

Received: 2016.12.16

Accepted: 2017.01.06

Published: 2017.09.28

# Effects of ABCDE Bundle on Hemodynamics in Patients on Mechanical Ventilation

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**Source of support:** Departmental sources

**Background:** Mechanical ventilation is an important part of advanced life support in the intensive care unit (ICU). This study aimed to investigate the effects of ABCDE bundle on hemodynamics in patients on mechanical ventilation (MV).





**Material/Methods:** This study used a cross-sectional overall controlled approach in which 143 patients on mechanical ventilation were divided into 2 groups. In the pre-ABCDE bundle group (n=70), conventional sedation and analgesia strategy were used. In the post-ABCDE bundle group (n=73), ABCDE bundle was used. Changes in hemodynamics parameters and related prognostic indicators were monitored at various time points before (T0) and at 1 d (T1), 3 d (T3), 5 d (T5), and 7 d (T7) after implementation of the 2 strategies.

**Results:** Mean arterial blood pressure (MAP), central venous pressure (CVP), heart rate (HR), and oxygenation index (PaO<sub>2</sub>/FiO<sub>2</sub>) in the bundle group were improved more significantly than those in the pre-ABCDE bundle group (P<0.05). For comparison between various monitoring time points in the same group, compared with before intervention, MAP, CVP, HR, and PaO<sub>2</sub>/FiO<sub>2</sub> changed significantly in the bundle group at 3 d, 5 d, and 7 d after intervention, and the difference was statistically significant (P<0.05). Compared with before intervention, differences in all hemodynamics indicators were statistically significant in the pre-ABCDE bundle group at 5 d and 7 d after intervention (P<0.05). Compared with the pre-ABCDE bundle group, differences in prognostic indicators in the post-ABCDE bundle were statistically significant (P<0.05).

**Conclusions:** ABCDE bundle is safe and effective for patients on mechanical ventilation, and can improve hemodynamics and enhance oxygenation index. ABCDE bundle might be helpful in reducing 28-d mortality and improving prognosis.

**MeSH Keywords:** **ABCD Bundle • Hemodynamics • Mechanical Ventilation • Oxygenation Index**

**Full-text PDF:** <https://www.medscimonit.com/abstract/index/idArt/902872>

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## Background

Mechanical ventilation is an important part of advanced life support in the ICU, and is essential in rescuing critically ill patients [1]. Pain and sedation therapy can alleviate pain, decrease anxiety and agitation, and induce therapy for anterograde amnesia [2]. Sedation and analgesia has become an essential part of intensive medical treatment, and is an option commonly used in the ICU [1]. The fundamental solution is to strengthen the monitoring and implementation of the intervention strategy. Based on evidence-based medicine, a sedative and analgesic bundle intervention, referred to as ABCDE bundle [3–5], has been used for ICU patients on mechanical ventilation to improve the quality of medical care and to optimize clinical outcomes. Specifically, ABC refers to the awakening and breathing coordination on a daily basis; D refers to the delirium monitoring/management; and E refers to early exercise/mobility. At present, most research on ABCDE bundle has focused on the prognosis of patients on mechanical ventilation and the prevention of ICU delirium and acquired weakness [6–11], but few studies have assessed the effects of hemodynamics. The hemodynamics index can show pathological and physiological changes and clinical development, which could also be applied in diagnosis and therapy in the ICU. Hemodynamics index monitoring is important in discovering the causes of disease at the early stage. To effectively strengthen sedation and analgesia management of ICU patients on mechanical ventilation, different intervention strategies were assessed in this study. By doing so, effects on the hemodynamics and prognosis of these patients were observed and evaluated.

## Material and Methods

### Design of study

This was a cross-sectional overall, before-after controlled study, which had been approved by the Ethics Committee of the hospital. Patients or their families agreed and voluntarily signed an informed consent for medical testing.

### Subjects

Inclusion criteria: 1) In accordance with the treatment indications of sedation and analgesia, and the application indications of mechanical ventilation [1]; 2) duration of mechanical ventilation and treatment time of sedation and analgesia  $\geq 48$  h; 3) length of stay in ICU  $\geq 48$  h; 4) age  $\geq 18$  years old; 5) type of artificial airway as orotracheal or tracheotomy tracheal intubation.

Exclusion criteria: 1) Suffering severe head trauma, cerebrovascular sequelae, and non-communicable patients with cognitive

disorders; 2) status epilepticus; 3) neuromuscular disease or limb movement disorder; 4) allergy to sedatives and analgesics.

