



# LUND UNIVERSITY

## Increased apparatus dead space and tidal volume increase blood concentrations of oxygen and sevoflurane in overweight patients: a randomised controlled clinical study.

Enekvist, Bruno; Bodelsson, Mikael; Johansson, Anders

*Published in:*  
European Journal of Anaesthesiology

*DOI:*  
[10.1097/EJA.0b013e328344b4b2](https://doi.org/10.1097/EJA.0b013e328344b4b2)

2011

[Link to publication](#)

*Citation for published version (APA):*  
Enekvist, B., Bodelsson, M., & Johansson, A. (2011). Increased apparatus dead space and tidal volume increase blood concentrations of oxygen and sevoflurane in overweight patients: a randomised controlled clinical study. *European Journal of Anaesthesiology*, 28(5), 382-386. <https://doi.org/10.1097/EJA.0b013e328344b4b2>

*Total number of authors:*  
3

### General rights

Unless other specific re-use rights are stated the following general rights apply:  
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Read more about Creative commons licenses: <https://creativecommons.org/licenses/>

### Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

LUND UNIVERSITY

PO Box 117  
221 00 Lund  
+46 46-222 00 00



LUND UNIVERSITY  
Faculty of Medicine

---

# LUP

*Lund University Publications*

Institutional Repository of Lund University

---

This is an author produced version of a paper published in European Journal of Anaesthesiology. This paper has been peer-reviewed but does not include the final publisher proof-corrections or journal pagination.

Citation for the published paper:  
Bruno Enekvist, Mikael Bodelsson, Anders Johansson

"Increased apparatus dead space and tidal volume increase blood concentrations of oxygen and sevoflurane in overweight patients: a randomised controlled clinical study."

European Journal of Anaesthesiology  
2011 28(5), 382 - 386

<http://dx.doi.org/10.1097/EJA.0b013e328344b4b2>

Access to the published version may require journal subscription.  
Published with permission from: Cambridge University Press

# Increased apparatus dead-space and tidal volume increases blood concentrations of oxygen and sevoflurane in overweight patients – a randomized controlled clinical study

BRUNO ENEKVIST, MIKAEL BODELSSON and ANDERS JOHANSSON

Section of Anaesthesiology and Intensive Care, Department of Clinical Sciences, Lund University, and Department of Intensive and Perioperative Care, Lund University Hospital, SE-221 85 Lund Sweden

Correspondence: Bruno Enekvist, RN, CRNA, BSc

Section of Anaesthesiology and Intensive Care, Department of Clinical Sciences, Lund University, and Department of Intensive and Perioperative Care, Lund University Hospital, SE-221 85 Lund Sweden

E-mail: [bruno.enekvist@skane.se](mailto:bruno.enekvist@skane.se)

## Abstract

**Background and objective:** General anesthesia impairs respiratory function in overweight patients. We wanted to determine if increased tidal volume ( $V_T$ ), with unchanged end-tidal carbon dioxide partial pressure ( $P_{ETCO_2}$ ), affects blood concentrations of oxygen and sevoflurane in overweight patients.

**Methods:** Prospective, randomized, clinical study. ASA physical status I and II patients with BMI over 25 scheduled for elective surgery of the lower abdomen were randomly assigned to one of two groups with 10 patients in each. One group was ventilated with normal  $V_T$  ( $NV_T$ ) and one group with increased  $V_T$  ( $IV_T$ ) achieved by increasing inspired plateau pressure 0.04 cm  $H_2O$   $kg^{-1}$  above initial plateau pressure. Extra apparatus dead space was added to maintain  $P_{ETCO_2}$  at 4.5 kPa. Respiratory rate was set at 15  $min^{-1}$ , and sevoflurane was delivered to the fresh gas by a vaporizer set at 3%. Arterial oxygenation, sevoflurane tensions ( $P_{asevo}$ ,  $F_{isevo}$ ,  $P_{ETsevo}$ ),  $P_aCO_2$ ,  $P_{ETCO_2}$ ,  $V_T$  and airway pressure were measured.

