Received: 13 March 2024 | Revised: 26 September 2024 | Accepted: 11 October 2024

DOI: 10.1111/nicc.13197

RESEARCH ARTICLE

BACN Nursing in Critical Care WILEY

The association of early passive mobilization with intracranial pressure in the adult intensive care unit: A prospective, cohort study

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Abstract

Background: Early mobilization are key components of the ABCDEF Care Bundle and critical treatments to reduce acquired muscle weakness, delirium and prolonged intensive care unit (ICU) stay.

Aim: This study aimed to determine whether routine early mobilization related to intracranial pressure in intensive care patients on mechanical ventilation, using optic nerve sheath diameter measurement (ONSD).

Study design: This study was planned as a prospective, cohort study in the third-step adult ICU of a faculty hospital. The study included only patients who were intubated and followed up on a mechanical ventilator and were clinically stable. Passive range of motion (PROM) exercises were performed daily by the physiotherapists as part of routine care from the day of hospitalization. ONSD was assessed before, during and 10 min after PROM exercises.

Results: The study included 20 eligible patients out of the 142 who were evaluated upon admission to the ICU. The median age of the patients was 65 years, and nine (45%) of them were female. The analyses showed that there was no statistically significant change in ONSD during and at the end of the PROM (ONSD right eye p:.621, Partial η^2: 0.025, ONSD left eye p:.935, Partial η^2: 0.004). Similarly, there was no statistically significant change in haemodynamic parameters in during and at the end of the PROM (Heart beat p:.849, Partial η^2: 0.009, Systolic Pressure p:.435,

The current study was presented at the 16th World Intensive and Critical Care Congress (WICC) as an oral presentation.

Partial η^2: 0.043, Diastolic Pressure *p*:.128, Partial η^2:0.103, Saturation *p*:.103, Partial η^2: 0.113 and Respiratory rate *p*:.071, Partial η^2:0.130).

Conclusion: This study suggests that daily extremity physiotherapy exercises can be safely applied without causing increased intracranial pressure or haemodynamic instability in intensive care patients followed up on mechanical ventilation, including patients with vasopressor therapy.

Relevance to Clinical Practice: Early mobilization, including PROM, is considered safe in terms of intracranial pressure for intubated patients in the ICU.

KEYWORDS

early mobilization, haemodynamics, intensive care unit, intracranial pressure, mechanical ventilation

1 | INTRODUCTION

Early mobilization is considered a standard treatment in intensive care management, and patients are regularly treated with active exercises or passive range of motion (PROM). Early mobilization in the early phase of critical illness is associated with favourable outcomes such as decreased ventilation time, shorter intensive care unit (ICU) stays, and decreased duration and frequency of delirium.[1–3] On the other hand, there are some concerns about complications that may occur early mobilization.

One such concern is the risk of increased intracranial pressure (ICP). In particular, this concern is heightened in cases of traumatic brain injury, while it is known that ICP can be increased in cases such as aspiration and positioning. Patients with intracranial events (subarachnoid haemorrhage, intracranial mass, etc.) are prone to elevated ICP, which may worsen the clinical condition of the patient. Fear of an increase in ICP empirically results in minimal patient contact in such patients. Even nursing activities or therapeutic procedures may be postponed or avoided.[4]

Invasive monitoring of ICP is recommended for patients with risk for increased ICP. Invasive monitoring of ICP has positive effects, such as rapid detection and appropriate management of elevated ICP. However, intraventricular implanted devices can be associated with complications such as bleeding, infection and the need for frequent calibration. The optic nerve sheath (ONS) is a continuation of the intracranial dura surrounding the subarachnoid space and is known to expand, particularly in the anterior retro bulbar region, with increased ICP. It is a non-invasive, bedside ultrasound measurement compared with other methods of intracranial monitoring.[5]

There are many studies in the literature showing that ICP can be assessed non-invasively by measuring the optic nerve sheath diameter (ONSD).[6,7] The results of the meta-analysis show that ONSD above 5 mm (ICP >20 mmHg) is associated with increased ICP.[8,9] To date, only a few studies with limited numbers of patients have examined the relationship between early mobilization and ICP using ONSD.[4,5]

What is known about the topic

- Early mobilization is an evidence-based practice recommended in recent guidelines on behalf of the ABCDEF care bundle.
- There is limited information on the association of early mobilization with intracranial pressure

What this paper adds

- Early mobilization, which consists of passive range of motion, is safe and feasible for mechanically ventilated individuals in the ICU in terms of intracranial pressure.
- Passive range of motion exercises do not significantly relate to haemodynamic parameters in mechanically ventilated individuals in the ICU.
- The optic nerve sheath diameter is a non-invasive method that can be used to monitor intracranial pressure during intensive care mobilization procedures.

