Does Closed Suctioning Have an Effect on Haemodynamic Parameters and Pain Perception in Mechanically Ventilated ICU Patients?

Fatma Ünlü
https://orcid.org/0000-0001-9448-7232
Ege University Hospital, Turkey
fatmayldrm222@gmail.com

Elif Günay İsmailoğlu
https://orcid.org/0000-0002-9152-3469
Izmir Bakircay University, Turkey
elif.ismailoglu@bakircay.edu.tr

Abstract

Background: Endotracheal suctioning is a common procedure used to mechanically remove pulmonary secretions from patients on artificial airways. Suctioning can be done with an open or closed suction system. Paradoxical conclusions have been drawn in the literature about the superiority of these methods. The aim of this study was to determine the effect of closed suctioning on haemodynamic parameters in intensive care mechanically ventilated patients.

Methods: This prospective observational study was conducted on intensive care patients who were mechanically ventilated at a university hospital between July and November 2022. Closed suctioning was performed on patients, and haemodynamic parameters and pain were registered before and after the suctioning by a research nurse.

Results: Sixty-seven patients were included (38 males and 29 females; total mean age 67.64 ± 16.16 years) in the study. Mean systolic blood pressure, respiratory rate, and oxygen saturation were higher one minute and 30 minutes after suctioning than before. Similarly, mean pulse rate and pain were higher at one, five, and 30 minutes after suctioning than before suctioning.

Conclusion: As a result, the closed suctioning technique caused significant changes in intensive care patients at both haemodynamic parameters and perceptual levels. Although this technique temporarily increases vital signs such as blood pressure and pulse in patients receiving mechanical ventilation, these increases remain within clinically safe limits. In addition, it has been determined that closed aspiration has a positive effect on oxygen saturation levels, indicating that this method plays a supportive role in oxygenation of patients.

Keywords: closed suction; haemodynamic parameters; intensive care units; mechanically ventilated patients; open suction; pain

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Introduction

Endotracheal suctioning is a common procedure used to remove mechanically the accumulated pulmonary secretions in patients with artificial airways (Faraji et al. 2015; Stilma et al. 2024). The presence of the endotracheal tube causes a decrease in ciliary movement and a deterioration in coughing. In addition, the production of respiratory secretions is increased in patients who are administered an endotracheal tube, while patients are unable to excrete these secretions themselves. Therefore, the secretions accumulated in the airline need to be aspirated according to the patient's needs (Blakeman et al. 2022; Gülsoy and Karagözoğlu 2020; Haghighat and Yazdannik 2015; Stilma et al. 2024).

Suctioning removes these secretions and cleans the patient's airway. This process increases oxygenation and prevents infection and atelectasis (Alavi et al. 2018; Stilma et al. 2021). Suctioning can be performed with an open (OSS) or a closed suctioning system (CSS). During open suctioning, the patient is disconnected from the ventilator in order to perform the procedure, and oxygenated air and airway pressure from the ventilator do not reach the patient during this time. Oxygen-rich air is also sucked out during open system suctioning due to discharge in the lungs, which decreases the partial oxygen pressure. During closed system suctioning, the patient remains connected to the ventilator, and oxygenated air and pressure continue to reach the patient (Yılmaz and Özden 2024). Desaturation and stimulation of peripheral chemoreceptors are symptoms of hypoxemia. During suctioning, the pulse, blood pressure, and breathing rate increase, and the tidal volume and peripheral oxygen saturation decrease (Yılmaz et al. 2021). In a closed system, the ventilator's oxygen-rich air can partially make up for the air loss, and fewer haemodynamic changes are expected in the patient during the suctioning procedure (Alavi et al. 2018; Faraji et al. 2015; Haghighat and Yazdannik 2015).

The introduction of closed system suctioning has necessitated a comparison with the open suction system. Compared to the latter, closed suctioning has a reduced adverse effect on patients' haemodynamic parameters such as oxygen saturation, arterial blood gas values, tidal volume, blood pressure, and pulse rate, and thus helps to maintain haemodynamic stability (Faraji et al. 2015; Widodo et al. 2020). CSS is also known to be more cost-effective in patients who need recurrent and frequent suctioning and decreases the time needed for suctioning (Imbriaco and Monesi 2021; Ramírez-Torres et al. 2023). In patients with prolonged mechanical ventilation, the CSS is more sustainable than the OSS (Stilma et al. 2024). Nevertheless, there are paradoxical conclusions in the literature about the superiority of these two methods (Kuriyama et al. 2015; Mohamed et al. 2023).

