Outcomes of Implementing the Nurse-Led Respiratory Care Intervention for Mechanically Ventilated Patients

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Abstract

Background: *Critically ill patients receiving mechanical ventilation have a high hospital mortality rate, which is related to nosocomial infection and unsuccessful weaning. The critical care nurse plays an essential role in minimizing these pulmonary complications through the application of different respiratory care interventions.* ***Objective:*** *To determine the outcomes of implementing the nurse-led respiratory care intervention for mechanically ventilated patients.* ***Settings:*** *The study was carried out in three adult ICUs at Alexandria Main University Hospital.* ***Subjects:*** *A convenience sample of 80 critically ill patients, which was divided randomly into two equal groups (40 patients in each). The intervention group was assigned to the nurse-led respiratory care intervention that included electrical diaphragmatic muscle stimulation, chest physiotherapy maneuvers, and patient mobilization, and the control group was subjected to hospital routine care.* ***Tools:*** *Three tools were used. Tool one: "Patient's profile data tool". Tool two: "The ventilator-associated events calculator". Tool three: "Modified Burns Wean Assessment Program (m-BWAP) Scores".* ***Results:*** *The study results showed that the occurrence of ventilator-associated events was significantly reduced in the intervention group compared to the control group (χ^2=6.348, pMC=0.022). Furthermore, the spontaneous breathing trial over five days showed a statistically significant difference (P=0.03) between the two groups.* ***Conclusion:*** *Implementation of the nurse-led respiratory care intervention significantly reduced the occurrence of ventilator-associated events and increased the success rate of spontaneous breathing trials.* ***Recommendations:*** *Critical care nurses should integrate the nurse-led respiratory care intervention into their daily practice of mechanically ventilated patient.*

Keywords:

Nurse-led, respiratory care intervention, mechanically ventilated patients.

Introduction

Mechanical ventilation (MV) is a life-sustaining intervention administered to over 20 million patients annually across the globe (Lippi et al., 2022). According to epidemiological research, up to 70% of ICU patients need MV at some point during their stay (Abate et al., 2023). Studies have estimated that 20 to 40% of all patients receive MV each year, which costs around $27 billion (Ali & Ahmed, 2023). Although MV is a necessary intervention, it carries numerous potential complications, such as lung injury, diaphragmatic muscle dysfunction, lung collapse, and ventilator-associated pneumonia (VAP). These pulmonary complications can lead to an extended period of MV and increase the risk of mortality by up to 45% (Grasselli et al., 2023).

Promoting airway clearance, lung re-expansion, and improving respiratory efficiency are the key tasks assigned to critical care nurses working in ICUs. These tasks can be accomplished by using electrical muscle stimulation, chest percussions, chest vibrations, air humidification, body position, mobilization, lung hyperinflation, tracheal suctioning, and oral care (Morais et al., 2020; Klompas et al., 2023). Transcutaneous electrical diaphragmatic stimulation (TEDS) is a cost-effective and risk-free method that uses an automated device to place surface electrodes on the skin, thereby stimulating nerve branches within the muscles and causing observable muscle contractions. Patients requiring MV have demonstrated its effectiveness in mitigating muscle loss, enhancing muscle strength, and increasing muscle mass (Hsin et al., 2022; Medrinal et al., 2023).

Early chest physiotherapy, initiated during MV, is considered an essential intervention because it improves inspiratory muscle strength and increases the likelihood of weaning success. Chest physiotherapy procedures are based on the idea that the application of an external force to the chest wall aids in the loosening of mucus, consequently promoting the movement and removal of airway obstructions. Additionally, early patient mobilization can break the cycle of prolonged MV by improving ventilation, lung compliance, and mucociliary clearance (Gutierrez-Arias et al., 2023; Nam et al., 2024).

However, despite the advantages of using these maneuvers alone to improve mechanically ventilated patients' outcomes, there is a lack of research about the benefits of using them in combination. Therefore, the researcher conducted a study on the combination of different respiratory care interventions, such as transcutaneous electrical diaphragmatic stimulation, chest physiotherapy maneuvers, and patient mobilization in mechanically ventilated patients.

Aims of the Study

This study aims to determine the outcomes of implementing the nurse-led respiratory care intervention for mechanically ventilated patents.

