

Nursing Liberation Bundle: Its Effect on Ventilation Duration And Weaning Readiness in Mechanically Ventilated Children

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Abstract

Background

Introduction: Prolonged mechanical ventilation (MV) in children delays weaning and may worsen outcomes. This study evaluated the influence of a nursing liberation bundle on weaning readiness and ventilation duration in mechanically ventilated children.

Method: A randomized controlled trial was carried out in a pediatric intensive care unit of a tertiary university hospital (July–December 2025). Of 68 children assessed, 8 were excluded; 60 children aged 1–6 years who had been ventilated for more than 48 hours were assigned at random to a liberation bundle group (n = 30) or a group receiving standard treatment (n = 30), with no loss to follow-up. The four-component bundle (pain assessment and comfort, spontaneous breathing trial [SBT] and weaning, sedation reduction, and family engagement) was applied daily from day 4 of ventilation until extubation. SBT readiness was assessed with a five-item tool, and ventilation duration was recorded in days.

Results: The groups were comparable at baseline. SBT readiness did not differ significantly up to day 6 but was higher in the bundle group on day 7 (90.0% vs. 46.7%, $p < 0.001$) and before extubation (90.0% vs. 56.7%, $p = 0.004$). Ventilation duration differed significantly ($p = 0.002$): 60.0% of the bundle group were ventilated for 4–7 days versus 23.3% of controls, and 16.7% versus 60.0% for 8 days or more.

Conclusion: In this small single-center trial, the bundle was associated with higher SBT readiness late in the intervention period and shorter ventilation duration. Larger, blinded, multicenter trials are needed.

Keywords: Patient Care Bundles; Ventilator Weaning; Pediatric Nursing; Respiration, Artificial; Intensive Care Units, Pediatric.

Introduction

Invasive mechanical ventilation (MV) is often necessary to maintain gas exchange in critically ill children. Although it is frequently life-saving, prolonged MV raises ventilator-associated pneumonia risk, ventilator dependence, and longer pediatric intensive care unit (PICU) and hospital stays, all of which can increase morbidity and mortality. Timely liberation from MV once the underlying condition improves is therefore an important goal in pediatric critical care (Machado et al., 2026; van Dijk et al., 2022).

Long-term mechanical ventilation and rising PICU survival rates have recently received considerable attention. Together, the American Society of Health-System Pharmacists, the Society of Critical Care Medicine (SCCM), and the American College of Critical Care Medicine created clinical practice guidelines for treating and preventing pain, agitation/sedation, delirium, immobility, and sleep disturbance in pediatric PICU patients. (Engel et al., 2022). The liberation bundle is an evidence-based, multicomponent, interprofessional team approach created to facilitate implementation of the SCCM guidelines, and each of its components targets patient-centered outcomes (Ali et al., 2025b).

The ABCDEF bundle is another name for the PICU liberation bundle., is an integrative, interprofessional care model that comprises six connected elements: (A) systematic Pain assessment, prevention, and treatment; (B) coordinated trials of respiration and spontaneous awakening; (C) selection of sedation and analgesia; (D) Screening for, preventing, and treating delirium; (E) progressive early mobilization and physical therapy; and (F) active

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Empowerment and involvement of the family (Fashina et al., 2026).

Pediatric nurses have a pivotal role in executing ventilator liberation protocols because they are continuously involved in assessing and controlling delirium, sedation, and pain, respiratory status, mobility, and family participation. Their frequent and close contact with ventilated children puts them in a sole position to detect changes in clinical readiness and to make sure regular application of evidence-based liberation strategies (Ali et al., 2025a; King et al., 2023). There is still little data on the efficacy of a nursing-led liberation bundle for weaning readiness and clinical outcomes in children on mechanical ventilation, despite increased awareness of protocolized ventilator liberation.

This trial therefore designed to assess the efficacy of a nursing liberation bundle on weaning readiness and ventilation duration in mechanically ventilated children. It was hypothesized that children getting the bundle would disclose higher readiness for a spontaneous breathing trial (SBT) and a shorter duration of MV than children obtaining routine care.