Although CSS has many benefits, nurses prefer OSS regardless of the risk of patients aspirating (Yilmaz, Ozden, and Arslan 2021). Despite their awareness of the possible complications, nurses fail to adhere to the recommended practice guidelines (Pinto, D'silva, and Sanil 2020). A study in Turkish hospitals revealed that 50.8% of nurses perceived the closed system as ineffective in suctioning viscous and sticky secretions from patient airways (Yilmaz, Ozden, and Arslan 2021). Furthermore, suctioning is among the most painful procedures in patients, and this practice can lead to various physical problems related to pain (Ebrahimian et al. 2020; Robleda et al. 2016). Studies have shown that both open and closed aspiration cause pain (Dastdadeh, Ebadi, and Vahedian-Azimi 2016; Khayer et al. 2020; Mohammadpour et al. 2015). Nevertheless, guidelines indicate that both suctioning techniques are safe to use (Blakeman et al. 2022).

Since the COVID-19 pandemic, closed suctioning has been recommended during endotracheal suctioning of patients in intensive care units (ICUs). Procedures that produce aerosols for COVID-19 patients put healthcare personnel at higher risk of infection. The open suctioning technique, even if they wear fully protective clothing and equipment, poses a serious threat to health workers (Ramírez-Torres et al. 2023). It is therefore crucial that nurses perform closed suctioning procedures. CSS is considered mandatory for patients with artificial airways in the intensive care unit (ICU) to reduce the risk of exposure of health workers to bioaerosol and contamination of the surrounding environment (Imbriaco and Monesi 2021). In light of the current guidelines, this study was conducted to determine the effects of closed suctioning on arterial blood pressure, heart rate, respiratory rate, oxygen saturation level, and pain in intensive care patients connected to a mechanical ventilator.

Significance of Study

The findings of the study will help to determine the effect of closed aspiration on haemodynamic parameters and pain. The resulting data may be valuable to reduce the concerns of nurses regarding the ineffectiveness of the closed system. In addition, the research results are important in terms of the safe application of the closed system in the clinic. The findings of the study will guide larger-scale studies to examine the effect of the closed system on other parameters.

Objectives of Study

The objective of this study was to determine the effect of CSS on arterial blood pressure, heart rate, respiratory rate, oxygen saturation level (SpO_2), and pain in mechanically ventilated patients in the ICU. CSS was evaluated as effective when pulse rate, respiratory rate, and arterial blood pressure values were similar to or slightly lower than SpO_2 values, and the degree of pain was similar to measures obtained prior to suctioning.

Methodology

Design

This was a prospective observational study and in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement on observational studies (Ghaferi, Schwartz, and Pawlik 2021). The clinical trial registration number is NCT06143865.

Sample

The sample was made up of patients who met the inclusion criteria and were hospitalised in the anaesthesia and reanimation intensive care unit of a university hospital in Izmir, Turkey, from July to November 2022. The criteria for selection of participants included patients that were at least 18 years of age, intubated (between two and seven days), and connected to a mechanical ventilator. However, patients who were sedated, had a neuromuscular blocking agent, chest tube, chest trauma that could cause chest pain, in a coma, or whose haemodynamic parameters were not at normal levels, were excluded.

Sample Size

The G* Power statistical power analysis program (version 3.1.9.4) was used to determine the appropriate sample size for this study. Due to the influence of repeated measures, at least 60 patients had to be included based on the 95% confidence (1-α), 95% G* power test (1-β), and the effect size (d = 0.35) (Khayer et al. 2020). Considering the possibility of withdrawal, we enrolled 72 participants. After excluding patients who did not meet the inclusion criteria, the study was completed with 67 patients. The study flow chart, depicting the sampling procedure followed and inclusion criteria employed, is shown in Figure 1.

Data Collection

The intensive care nurse responsible for the patients participating in this study performed the closed suctioning procedure when patients required aspiration. The best indicators of endotracheal suctioning in the adult population include breath sounds, visible secretions in the artificial airway, and a sawtooth pattern on the mechanical ventilation wave form (Blakeman et al. 2022). Prior to data collection, one intensive care nurse received in-service training on the correct application of closed system aspiration, in accordance with the American Association for Respiratory Care (AARC) Clinical Practice Guidelines. Following the verbal instruction, the suctioning application of the nurse was observed, and the data collection phase began once the procedure was completed correctly. Subsequent to training, the nurse fulfilled suctioning according to the practice guidelines (Figure 2). Suctioning was performed once for each patient.

