

Parameters affecting the tidal volume during expiratory abdominal compression in patients with prolonged tracheostomy mechanical ventilation

AKIRA MORINO, MS, PT¹*, MASAHIRO SHIDA, MS, PT¹), MASASHI TANAKA, MS, PT¹), KIMIHIRO SATO, MS, PT¹), TOSHIKI SEKO, PT¹), SHUNSUKE ITO, PT¹), SHUNICHI OGAWA, PT¹), NAOAKI TAKAHASHI, PhD, PT²)

¹) Department of Physical Therapy, Hokkaido Chitose Institute of Rehabilitation Technology: 10 Satomi 2-chome, Chitose 066-0055, Japan

²) Department of Physical Therapy, Health Sciences, School of Rehabilitation Sciences, University of Hokkaido, Japan

Abstract. [Purpose] The aim of this study was to clarify physical parameters affecting the tidal volume during expiratory abdominal compression in patients with prolonged tracheostomy mechanical ventilation. [Methods] Eighteen patients with prolonged mechanical ventilation were included in this study. Expiratory abdominal compression was performed on patients lying in a supine position. The abdomen above the navel was vertically compressed in synchronization with expiration and released with inspiration. We measured the tidal volume during expiratory abdominal compression. [Results] The mean tidal volume during expiratory abdominal compression was higher than that at rest (430.6 ± 127.1 mL vs. 344.0 ± 94.3 mL). The tidal volume during expiratory abdominal compression was correlated with weight, days of ventilator support, dynamic compliance and abdominal expansion. Stepwise multiple regression analysis revealed that weight ($\beta = 0.499$), dynamic compliance ($\beta = 0.387$), and abdominal expansion ($\beta = 0.365$) were factors contributing to the tidal volume during expiratory abdominal compression. [Conclusion] Expiratory abdominal compression increased the tidal volume in patients with prolonged tracheostomy mechanical ventilation. The tidal volume during expiratory abdominal compression was influenced by each of the pulmonary conditions and the physical characteristics.

Key words: Expiratory abdominal compression, Tidal volume, Prolonged mechanical ventilation

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INTRODUCTION

Airway clearance is important for improvement of respiratory conditions and prevention of ventilation associated pneumonia in patients with respiratory failure¹). There are several techniques for airway clearance. The manual breathing assist technique is one of the techniques for improvement of airway clearance in clinical settings. This technique consists of compression on the chest wall synchronized with physiological movement of the chest wall²). Therefore, it has a risk of fracture of the ribs in patients with osteoporosis, which occurs in long-term bedridden patients³).

Expiratory abdominal compression (EAC) is a breathing assistance technique performed by abdominal compression during expiration. In previous studies, EAC for patients with neuromuscular disease or bronchial asthma was performed

with powerful compression on the abdomen like the Heimlich maneuver⁴⁻⁷). In contact, EAC for patients with spinal cord injuries, patients after thoracoabdominal surgery, or patients with prolonged mechanical ventilation was performed gently⁸). There is very little empirical evidence for EAC. Kaneko et al. reported that EAC for healthy subjects improved the tidal volume (VT)⁹). Previous reports revealed that the forced vital capacity and peak expiratory flow were increased by EAC in patients with restrictive lung disease¹⁰). However, few studies have focused on EAC in patients with prolonged tracheostomy mechanical ventilation.

The aim of this study was to elucidate the impact of EAC on the responses of VT and to clarify the physical parameters affecting the VT during EAC in patients with prolonged tracheostomy mechanical ventilation.

SUBJECTS AND METHODS

Subjects

Eighteen inpatients with prolonged tracheostomy mechanical ventilation lasting for more than a month were enrolled. A Servo s (Fukuda Denshi, Tokyo, Japan) ventilator was used and set in synchronized intermittent mandatory ventilation mode. The exclusion criteria were trouble with

*Corresponding author. Akira Morino (E-mail: a-morino@chitose-reha.ac.jp)

the synchronization of the ventilator, rib fracture, presence of a chest tube, hemodynamic instability, and pneumonia within two weeks prior to the measurements of VT during EAC.

A prospective observational study design was utilized. The Institutional Review Board of Heiseikai Hospital approved this study (No. 11H23), and the patients or their legally acceptable representative gave written informed consent.

Methods

EAC was performed on patients lying in a supine position. To quantify the pressure, a handheld dynamometer (μ Tas F-1, Anima Corporation, Tokyo, Japan); with sensor dimensions of 56 mm by 56 mm, was used. The abdomen above the navel was vertically compressed in synchronization with expiration and released with inspiration.

EAC was performed with a pressure of 2 kgf. The monitor of the ventilator was recorded with a video camera during the measurements. The monitor of the ventilator during EAC was not checked, so the VT with the pressure support was collected after the measurements. EAC was performed by an experienced physiotherapist.

The age, height, weight, diseases, and Glasgow coma scale were collected from the patients' medical records as patient characteristics. The setting of the ventilator was confirmed on the monitor of the ventilator. Dynamic compliance (C_{dyn}) was calculated as follows: C_{dyn} = VT at rest / (peak inspiratory pressure – positive end-expiratory pressure)¹¹. The expansion of the abdomen was measured three times with a tape measure. The difference of the diameter between in expiration and in inspiration was recorded. The highest value was used in this study. The impairment of consciousness was evaluated with the Glasgow coma scale.