2 | AIMS AND OBJECTIVES OF STUDY

The aim of our study was to evaluate whether passive early mobilization exercises have an association with ICP.

3 | DESIGN AND METHODS

3.1 | Design

This is a prospective observational cohort study conducted in the tertiary adult ICU of Karadeniz Technical University Faculty of Medicine Hospital. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline was used to report the study.[10]

3.2 | Participants

Patients on mechanical ventilation support, with appropriate sedation levels and without acute neurological events, were included in the study. Exclusion criteria were as follows: < 24 h stay in ICU; patients not on mechanical ventilation support; conditions affecting ONSD measurement (optic nerve neoplasia-inflammatory diseases, arachnoid cyst, sarcoidosis, pseudotumor cerebri, Graves' disease, glaucoma, advanced age [>85 years]); clinical deterioration during physiotherapy, acute phases of intracranial events; and patients whose consent could not be obtained. None of the patients had pre-existing chronic intracranial hypertension or hydrocephalus. Of the 142 patients followed up in our ICU during the defined period, 20 patients who met the criteria were included in the study (Figure 1). All patients were mechanically ventilated and sedated to the extent that they could not exert themselves. Patients' sedation levels were standardized using the Richmond Agitation-Sedation Scale (RASS). Patients with RASS scores between −2 and −4 were included in the study.

3.3 | Settings

Early mobilization is routinely applied in our ICU based on ABCDEF care bundle recommendations.[11] As the study participants were sedated and mechanically ventilated, the early mobilization exercises involved PROM exercises. PROM is routinely applied in intubated and sedated patients in our unit. PROM is applied once a day as part of routine intensive care treatment, starting on the day of admission and after the patient's clinical stability is ensured. Passive joint movement was performed with 10 × 2 repetitions throughout the patient's normal range of motion in the supine position in all planes of joint movement, including the shoulder, elbow, wrist, fingers, hip, knee, ankle and toes. Early mobilization was performed by continuous PROM for a period of 20 min, according to the standard protocol for physiotherapy in our ICU. Passive joint movement was performed by two physiotherapists with 10 and 15 years of experience in physiotherapy and rehabilitation.

3.4 | Data collection

The study included patients who met the inclusion criteria and were followed up in our unit from March 2023 to July 2023. Demographic information, primary diagnoses and comorbidities, important laboratory tests, patient outcomes, clinical severity scores (Apache II, SOFA) and sedative medications were recorded. Physiological data such as saturation, blood pressure and pulse rate were measured before, during and after exercise using the GE Healthcare monitor.

Ultrasound measurement of the ONSD was conducted by a trained intensivist to detect changes in diameter. ONSD measurements were performed before, during and 10 min after the physiotherapy session. Measurements were performed with an ultrasound device (GE Vivid®) and L38e/10–5 MHz. All measurements were made by the same person. Two measurements were done bilaterally for each optic nerve: the first in the transverse plane, with the probe horizontal; and the second in the sagittal plane, with the probe vertical. The ONSDi presented is the mean of the two measurements.[12,13]

Each patient underwent orbital ultrasound while lying down with their eyes closed, and the internal optic nerve sheath diameter (ONSDi) was measured. Inside diameter (ONSDi) is the distance