Methods

Study Design and Setting

A randomized controlled experiment with parallel groups was carried out over six months, from 1 July 2025 to 31 December 2025, within a PICU of a tertiary university children's hospital. The study was approved by the research ethics committee of the Faculty of Nursing, Assiut University (approval number 1120251109, date: [25-5-2025]).

Participants and Sample Size

The participants were mechanically ventilated children entered the PICU during the trial period. Inclusion criteria were age of 1–6 years, to obtain a homogeneous sample and reduce variability in physiological and behavioral responses, and intubation for longer than 48 hours. Exclusion criteria were receipt of neuromuscular blocking agents (which interfere with behavioral assessments), brain death, severe brain injury preventing assessment of response to pain or sedation, tracheostomy, and ventilator dependence at baseline.

The sample size was determined using G*Power 3.1.9.7 using a fixed-effects, one-way analysis of variance with two groups, an effect size (f) of 0.4, a significance level of 0.05, and a power ($1 - \beta$) of 0.92. The calculation indicated a minimum of 57 children. Sixty eligible children were enrolled. A total of 68 children were assessed for eligibility; eight were omitted (four because their parents rejected to continue and four since they didn't fit the requirements for inclusion.), and 60 were randomized (Figure 1). No child was lost to follow-up

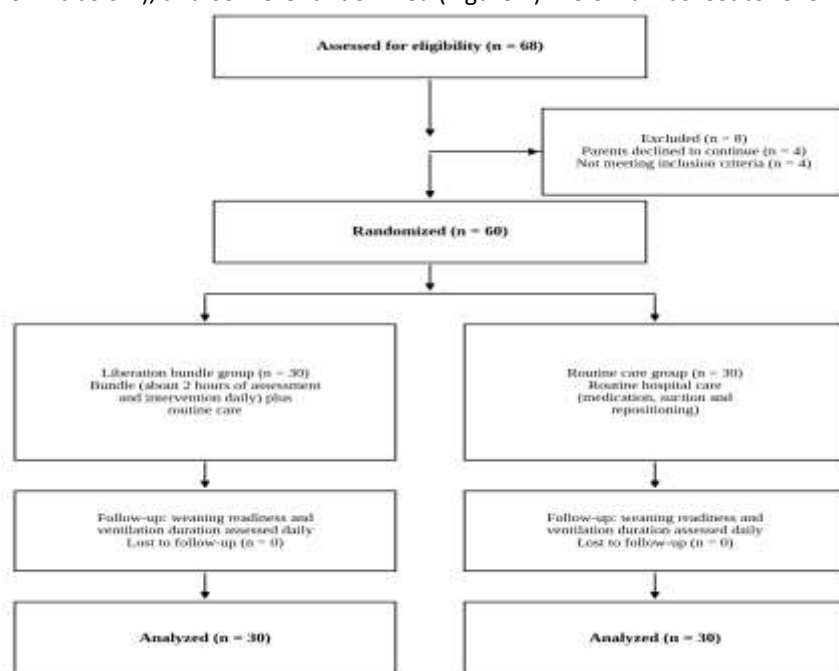


Figure 1. Flow diagram of the participants through the study.

Randomization

Children were allocated to the liberation bundle group or the routine care group using a computer-generated randomization sequence created with Research Randomizer (www.randomizer.org). The sequence was generated independently, without input from or later modification by the principal investigator, to avoid selection bias.

Variables and Instruments

The primary outcomes were readiness for SBT and duration of MV. Duration of MV was expressed in days from the start of the liberation bundle until extubation. Two tools were used.

Tool I. A structured tool developed by the researchers was employed to gather demographic information (age, gender, birth order, residence, mother's education, and mother's occupation) and medical data (etiology of PICU admission, previous PICU admission and its causes, indication for MV, duration of connection to MV, and Pediatric Risk of Mortality [PRISM] score on admission).

Tool II. Readiness for SBT was consisted from a structured five-item tool adapted from Blackwood et al. (2021). The tool includes five clinical criteria: fraction of inspired oxygen (FiO_2) ≤ 0.45 , peripheral oxygen saturation (SpO_2) $\geq 95\%$, positive end-expiratory pressure (PEEP) ≤ 5 cm H_2O , peak inspiratory pressure (PIP) ≤ 22 cm H_2O , and presence of an effective cough reflex. Each criterion was scored 0 (not met) or 1 (met). A total score of five meant that the child was ready for SBT and weaning, whereas a score below 5 meant that the child was not ready. Data were collected from the third day of MV until extubation.

