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ORIGINAL ARTICLE

# Breathing movements of the chest and upper abdomen in mechanically ventilated paralyzed patients

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**Abstract**
*Aim* Assessment of breathing on clinical examination requires visualization of "chest" wall movement. However, in mechanically ventilated paralyzed patients, chest expansion is smaller than that of the abdomen. The aim of this study was to determine chest and upper abdominal movements in mechanically ventilated patients under general anesthesia.
*Methods* The subjects were 68 patients scheduled for general anesthesia. Chest and upper abdominal wall movements were measured using laser light at tidal volumes (VT) of 6, 10, and 15 mL/kg. The subjects were divided into the Lean group [body mass index (BMI) < 18.5 kg/m$^2$], Normal group (BMI 18.5–24.9 kg/m$^2$), and Obese group (BMI $\geq$ 25 kg/m$^2$), and the relationships between chest and upper abdominal wall excursions and BMI at each VT were investigated.
*Results* At VT of 10 mL/kg in all subjects, chest and upper abdominal wall excursions were 4.4 and 9.4 mm, respectively. The same pattern (upper abdominal wall excursions were twice as much as those of the chest wall) was noted in all groups and all VTs.
*Conclusion* Upper abdominal wall excursions were significantly larger than those of the chest wall in mechanically ventilated paralyzed patients, regardless of BMI. Assessment of breathing by clinical examination should avoid emphasis on "chest" wall movement alone, and instead include upper abdominal wall movement.

**Keywords** Breathing movement · Paralyzed patient · Confirming ventilation · Physical examination

## Introduction

Airway management is essential in caring for patients in the operating room, post-anesthesia care unit and intensive care unit. Although some of the standard physical assessment techniques for ventilation are unreliable [1–4], physical examination, i.e., inspection, palpation and auscultation, forms the basis of clinical examination.

In general, when assessing ventilation, physicians are instructed to observe bilateral "chest" expansion [5, 6]. In paralyzed patients under general anesthesia, however, it is not uncommon to see only limited chest wall expansion with apparent upper abdominal wall expansion.

The aim of this study was to assess breathing by measurement of the chest and abdominal wall motion in mechanically ventilated paralyzed patients under general anesthesia. Changes in the anteroposterior dimension of the chest and upper abdomen were measured during mechanical ventilation by a laser light at different tidal volumes (VT) in subjects of different physique.

## Methods

### Subjects and measurements

The study protocol was approved by the Institutional Review Board of Yao Tokusyukai General Hospital. The study subjects were 68 patients with American Society of Anesthesiologists (ASA) physical status classification I–II who were scheduled for general anesthesia. A written

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informed consent was obtained from each subject. Patients with respiratory disease and morbid obesity [body mass index (BMI) ≥ 40 kg/m$^2$] were excluded. All patients were anesthetized using a standard technique, which included propofol 1-2 mg/kg, remifentanil 1 µg/kg/min, and rocuronium 0.6 mg/kg, to facilitate tracheal intubation. Anesthesia was maintained with sevoflurane 1.5 % and remifentanil 0.25 µg/kg/min. All patients were ventilated mechanically.

The subjects were divided into three groups according to BMI: the Lean group (BMI < 18.5 kg/m$^2$), Normal group (BMI 18.5–24.9 kg/m$^2$), and Obese group (BMI ≥ 25.0 kg/m$^2$). The classification was determined in accordance with the World Health Organization (WHO) international standards [7].

Chest and upper abdominal wall excursions were measured using a laser light and a ruler (Fig. 1). A laser pointer was placed at the site of measurement, and the laser light reflected on a ruler placed on a white board. Changes in the vertical dimensions of the chest and abdominal walls due to breathing movements were measured manually from the movement of the laser light. Changes in the vertical dimension of the chest wall were measured at the level of the nipples, while changes in the vertical dimensions of the upper abdominal wall were measured at midpoint between the xiphoid process and the umbilicus. VT was set at 6, 10, and 15 mL/kg, and chest and upper abdominal wall excursions were measured at each VT. The relationships between chest and abdominal wall excursions and BMI were analyzed.