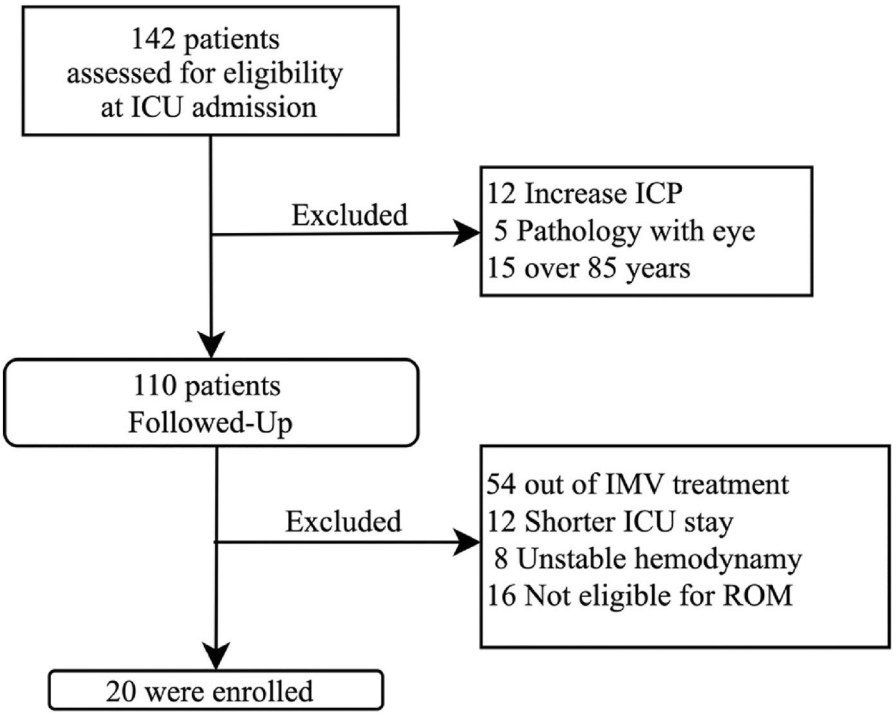

FIGURE 1 Flow chart of study. ICP, intracranial pressure; ICU, intensive care unit; IMV, invasive mechanical ventilation; ROM, range of motion exercise.

between the external borders of the hyperechoic area surrounding the optic nerve, which also refers to the distance between internal edges of the echolucent lines surrounding this hyperechogenic space. ONSDi (distance between outer edges of the pia mater) measurements were performed 3 mm below the papilla (because the contrast difference with the surrounding tissue on USG is best at this level).[12,13] No additional method was used for ICP monitoring. Systolic/diastolic/mean arterial pressures, heart rate and fingertip saturation values (SpO_2) were recorded simultaneously during each measurement.

3.5 | Sample size

Using G*Power software (Version 3.1.9.2; Universitat Kiel, Kiel, Germany) with $\alpha = .05$, a sample size calculation determined that 19 patients would be required to detect an ONSD measurement difference of >1 mm at an SD of 0.1 mm after exercise with a power of 0.80.[14] Post hoc analysis revealed that 20 patients with $\alpha = .05$ and $f = 0.3$ corresponds to Power (1-β err prob) = 0.8141908.

3.6 | Data analysis

Data were analysed using IBM SPSS V23 (Chicago, USA). Continuous variables are expressed as mean ± standard deviation, or as median (interquartile range) according to the distributions examined by the Kolmogorov–Smirnov test. Categorical variables are presented as frequency and proportion. The baseline value of optic nerve diameter was compared with the value during and after PROM application using repeated measures ANOVA. Bonferroni correction was applied for pairwise comparisons in case of significant differences.

4 | ETHICAL AND RESEARCH APPROVALS

The study was approved by the Ethics Committee of the Karadeniz Technical University, Faculty of Medicine, with approval number (2022/256). Informed consent was obtained from the legally authorized representative of each unconscious patient before enrollment. The legally authorized representatives were informed about the purpose of the study, the methods, the potential risks and benefits, and their rights regarding participation. The confidentiality of the data collected, and the patients' privacy were protected. The legally authorized also had the option to withdraw from the study at any time.

5 | RESULTS

Twenty patients were enrolled out of 142 patients assessed for eligibility during the study period. The median age of the patients was 65 years, and 9 (45%) were female. The most common diagnosis of ICU admission was respiratory causes. The most common comorbidity was hypertension. The median APACHE II score of the patients included in the study was 21. All demographic information of the patients is given in Table 1. Vasopressor was started in 13 patients (65%). The mean sedation and vasopressor doses and patient outcomes during hospitalization are shown in Table 1.

Measurements were performed at the beginning, during and end of the PROM exercises. The analyses showed no statistically significant change in ONSD during or after the procedure compared with before the procedure (Table 2, Figure 2). Similarly, there was no statistically significant change in heart rate (Figure 3), systolic pressure (Figure 4), diastolic pressure (Figure 5), saturation (Figure 6) or respiratory rate (Figure 7) parameters during and at the end of the procedure compared with before the procedure.