Haemodynamic parameters (arterial blood pressure, heart rate, respiratory rate, oxygen saturation level) and pain were assessed and recorded by one researcher (the intensive care nurse) immediately before suctioning and again one, five and 30 minutes afterwards. Haemodynamic parameters were recorded from the IntelliVue® MX800 and Philips® bedside monitor.

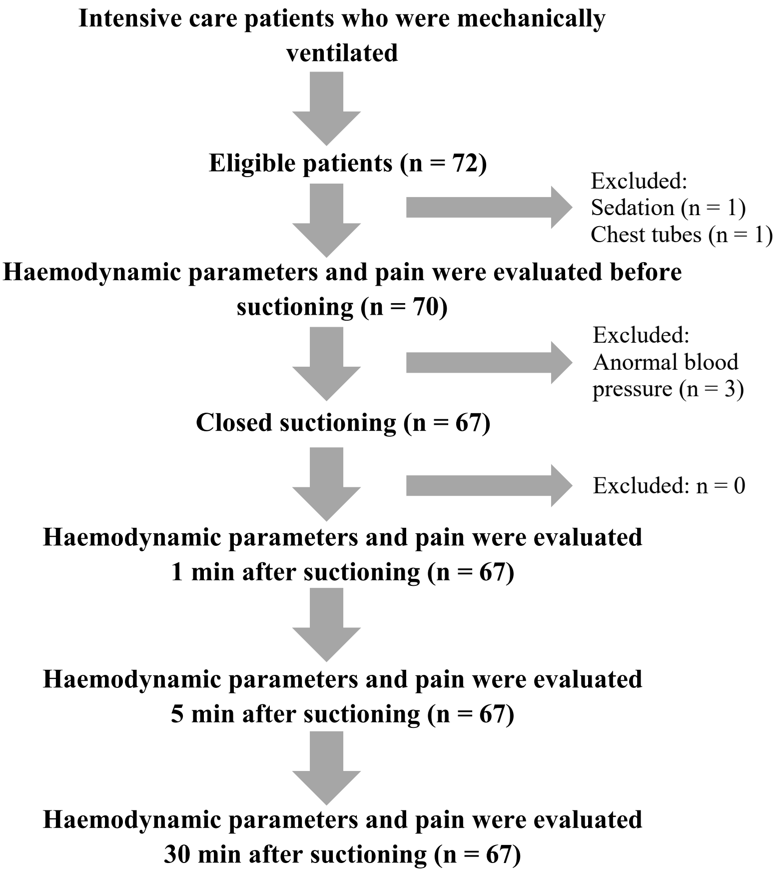

Figure 1: Study flow chart.

Data were collected using the Patient Identification form, Haemodynamic Status and Pain Monitoring form, and the Behavioural Pain Scale. The Patient Identification form consists of seven patient-identifying questions such as age, gender, diagnosis, duration of hospital stay, duration of stay on mechanical ventilation, and the Glasgow coma scale score (Dastdadeh, Ebadi, and Vahedian-Azimi 2016; Khayer et al. 2020; Mohammadpour et al. 2015). The Patient Identification form was filled out using the patient file.

T-connection is secured with the non-dominant hand

↓

Closed suctioning catheter is moved forward with the index finger and thumb of the dominant hand

↓

Catheter is moved until the carina (until resistance is felt) and pulled back by 1 cm

↓

Catheter is removed by rotation, while suctioning is performed at intervals by pushing the suctioning control button for 2–3 cm and then releasing it

↓

Catheter is pulled back until the black line is seen at the corner of the T-junction

↓

The connector of the suctioning tube is removed from the closed suctioning catheter, and the cap of the catheter is closed

Figure 2: Steps for closed system suctioning (Özden and Görgülü 2012).

The behavioural pain scale was developed by Payen et al. (2001). It is a validated tool used for assessing pain in patients who are unable to verbally communicate their pain level, such as sedated or mechanically ventilated patients. The three main components are facial expressions, upper limb movements, and compliance with the mechanical ventilator. Each component of the behavioural pain scale has a range score of 1–4. The total score ranges between 3 and 12. A higher score indicates an increase in the severity of the pain. The Cronbach alpha value, which indicates the reliability of the pain score (Kahraman and Ozdemir 2016; Payen et al. 2001), was found to be between 0.71–0.93.