**Results:** The two groups of patients were similar with regard to gender, age, weight, height and BMI. Arterial oxygen tension (mean  $\pm$  SD) was significantly higher in the  $IV_T$  group ( $15 \pm 4.3$  kPa vs.  $10 \pm 2.7$  kPa after 60 min anesthesia,  $P < 0.05$ ). Mean  $P_{ETsevo}$  did not differ between the groups, while arterial sevoflurane tension (mean  $\pm$  SD) was significantly higher in the  $IV_T$  group ( $1.74 \pm 0.18$  kPa vs.  $1.43 \pm 0.19$  kPa after 60 min anesthesia,  $P < 0.05$ ).

**Conclusion:** Ventilation with larger tidal volumes with isocapnia maintained with added apparatus dead-space increases the tension of oxygen and sevoflurane in arterial blood in overweight patients.

**Key words:** anesthesia, sevoflurane, FRC, pulmonary gas exchange

## Introduction

Respiratory function and pulmonary gas exchange are regularly impaired during general anesthesia. Atelectasis appears in around 90% of all patients after induction of anesthesia and Rothen and colleagues found a linear correlation between atelectasis and shunt.<sup>1-4</sup> Some authors describe a relationship between airway closure and the body constitution under general anesthesia with mechanical ventilation, i.e. the functional residual capacity and respiratory compliance decreases exponentially in the supine position with increased body mass index.<sup>4,5</sup> In morbidly obese patients general anesthesia and paralysis lead to even more atelectasis and an increased risk of hypoxemia.<sup>6</sup>

Luttrupp and Johansson demonstrated a method to ventilate with larger tidal volumes during general anesthesia with maintained isocapnia by introducing increased apparatus dead-space for partial rebreathing of CO<sub>2</sub>.<sup>7</sup> In previous studies we found moderately improved oxygenation and a reduced difference between arterial and exhaled carbon dioxide tension with larger tidal volumes achieved this way in patients with BMI less than 25.<sup>8</sup> The results were similar to what could be expected from an increase in functional residual capacity (FRC) and also included a more efficient uptake of sevoflurane.<sup>9</sup> We hypothesized that larger tidal volumes would increase arterial concentration of oxygen and volatile anaesthetics in overweight patients as well. In the present study we therefore determined if larger tidal volumes affect arterial concentration of oxygen and sevoflurane in patients with BMI over 25 kg m<sup>-2</sup> undergoing abdominal surgery.

## Method

### *Ethics*

Ethical approval for this study according to the standards set in the Helsinki declaration (Regional Ethics Committee, Dnr: 480/2007) was provided by Regional Ethics Committee Lund, Sweden (Chairperson L. Noltorp) on 6 November 2007. Consent to participate in the study was received from each patient.

### *Patients*

The investigation included 20 patients, ASA physical status 1 or 2, scheduled for elective colon surgery at Skane university hospital, Lund Sweden, between September 2009 to January 2010. Patients were considered for inclusion in the trial if they were over 18 yr age and had a BMI > 25 kg m<sup>-2</sup>. All procedures were estimated to last more than 60 minutes. Patients with known pulmonary or cardiovascular disease were excluded. Patients were randomized to one of two groups with 10 patients in each group via randomly mixed sealed envelope assignment at the start of the procedure in the operating theatre (Fig1).

### *Experimental procedure*

Before start of anesthesia, an unused carbon dioxide absorber was applied (Drägersorb, Dräger Medical, Lübeck, Germany) to the anesthesia ventilator (Dräger Primus™, Dräger Medical, Lübeck, Germany). All patients were preoxygenated with 100% oxygen for 3-4 minutes with a fresh gas flow of 5 liters minute<sup>-1</sup>. Anesthesia was induced with 2 µg kg<sup>-1</sup> fentanyl and 1.5-3.0 mg kg<sup>-1</sup> propofol. Atracurium 0.6 mg kg<sup>-1</sup> was administered for muscle paralysis. Ventilation was assisted manually with 100% oxygen via a semiopen circle system (4.5 L volume) until tracheal intubation and then by means of ventilator with a FiO<sub>2</sub> at 0.35 in nitrogen. No positive end expiratory pressure (PEEP) was applied. Propofol 8 mg kg<sup>-1</sup> h<sup>-1</sup> was infused until an arterial cannula had been inserted in the radial artery.

