

Test-retest reliability of expiratory abdominal compression with a handheld dynamometer in patients with prolonged mechanical ventilation

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Abstract. [Purpose] The present study aimed to examine the test-retest reliability of expiratory abdominal compression with a handheld dynamometer in patients with prolonged mechanical ventilation. [Subjects and Methods] We recruited 18 patients with prolonged mechanical ventilation. All patients had impaired consciousness. The mode of the ventilator was synchronized intermittent mandatory ventilation. The abdomen above the navel was vertically compressed using a handheld dynamometer in synchronization with expiration. Expiratory abdominal compression was performed two times. We measured the tidal volume during expiratory abdominal compression. There was an interval of 5 minutes between the first and second measurements. Intraclass correlation coefficient (ICC) and Bland-Altman analysis were performed to examine the test-retest reliability of expiratory abdominal compression with a handheld dynamometer. [Results] The test-retest reliability of expiratory abdominal compression was excellent (ICC(1, 1): 0.987). Bland-Altman analysis showed that there was no fixed bias and no proportional bias. [Conclusion] The findings of this study suggest that expiratory abdominal compression with a handheld dynamometer is reliable and useful for patients with respiratory failure and prolonged mechanical ventilation.

Key words: Reliability, Expiratory abdominal compression, Bland-Altman analysis

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INTRODUCTION

Airway clearance techniques, range of motion exercise, and mobilization are performed in pulmonary rehabilitation for mechanically ventilated patients¹. Airway clearance prevents ventilator-associated pneumonia. The manual breathing assist technique is widely used for improvement of airway clearance in pulmonary rehabilitation. This technique consists of compression on the chest wall synchronized with physiological movement of the chest wall². This technique is often performed for patients with respiratory dysfunction (i.e., chronic obstructive lung disease, bronchial asthma, spinal cord injuries, and neuromuscular disease). However, the manual breathing assist technique for patients with prolonged mechanical ventilation (PMV) has a risk of fracture of the ribs because of the osteoporosis caused by long-term bed rest³.

Expiratory abdominal compression (EAC) is an airway clearance technique similar to the manual breathing assist technique. The difference between EAC and manual breathing assist is the parts of the body to be compressed. EAC is performed using compression on the abdomen above the navel. Several studies reported application of EAC to patients with respiratory failure such as amyotrophic lateral sclerosis, spinal cord injuries, central nervous system disease, and muscular dystrophy⁴⁻⁸. Another reported EAC with powerful compression, like the Heimlich maneuver, synchronized with coughing for the purpose of assisting coughing⁹. In contrast, EAC aimed at shifting sputum from the peripheral bronchus to the central bronchus is performed gently and synchronized with expiration. EAC is often used for such patients; nevertheless, little had been reported on EAC. It was considered that EAC increased the cough peak flow, forced vital capacity, and forced expiratory volume in 1 second in those patients. Kaneko et al. revealed that EAC increased the tidal volume (V_T) in healthy subjects¹⁰.

However, the empirical evidence for the manual breathing assist technique is poor, because most studies concerning the manual breathing assist technique did not quantify the pressure of the compression. It is important to establish evaluation methods with good reliability for revealing the effect of the manual breathing assist technique.

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A handheld dynamometer (HHD) is often used to evaluate peripheral muscle force. An HHD is excellent in terms of portability and conveniently. It is possible that an HHD could be used to examine the pressure of EAC objectivity.

In this study, the V_T during EAC was measured while quantifying the pressure using an HHD. The aim of this study was to examine the test-retest reliability of EAC in patients with PMV.

SUBJECTS AND METHODS

Subjects

Eighteen inpatients with PMV were enrolled in this study. The patients had required tracheostomy mechanical ventilation for more than a month. A servo s (Fukuda Denshi, Tokyo, Japan) ventilator was used and set in synchronized intermittent mandatory ventilation mode. Individuals who had trouble with the synchronization of the ventilator, rib fracture, presence of a chest tube, hemodynamic instability, and pneumonia within two weeks prior to the measurements of V_T during EAC were excluded in this study.

A prospective observational study design was utilized. The Institutional Review Board of Heiseikai Hospital approved this study, and the patients or their legally acceptable representative gave written informed consent.