Closed System Suctioning Standard

All patients received 100% oxygen for one minute before and after suctioning. Negative pressure was adjusted to 150–200 mm Hg in all patients. Each suctioning process lasted a maximum of 15 seconds; the suctioning was not repeated more than three times in a row, and deep suctioning was avoided (Blakeman et al. 2022). It was noted that the patient did not receive any painful stimuli 30 minutes before the suctioning procedure. No endotracheal suctioning-related complications were observed in any of the patients. We used the Easyflow® 16-French thick catheter typically available in our hospital. The Lagoon 600 Egypt® aspirator, which had a vacuum power of 150 mmHg was used as a negative pressure source in each application.

Blinding and Bias in the Study

To prevent differences in personal interpretation between assessors, one nurse conducted the haemodynamic parameter and pain evaluation for all patients.

Data Analysis

The results were expressed as descriptive statistics in the form of numbers, percentages, averages, standard deviations, minimums, and maximums. The Shapiro-Wilk test was used for the normality assumption. Assumptions were tested to compare the averages of haemodynamic and pain measurements obtained at different times. ANOVA and Friedman tests were used to analyse repeated measurements. The post hoc and adjusted Bonferroni tests were used to identify significantly different groups. The analyses were carried out using the IBM SPSS 25 program. Statistical significance was set as $p \leq 0.05$.

Ethical Considerations

Ethical clearance was obtained from the Ethics Committee of Izmir Bakircay University (ethics code: E-399) on 1 December 2021. Written consent was obtained from the relatives of the patients. This research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki (World Medical Association 2025). The patient's relatives were informed about the purpose of the study, that the patient's identity information would not be published, and that the necessary information about the procedure and written permission were obtained.

Results

The distribution of demographic and clinical characteristics of patients is shown in Table 1. The mean age of the patients was 67.64 ± 16.16 years; the majority of participants (56.7%) were male. The average intensive care stay and mechanical ventilation duration were 3.79 ± 1.86 and 3.69 ± 1.86 days, respectively (Table 1).

Statistically significant differences were found between the mean measurements for systolic blood pressure (SBP), pulse rate, respiratory rate, oxygen saturation level, and pain, and time (Table 2). The mean SBP values one minute ($p = 0.001$) and 30 minutes ($p = 0.006$) after suctioning were higher than before. There was no significant difference between average diastolic blood pressure and time ($p = 0.17$; Table 2). The mean pulse rate was higher one ($p = 0.000$), five ($p = 0.000$), and 30 minutes ($p = 0.002$) after suctioning compared to before the procedure. The mean respiratory rate was higher one minute ($p = 0.004$) and 30 minutes ($p = 0.000$) after suctioning than before (Table 2). The mean saturation was consistently higher during the 30-minute period after suctioning (Table 2; Fig. 3); values at one minute ($p = 0.018$) and 30 minutes ($p = 0.023$) after suctioning were significantly higher than before. The mean pain score was higher one minute ($p = 0.000$), five minutes ($p = 0.000$), and 30 minutes ($p < 0.001$) after suctioning than before the procedure (Table 2).

Table 1: Demographic and medical characteristics of patients.

Patient information	**n**	**%**
Gender		
Female	29	43.3
Male	38	56.7
Age, y (M ± SD)	67.64 ± 16.16	
22–44	8	11.9
45–64	16	23.9
65–74	16	23.9
75 years and above	27	40.3
Length of stay in intensive care, d (M ± SD)	3.79 ± 1.83	
2	23	34.3
3	15	22.4
4–6	19	28.4
7	10	14.9
Length of stay on mechanical ventilation, d (M ± SD)	3.69 ± 1.86	
2	25	37.3
3	15	22.4
4–6	17	25.4
7	10	14.9
Diagnosis		
Cerebral haemorrhage	11	16.4
Cancer	13	19.4
Traffic accident	6	9.0
Heart disease	10	14.9
Cardiac arrest	13	19.4
Other*	14	20.9
Glasgow Coma Scale (M ± SD)	9.40 ± 1.12	

*Septicaemia, pulmonary embolism, especially cirrhosis, alcohol intoxication, anaphylactic shock, cholangitis; M = mean, SD = standard deviation, y = year, d = day

Table 2. Haemodynamic and pain levels before and after suctioning (n = 67).