Research hypotheses

- Mechanically ventilated patients who receive the nurse-led respiratory care intervention exhibit a lower incidence of ventilator-associated events than those subjected to routine hospital care.
- Mechanically ventilated patients who receive the nurse-led respiratory care intervention exhibit a higher frequency of spontaneous breathing trials than those subjected to routine hospital care.

Materials and Method

Materials

Design: A quasi-experimental research design was used to conduct this study.

Settings: This study was carried out in three adult ICUs at Alexandria Main University Hospital namely; unit II that contains 14 beds, unit III that contains 16 beds, and unit IV that contains 8 beds. These general ICUs

receive patients who have a variety of disorders in the acute stage of illness. These patients are admitted directly from the emergency department or transferred from other hospital departments.

Subjects: A convenience sample of 80 adult patients aged 18-60 years old with a Glasgow Coma Scale (GCS) ≥ 9 and mechanically ventilated for more than 6 hours were included in the study for 5 consecutive days. Those patients were newly admitted to the previously mentioned setting. Patients who met the inclusion criteria were assigned to one of the two groups: the "intervention group" initiated nurse-led respiratory care intervention, and the "control group" received routine hospital care. Patients who were hemodynamic unstable, or contraindicated to chest physiotherapy e.g. (chest trauma, untreated pneumothorax, spinal cord injury, pulmonary embolism, uncontrolled hypertension, and empyema). Also, patients who were pregnant or had a pacemaker were excluded from the study.

The study sample size calculation was based on power analysis using PASS program version 20; minimum sample size = 40 in each group; level of significance = 0.05; power = 95%.

Tools: In order to collect the necessary data for the study three tools were used:

Tool one: "Patient's profile data". This tool was developed by the researcher after reviewing the related literature (Javaherian et al., 2021; Roldán et al., 2022; Lin et al., 2023). This tool was used to assess mechanically ventilated patients' bassline data before implementing nurse-led respiratory care intervention. **It consists of two parts:**

Part I: Patients' sociodemographic characteristics: This part includes data such as patient age, gender, level of education, and marital status.

Part II: Patients' clinical data: This part includes data such as admission date, diagnosis, level of consciousness, duration on mechanical ventilation, agitation level, smoking history, body mass index, comorbidities, length of ICU stay, treatment and previous admission to ICU, current medication, lab investigation, and the severity of illness.

Tool two: "The ventilator-associated events calculator". This tool was adopted and pre-validated calculator from the Centers for Disease Control (CDC) (2022). A calculator is a web-based application available on the CDC website, version 9.0. This calculator was utilized to ascertain the clinical criteria for the ventilator-associated events. It includes three levels: ventilator-associated condition (VAC), infection-related ventilator-associated complications (IVAC), and possible ventilator-associated pneumonia (PVAP). The information needed to compute the VAC is the minimal FiO2 and PEEP (cmH2O) are required to compute the VAC. The data utilized to calculate IVAC comprises body temperature, white blood cell count, and antibiotic administration. The characteristics of the tracheal aspirate specimen culture provide the necessary information to compute PVAP.

Tool three: "Modified Burns Wean Assessment Program (m-BWAP) Scores". This tool was adopted from Jeong & Lee (2018) to assess the mechanically ventilated patient's readiness for the weaning and spontaneous breathing trial and whether weaning is successful or failure. The m-BWAP score is elevated in patients with successful weaning, utilizing a cut-off value of 55. The tool specificity and sensitivity to predict successful weaning were 84.85%, and 73.77% respectively, $p<0.001$ at study of Abdelaleem et al. (2020).

Method

Approval from the Research Ethics Committee (REC) of the Faculty of Nursing Alexandria University was obtained before conducting the study (permission no.4-10-2023, IRB00013620 (9/19/2025). Permission

to conduct the study was obtained from the administrative authorities of the previously mentioned settings after explanation of the aim of the study. The researcher obtained a certificate of attending a training course on how to use the TEDS device from Alexandria University's Department of Physiotherapy, Faculty of Medicine. The study tools were tested for content validity by five experts in the field of the study. Accordingly, necessary modifications were done. A pilot study was carried out on eight critically ill patients who represent 10% of the sample size to assess the clarity and applicability of the research tool. The pilot sample was excluded from the study sample. The pilot study revealed that further modifications were not needed. Reliability of tool one was done using the coefficient alpha test; its result was 0.751, which is acceptable. Data were collected by the researchers during the period from November 2023 to March 2024.