Methods

The characteristics of the patients were collected from their medical records. The setting of the ventilator was confirmed from the display of the ventilator. To quantify the pressure, an HHD (μ Tas F-1, Anima Corporation, Tokyo, Japan) with sensor dimensions of 56 mm by 56 mm was used. The tester held the pressure sensor of the HHD in a single hand. The abdomen above the navel was vertically compressed through the only whole attachment cover of the sensor. The peak pressure of compression during EAC was 2 kgf in this study. EAC was performed on patients lying in a supine position. The compression was performed in synchronization with expiration and released with inspiration. Prior to measurement, no water in the corrugated tube of the ventilator and no sputum retention in the lung and airway of the patients were confirmed by visual observation and auscultation. EAC was performed two times. There was an interval of 5 minutes between the first and second measurements. The V_T during EAC was measured. The display of the ventilator was recorded with a video camera during the measurements. The display of the ventilator during EAC was not checked, so the value of the V_T with pressure support was collected after the measurements. EAC was performed by an experienced physiotherapist. Other maneuvers of the

breathing technique (i.e., vibration and springing) were not combined with EAC.

To examine the test-retest reliability of EAC, the ICC(1, 1) was calculated. Furthermore, Bland-Altman analysis was performed in order to conform whether there was the fixed bias and proportional bias¹¹⁾. Furthermore, the minimal detectable change (MDC) at the 95% confidence level was calculated¹²⁾. Statistical analyses were performed using R2.8.1, and $p < 0.05$ was considered to represent statistical significance.

RESULTS

Table 1 shows the characteristics of the 18 patients. The V_T values from the first and second measurements were 427.9 mL (SD: 127.4) and 430.4 mL (SD: 128.9). The results of calculation of the ICC and Bland-Altman plot are shown in Table 2. The MDC was 42.0 mL. The Bland-Altman plot revealed that there was no fixed bias and no proportional bias.

Table 1. Characteristics of the 18 patients

| Variables | Values |
|----------------------------------|-------------------|
| Age, yr | 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) |
| 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 |
| F _I O ₂ | 0.23 \pm 0.02 |

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; F_IO₂: fraction of inspired oxygen

Table 2. The results of the ICC and Bland-Altman analysis

| ICC | | Bland-Altman analysis | | | MDC ₉₅ | |
|-----------|----------------|-----------------------|------------------------|--------|-------------------|------|
| ICC (1,1) | 95% CI | Fixed bias 95% CI | Proportional bias R | Bias | | |
| 0.987 | [0.965, 0.995] | [-13.156, 8.156] | No | -0.073 | No | 42.0 |

ICC: intraclass correlation coefficient; CI: confidence interval; R: correlation coefficient; MDC₉₅: minimal detectable change at the 95% confidence level

DISCUSSION

The present study examined the reliability of EAC in patients with PMV. Based on current knowledge, this is the first report to examine the reliability of EAC. The fact that the reliability of EAC was excellent and there was no fixed bias and no proportional bias indicates that EAC would be useful for the pulmonary rehabilitation in patients with PMV.

The ICC(1, 1) was 0.987 in this study. Landis et al. reported that the ICC was almost perfect, above 0.81¹³. The reliability of EAC in this study was excellent. ICC could evaluate the error including the measured value was an individual difference and a measurement. However, it could not be used to evaluate a systematic error. In contrast, Bland-Altman analysis is a statistical method that can be used to evaluate a systematic error such as a fixed bias or proportional bias. The reliability of EAC was excellent regardless of the magnitude of the V_T , because Bland-Altman analysis confirmed that there was no systematic error in this study. The MDC of 42.0 mL meant that the any V_T less than that value was considered a random error. These findings might be important in future assessments of the effect of EAC on pulmonary rehabilitation in patients with respiratory failure.

The V_T in this study was about 430 mL and was less than that reported by Kaneko et al. (1011 mL, SD: 340)¹⁰. EAC increased the intra-abdominal pressure, so the diaphragm was pushed up. A previous study reported that the V_T during EAC was increased by an increase in the intrathoracic pressure due to pushing up of the diaphragm¹⁴. Therefore, the pressure of the compression affected the V_T during EAC. Although the pressure of the compression in the study of Kaneko et al. was not quantified¹⁰, the pressure in the present study might have been lower than theirs. The subjects in their study were healthy and younger than those in the present study (20.6 years [SD: 0.5] vs. 69.7 years [SD: 15.9]). Because V_T decreases with age, the V_T during EAC in the present study was less than that in their study.

This study has a limitation. EAC in this study was performed through an HHD. The manual breathing technique is generally performed by placing the whole palm against the patient's body. Therefore, it is necessary to be careful when

attempting to generalize.

In conclusion, it was found that EAC had excellent reliability, no fixed bias, and no proportional bias. The present findings suggest that EAC with an HHD is useful for evaluation of patients who require EAC in pulmonary rehabilitation objectively.

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