In the group with normal tidal volume (NV<sub>T</sub>), respiratory rate was set to 15 min<sup>-1</sup> and V<sub>T</sub> was adjusted as to achieve a P<sub>ET</sub>CO<sub>2</sub> at 4.5 kPa. In the group with increased tidal volume (IV<sub>T</sub>), respiratory rate was set to 15 min<sup>-1</sup>. Initial plateau pressure (P<sub>plateau</sub>) was monitored and then V<sub>T</sub> was increased until P<sub>plateau</sub> was 0.04 cm H<sub>2</sub>O kg<sup>-1</sup> over the initial P<sub>plateau</sub>. In a previous study an increase in P<sub>plateau</sub> of 0.04 cm H<sub>2</sub>O kg<sup>-1</sup> was found to result in a mean increase in tidal volume of 3.3 ml kg<sup>-1</sup> in adult patients.<sup>7</sup> The P<sub>ET</sub>CO<sub>2</sub> was then adjusted to 4.5 kPa with a

flexible corrugated hose (disposable plastic tube, Medcore, AB Uppsala, Sweden) placed between the Y-piece of the anesthesia circle system and the heat and moisture filter (HME) attached to the endotracheal tube.<sup>7</sup> This flexible corrugated hose increased the dead-space volume and provided adjustable rebreathing of carbon dioxide. In both groups, inspiratory:expiratory ratio was 1:2 including an inspiratory plateau of 10%. When stable  $P_{ET}CO_2$  values reached 4.5 kPa, a control (time zero) sample of arterial blood was obtained and sevoflurane administration was started with a vaporizer (sevoflurane Dräger Vapor 2000: Medical, Lübeck, Germany) set to 3%. After 5 minutes the fresh gas flow was adjusted to 1.0 L min<sup>-1</sup> with an unchanged vaporizer setting throughout the anesthesia period.

Blood samples of 3 ml were drawn from the arterial line into heparinized syringes at 0, 1, 3, 5, 10, 15, 30, 45 and 60 minutes after the start of the sevoflurane administration (totally 27 ml). Arterial oxygen tension ( $P_aO_2$ ), oxygen saturation ( $S_aO_2$ ) and carbon dioxide tension ( $P_aCO_2$ ) were analyzed using an automatic blood gas analyzer (ABL 725™, Radiometer, Copenhagen Denmark). Sevoflurane concentration was analyzed with gas chromatography (GC) on a Perkin-Elmer 3920 gas liquid chromatograph, as previously described.<sup>9, 10</sup>

Patients were monitored with 3-lead ECG, heart rate, oxygen saturation, as measured by pulse oximeter ( $SpO_2$ ), invasive arterial blood pressure via the arterial cannula, (Intelli Vue MP70 Anesthesia, Philips Medizin System, Boeblingen Germany), inspiratory and expiratory oxygen partial pressure ( $F_iO_2$ ,  $P_{ET}O_2$ ), sevoflurane inspiratory and expiratory partial pressure ( $F_i\text{sevo}$ ,  $P_{ET}\text{sevo}$ ) and carbon dioxide inspiratory and expiratory partial pressure ( $F_iCO_2$ ,  $P_{ET}CO_2$ ) as analyzed by the ventilator. Total ventilation min<sup>-1</sup>, tidal volumes and airway pressures as peak pressure, plateau pressure and mean pressure were measured and documented at the same intervals. Static compliance of the respiratory system was calculated as tidal volume divided by the inspiratory plateau pressure.

Extra doses of fentanyl (50-100 µg) were given if mean arterial blood pressure (MAP) increased more than 20% above the initial baseline level. Hypotension (MAP < 60 mmHg) was treated with 5-10 mg ephedrine intravenously. All patients received 3-5 ml kg<sup>-1</sup> h<sup>-1</sup> of glucose solution 2.5% with sodium (70 mmol l<sup>-1</sup>), chloride (45 mmol l<sup>-1</sup>) and acetate (25 mmol l<sup>-1</sup>) intravenously. Neuromuscular blockade was monitored with a neuromuscular transmission analyzer (TOF-Watch™; Organon Technology B V., Boxel Netherlands).

Additional doses of atracurium were given at the discretion of the anesthetist.

