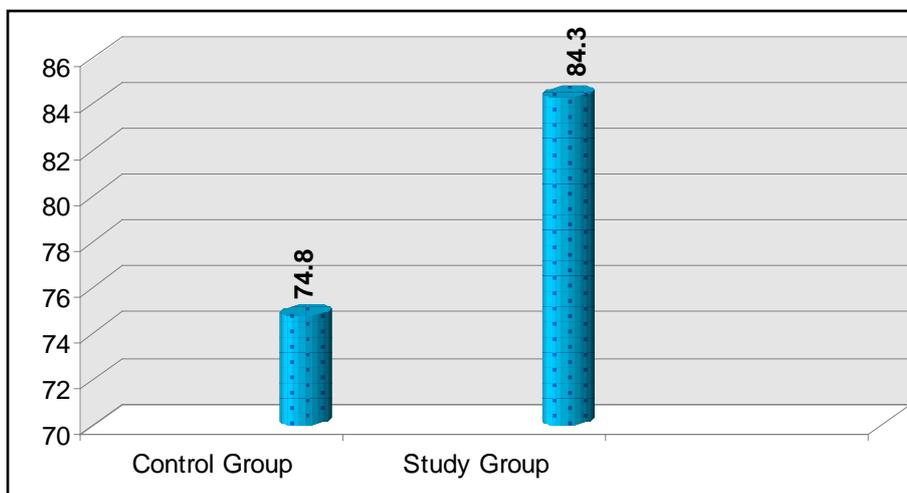


Figure 1. The Effect of Head of Bed Elevation at 30 degrees During Endotracheal Suctioning on Cerebral Perfusion Pressure

Table 3. The Effect of Head of bed Elevation at 30 Degrees during Endotracheal Suctioning on Oxygenation

Oxygenation	Study Group (n=50) Mean \pm SD	Control Group (n=50) Mean \pm SD	Student's t test	P value
pH	7.42 \pm 0.03	7.32 \pm 0.06	6.43	<0.05 S
PaO ₂	88.57 \pm 11.50	73.57 \pm 11.24	5.03	<0.05 S
SaO ₂	97.43 \pm 2.88	88.67 \pm 1.72	8.01	<0.05 S
PaCO ₂	39.57 \pm 2.34	32.87 \pm 6.46	4.85	<0.05 S

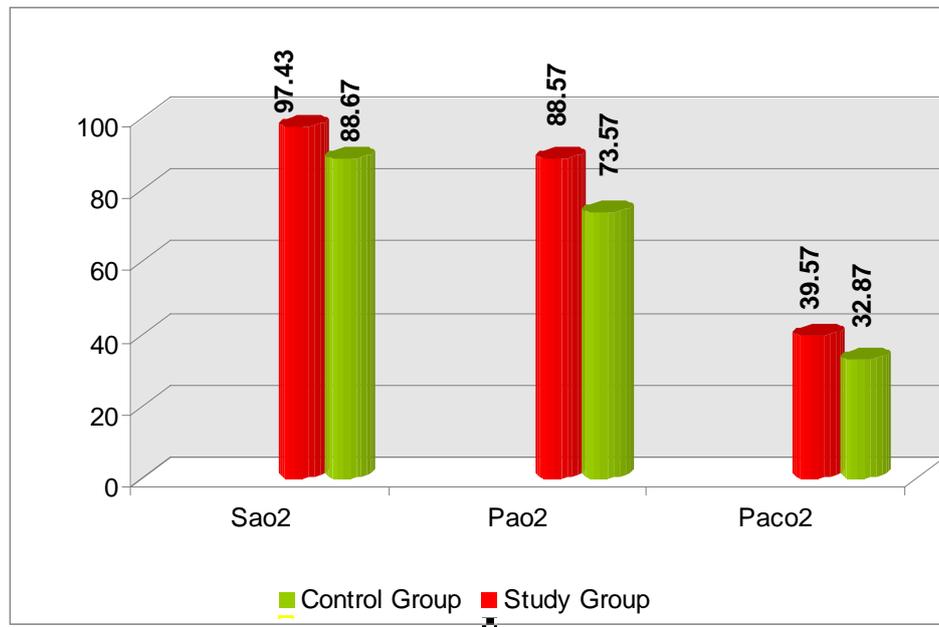
**Figure 2.** The Effect of Head of bed Elevation at 30 degrees during Endotracheal Suctioning on Oxygenation

Figure 2 showed that there was a statistically significant difference between the study and the control group regarding SaO₂, PaO₂ and PaCO₂ after suctioning.

6. Discussion

In patients with head injury, endotracheal suctioning is a potentially dangerous nursing procedure because it can increase intracranial pressure (ICP) and decrease cerebral perfusion pressure (CPP). Elevated ICP more than 40 mm Hg after traumatic brain injury can affect the protective mechanism of the brain which is responsible for sustaining Cerebral Blood Flow (CBF) after injury. Head of bed elevation of 30 degrees was chosen in the present study based on the traditional recommended position to improve cerebral venous outflow in patients with brain injury. This position places the cranial vault above the level of the heart, thus, facilitating venous outflow by decreasing hydrostatic pressure outside the thoracic circulatory system and help to maintain the desired ranges of intracranial pressure and cerebral perfusion pressure.