### Grouping

From May 2015 to October 2016, 143 patients on mechanical ventilation admitted at the ICU in our hospital were included, and were then grouped and numbered according to the order of admission. Those admitted from May to December 2015 were classified into the pre-ABCDE bundle group (n=70) and received conventional sedation and analgesia; while those admitted from January to October 2016 were classified into the post-ABCDE bundle group (n=73) and received ABCDE bundle. Patients were ages 29–76 years old, with an average age of (61.1 $\pm$ 10.7) years, including 77 males and 66 females. The APACHE II scores were (21.1 $\pm$ 5.2), and the causes included 72 cases of severe pneumonia, 31 cases of chronic obstructive pulmonary disease, 25 cases of sepsis, 6 cases of cardiogenic shock, 2 cases of severe pancreatitis, and 7 cases “other”.

### Methods and parameters of mechanical ventilation

Included patients underwent tracheal intubation or tracheostomy to install a ventilator (PB840, USA). The parameter settings of the mechanical ventilation should be in accordance with the actual conditions of the patients; therefore, we selected the ventilation mode and set the parameters. The basic ventilation models were pressure switch and the capacity switch. Assisted respiration and controlled respiration are the most basic model for breathing machine, which could be selected according to the clinical practice. The parameters were listed as the followings: with respiratory rate of 12 to 20 breaths/min, tidal volume of 6 to 12 ml/kg, triggering sensitivity of 1.5–3.0 L/min, fraction of inspired oxygen  $\leq 0.6$ , pressure support of 8–20 cm H<sub>2</sub>O (1 cm H<sub>2</sub>O=0.098 kPa), and positive end expiratory pressure of 3–8 cm H<sub>2</sub>O. The patient's conditions were carefully assessed and the parameter settings were individualized according to ventilator monitoring data: tidal volume (VT), positive end expiratory pressure (PEEP), plateau pressure (Pplat), inspiratory flow, inspiratory time, fraction of inspired oxygen (FiO<sub>2</sub>), and respiratory rate (RR) [12].

### Sedatives and analgesics

According to the *Clinical Practice Guidelines for the Management of Pain, Agitation, and Delirium in Adult Patients (2013)* [1], all subjects were recommended to use sedatives and analgesics of non-benzodiazepines (propofol, dexmedetomidine) or benzodiazepines (midazolam, lorazepam), and the dosage and pump speed were adjusted according to the patient's condition and delirium score.

## Implementation of ABCDE bundle

For each strategy, the bundle team members, consisting of physicians, nurses, respiratory therapists, and physiotherapists, were trained by professional staff to achieve cooperation of multiple disciplines [13,14]. ABCDE bundle was routinely implemented for patients on mechanical ventilation every day. After that, each intervention strategy and its results were recorded by the nurses in a Critical Care Record, and the data were input into a Hospital Nursing System Electronic Form in a timely manner. The specific implementation is as follows:

**A**: The awakening and breathing coordination; every morning, a wake-up was carried out and evaluated by the nurse; the spontaneous breathing test was evaluated and implemented by the physician at bedside, and the problems occurring during the implementation were monitored and treated by the nurses in a timely manner. During the wake-up and spontaneous breathing test, changes in patient's consciousness and vital signs were observed, as well as the working status of the ventilator, the adopted mode, the parameters, and man-machine coordination [15].

**D**: Delirium monitoring/management; every morning, the delirium in patients on mechanical ventilation was assessed by trained nurses with the ICU delirium assessment diagnostic table (CAM-ICU), and the delirium scores were obtained with Richmond agitation-sedation scale (RASS) and sedation agitation scale (SAS) [1]. The progression of delirium was monitored and the daily assessment scores of patients on mechanical ventilation were recorded. On this basis, the dose of the sedatives and analgesics used was adjusted. Those diagnosed as positive were further identified by the physicians.

**E**: Early exercise/mobility; according to the conditions of patients on mechanical ventilation, a 3-stage activity was adopted [11]: sitting on the bed, standing by the bed or sitting in a chair, and exercising at the bedside. The specific program of exercise was developed by the physician. Sitting on the bed, the patient was assisted by the nurse to turn over and change posture, and passive joint movement was carried out. If the patient's condition permits, he/she could be guided and encouraged by the nurse to maintain sitting and to perform active joint movement. Eventually, the patient was jointly assisted by the physician, physiotherapist, and nurse to perform a small range of exercises, and whether the exercise should be stopped or its interval should be extended was evaluated in a timely manner; adverse events, such as falling out of bed or the tube falling off, should be prevented during exercise.