### **Statistics**

All statistical analysis were performed with SPSS 16.0 for Windows, (SPSS Inc., Chicago, IL, USA). An initial power analysis assuming a  $P_{a\text{sevo}}$  concentration difference at 0.3 kPa with a SD of 0.2 kPa, revealed that 7 patients in each group would be needed to achieve a power of 0.8 at  $P < 0.05$ . Ten patients in each group were enrolled. Descriptive variables, tidal volumes, airway pressures,  $S_pO_2$  and lung compliance are expressed as median and inter quartile range in square brackets and analyzed with a non-parametric method according to Mann-Whitney test. The values of  $F_iO_2$ ,  $P_{ET}O_2$ ,  $F_{i\text{sevo}}$ ,  $P_{ET\text{sevo}}$ ,  $P_{a\text{sevo}}$  and  $P_{ET}CO_2$  are presented as mean  $\pm$  SD and the analysis was conducted with an independent two-tailed t-test. For change of values over time, an analysis with a two-way repeated measurement ANOVA was used. The ANOVA analysis was followed by Greenhouse-Geisser *post hoc* test. A  $P$ -value  $< 0.05$  was considered to indicate statistical significance.

## Results

The two groups of patients were similar with regard to gender, age, weight, height and body mass index (BMI, Table 1). No intraoperative problems were noted during the study. All patients recovered from anesthesia and left the postoperative unit in accordance with the routines assigned for the surgical procedure.

Tidal volumes were significantly larger in the IV<sub>T</sub> group, (Table 2). Peak and mean airway pressure were also significantly higher in the IV<sub>T</sub> group compared to the NV<sub>T</sub> group (Table 2). The median adjustable dead-space volume between the Y-piece and HME in the IV<sub>T</sub> group was 3.0 [2.8-4.0] ml<sup>-1</sup> kg and lung compliance was higher in the IV<sub>T</sub> group throughout the observation period ( $P < 0.05$ , Table 2).

Mean end-tidal carbon dioxide values ( $P_{ET}CO_2$ ) were similar in the two groups (Table 3).  $P_aCO_2$  was, however, lower in the IV<sub>T</sub> group throughout the observation period ( $P < 0.05$ , Table 3) and the difference between  $P_aCO_2$  and  $P_{ET}CO_2$  was smaller in the IV<sub>T</sub> group compared to the NV<sub>T</sub> group ( $P < 0.05$ , Table 3).

All patients received ventilation with a  $F_iO_2$  of 35%, except three patients from the NV<sub>T</sub> group, which received an increased  $F_iO_2$  after a period of  $S_pO_2$  less than 91%. The values of  $S_pO_2$  and  $P_aO_2$  were significantly higher in the IV<sub>T</sub> group compared to the NV<sub>T</sub> group ( $P < 0.05$ , Table 4).

$P_{ET}sevo$  was lower in the IV<sub>T</sub> group between 1-5 min ( $P < 0.05$ , fig. 2), but not between 10 and 60 minutes (Table 5). Mean  $P_asevo$  was higher in the IV<sub>T</sub> group compared to the NV<sub>T</sub> group from 5 minutes and the difference increased with time ( $P < 0.05$ , Table 5, Fig. 2). The difference between  $P_asevo$  and  $P_{ET}sevo$  was smaller in the IV<sub>T</sub> group compared to the NV<sub>T</sub> group ( $P < 0.05$ , Table 5, Fig. 2).

## Discussion

In the present study, mean  $P_aO_2$  and  $P_{a\text{sevo}}$  were found to be higher in overweight patients ventilated with larger tidal volumes. This is in line with previous results obtained from patients with normal weight.<sup>8,9</sup> Mean  $F_iO_2$  and  $F_{i\text{sevo}}$  did not differ between the groups. Thus, differences in inspired concentrations could be ruled out as explanations for the increased oxygen and sevoflurane uptake in the  $IV_T$  group.