Data were collected from the "control group" first, and after its completion, data were collected from the "intervention group" to avoid the double contamination effect.

The study was conducted in three phases:
Phase I: Patients` assessment for both groups: the demographic and clinical data, such as the patient's age, gender, level of education, and marital status, admission date, diagnosis, level of consciousness, duration on mechanical ventilation, agitation level, severity of illness, smoking history, body mass index, comorbidities, length of ICU stay, treatment and previous admission to ICU, current medication, and lab investigation, were assessed and recorded using Tool one.

Phase II: Implementation phase. Patients in the routine care group were subjected to hospital routine care, which was implemented by nursing staff who were assigned to care for them. The routine hospital care involved random oral care, occasional chest percussion, tracheal suctioning when necessary, and the application of the manual hyperinflation technique solely to ensure endotracheal tube patent. Patients in the nurse-led respiratory care intervention group received the respiratory care intervention after 6 hours of being attached to a mechanical ventilator and continued for 5 consecutive days. The nurse-led respiratory care intervention consisted of the following measures:

Part I: Transcutaneous electrical diaphragmatic stimulation (TEDS): The session was performed by the researcher for each patient once per day in the morning. The patient was placed in the semi-fowler position (30–45º). The skin was intact and free from abrasion and injury. The electrically conductive gel was applied to the four electrodes. The mechanical ventilator mode was transferred to pressure support mode before starting the session of TEDS by the physician. The session lasted for 20 minutes over five consecutive days. The four silicone-carbon electrodes were placed on the skin: two electrodes were placed on the right and left sides of the xiphoid process, and the other two electrodes were placed on the right and left midaxillary lines of the seventh and eighth anterior intercostal spaces. The electrical intensity of the device was adjusted at a frequency of 50 Hz; TEDS intensity was started at a minimum and gradually increased until visible muscle contraction occurred.

Part II: Chest physiotherapy maneuvers:
(1) Chest vibration technique was performed every 12 hours for each patient to enhance airway drainage. Each session lasted 10 minutes over five consecutive days. The technique was implemented by applying vibration waves over the chest wall with both hands.

(2) Chest percussion technique was performed manually for each patient every 12 hours to enhance the secretion mobilization. Each session lasted for 10 minutes over five consecutive days. The technique was provided by cupping hands to provide more force on the chest anteriorly, posteriorly, and laterally.

(3) Hyperinflation technique was provided by the researcher through the sigh button in the mechanical ventilator. The session was using a sigh frequency of 10 sighs per hour. Each session was applied every 12 hours for 5 consecutive days to lung mechanics in mechanically ventilated patients.

(4) Tracheal suctioning was implemented after vibration and percussion techniques according to the patient's respiratory assessment, including auscultation of the chest and visual inspection of ventilator parameters. Mechanical hyperoxygenation of 100% was applied before suctioning, and the duration was limited to 10 seconds.

(5) Oral care with chlorhexidine three times daily for five consecutive days to prevent VAP in mechanically ventilated patients.

Part III: Patient mobilization:
(1) The elevation of the head of the bed is 30-45°.

(2) The patient's position changes every 2 hours to allow for secretion mobilization and enhance aeration of the lung.

(3) The range of motion (ROM) exercises were performed one session per day in the evening for a duration of 20 minutes over five consecutive days. The session consisted of 10 repetitions for each joint of the four extremities. The exercises can be in the form of passive or active assisted movements, or active movements, depending on the patient's condition. For the upper extremities, the ROM exercises included fingers and wrist flexion, extension, abduction, and adduction; elbow flexion, extension, forearm supination, and pronation; and shoulder flexion, extension, abduction, and adduction. For the lower extremities, the ROM exercises included toe flexion and extension, ankle dorsiflexion, knee flexion and extension, hip flexion, extension, abduction, and adduction.

Phase III: Evaluation phase. The outcomes were compared for both groups, including the incidence of pulmonary infection, the patient's readiness for weaning, and spontaneous breathing trials, were assessed and recorded for both groups daily for five days.