Procedures

The research was conducted in four stages: preliminary, assessment, application, and appraisal.

Preliminary phase. The PICU's medical director granted formal administrative permission before data collection. A pilot study was conducted on 10% of the sample to verify the tools' applicability, feasibility, and clarity ($n = 6$). Written informed consent was acquired from each participating child's parents who were assured that the data would remain confidential and be used only for research purposes.

Assessment phase. Before the intervention, baseline data were collected with the standardized tools, including demographic and medical data and readiness for SBT (Tool II). All baseline assessments were performed on the third day of MV. The nursing liberation bundle was started after the first 48 hours of ventilation because children are usually more stable at that stage and are suitable candidates for liberation interventions; starting the bundle then allows early optimization of sedation and assessment of weaning readiness.

Application phase. Liberation bundle group. The bundle was a modified version of the ABCDEF bundle with four components; delirium screening (D) and early mobilization (E) were not included. The components were applied daily on the fourth, fifth, sixth, and seventh days of MV and before extubation.

Component 1: Assessment, prevention, and management of pain. In a quiet setting, a recording of the mother's voice was played to the child for 15–20 minutes. Environmental changes, including reducing noise and excessive light to encourage comfort and relaxation. During the session, the researcher checked the child's oxygen saturation and vital indicators, including blood pressure, heart rate, and breathing rate. Pain was assessed with the Face, Legs, Activity, Cry, Consolability (FLACC) scale (Merkel et al., 1997) immediately after the auditory stimulation.

Component 2: SBT and weaning. Strict infection control measures were followed when doing airway suctioning and chest physical therapy. Every two hours, the infant was moved to encourage lung expansion, enhance oxygenation, and avoid complications like pressure injuries. Ventilatory support was progressively decreased and the mode was switched to a weaning-supportive mode in consultation with the doctor to facilitate readiness for SBT. Readiness for SBT and weaning was then assessed with Tool II.

Component 3: Sedation management. Sedation was gradually decreased in accordance with the doctor's instructions.

Component 4: Family engagement. The mother was updated on the child's health and daily development during visiting hours. The child's favorite toys were brought to the bedside. Additionally, the mother's voice was recorded while she narrated familiar stories.

Routine care group. The children in this group just received standard hospital care (medication, suction, and repositioning).

Appraisal phase. Following the intervention, the two groups' readiness for SBT and MV duration were assessed and contrasted.

Data Analysis

Data analysis was carried out utilizing SPSS version 26. Frequencies, percentages, means, and standard deviations are used to display descriptive statistics. The chi-square (χ^2) test was used to compare categorical variables, whereas the independent-samples t test was used to examine continuous variables. Statistical significance was defined as a two-tailed p value less than 0.05.

Ethical Considerations

The research proposal was authorized by the research ethics committee of the Faculty of Nursing (approval number: 1120251109). To safeguard autonomy and confidentiality, Each participating child's parents provided signed informed permission after receiving written and spoken information about the study.

Results

Sixty children on mechanical ventilation were recruited and allocated at random in equal numbers to the liberation bundle group (n = 30) and the routine care group (n = 30) (Figure 1).

Baseline demographic and medical characteristics are presented in Table 1. Children aged 3–6 years represented 60.0% of the liberation bundle group and 63.3% of the routine care group, and 60.0% of the children in each group were male. The groups did not differ statistically significantly in etiology of PICU admission, previous PICU admission, cause of previous admission, or PRISM score on admission. Respiratory diseases were the most common cause of admission (33.3% in the liberation bundle group and 36.7% in the routine care group). Most children had no previous PICU admission (76.7% and 73.3%, respectively); among those with a previous admission, respiratory diseases were the most common cause (42.9% and 50.0%).