Reduced FRC makes airway closure more frequent, which is a likely explanation for the appearance of regions with a low ventilation/perfusion ratio and atelectasis during anesthesia.<sup>4,11</sup> In fact, atelectasis and airway closure may explain 75% of the deterioration in  $PaO_2$ .<sup>4</sup> Neumann and colleagues demonstrated a significant inverse correlation between  $PaO_2$  and atelectasis.<sup>12</sup> In the present study, plateau pressure did not differ between the two groups but tidal volume was considerably larger in the  $IV_T$  group compared the  $NV_T$  group resulting in larger lung compliance in the  $IV_T$  group. A plausible explanation to the increase in compliance is recruitment or decreased loss of ventilated lung tissue by the larger tidal volume. This is supported by the findings by Erlandsson and colleagues who showed that a recruitment maneuver resulted in decreased plateau pressure and increased lung compliance with a decreased shunt  $VD_{\text{alv}}/VT$ .<sup>13</sup>

It is reasonable to assume that the recruitment of ventilated lung tissue increased FRC in the  $IV_T$  group. This is in line with the results presented by Reinius and colleagues who showed that a recruitment maneuver followed by PEEP reduced atelectasis, improved oxygenation and increased compliance in obese patients.<sup>14</sup> Conversely, the lower value of lung compliance in the  $NV_T$  group could indicate more atelectasis of lung tissue in this group. This is supported by the need to increase  $F_iO_2$  in three patients of this group in order to maintain a  $S_pO_2$  above 90%, indicating pulmonary shunting of venous blood. Pelosi and colleagues found that an increase in BMI can be related to a reduction in FRC after induction of anesthesia, which makes atelectasis more frequent.<sup>5</sup> It should be noted that we did not directly assess the development of atelectasis in the present study. Thus, apart from reduced atelectasis our findings could at least partly be explained by increased alveolar ventilation in the  $IV_T$  group.

Patients in the NV<sub>T</sub> group received an average tidal volume of 5.0 ml kg<sup>-1</sup> (total weight), and apparently is developed of regions with abnormal ventilation/perfusion. Routinely, PEEP of 5-10 cmH<sub>2</sub>O is applied in order to prevent this. The present results suggest that increasing tidal volumes might have a similar effect but at a lower expense by means of lower mean airway pressure and perhaps subsequent reduction of lung injury and circulatory impairment. A randomized study comparing PEEP with large tidal volumes during anesthesia to overweight patients is, however, needed to test this hypothesis. There is, however, one influence on the present oxygenation and arterial sevoflurane concentration in this study which has not been ruled out, a possible intrinsic PEEP. Unfortunately, our equipment did not measure intrinsic PEEP levels. This is a limitation of the study.

The P<sub>a</sub>CO<sub>2</sub> levels were slightly lower in the IV<sub>T</sub> group and could contribute to increased P<sub>a</sub>sevo levels by mean of just increased ventilation. However, the P<sub>ET</sub>CO<sub>2</sub> were similar between the groups and indicates that the increased levels of P<sub>a</sub>sevo could be explained by increased alveolar ventilation in the IV<sub>T</sub> group. The P<sub>ET</sub>sevo – P<sub>a</sub>sevo difference was greater in the group ventilated with smaller tidal volumes in the absence of PEEP. This must be kept in mind in order to avoid overestimation of depth of anesthesia when assessed on the basis of P<sub>ET</sub>sevo in patients ventilated this way.

In conclusion, in patients with BMI over 25, ventilation with larger tidal volumes with isocapnia accomplished with an added apparatus dead-space improves oxygen and sevoflurane uptake in arterial blood.

## **Acknowledgement**

Funding was not restricted to institutional and department sources and there were no conflicts of interest.