The Effects of Positioning During Endotracheal Suctioning on Cerebral Perfusion Pressure

Traumatic brain injury patients are at risk for intracranial hypertension and decreased CPP as a result of tissue edema and vasodilation. There are conflicting findings about the effects of endotracheal suctioning on CPP in previous studies. Kerr et al., (1999) [14] reported an increase in CPP during suctioning, while Thiesen et al.,

(2005) [27] reported a decrease in CPP. Whereas, Cerqueira-Neto et al., (2010) [28] found no significant changes in CPP. The current study hypothesized that patients with TBI who are receiving head of bed elevation at 30 degrees during endotracheal suctioning are more likely to have improvement of cerebral perfusion pressure than patients who are not receiving the head of bed elevation with the 30 degree intervention. The findings of the present study revealed that there is a statistically significant improvement in MAP, CVP and CPP at the three measurement points (immediately, 5 and 15 minutes) after suction in the study groups compared with the control group.

Additionally, the association between the head of bed position and ICP and CPP has been examined in previous studies [29,30,31,32,33]. Durward et al., (1983) [29] found a decreased ICP at 30 degrees and no change in CPP at the 15 & 30-degree elevation. Feldman et al., (1992) [30] found decreased ICP at the 30-degree elevation and decreased CPP in half of the subjects with the 30 degree elevation. March et al., (1990) [31] found no difference in ICP or CPP at 15, 30, or 45-degree elevation. Parson & Wilson (1984) [32] findings revealed that all patients positioned at more than 35 degrees had decreased CPP. Also, [33] found decreased CPP at 10, 20, 30, 40 and 50- degree elevation. The differences in these study findings may be explained by some methodological issues such as: the small sample sizes (range from 18 to 22) used in these studies; some studies did not mention the rest period before position change which makes it difficult to

compare findings. Also, most of these studies had a single point measurement. The fact that changes in MAP and ICP are associated with cardiac and respiratory cycles thus, the magnitude of change in CPP may not appear by using single point measurement. Another explanation could be the relatively younger age of the participants in the present study (the mean ages were 35 and 36 years old) without the deteriorating hemodynamic status that occurs in aging.

The Effects of Positioning During Endotracheal Suctioning on Oxygenation

The interruption of mechanical ventilation and drainage of oxygenated air and secretion through the respiratory tract during endotracheal suctioning resulted in decrease in PaO₂ and hypoxemia. Decreased PaO₂ and increased PaCO₂ [34,35] resulted in increase in vasodilatation, thus increasing cerebral blood flow and consequently ICP and decreasing CPP [36,37].

Head of bed elevation of 30° is the traditional recommended position to improve cerebral venous outflow in patients with brain injury. This position places the cranial vault above the level of the heart, thus, facilitating venous outflow by decreasing hydrostatic pressure outside the thoracic circulatory system. The current study hypothesized that patients with TBI who are receiving head of bed elevation of 30 degrees during endotracheal suctioning are more likely to have improvement of oxygenation than patients who are not receiving the head of bed 30 degree intervention. The findings of the present study revealed that there is a statistically significant improvement in pH, Pao₂ and Sao₂ and a decrease Paco₂ at the three measurement points (immediately, 5 and 15 minutes) after suctioning in the study groups compared with the control group. Similar findings have been reported by [38] who studied the effect of different degrees of head of the bed elevation of 30 degrees on respiratory parameters among mechanically ventilated patients after traumatic brain injury and found a statistically significant increase in pH, Pao₂, SaO₂, SpO₂, and a significant decrease in PaCO₂.

However, the finding of the current study is different from what was reported by [39] who reported that arterial blood oxygen saturation decreased after suctioning. Also, [40] reported a decreased respiratory rate, peak airway pressure, oxygen-saturated hemoglobin and tidal carbon dioxide after suction.

7. Limitations of the Study

In the present study, arterial blood gas values were used as an indicator of oxygenation to examine the effects of hypoxemia-induced oxygen saturation CPP. Stronger results could have been obtained by using jugular venous oxygen pressure, which directly reflects cerebral oxygenation during suctioning.

Participants were recruited from a single site and responses for the head of bed elevation intervention may be due to the institutional policy and nursing practices during suctioning procedure rather than position change alone.

The study findings can only be generalized to relatively younger patients with traumatic brain injury with clinically stable conditions and few co-morbidities.

8. Conclusion

Head of bed elevation of 30 degrees is a safe and effective position for patients with traumatic brain injury. This position resulted in enhancing CPP and improving oxygenation.

9. Recommendations

- Initiate the development of clinical practice guidelines for critical care nurses to use head of bed elevation of 30 degrees as routine care during endotracheal suctioning to improve cerebral pressure perfusion and oxygenation for patients with traumatic brain injury.
- Information generated from the current study will help critical care nurses understand the pattern and difference in traumatic brain injury patients' responses and thus nurses can tailor individual interventions.
- Replicate the study using a more heterogeneous sample to achieve appropriate representation of the studied population and conducting the study in more than one site.

10. Implications for Future Research

Further research is needed to evaluate whether other head of bed positions such as 20 or 45 degrees are effective in promoting therapeutic ranges of CPP during suctioning in patients with traumatic brain injury.

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