6 | DISCUSSION

Early mobilization is accepted as a part of standard therapy in ICUs, and patients are systematically treated with active exercises or PROM.[15] In ICUs, there is a concern about increased ICP in physiotherapy applications as well as in various procedures. For example, increased ICPs have been detected during bronchoscopy procedure, endotracheal aspiration and intramuscular injection applications.[16–18] ICP has also been shown to increase during health care activities that involve turning the whole body, turning the head only or moving the patient in bed, such as PROM. In fact, patients with severely elevated ICP often empirically result in 'minimal touch therapy'.[19,20] However, most of these studies were conducted in brain-injured patients at high risk of increased ICP. There are a small number of studies suggesting that physiotherapy with PROM can be used safely in patients with acute neurological disease, even if ICP is elevated before treatment.[5,21] In these studies, measurements were frequently performed with invasive ICP monitoring. In our study, we evaluated the association of routine physiotherapy applications with ICP in critically ill patients followed with mechanical ventilation by ultrasonographic ONSD measurement, which is a non-invasive and easy method. Sedated and immobilized patients according to RASS scores were included in the study. However, patients had high mortality (APACHE II: 21 [18–24.75]) and organ failure scores (SOFA: 9 [7–11.75]) and most of them (65%) were receiving vasopressors. No significant change in haemodynamic parameters and ICP was observed with passive ROM exercises. Based on our findings, we suggest that PROM exercises appear to be a safe physiotherapy practice that does not significantly increase ICP in selected mechanically ventilated critically ill patients. Invasive intracranial pressure monetarization is difficult to perform and maintain because it requires specific personnel, invasive catheterization and has a high risk of infection. Moreover, there is not enough evidence for invasive methods for ICP monitoring.[22] The ONS is directly connected with the subarachnoid space, and, differently from the skull that it is inextensible, the intraorbital subarachnoid meningeal prolongation is then free of swelling with the pressure increase in the cerebrospinal fluid. Recommendations for these cut-off values have varied from 5.0 to 5.9 mm, with sensitivities and

TABLE 1 Characteristics of patients at admission and at end points.

Characteristic at admission	M (IQR 25–75)	End points	M (IQR 25–75)
Age, years	65.5 (56.5–75)	Midazolam, mg/h	5 (3–6.5)
SOFA score	9 (7–11.75)	Fentanyl, µg/h	200 (100–275)
APACHE score	21 (18–24.75)	Ketamine, mg/h	80 (65–90)
RASS	−4 (−4 to −4)	Vasopressor use, *n* (%)	13 (65)
GCS	4 (4–4)	Noradrenaline, µg/kg/h	0.09 (0.05–0.13)
Hgb, g/dL	9.4 (8.1–11.23)	Tracheostomy	2 (10)
Plt count, ×1000/µL	159 (26–271.75)	ICU Stay, day	14.5 (7.5–28.75)
WBC, ×1000/µL	10 (3.53–14.8)	IMV Duration, day	7 (4.5–23)
CRP, mg/L	95 (47.5–151.5)	Survived, *n* (%)	8 (40)
Female, *n* (%)	9 (45)	Intracranial pathology, *n* (%)	4 (20)
Primary diagnoses	*n* (%)		
Pulmonary	13 (65)		
Cardiac	2 (10)		
Malignancy	3 (15)		
Neurological	2 (10)		
Sepsis	14 (70)		
Comorbidity	*n* (%)		
Asthma, COPD	5 (25)		
CRF	2 (10)		
DM	6 (30)		
Malignancy	6 (30)		
HT	8 (40)		
Other	11 (55)		

Note: All data are shown as median (IQR 25–75).
Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; COPD, chronic obstructive pulmonary disease; CRF, chronic renal failure; CRP, c-reactive protein; DM, diabetes mellitus; GCS, Glasgow Coma Score; Hgb, haemoglobin; HT, hypertension; ICU, intensive care unit; IMV, invasive mechanical ventilation; Plt, platelet; RASS, Richmond Agitation-Sedation Scale; SOFA, Sequential Organ Failure Assessment; WBC, white blood cell.

specificities ranging from 70% to 100% and 30% to 100%, respectively, depending on the study and the optimal cut-off value identified.[7,9] In cases such as stroke, intracerebral or subarachnoid haemorrhage, higher ONS values such as 0.59–0.63 cm have been reported.[23–25] The distance between the inner and outer edges of the echo lucent lines around hyperechoic area surrounding the optic nerve (ON) was identified as ONSD external (ONSDext) and ONSD internal (ONSDi). ONSDext has been questioned in previous studies, although it is a more common method. The dura mater is not considered part of the dilatory component, and Stevens et al. recommend measuring from the internal part of the dura.[26] In our study, ONSDi measurements were performed in real time in both eyes and during physiotherapy. In addition, one of the reasons why ONSD assessment with ultrasound is useful for ICU patients is that it can be performed at the bedside with a short training. Therefore, it is an easy and non-invasive diagnostic tool for early diagnosis of intracranial hypertension.