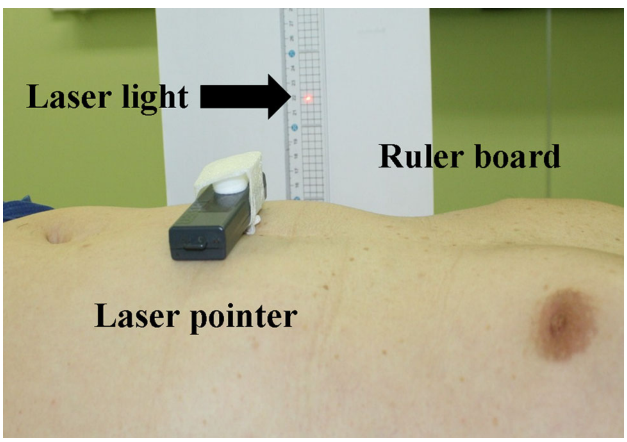


**Fig. 1** The laser pointer is placed on the chest (at the level of the nipples) or the upper abdomen (at the midpoint between the xiphoid process and the umbilicus). The laser light is reflected on a board, with a ruler attached to the side of the subject's body. Breathing-related chest and abdominal wall excursions are measured

## Statistical analysis

The Chi square test and one-way analysis of variance (ANOVA) followed by Scheffé's post hoc test were used for between-group comparisons of patient characteristics as appropriate. The student's *t* test was used to compare chest and upper abdominal wall motions for different VTs and groups. One-way ANOVA was used for between-group comparisons of chest and abdominal wall excursions. Differences were considered significant at $p < 0.05$.

## Results

Significant differences were noted in body weight and BMI among the three groups, but there were no differences in the anteroposterior diameter of the chest (Table 1). The vertical movements of the chest and upper abdomen are shown in Fig. 2 for all subjects, patients of the Lean group, Normal group, and Obese group, at VTs of 6, 10, and 15 mL/kg. In all groups and at all VTs, the vertical movement of the upper abdomen was greater than that of

**Table 1** Patients' characteristics and anteroposterior diameter of the chest in the supine position

| | Total ($n$ = 68) | Lean ($n$ = 14) | Normal ($n$ = 38) | Obese ($n$ = 16) | $p$ value |
|---|---|---|---|---|---|
| Age (years) | 62 ± 21 (16–95) | 68 ± 20 (24–86) | 62 ± 20 (16–95) | 59 ± 25 (25–89) | 0.49[a] |
| Male/female | 44/24 | 6/8 | 28/10 | 10/6 | 0.11[b] |
| Height (cm) | 161 ± 10 (138–176) | 158 ± 7 (150–165) | 163 ± 8 (138–176) | 159 ± 12 (140–176) | 0.25[a] |
| Weight (kg) | 61 ± 15 (35–103) | 42 ± 5 (35–48) | 60 ± 8* (46–70) | 79 ± 14*‡ (61–103) | <0.001[a] |
| Body mass index (kg/m$^2$) | 24 ± 5 (15–37) | 17 ± 1 (15–18) | 23 ± 1* (20–24) | 31 ± 3*‡ (28–37) | <0.001[a] |
| AP diameter of the chest (cm) | 18 ± 3 (13–24) | 18 ± 3 (14–21) | 18 ± 2 (13–22) | 19 ± 3 (16–24) | 0.31[a] |

Values are mean ± standard deviation (range)

*AP* anteroposterior

[a] One-way ANOVA

[b] Chi square test

* $p < 0.001$ vs. the Lean group (Scheffé's test)

‡ $p < 0.001$ vs. the Normal group (Scheffé's test)