Haemodynamic and pain measurements	Time of measurement	M	SD	MR	Significance test	p-value
Systolic blood pressure (mmHg)	Before suction	120.21	13.432	2.19	17.321**	0.001*
	1st min after suction	126.93	21.055	3.02		
	5th min after suction	120.12	21.942	2.50		
	30th min after suction	120.82	15.870	2.29		
Diastolic blood pressure (mmHg)	Before suction	61.67	12.810	-	1.700***	0.17
	1st min after suction	63.84	13.259	-		
	5th min after suction	62.15	13.187	-		
	30th min after suction	62.12	12.808	-		
Pulse rate (beats/min)	Before suction	84.49	20.718	1.88	59.850**	0.000*
	1st min after suction	96.34	19.071	3.41		
	5th min after suction	89.46	17.434	2.60		
	30th min after suction	86.63	16.867	2.10		
Respiratory rate (breaths/min)	Before suction	18.81	4.847	2.30	22.508**	0.000*
	1st min after suction	20.84	6.761	3.06		
	5th min after suction	18.97	5.114	2.48		
	30th min after suction	18.22	4.608	2.16		
SpO_2 (%)	Before suction	96.63	11.052	2.68	13.963**	0.003*
	1st min after suction	97.40	2.406	2.15		
	5th min after suction	97.78	2.073	2.51		
	30th min after suction	97.84	2.042	2.66		
Pain	Before suction	3.00	0.000	1.93	181.109**	0.000*
	1st min after suction	6.69	1.877	3.95		
	5th min after suction	3.25	0.636	2.19		
	30th min after suction	3.00	0.000	1.93		

*$p < 0.05$; **Friedman test; *** repeated measures ANOVA test; SpO_2: oxygen saturation; min: minute; M = mean; SD = standard deviation; MR = mean rank

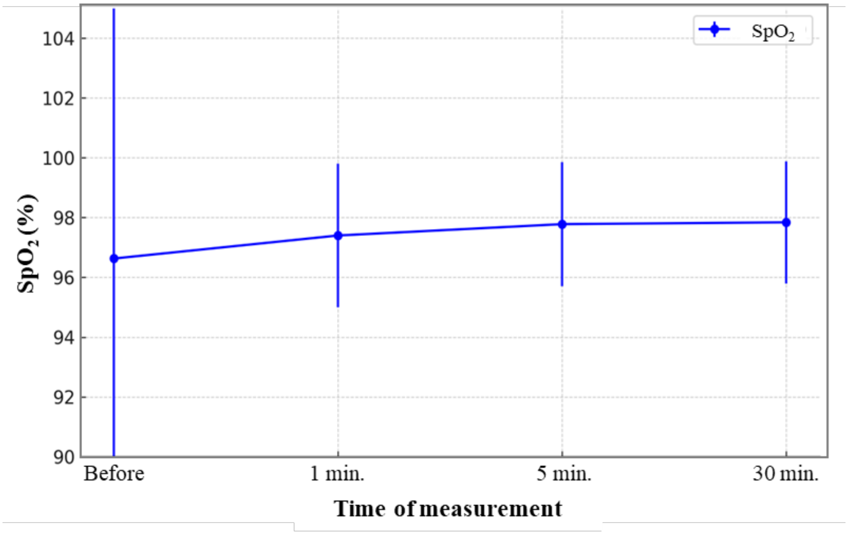

Figure 3: Change in saturation over time.