Table 1 Demographic and medical Characteristics of the Studied Children (N = 60)

Characteristic	Liberation bundle group (n = 30), n (%)	Routine care group (n = 30), n (%)	Test statistic	p
Age				
1 to < 3 years	12 (40.0)	11 (36.7)	$\chi^2 = 0.071$	0.791
3–6 years	18 (60.0)	19 (63.3)		
Mean $\pm$ SD (years)	3.2 $\pm$ 1.7	3.4 $\pm$ 1.8	t = 0.368	0.714
Gender				
Male	18 (60.0)	18 (60.0)	$\chi^2 = 0.000$	1.000
Female	12 (40.0)	12 (40.0)		
Residence				
Urban	13 (43.3)	12 (40.0)	$\chi^2 = 0.069$	0.793
Rural	17 (56.7)	18 (60.0)		
Mother's education				
Cannot read or write	5 (16.7)	4 (13.3)	$\chi^2 = 1.247$	0.870
Primary	6 (20.0)	6 (20.0)		
Preparatory	3 (10.0)	6 (20.0)		
Secondary	7 (23.3)	6 (20.0)		
University	9 (30.0)	8 (26.7)		
Etiology of PICU admission				
Respiratory diseases	10 (33.3)	11 (36.7)	$\chi^2 = 0.159$	0.999
Gastrointestinal diseases	5 (16.7)	4 (13.3)		
Neurological diseases	6 (20.0)	6 (20.0)		
Renal diseases	3 (10.0)	3 (10.0)		
Diabetic ketoacidosis	3 (10.0)	3 (10.0)		
Others	3 (10.0)	3 (10.0)		
Previous PICU admission				
Yes	7 (23.3)	8 (26.7)	$\chi^2 = 0.089$	0.766
No	23 (76.7)	22 (73.3)		
Cause of previous admission (n = 7 and n = 8)				
Respiratory diseases	3 (42.9)	4 (50.0)	$\chi^2 = 1.416$	0.702
Gastrointestinal diseases	2 (28.6)	2 (25.0)		
Neurological diseases	1 (14.3)	2 (25.0)		
Diabetic ketoacidosis	1 (14.3)	0 (0.0)		
PRISM score on admission				
Mean $\pm$ SD	8.07 $\pm$ 1.3	8.1 $\pm$ 1.4	t = 0.096	0.924

Note. SD = standard deviation; PICU = pediatric intensive care unit; PRISM = Pediatric Risk of Mortality. Categorical variables were compared with the chi-square test and continuous variables with the independent-samples t test.

The indications for MV are shown in Figure 2. Respiratory failure was the most frequent indication (33.3% in the liberation bundle group and 26.7% in the routine care group), and the distribution did not differ significantly between groups ($p = 0.883$).

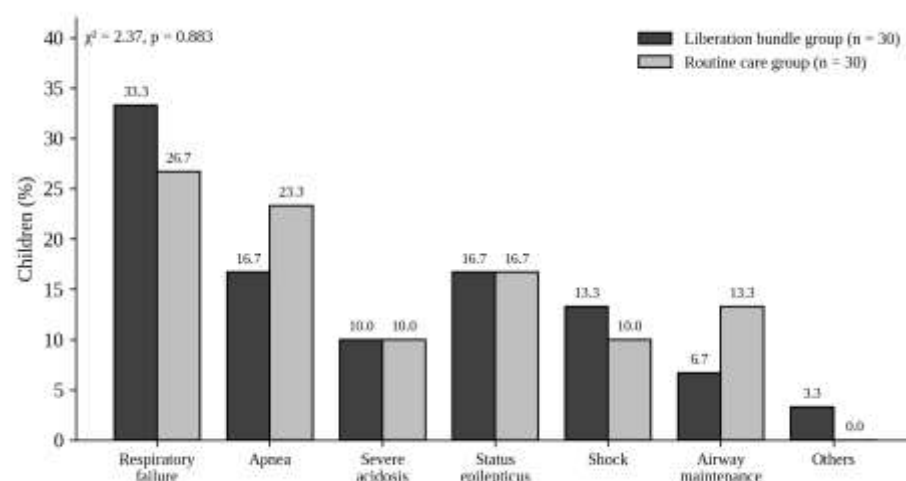


Figure 2. Distribution of the studied children according to indication for mechanical ventilation (N = 60).