Ethical considerations:

Written informed consent was obtained from patients or their families after explaining the aim of the study, the right to refuse to participate in the study was emphasized to subjects. Patients' privacy was maintained during the implementation of the study. Confidentiality of the collected data were maintained during the implementation of the study. The patient has the right to withdraw from the study at any time was assured.

Statistical Analysis

Data of this study were analyzed using the Statistical Package of Social Science (SPSS) version 29. Continuous normally distributed variables were presented in mean and standard deviation using the t test for comparison, while categorical variables were presented in number and percentage using the chi square test for comparison and the Montecarlo test for correction. The significance of the obtained results was judged at the 5% level.

Results

Table 1 presents the comparison between the intervention and control groups according to demographic data. Eighty patients were recruited in the current study. There was no significant difference between two groups regarding age ($p = 0.436$), and gender ($p = 0.820$).

Table 2 shows the distribution of study groups according to clinical data. The most common diagnosis was renal disease, accounting for 47.5% and 35.0% in the intervention group and control group, respectively ($p=0.256$). The mean BMI was 25.62 ± 3.36 and 25.68 ± 4.02, respectively in both groups, with no significant difference

(p=0.706). In the APACHE II score, the mean scores of the intervention and control groups were 13.78±1.31 and 13.65±1.21 respectively, with no significant difference (p=0.835). In the RASS scale, mean score was 0.18 ± 0.64 in the intervention group and 0.13 ± 0.72 in the control group, with no significant difference (p=0.870). Finally, the mean FOUR score of the intervention group was 11.88 ± 0.82, while that of the control group was 11.75 ± 0.81. There was no statistically significant difference between the two groups (p=0.939).

Table 3 illustrates the comparison between the intervention and control group according to the occurrence of ventilator-associated events (VAEs). There was a statistically significant difference between the two groups (χ^2=6.348, pMC=0.022). The intervention group had a higher percentage of no VAEs compared to the control group (75.0% vs. 47.5%). The prevalence of VAC was higher in the control group (32.5%) than in the intervention group (15.0%). Regarding IVAC, the control group had a higher percentage (15%) compared to the intervention group's (7.5%). The control group had 5.0% of PVAP, while the intervention group had 2.5%.

Figure 1 shows the mean and error bars for comparing the spontaneous breathing trial outcomes between the intervention and control groups. In the spontaneous breathing trial, the chart shows that the intervention group has a significantly higher mean value (mean = 2.50, 95% CI: 2.25 to 2.75) than the control group (mean = 2.25, 95% CI: 2.00 to 2.50). The 95% confidence intervals for the means show that this difference is statistically significant (P=0.03). This means that the intervention is associated with increased successful breathing trials for patients.

Discussion

The main study findings indicated the effectiveness of nurse-led respiratory intervention in mechanically ventilated patients. Compared to patients receiving routine hospital care, those receiving nurse-led respiratory intervention experienced a lower incidence of VAEs. This may be attributed to the application of various respiratory care interventions that significantly contribute to lung re-expansion, airway secretion clearance, and reduced mechanical ventilator days, thereby reducing the risk of pulmonary infection and VAEs. Liu & Zhang (2020), consistent with this study's findings, investigated the impact of comprehensive rehabilitation intervention on the incidence of VAP in critical patients. The results showed that the comprehensive rehabilitation intervention, which included neuromuscular electrical stimulation, lung hyperinflation, oral care, suctioning, upper and lower limb exercises, and changing positions, had a significant decrease in the incidence of VAP and increased the success rate of weaning from MV.

Wu et al. (2024) conducted a study on the effects of diaphragm electrical stimulation in treating respiratory dysfunction during MV after intracerebral hemorrhage, which matched with these results. The results revealed that the diaphragm electrical stimulation had a significantly lower incidence of VAP and length of stay in the ICU. Additionally, a study by Rizvi et al. (2020), supported the current study's results by examining the effectiveness of passive chest physiotherapy in the prevention of VAP. The results showed that there was a significant decrease in the occurrence of VAP and mortality rate after passive chest physiotherapy when compared with before initiation of passive chest physiotherapy.