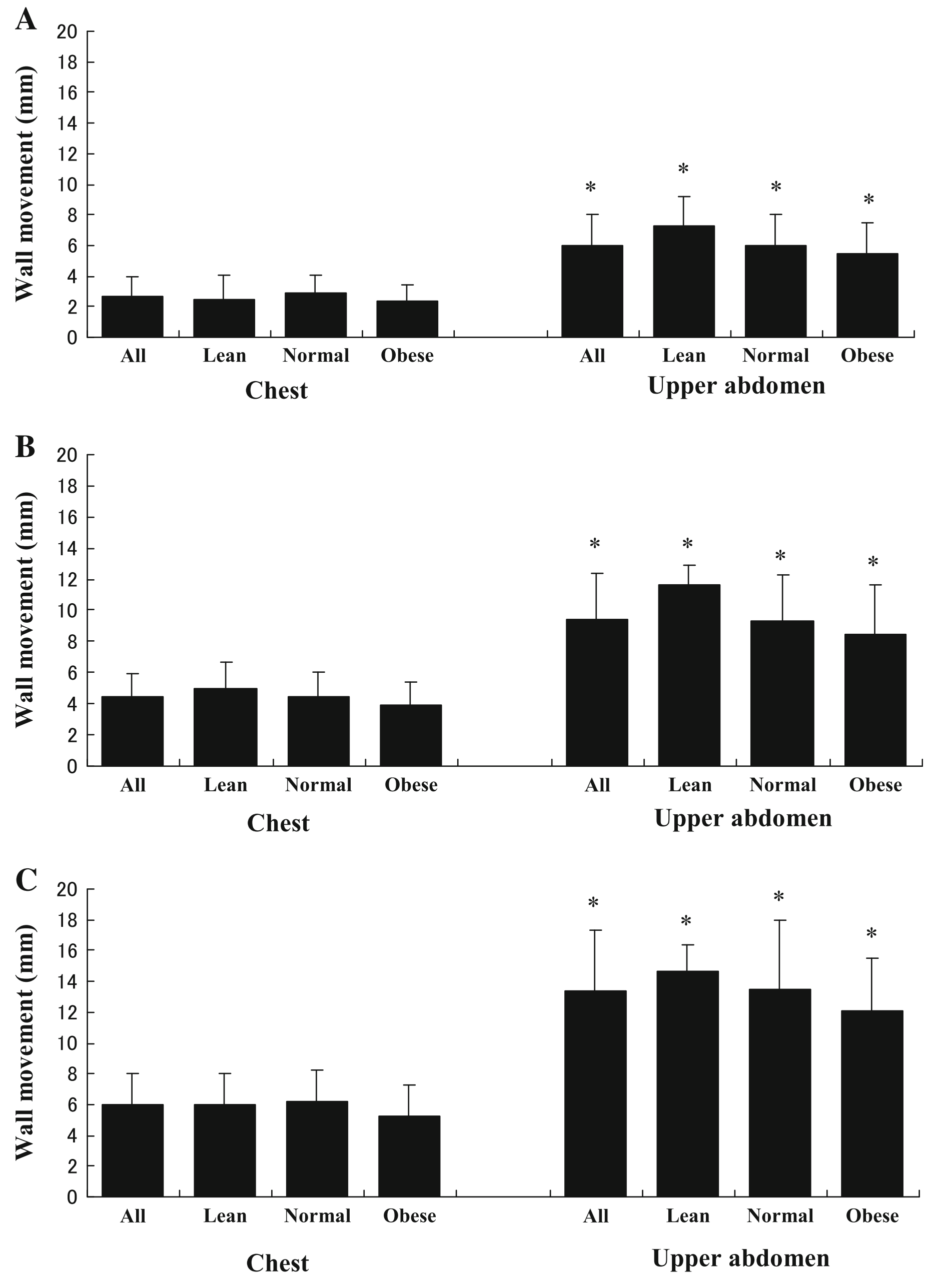


**Fig. 2** Comparison of chest and upper abdominal wall excursions among all subjects, Lean group (BMI < 18.5 kg/m$^2$), Normal group (BMI 18.5–24.9 kg/m$^2$), and Obese group (BMI $\geq$ 25 kg/m$^2$) at tidal volumes of **a** 6 mL/kg, **b** 10 mL/kg, and **c** 15 mL/kg. Data are mean ± SD of 68 subjects. *$p < 0.001$, compared with the chest wall movement of the same BMI group

the chest. There were no differences in the vertical movements of the chest and upper abdomen among the groups.

## Discussion

This study showed greater movement of the upper abdomen, relative to that of the chest wall, in mechanically ventilated paralyzed patients. The ratio was about 2:1, and the relationship was constant, regardless of the differences in patients' physique and VTs. Thus, despite adequate ventilation with tracheal intubation, the upper abdomen showed significantly greater movement than the chest in mechanically ventilated paralyzed patients. These results pose a problem regarding the conventional method used for assessment of ventilation that emphasizes the importance of "chest" wall movement alone.

### Laser monitor

Various devices that are applied on the surface of the chest wall are available for measurement of respiratory mechanics. Currently available devices include respiratory inductive plethysmography (PIP), strain gauges and magnetometry [8]. These monitors require complex sensors attached to the chest wall and their usefulness in clinical situation is limited. Laser signals have been used as a tool in a variety of measuring instruments. In this study, we used a simple technique comprising a laser light and a ruler to manually measure chest and upper abdominal wall excursions. To our knowledge, no study has used this technique. This simple technique could improve the quality of measurements, making it suitable for use in the operating room.