Readiness for SBT and weaning at each time point is summarized in Table 2. At baseline (day 3), 63.3% of the liberation bundle group and 60.0% of the routine care group were ready for SBT and weaning ($p = 0.791$). The difference was not statistically significant on day 4 (60.0% vs. 56.7%, $p = 0.793$), day 5 (56.7% vs. 33.3%, $p = 0.069$), or day 6 (76.7% vs. 56.7%, $p = 0.100$). On day 7, 90.0% of the liberation bundle group and 46.7% of the routine care group were ready ($\chi^2 = 13.02$, $p < 0.001$), and before extubation the corresponding proportions were 90.0% and 56.7% ($\chi^2 = 8.52$, $p = 0.004$).

Table 2 Readiness for SBT and Weaning Before and After the Intervention (N = 60)

Time point	Liberation bundle group (n = 30), n (%)	Routine care group (n = 30), n (%)	χ^2 (df = 1)	P
Before intervention (day 3)	19 (63.3)	18 (60.0)	0.071	0.791
Day 4	18 (60.0)	17 (56.7)	0.069	0.793
Day 5	17 (56.7)	10 (33.3)	3.300	0.069
Day 6	23 (76.7)	17 (56.7)	2.700	0.100
Day 7	27 (90.0)	14 (46.7)	13.017	< 0.001
Before extubation	27 (90.0)	17 (56.7)	8.523	0.004

Note. Values are the number (percentage) of children who were ready for SBT and weaning (all five criteria met). Groups were compared with the Pearson chi-square test.

Duration of mechanical ventilation varied considerably amongst the groups. ($\chi^2 = 12.52$, $df = 2$, $p = 0.002$; Figure 3). Most children in the liberation bundle group (60.0%) were ventilated for 4–7 days, compared with 23.3% of the routine care group, whereas 60.0% of the routine care group were ventilated for 8 days or more, compared with 16.7% of the liberation bundle group. Ventilation for 1–3 days occurred in 23.3% and 16.7% of the children, respectively.

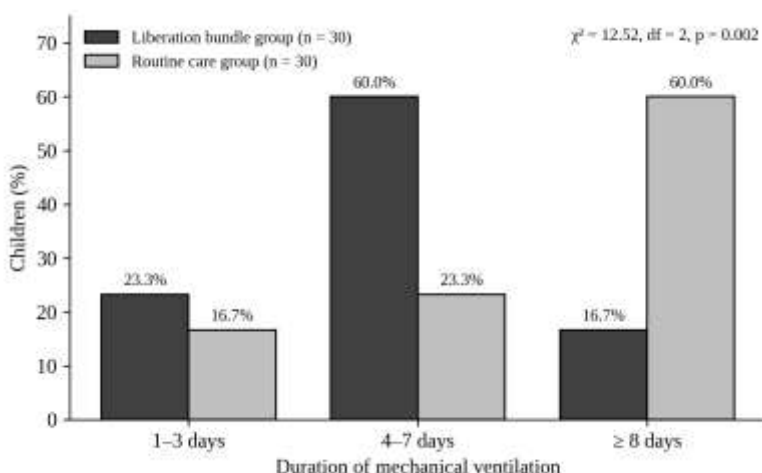


Figure 3. Distribution of the studied children according to duration of mechanical ventilation (N = 60).

Discussion

Timely liberation from mechanical ventilation is a main objective for acute care clinicians, because prolonged ventilation increases the risk of complications and strains critical care resources. The liberation bundle is an evidence-based paradigm that addresses pain, sedation, delirium, mobility, and family involvement in order to improve outcomes for critically ill patients. (Islam et al., 2026). Although its components are well known in adult critical care, comprehensive and protocolized evidence on its implementation in pediatric populations, particularly its effect on ventilation duration and SBT readiness, remains limited. Variations in clinical settings and the scarcity of controlled trials evaluating the collective effect of the bundle in the PICU highlight a gap in optimizing pediatric weaning pathways (Walz et al., 2020). The present study therefore evaluated the influence of a nursing liberation bundle on weaning readiness and length of MV in kids on mechanical ventilation.