The main interest of this study was the relationship between physiotherapy and ICP, which in recent years has played an important role in improving the quality of patient care, contributing to patient mobilization and recovery rate, and adaptation to life outside the hospital. For example, while there is literature data on increased ICP during various procedures such as endotracheal aspiration, bronchoscopy or intramuscular injections, there was a lack of data on ICP changes during PROM, a relatively new routine in ICUs.[17] There have been only a few other studies on cerebral haemodynamic changes during PROM.[4,5,20,21] However, ICP measurements in these studies are usually invasive measurements. The difference of our study was to introduce ONSDi measurement into clinical practice, which is an ICP assessment method that even physiotherapists can measure themselves with short training while performing bedside physiotherapy in critically ill patients. On the other hand, some authors emphasize that measuring ONSD is not a simple task. They disagree with the idea that ONSD assessment can be performed with a short training of almost any medical and paramedical personnel. It is true that ultrasound can be used to detect changes in ICP in real time, but they recommend the use of A-scan, which is less susceptible to personal error but requires skill to obtain reliable measurements.[27,28] In this study, all measurements were performed by a trained intensive care specialist. We think that ONSD measurement can be performed accurately with

TABLE 2 Assessments before, during and after ROM exercise.

$N = 20$	Before ROM	During ROM	After ROM	Partial η^2	p value
ONSDi right eye, cm	0.602 ± 0.06	0.598 ± 0.05	0.600 ± 0.06	0.025	.621
ONSDi left eye, cm	0.590 ± 0.05	0.592 ± 0.06	0.591 ± 0.05	0.004	.935
Heartbeat, beat/min	90.85 ± 18.70	91.55 ± 18.09	91.60 ± 18.63	0.009	.849
Systolic pressure, mmHg	112.65 ± 27.36	120.7 ± 15.04	114.5 ± 28.62	0.043	.435
Diastolic pressure, mmHg	59.45 ± 8.48	63.5 ± 9.3	61.65 ± 10.57	0.103	.128
Saturation, %	95.85 ± 3	94.65 ± 3.6	95.8 ± 3.27	0.113	.103
Respiratory rate, breath/min	18.35 ± 4.79	18.5 ± 4.85	18.55 ± 4.94	0.130	.071

Note: Values are shown as mean ± SD.
Abbreviations: ONSDi, distance between outer edges of the pia mater; ROM, range of motion exercise; η^2, eta squared.

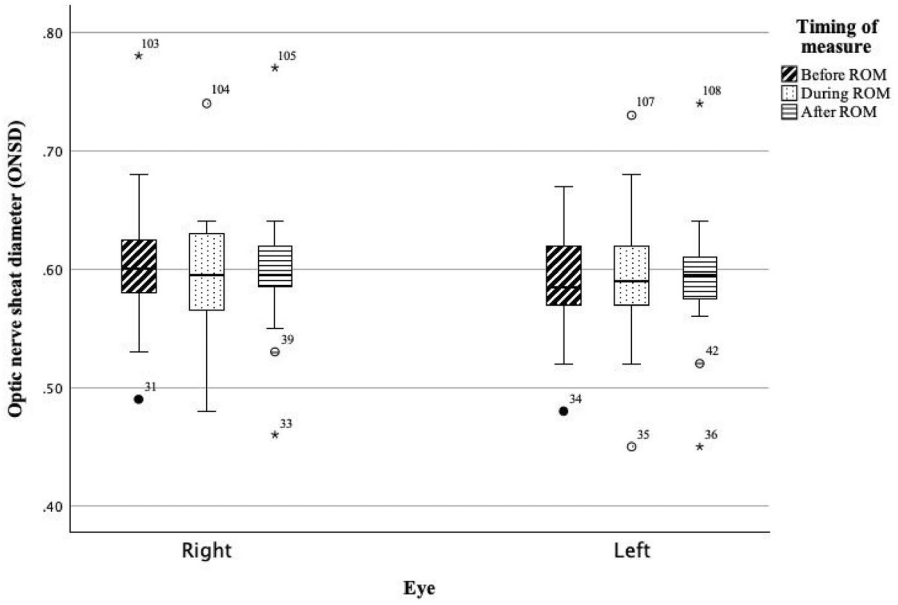

FIGURE 2 Graphics of ONSD measures. ONSD; optic nerve sheath diameter; ROM, range of motion exercise.