To examine the degree of correlation between the VT during EAC and each of the parameters, bivariate analyses were performed using the Pearson product-moment correlation coefficient. Furthermore, multivariable stepwise linear regression analysis was performed to investigate the parameters that affected the VT during EAC. The variables related significantly to the VT during EAC in the bivariate analysis were selected as candidates for independent variables for a multivariable analysis. Statistical analyses were performed using SPSS software version 19 (SPSS Japan Inc., Tokyo, Japan), and we considered $p < 0.05$ to represent statistical significance.

RESULTS

Table 1 shows the characteristics of the 18 patients. The mean age of the patients was 69.7 years (SD: 15.9). All patients had impaired consciousness. The VT during EAC (430.6 ± 127.1 mL) was significantly higher than that at rest (344.0 ± 94.3 mL) ($p < 0.001$).

The correlation between the VT during EAC and each of the parameters is shown in Table 2.

Weight, days of ventilator support, C_{dyn}, and the expansion of the abdomen were selected as the independent variables for the multivariable analysis. Multivariable analysis revealed that weight, C_{dyn}, and expansion of the abdomen

Table 1. Characteristics of the 18 patients

Variables	Values
Age, yrs	69.7 \pm 15.9
Gender M/F, No.	9/9
Height, cm	156.3 \pm 11.2
Weight, kg	47.6 \pm 9.4
BMI, kg/m ²	19.5 \pm 3.6
Disease, No. (%)	
Hypoxic-ischemic encephalopathy	7 (38.9)
Chronic respiratory failure	4 (22.2)
Cerebrovascular disease	3 (16.7)
Spinal cord injury	2 (11.1)
Neurodegenerative disease	2 (11.1)
Glasgow coma scale [†]	4.0 (3.0–6.0)
Expansion of abdomen, mm	3.0 \pm 1.4
Days of ventilator support, days	830.4 \pm 745.3
Setting of ventilator	
PC (cmH ₂ O)	8.9 \pm 2.2
PS (cmH ₂ O)	7.1 \pm 2.9
PEEP (cmH ₂ O)	5.7 \pm 1.6

Values are expressed as the mean \pm SD unless otherwise indicated.

[†]Median (interquartile range)

BMI: body mass index; PC: pressure control; PS: pressure support; PEEP: positive end-expiratory pressure

Table 2. Correlations between characteristics of the patients and the VT during EAC

Variable	Correlation coefficient
Age	-0.006
Weight	0.620 **
Days of ventilator support	0.478 *
PS	0.345
PEEP	0.178
C _{dyn}	0.598 **
Expansion of abdomen	0.499 *

* $p < 0.05$; ** $p < 0.01$

VT: tidal volume; EAC: expiratory abdominal compression; PS: pressure support; PEEP: peak end-expiratory pressure; C_{dyn}: dynamic compliance

were parameters contributing to the VT during EAC (adjusted $R^2 = 0.927$, $p < 0.001$) (Table 3).

DISCUSSION

The present study revealed that EAC increased the VT in patients with prolonged tracheostomy mechanical ventilation. Multivariable stepwise linear regression clarified that the VT during EAC was influenced by weight, C_{dyn} and the expansion of the abdomen. To our knowledge, this is the first report to examine the factors contributing to the VT during EAC. Our results might help pulmonary rehabilitation in patients with prolonged tracheostomy mechanical ventilation

Table 3. Results of the multivariable stepwise linear regression

Variable	Unstandardized coefficient		Standardized coefficient	95% confidence interval	
	B	Std. error		Lower	Upper
(Constant)	-181.788	106.361		-409.909	46.334
Weight	6.751	1.959	0.499 **	2.548	10.953
Cdyn	4.664	1.798	0.387 *	0.808	8.052
Expansion of abdomen	338.225	134.521	0.365 *	49.706	626.744

* $p < 0.01$; ** $p < 0.05$

Cdyn: dynamic compliance

and trouble in airway clearance.

The VT during EAC was significantly affected by weight. In a previous study, both the movement distance of the diaphragm and the size of the thorax affected the VT¹²). It was considered that body size was related to the size of thorax and lung. EAC acted to support the diaphragm.

EAC increased the intra-abdominal pressure, so the diaphragm was pushed up. A previous study reported that the VT during EAC was increased by an increase in the intrathoracic pressure due to pushing up of the diaphragm³). Cdyn is an index expressing the expandability of the lung. In our study, the pressure of EAC was quantified. It was considered that the intra-abdominal pressure in patients with high expansion of the abdomen was higher than that in patients with low expansion of the abdomen. Therefore, the expandability of the lung and the expansion of the abdomen affected the VT during EAC.

Our study has some limitations that need to be addressed. First, the sample size was small. Second, we included subjects with several diseases. Future studies will require disease-based examinations.

In conclusion, we found that the VT of patients with prolonged tracheostomy mechanical ventilation during EAC was increased and affected by each of the pulmonary conditions and bodily characteristics.

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