There were no statistically significant differences between the two groups at baseline in terms of age, gender, place of residence, maternal education, and clinical features. Baseline comparability enhances the comparison's internal validity and lowers the possibility of confounding.

Preschoolers between the ages of three and six made up the bulk of the ventilated children in this trial. This is consistent with Loberger et al. (2022), who stated that a significant percentage of preschool-aged PICU children require invasive ventilation. In contrast, Lin et al. (2023) reported a higher incidence of infants and younger children. Differences in study settings, admission diagnoses, sample characteristics, and PICU admission criteria could explain this difference. In terms of gender, both groups were predominately male (60.0% each), in agreement with Ebrahim et al. (2023), who reported a male-to-female ratio of 2.4:1.

The majority of the children in both categories were admitted for medical reasons, with respiratory conditions accounting for almost one-third of these cases (33.3% and 36.7%). This agrees with Baraka and Hegazy (2024), El-Rebigi et al. (2025), and Kokeb and Biazen (2023), who all discovered that the most common diagnosis among pediatric patients requiring ventilation was respiratory illness.

Regarding ventilation duration, children in the liberation bundle group were ventilated for significantly shorter periods than children in the routine care group ($p = 0.002$): 60.0% of the bundle group were ventilated for 4–7 days, whereas 60.0% of the routine care group were ventilated for 8 days or more. These findings are in line with Blackwood et al. (2021), who reported that the time to first effective extubation was considerably shortened by sedation and ventilator liberation intervention. Similarly, Ali et al. (2025b) reported that, after an educational program on the liberation bundle, fewer than half of the bundle group remained ventilated for less than a week in contrast to more than half of the control group who remained ventilated for two weeks or more. Vallabhaneni et al. (2024) also found that protocolized sedation improved sedation control and shortened ventilation duration ($p = 0.008$), and Anukul et al. (2019) found that 60% of children were ventilated for less than one week after implementation of bundle care. In addition, Di Nardo et al. (2021), Eweas et al. (2020), and Pun et al. (2019) reported that complete bundle performance shortened ventilation days and reduced the likelihood of ventilation on the

following day.

In contrast, Jana (2025) observed shorter ventilation courses in most pediatric patients (56% ventilated for 1–3 days and only 11% for more than 8 days). This discrepancy may reflect differences in baseline clinical severity; Payen et al. (2012) identified age under 12 months, a PRISM score of 15 or more at admission, high mean airway pressure, continuous sedation, and prior noninvasive ventilation as risk factors for prolonged ventilation in children.

With regard to readiness for SBT, the groups did not differ significantly before the intervention or on days 4 to 6, but the bundle group had a significantly higher proportion of children ready for SBT on day 7 and before extubation. Similar improvements in SBT readiness after bundle implementation were reported by Lin et al. (2023), and higher rates of successful weaning in intervention groups were reported by Abdelrazic et al. (2022), Ali et al. (2025b), and Choi et al. (2019). Ferreira et al. (2019) likewise found higher rates of successful weaning and extubation among children who underwent protocolized SBTs than among children managed by clinical judgment alone. The temporal pattern in the present study, in which differences emerged only after several days of the bundle, suggests that the effect may require repeated daily application, although the differences on days 5 and 6 did not reach statistical significance and the study was not powered for time-point comparisons.

Limitations

It was a small-scale, single-center study with both short-term and long-term results. Such as post-intensive care syndrome were not assessed. The bundle was a modified four-component version (delirium screening and early mobilization were not included), so the contribution of each component could not be determined.

Conclusion

In this single-center randomized trial, the nursing liberation bundle was associated with higher readiness for SBT late in the intervention period (day 7 and before extubation) and with shorter duration of mechanical ventilation in children aged 1–6 years, which is consistent with the study hypothesis. These results are preliminary. Larger, blinded, multicenter trials with registered protocols, validated assessment tools, and clinical and safety outcomes (reintubation, mortality, length of stay) are recommended, together with studies that evaluate the individual bundle components and include delirium screening and early mobilization.

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Declaration of Conflicting Interests

The Author affirm that there is no conflict of interest.

Availability of Data and Materials

The corresponding author can provide the datasets created during the current investigation upon reasonable request.

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