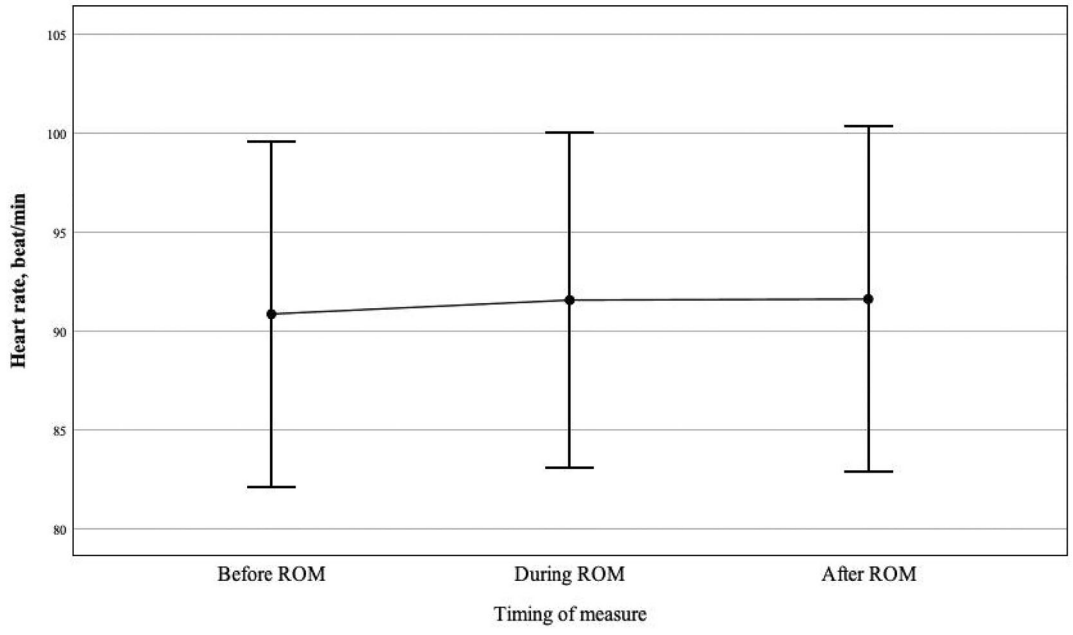

FIGURE 3 Heart rate before, during and after ROM. ROM, range of motion exercise.

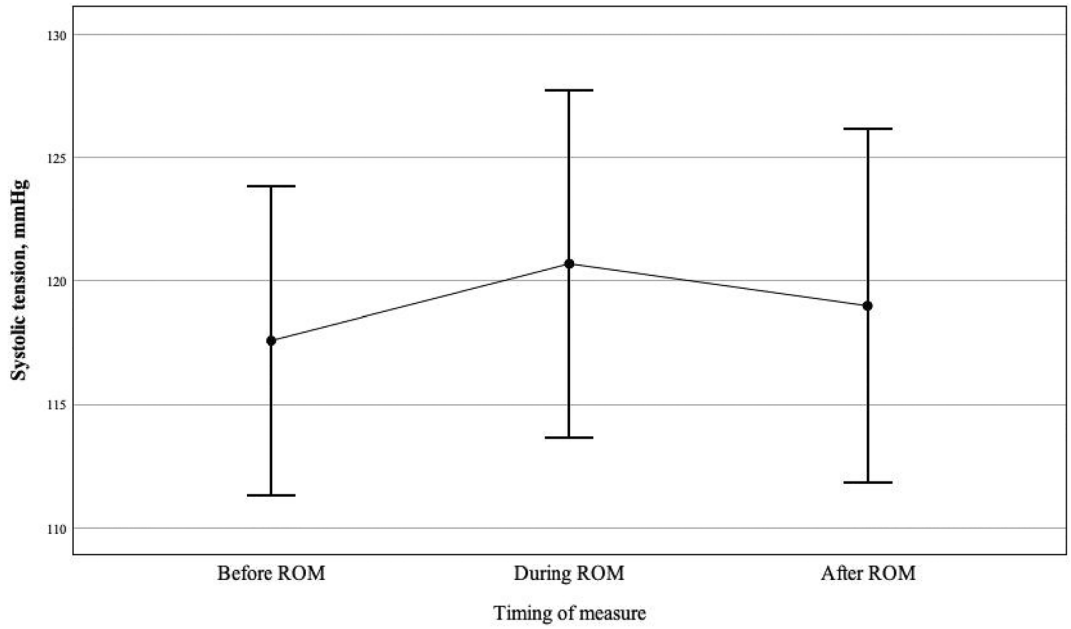

FIGURE 4 Systolic tension before, during and after ROM. ROM, range of motion exercise.