**Pre-ABCDE bundle group**: The conventional sedation and analgesia strategies were used, and the patient's levels of sedation and consciousness were monitored to avoid hypotension and excessive sedation; heart rate, cardiac rhythm, blood

pressure, central venous pressure, breathing, and blood oxygen saturation were routinely and closely monitored.

## Observation index

MAP, CVP, HR, and  $\text{PaO}_2/\text{FiO}_2$  of patients in the pre-ABCDE bundle and post-ABCDE bundle group at time points of T0, T1, T3, T5, and T7 were recorded, and 5 consecutive cycles were averaged; we also recorded the dosage of sedatives and analgesics used, the related prognostic indicators: mechanical ventilation duration, length of stay in ICU, and 28-d survival rate.

## Statistical analysis

SPSS17.0 statistical software was used for statistical analysis. Repeated measures analysis of variance was used for comparison of repeated measurements, the *t* test was used for comparison of the means of 2 groups, and the  $\chi^2$  test was used for comparison of the rates of both groups.  $P < 0.05$  was considered statistically significant.

## Results

### General data

Differences in age, sex, and APACHE II scores between groups were not statistically significant ( $P > 0.05$ ). Furthermore, differences in MAP, CVP, HR, and  $\text{PaO}_2/\text{FiO}_2$  were not statistically significant before intervention ( $P > 0.05$ ) and were thus comparable (Tables 1, 2).

### Hemodynamics indicators

Compared with the pre-ABCDE bundle group, improvements of MAP, CVP, HR and  $\text{PaO}_2/\text{FiO}_2$  were most significant in the post-ABCDE bundle group at 3 d, 5 d, and 7 d after intervention, and the difference was statistically significant ( $P < 0.05$ ). The number of offline patients for the corresponding time period was higher in the post-ABCDE bundle group than in the pre-ABCDE bundle group ( $P < 0.05$ ). Comparison at different monitoring time points in the same group, compared with before intervention, showed that hemodynamics indexes in the post-ABCDE bundle group at 3 d, 5 d, and 7 d after intervention decreased significantly ( $P < 0.05$ ). Compared with before intervention, the differences in the hemodynamics indicators in the pre-ABCDE bundle group at 5 d and 7 d after intervention were statistically significant (Table 3,  $P < 0.05$ ).

### Sedatives and analgesic drugs

Comparison of the dose of sedatives and analgesic drugs between groups showed that the dose used in the pre-ABCDE

**Table 1.** Comparison of general data between two groups ( $\bar{x}\pm s$ ).

Groups	Age (Y)	Gender (M/F)	APACHE II scores
Pre-ABCDE bundle group	62.26±9.8	34/36	20.54±4.9
Post-ABCDE bundle	60.00±11.5	43/30	21.79±5.5
F value/X <sup>2</sup>	1.063*	0.489**	2.014*
P value	0.305	0.485	0.158

\* F value; \*\* X<sup>2</sup> value.

**Table 2.** Comparison of hemodynamics indexes before intervention between two groups ( $\bar{x}\pm s$ ).

Groups	MAP	CVP	HR	PaO <sub>2</sub> /FiO <sub>2</sub>
Pre-ABCDE bundle group	77.6±7.3	8.04±2.2	105.31±9.0	166.60±17.3
Post-ABCDE bundle	78.4±6.8	7.84±2.1	106.65±10.4	167.40±17.3
F value	0.429	0.834	0.668	0.070
P value	0.514	0.363	0.415	0.792