### Paradoxical breathing movements

Paradoxical breathing movements are common during anesthesia. This involves a greater upper abdomen movement than chest wall movement in paralyzed patients under general anesthesia. Froese and Bryan [9] explained this breathing pattern based on the movement of the diaphragm during breathing as follows: the dependent part of the diaphragm shifts cranially due to paralysis, and breathing movement becomes smaller, making it somewhat easier for the nondependent part of the diaphragm to move. Chest expansion associated with inspiration decreases, and consequently, abdominal wall movement becomes the dominant breathing movement.

### Facemask airway

Facemask ventilation requires certain skills not only in anesthesia but also during CPR. Excessive ventilation should be avoided during facemask ventilation. A high breathing frequency and/or large VT can cause gastric distension [10]. More importantly, excessive ventilation increases intrathoracic pressure, leading to a reduction in venous return to the heart, and reduced survival in cardiopulmonary resuscitation (CPR) [11].

In this study, the VT of 6 mL/kg was assumed to be “not too large” a VT recommended with the use of facemask airway. The vertical movement of the chest wall at VT of 6 mL/kg was only about 3 mm, and clear visual recognition of this small movement was difficult. In contrast, the upper abdomen movement at this VT was 6 mm, which should be easier to perceive than the chest movement. At “not too large” a VT, it is possible that the chest wall movement is masked by movement of the upper abdomen and cannot be recognized. We must be aware that appropriate facemask ventilation produces only minimal chest wall expansion.

### Confirmation of advanced airways placement

Confirmation of advanced airway placement by physical examination is important, but caution is needed because a high error level has been observed [12]. The VT of 15 mL/kg in this study was assumed to be the VT required for confirmation of advanced airways. The vertical movement of the chest wall at a VT of 15 mL/kg was about 6 mm, which can be adequately visualized on inspection. However, the upper abdominal wall movement was more than twice that value, an amount that could suggest gastric distention to a physician unaccustomed to airway management. Distinguishing between correct intubation (endotracheal intubation) and incorrect intubation (esophageal intubation) is sometimes difficult by physical examination alone. This was also the perception in the present study. Visual assessment of the chest and abdominal movement is of limited value in confirming endotracheal tube position. According to the standard guidelines, devices such as waveform capnography should be used to confirm the correct placement of the endotracheal tube [13].

### Relationship between chest and abdominal wall movements according to physique

In general, assessment of ventilation is difficult in obese patients, and the technique used in this study was anticipated to allow a better assessment. However, there were no differences in the excursions of the chest and upper abdominal walls among the groups. In this study, the VT was set according to actual body weight for simplicity. In clinical situation, however, obese patients tend to be ventilated using small VTs based on the low respiratory compliance, making it difficult to recognize breathing movements.

The subjects of this study were Japanese, who have smaller physiques than Western people; with a mean BMI of 24 kg/m$^2$ (maximum BMI = 37 kg/m$^2$). In morbidly obese patients, who were not examined in this study, various factors hinder visual recognition of breathing movements. Further investigation of breathing movements in obese patients is needed.

### Clinical implications

The present study was conducted with the notion that the instructions for assessment of ventilation using the statement: “visualize chest wall movement” is one reason for the difficulty in assessing ventilation by physical examination. Despite adequate ventilation with tracheal intubation, the upper abdominal wall movement was significantly greater than that of the chest wall in mechanically ventilated paralyzed patients. Airway management experts usually make correct assessment instinctively, based on the relationship between chest wall breathing movement and upper abdominal wall movement. However, for residents or health care providers not often involved with CPR, the educational material provided and clinical instructions on physical examination may negatively affect their learning of the technique, and thus the assessment of ventilation.

Based on the present results, further studies are needed to devise an instruction method with a proper manual and to improve the accuracy of assessment of ventilation by physical examination.

## Conclusions

The present study demonstrated that movement of the upper abdominal wall was about twice that of the chest wall during mechanical ventilation in paralyzed patients. Instructions for assessment of ventilation by physical examination should be based on the relative movement of the chest and upper abdominal walls, without the use of *conspicuous* expressions focused on "chest" wall movement.

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