Regarding MV weaning, the results of the current study reveal that spontaneous breathing trials and overall weaning from MV were significantly more successful in the intervention group compared to the control group. This could be attributed to the mechanically ventilated patients who underwent respiratory care interventions, specifically transcutaneous electrical diaphragmatic stimulation, which aimed to

strengthen the respiratory muscles, particularly the diaphragm, the primary muscle of respiration, increase muscle mass, and facilitate early weaning off the ventilator. In addition, the chest physiotherapy maneuvers, and mobilization enhance lung aeration and ventilation perfusion matching, which decrease the duration of the mechanical ventilator. This study's results were in agreement with a study by Hsin et al. (2022), which examined the impact of transcutaneous electrical diaphragmatic stimulation on breathing in patients undergoing long-term MV. They reported that there was a significantly higher rate of weaning success in the intervention group that received transcutaneous electrical diaphragmatic stimulation compared to those in the control group who didn't receive such stimulation.

Moreover, the current study's results were consistent with a study by Ahmed Sayed (2020), which investigated the effect of multimodality chest physiotherapy on extubation and critically ill mechanically ventilated patients' outcomes. The chest physiotherapy modalities included inspiratory muscle training, ROM exercises, early mobilization and chest physiotherapy. In conclusion, he reported that multimodality chest physiotherapy can reduce MV duration, incidence of extubation failure, mortality rate, ICU length of stay, and reintubation rate. Contrary to the findings of this study, Medrinal et al. (2023) studied the effect of transcutaneous electrical diaphragmatic stimulation on mechanically ventilated patients. The study revealed that the intervention group receiving electrical diaphragmatic stimulation showed no significant improvement in weaning from MV or extubation success rate. This could be related to the patients in this study received only transcutaneous electrical diaphragmatic stimulation without any chest physiotherapy or mobilization that caused lung re-expansion, cleared airway secretion, and enhanced gas exchange.

Conclusion

Based upon the findings of the current study, it could be concluded that implementing the nurse-led respiratory care intervention significantly reduces the incidence of VAEs, increases the success rate of spontaneous breathing trials, and facilitates early weaning from MV.

Recommendations

In line with the findings of the study, the following recommendations are suggested:

- Integrate the nurse-led respiratory care intervention into nursing daily practice to enhance the mechanically ventilated patient's outcomes.
- Incorporate the concept of the nurse-led respiratory care intervention for mechanically ventilated patients, focusing on its positive outcomes in the curricula of undergraduate nursing students and graduate nurse programs in both theory and practice.
- Develop policies and protocols to simplify the documentation system associated with mechanically ventilated patient assessment and implementation of the nurse-led respiratory care intervention.
- Replicate the study on a large probability sample is recommended for generalization of the findings.

Author contribution:

Nadia Taha Mohamed Ahmed, Professor Emeritus: Supervised and provided expert guidance throughout the study. Assisted with the study design and conducted the final review of the research.

Ayat Reda Elmitwally Abass, Assistant Lecturer: Played a significant role in data collection, analysis and interpretation.

Bassem Nashaat Beshay, Professor: Provided essential modifications and expertise in the analysis of the results.

Eman Arafa Hassan Ali, Assistant Professor: played a significant role in writing the discussion and literature review sections.

Table 1: Frequency distribution of the studied groups according to the demographic data.

Demographic data		Studied groups				Test of Sig.	P
		Intervention group (n=40)		Control group (n=40)			
		N	%	N	%		
Age	18-≤40	7	17.5%	10	25.0%	χ^2= 2.701	0.436
	>40-≤50	14	35.0%	17	42.5%		
	>50-≤60	19	47.5%	13	32.5%		
Gender	Male	23	57.5%	24	60.0%	χ^2= 0.052	0.820
	Female	17	42.5%	16	40.0%		

SD: **Standard deviation** χ^2: **Chi square** test**,** p: p value for comparing between the two studied groups

Table 2: Frequency distribution of the studied groups according to the clinical data.