**Table 3.** Dynamic changes of hemodynamics indexes in two groups ( $x\pm s$ )

Groups	Time	MAP (mmHg)	CVP (cmH <sub>2</sub> O)	HR (bpm)	PaO <sub>2</sub> /FiO <sub>2</sub> (mmHg)
Pre-ABCDE bundle group	T0	77.6±7.3	8.04±2.2	105.31±9.0	166.6±17.3
	T1	79.6±8.5	8.51±2.9	103.50±7.1	168.8±16.5
	T3	80.0±6.4 <sup>b</sup>	8.37±2.6 <sup>b</sup>	102.70±8.2 <sup>b</sup>	171.3±14.4 <sup>b</sup>
	T5	82.1±6.4 <sup>*b</sup>	9.54±3.2 <sup>*</sup>	95.91±7.0 <sup>*b</sup>	213.7±31.3 <sup>*b</sup>
	T7	81.4±6.4 <sup>*b</sup>	9.47±3.2 <sup>*b</sup>	90.41±6.9 <sup>*b</sup>	227.3±25.3 <sup>*b</sup>
Bundle group	T0	78.4±6.8	7.84±2.1	106.65±10.4	167.4±17.3
	T1	80.3±9.5	8.00±2.9	105.09±8.7	171.8±17.2
	T3	83.6±7.7 <sup>*a</sup>	8.90±3.4 <sup>*a</sup>	98.46±7.3 <sup>*a</sup>	194.3±28.1 <sup>*a</sup>
	T5	84.5±7.9 <sup>*a</sup>	8.41±3.1 <sup>*a</sup>	93.42±6.7 <sup>*a</sup>	240.2±39.3 <sup>*a</sup>
	T7	83.7±6.9 <sup>*a</sup>	8.72±3.0 <sup>*a</sup>	85.61±7.2 <sup>*a</sup>	257.0±39.0 <sup>*a</sup>

Compared with T0: \*P<0.05; compared with the pre-ABCDE bundle group: <sup>a</sup>P<0.05; compared with the post-ABCDE bundle group: <sup>b</sup>P<0.05; T0 – before intervention; T1 – 1d after MV; T3 – 3d after MV; T5 – 5d after MV; T7 – 7d after MV.

bundle group was higher than in the post-ABCDE bundle group, and the difference was statistically significant (P<0.05, Table 4).

### Prognostic indicators

Comparison of delirium incidence, 28-d survival, mechanical ventilation duration, and length of ICU stay between 2 groups showed that the delirium incidence in the pre-ABCDE bundle group was higher than in the post-ABCDE bundle group, while the prognostic indicators in the post-ABCDE bundle group were

better than in the pre-ABCDE bundle group, and the difference was statistically significant (P<0.05, Table 5).

### Discussion

Monitoring the hemodynamics index is an important clinical strategy for critically ill patients, which can not only determine the real-time response of the body, but also assist in clinical interventions, all of which can guide therapy and improve

**Table 4.** Comparison of the dose of sedatives and analgesics between two groups (x±s).

Groups	n	Sufentanil		Midazolam	
		Total dose (mg)	Average dose (mg/kg·h)	Total dose (mg)	Average dose (mg/kg·h)
Pre-ABCDE bundle group	70	292.1±58.6	0.030±0.007	286.7±58.1	0.029±0.007
Post-ABCDE bundle	73	170.8±73.6	0.018±0.009	164.6±70.4	0.017±0.009
T value		10.860	8.746	11.268	8.430
P value		0.000	0.000	0.000	0.000

Comparison between the pre-ABCDE bundle and post-ABCDE bundle groups:  $P < 0.05$ ;

**Table 5.** Comparison of delirium incidence, 28d survival, mechanical ventilation duration, and length of stay in ICU between two groups (x±s).

Groups	n	Delirium		28 d survival		Mechanical ventilation duration	Length of stay in ICU
		n	Survival rate (%)	n	Survival rate (%)		
Pre-ABCDE bundle group	70	29	41.4	51	72.9	7.51±3.36	9.76±3.75
Post-ABCDE bundle	73	13	17.8	64	87.7	5.67±3.03	7.47±2.53
T value/X <sup>2</sup>			9.611**		4.980**	4.856*	4.435*
P value			0.002		0.026	0.001	0.000

\* T value; \*\* X<sup>2</sup> value.

tissue perfusion. Mechanical ventilation can recover the effective ventilation of patients, strengthen spontaneous breathing work, and enhance the active breathing capacity of the ventilator. However, increased heart rate and other discomfort may be caused in ICU patients on mechanical ventilation. Sedation and analgesia treatment can make patients “comfortable and safe”, but has a non-selective inhibition on the circulatory and respiratory center [16]. Nevertheless, the application of ABCDE bundle is safe and effective [15–18]. At present, the effect of ABCDE bundle on the hemodynamics of patients on mechanical ventilation has been rarely investigated [19]. Therefore, in this study, 2 intervention strategies were used to dynamically monitor the hemodynamics of patients on mechanical ventilation at 5 time points in an attempt to reveal the changing pattern of their hemodynamics and to explore the influences of ABCDE bundle on the hemodynamics and prognosis of patients on mechanical ventilation [20].