Discussion

In this study, the effects of closed suctioning on arterial blood pressure, heart rate, respiratory rate, oxygen saturation level, and pain in ICU patients on mechanical ventilators were evaluated. Our research shows that closed suctioning applied to intensive care patients causes short-term but significant changes in various physiological parameters. SBP and pulse values reached the highest level in the first minute after suctioning although these increases were within normal limits. Özden and Görgülü (2015) and Gülsoy and Karagözoglu (2020) similarly reported a significant increase in mean blood pressure and pulse rate immediately after closed suctioning. The increase observed reveals an acute stress response created by CSS in the patient (Dayoub and Jena 2015; Gülsoy and Karagözoglu 2020). In some studies comparing the two methods, it was determined that the increase seen after open suctioning was greater than after closed suctioning (Afshari et al. 2014; Alavi et al. 2018; Özden and Görgülü 2015; Uğraş and Aksoy 2012). By contrast, other studies showed similar blood pressure changes in OSS and CSS post-suctioning (Ebrahimian et al. 2020; Mohamed et al. 2023; Sayed 2019; Siyasari et al. 2018). In one such study, it was additionally demonstrated that this increase dropped back to initial levels after 15 minutes, following closed suctioning, while these levels were still slightly higher after open suctioning (Afshari et al. 2014). This finding suggests that closed suctioning did not generally have a detrimental impact on patient pulse rates. The fact that SBP and pulse values reach their highest level at one minute after aspiration indicates that this procedure creates a short-term stress response on the body. Although these increases remain within normal limits, they necessitate the need for close monitoring of the haemodynamic stability of the patients and the need for intervention.

One of the main advantages of the closed suction system is that it allows aspiration to be performed without disconnecting the patient from the ventilator. This minimises changes in oxygenation and ventilation, thereby preventing lung volume loss (Mohammadpour et al. 2015). In this study, the saturation value reached its highest level in the first minute after suctioning. This finding supports the fact that closed suctioning systems are effective in minimising oxygen loss. Similar findings were reported by Gülsoy and Karagözoğlu (2020). Likewise, Şimşek et al. (2019) and Sayed (2019) indicated that oxygen saturation levels were higher compared to open suctioning. By contrast, in some studies, the mean oxygen saturation reduced after closed suctioning (Elmelegy and Ahmed 2016; Mohamed et al. 2023; Widodo et al. 2020). Faraji et al. (2015) also demonstrated that respiratory parameter changes were less pronounced with the closed technique. Overall, the literature suggests no clear superiority between the two methods, and findings vary depending on methodological differences (Kuriyama et al. 2014).

One of the complications of suctioning is pain. The suctioning process causes even semi-conscious patients to experience pain (Dastdadeh, Ebadi, and Vahedian-Azimi 2016; Gülsoy and Karagözoğlu 2020; Kuriyama et al. 2015; Mohammadpour et al.

2015; Özsaban et al. 2023; Shahiri et al. 2020). The peak in pain level during the first minute after suctioning indicates that the closed suction technique is also perceived by patients as a distressing and painful procedure. Endotracheal suctioning increases pain due to its discomfort, and patients who underwent closed suctioning experienced the highest level of pain during the procedure (Gülsoy and Karagözoğlu 2020; Gülsoy and Kol 2024). Both open and closed suctioning methods increase pain in patients compared to the pre-suctioning period (Dastdadeh, Ebadi, and Vahedian-Azimi 2016; Faraji et al. 2015; Khayer et al. 2020; Mohammadpour et al. 2015). In contrast, Açıkgöz and Yıldız (2015) reported increased pain levels among newborns who were suctioned using an open suctioning method compared to the closed suctioning method.

Recommendations

Based on these results, it is suggested that the closed suctioning technique can be used as a reference in the treatment of mechanically ventilated patients, especially to predict the occurrence of hypoxia. Also, pain assessment before closed suctioning and observation of the patient during the procedure are important. In line with these results, future studies should be conducted in which closed and open suctioning are evaluated together.

The findings of the study will help to determine the effect of closed aspiration on haemodynamic parameters and pain. The resulting data will be valuable in reducing nurses' concerns about the ineffectiveness of the closed system. In addition, the research results are important in terms of the safe application of the closed system in the clinic. The findings of the study will guide larger-scale studies to examine the effect of the closed system on other parameters.

Limitations

This study was conducted in a single centre during the COVID-19 pandemic. Accordingly, the study was carried out with a single cohort subjected to the closed suction technique.

Conclusions

SBP, pulse, and respiratory rate values reached their highest levels in the first minute after performing closed suctioning. However, the fact that these elevations were within normal limits and they decreased to the baseline level within 30 minutes after suctioning suggests that closed suctioning did not have a negative effect on the haemodynamics of the patients. Furthermore, immediately following closed suctioning, there was a considerable rise in oxygen saturation. As a result, it can be concluded that the closed suctioning technique has a marked positive effect on oxygen saturation values in patients undergoing mechanical ventilation in the ICU. However, pain level after closed suctioning was also found to be higher than before the procedure.

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