Clinical data		Studied groups				Test of Sig.	P
		Intervention group (n=40)		Control group (n=40)			
		N	%	N	%		
Admission diagnosis	Cardiovascular disease	8	20.0%	5	12.5%	χ2=0.827	0.363
	Respiratory disease	6	15.0%	3	7.5%	χ2=1.127	0.288
	Renal disease	19	47.5%	14	35.0%	χ2=1.289	0.256
	Neurological disease	14	35.0%	11	27.5%	χ2=0.524	0.469
	Gastrointestinal disease	3	7.5%	6	15.0%	χ2=1.127	0.288
	Endocrine/metabolic disease	6	15.0%	8	20.0%	χ2=0.346	0.556
	Hematological disorder	3	7.5%	1	2.5%	χ2=1.053	0.305
BMI, Mean ±SD		25.62 ± 3.36		25.68 ± 4.02		t=0.38	0.706
APACHE II Score, Mean ±SD		13.78 ± 1.31		13.65 ± 1.21		t=0.21	0.835
RASS Score, Mean ±SD		0.18 ± 0.64		0.13 ± 0.72		t=0.16	0.870
FOUR Score, Mean ±SD		11.88 ± 0.82		11.75 ± 0.81		t=0.08	0.939

APACHE II: Acute Physiology and Chronic Health Evaluation **BMI:** Body Mass Index **FOUR:** Full Outline of Unresponsiveness **RASS**: Richmond agitation sedation scale t: **Student t-test**, SD: **Standard deviation**, χ^2: **Chi square** test**,** p: p value for comparing between the two studied group

Table 3: Comparison between the studied groups according to the occurrence of ventilator-associated events.

VAEs	Intervention group (n=40)		Control group (n=40)		$\chi2$ (p^{MC})
	No	%	No	%	
No ventilator associated events	30	75.0%	19	47.5%	$\chi2$ = 6.348 P^{MC}= 0.022*
Ventilator-associated condition (VAC)	6	15.0%	13	32.5%	
Infection-related ventilator-associated complication (IVAC)	3	7.5%	6	15.0%	
Possible ventilator-associated pneumonia (PVAP)	1	2.5%	2	5.0%	

VAEs: ventilator-associated events p: p **value for the test of significance** MC is **Montecarlo test**.

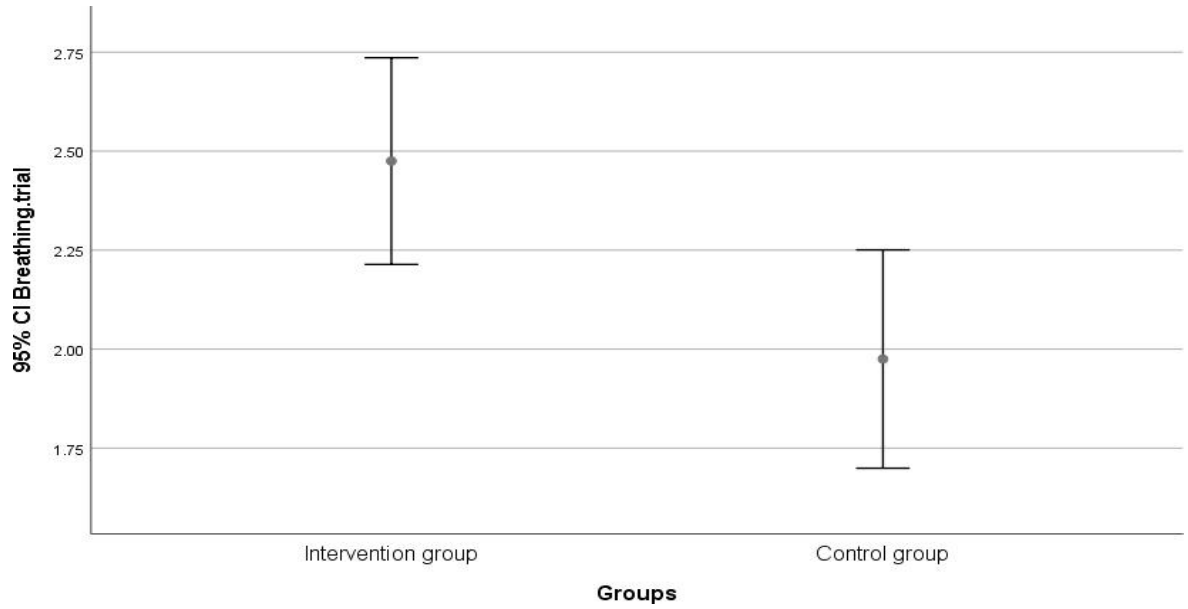

Figure 1: Mean and error bars for comparison of spontaneous breathing trial outcome between the intervention and control group

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