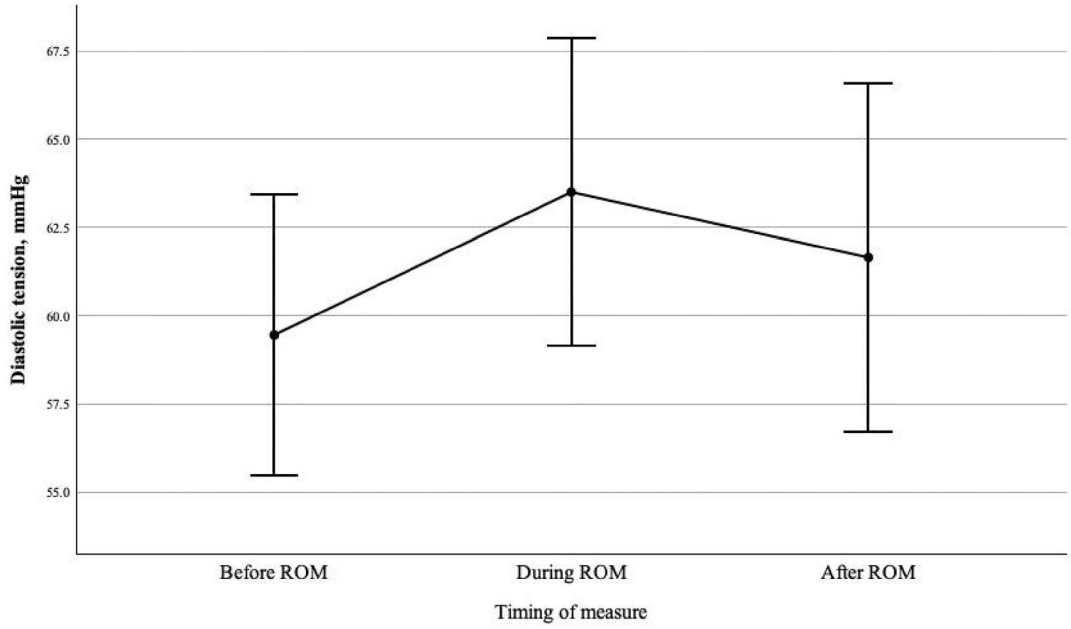

FIGURE 5 Diastolic tension before, during and after ROM. ROM, range of motion exercise.

adequate training and repetitive measurement experience. In our study population, only four patients had neurological impairment but were clinically stable, and no significant change in PROM-related ICP was observed in these patients. The implications of these results in patients with severe cerebral diseases and high ICP remain unclear. It is also possible that extremity movements may lead to improved drainage of the cerebral venous system and, thus, to a decrease in ICP. Therefore, as a safer step, we plan to continue this study in patients with intracranial hypertension.

7 | LIMITATIONS

The limitations of the study are that direct invasive ICP measurement was not performed simultaneously with ONSDi. Patients without an initial acute neurological diagnosis were selected, but no extra imaging modality was used to recognize these patients—it was clinically based. We think that this is not a major concern, as our number of patients was small but our exclusion criteria were large to obtain a specific patient population. Another limitation is that

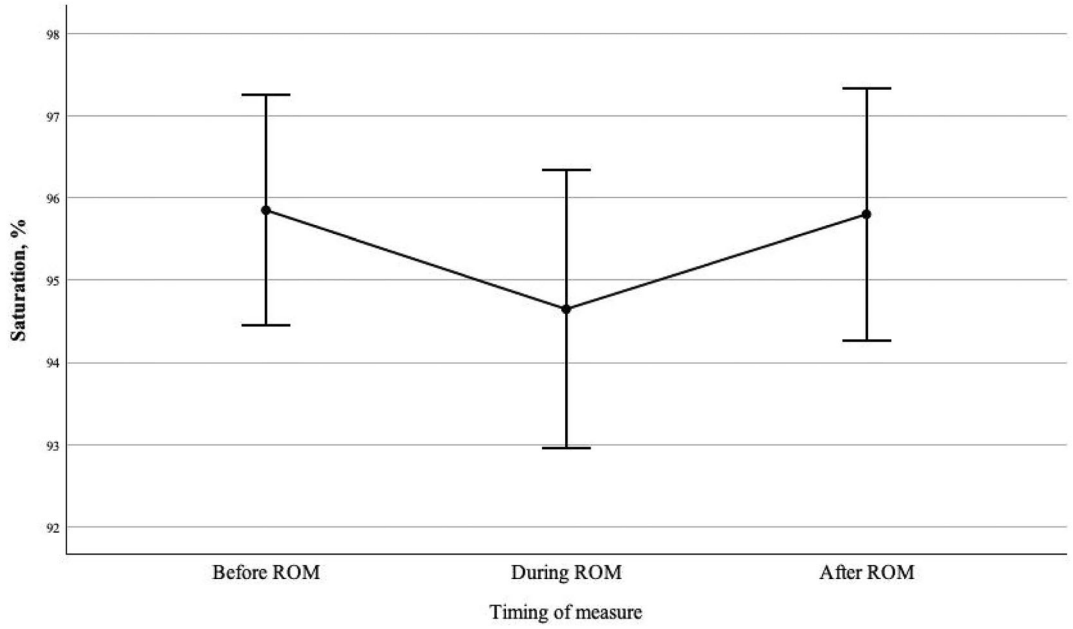

FIGURE 6 Saturation before, during and after ROM. ROM, range of motion exercise.