Our results show that data in the pre-ABCDE bundle group, MAP, CVP, HR, and PaO<sub>2</sub>/FiO<sub>2</sub> did not change significantly at 1 d and 3 d after intervention ( $P > 0.05$ ); in the post-ABCDE bundle group, the hemodynamics indicators showed no difference at 1 d after intervention compared with before intervention ( $P > 0.05$ ). Mechanical ventilation imposes obvious

tensile stress and compressive stress on the alveolar epithelium during the breathing movement [21]. If the duration and intensity of such tensile and compressive stimulation were too great, these excessive biophysical stimuli might be transformed into the regulatory signals of cytotoxicity and inflammation, leading to cell and tissue damage [22], and the hemodynamics indicators can't change significantly in the short term. Moreover, our patients were relatively old (61.1±10.7 years). Lung function declines with age, and the intervention time was too short; therefore, the short-term intervention effects were inadequate. Compared with the pre-ABCDE bundle group, the hemodynamics indicators in the post-ABCDE bundle group were improved more significantly at 3 d, 5 d, and 7 d after intervention ( $P < 0.05$ ), with more offline patients than in the pre-ABCDE bundle group during the same period ( $P < 0.05$ ). The dose of sedatives and analgesics used in the pre-ABCDE bundle group was higher than in the post-ABCDE bundle group ( $P < 0.05$ ). The incidence of delirium in the post-ABCDE bundle group was lower than in the pre-ABCDE bundle group, which might be mainly attributed to use of the ABCDE bundle for the following reasons. 1) It can effectively strengthen the patient's own breathing work and improve the patient's respiratory muscle function [8], and eventually increases diaphragm activity [23], leading to spontaneous improvement of

the oxygenation index. 2) Early exercise therapy can reduce the body disorders and delirium incidence [3], promoting the autonomous movement function of the respiratory muscle [24], due to the spontaneous enhancing the oxygenation index. 3) After hemodynamics indicators improved, the patient's cardio-pulmonary function increased, the number of offline patients increased accordingly, and the dose of sedatives and analgesics was reduced. Sedative drugs can inhibit the sympathetic nervous system, leading to decreased angiectasis and myocardial suppression, which all lead to the hemodynamics effects. Therefore, appropriate use of sedative drugs can stabilize hemodynamics status, decrease stress response, down-regulate oxygen consumption, and enhance comfort of the patients and efficacy of the therapeutic strategy. Compared with before intervention, the hemodynamics indicators in the pre-ABCDE bundle group were improved at 5 d and 7 d after the intervention ( $P<0.05$ ). Compared with before intervention, MAP, CVP, and HR in the post-ABCDE bundle were significantly reduced at 3 d, 5 d, and 7 d after the intervention, and  $\text{PaO}_2/\text{FiO}_2$  increased significantly. MAP, CVP, HR and  $\text{PaO}_2/\text{FiO}_2$  were significantly improved at 7 d ( $P<0.05$ ) compared with 1 d, indicating that both intervention strategies improve the hemodynamics indicators of patients on mechanical ventilation. This might be because both intervention strategies can expand the airway, lower mucus viscosity, and make airway secretions easier to discharge. Furthermore, both strategies activate and release lipoproteinase on the alveolar wall, relieve bronchial spasm, and alleviate the inflammatory exudation of lung tissues. As a result, the hydrolysis of mucus secretion is enabled, helping dilute sputum discharge, promote micro-circulation of the lung [25], improve the ratio of ventilation/blood flow and the circulatory function, enhance oxygenation index, and improve the patient's hemodynamics indicators.

The difference in the prognosis between the bundle and pre-ABCDE bundle groups was statistically significant ( $P<0.05$ ), as

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## Conclusions

ABCDE bundle can significantly improve the hemodynamics indicators of patients on mechanical ventilation, reduce the dose of the sedatives and analgesics used, and keep the hemodynamics indicators, including MAP, CVP, and HR, at levels beneficial to patients. Finally, according to the patients' response, ABCDE bundle could achieve the optimal therapeutic ends. Based on satisfying the volume state of the tissue perfusion, the ABCDE bundle is not only beneficial to the venous return, cardiac work, but also could protect the other organs, all of which could increase the oxygenation index and improve the circulatory function.

Therefore, application of the hemodynamics therapy mediated targeted therapy strategy is the crucial factor for improving the outcomes of the patients.

## Conflict of interests

None.

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