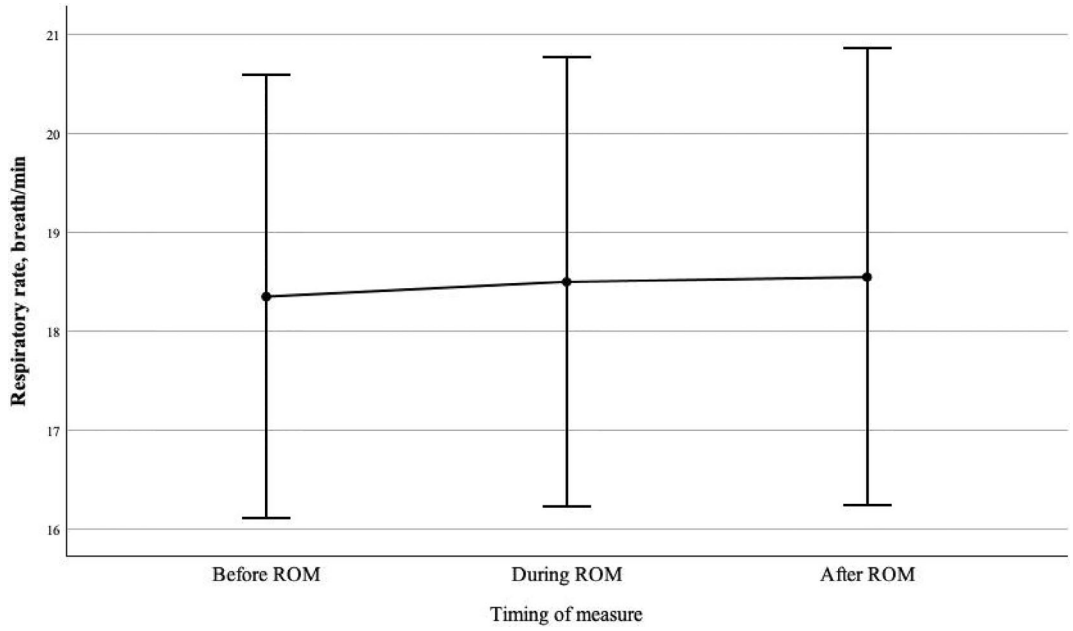

FIGURE 7 Respiratory rate before, during and after ROM. ROM, range of motion exercise.

sedated and intubated patients were selected to ensure the accuracy of ONSD measurements and to obtain minimal head and eye movements. This may have led to both a decrease in the number of patients in the study group and a departure from the reality in daily practice. Another is that various diagnoses were included; hence, the data are heterogeneous, both clinically and epidemiologically. We also did not specify a threshold value for a single ONSDi to detect increased ICP because different studies used different ultrasound techniques with variable thresholds.

8 | IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Our result suggests that early mobilization consisting of PROM exercises is safe and feasible for mechanically ventilated patients in the ICU in terms of ICP. These exercises may not be significantly associated with haemodynamic parameters in these patients. Additionally, the ONSD is a non-invasive method that can be used to monitor ICP

during intensive care mobilization procedures. The patient group selected for this study was very specific, and we believe that evaluating the outcomes of similar exercises in more alert and/or more unstable patients would significantly contribute to scientific knowledge.

In conclusion, early mobilization with PROM appears to be safe and feasible for selected ICU patients, even those with high mortality and organ failure scores and on mechanical ventilation. With careful patient selection, PROM does not seem to significantly relate to ICP or haemodynamics in patients with normal ICP, as measured by ONSDi.

CONFLICT OF INTEREST STATEMENT

The author declares no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

The study was approved by the Ethics Committee of the Faculty of Medicine, Karadeniz Technical University, on 24 February 2023 (2022/256).

PATIENT CONSENT STATEMENT

Informed consent was obtained from the legally authorized representative of each unconscious patient before enrollment. The legally authorized representatives were informed about the purpose of the study, the methods, the potential risks and benefits, and their rights regarding participation.

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How to cite this article: Küçük AO, Hatınoğlu N, Apaydin U, Altunalan T, Küçük MP. The association of early passive mobilization with intracranial pressure in the adult intensive care unit: A prospective, cohort study. *Nurs Crit Care*. 2025; 30(3):e13197. doi:10.1111/nicc.13197