## References

1. Lundquist H, Hedenstierna G, Strandberg A, Tokics L, Brismar B. CT-assessment of dependent lung densities in man during general anaesthesia. *Acta Radiol.* 1995; **36**:626-32.
2. Gunnarsson L, Strandberg A, Brismar B, Tokics L, Lundquist H, Hedenstierna G. Atelectasis and gas exchange impairment during enflurane/nitrous oxide anaesthesia. *Acta Anaesthesiol Scand.* 1989; **33**:629-37.
3. Brismar B, Hedenstierna G, Lundquist H, Strandberg A, Svensson L, Tokics L. Pulmonary densities during anesthesia with muscular relaxation--a proposal of atelectasis. *Anesthesiology.* 1985; **62**:422-8.
4. Rothen HU, Sporre B, Engberg G, Wegenius G, Hedenstierna G. Airway closure, atelectasis and gas exchange during general anaesthesia. *Br J Anaesth.* 1998; **81**:681-6.
5. Pelosi P, Croci M, Ravagnan I, Tredici S, Pedoto A, Lissoni A, et al. The effects of body mass on lung volumes, respiratory mechanics, and gas exchange during general anesthesia. *Anesth Analg.* 1998; **87**:654-60.
6. Pelosi P, Croci M, Ravagnan I, Cerisara M, Vicardi P, Lissoni A, et al. Respiratory system mechanics in sedated, paralyzed, morbidly obese patients. *J Appl Physiol.* 1997; **82**:811-8.
7. Luttrupp HH, Johansson A. Soda lime temperatures during low-flow sevoflurane anaesthesia and differences in dead-space. *Acta Anaesthesiol Scand.* 2002; **46**:500-5.
8. Enekvist BJ, Luttrupp HH, Johansson A. The effect of increased apparatus dead space and tidal volumes on carbon dioxide elimination and oxygen saturations in a low-flow anesthesia system. *J Clin Anesth.* 2008; **20**:170-4.
9. Enekvist BJ, Bodelsson M, Stureson LW, Johansson A. Larger tidal volume increases sevofluran uptake in blood: a randomized clinical study. *Acta Anaesthesiol Scand.* [RTC]. 2010; **54**:1111-6.
10. Stureson LW, Johansson A, Bodelsson M, Malmkvist G. Wash-in kinetics for sevoflurane using a disposable delivery system (AnaConDa) in cardiac surgery patients. *Br J Anaesth.* 2009; **102**:470-6.
11. Hedenstierna G. Alveolar collapse and closure of airways: regular effects of anaesthesia. *Clin Physiol Funct Imaging.* 2003; **23**:123-9.
12. Neumann P, Rothen HU, Berglund JE, Valtysson J, Magnusson A, Hedenstierna G. Positive end-expiratory pressure prevents atelectasis during general anaesthesia even in the presence of a high inspired oxygen concentration. *Acta Anaesthesiol Scand.* 1999; **43**:295-301.
13. Erlandsson K, Odenstedt H, Lundin S, Stenqvist O. Positive end-expiratory pressure optimization using electric impedance tomography in morbidly obese patients during laparoscopic gastric bypass surgery. *Acta Anaesthesiol Scand.* 2006; **50**:833-9.
14. Reinius H, Jonsson L, Gustafsson S, Sundbom M, Duvernoy O, Pelosi P, et al. Prevention of atelectasis in morbidly obese patients during general anesthesia and paralysis: a computerized tomography study. *Anesthesiology.* 2009; **111**:979-87.

**Table 1**

Patient data. Values are median with interquartile range within brackets. The two groups were similar regarding gender, age, weight, height or BMI.

|                                     | NV <sub>T</sub>  | IV <sub>T</sub>  |
|-------------------------------------|------------------|------------------|
| Number of patients                  | 10               | 10               |
| Women (n)                           | 6                | 5                |
| Age, years                          | 64 [52-78]       | 64 [54-68]       |
| Weight, kg                          | 84 [78-101]      | 81 [79-85]       |
| Height, meter,                      | 1.64 [1.60-1.75] | 1.74 [1.65-1.77] |
| Body Mass Index, kg m <sup>-2</sup> | 30 [26-36]       | 27 [26-28]       |

**Table 2**

Comparison of tidal volumes ( $V_T$ ), tidal volume  $\text{kg body weight}^{-1}$ , peak, plateau, mean airway pressures and lung compliance in the normal tidal volume group ( $NV_T$ ) and increased tidal volume group ( $IV_T$ ). Values are median [inter quartile range],  $n = 10$  in each group. P-Plateau values were not statistically significantly different between the two groups. The values of  $V_T$ ,  $V_T (\text{ml kg}^{-1})$ , P-Peak, P-Mean and Lung Compliance were statistically significantly larger in the  $IV_T$  group compared to the  $NV_T$  group Mann-Whitney test (\*,  $P < 0.05$ ).

|                                                       |        | 5 min             | 30 min            | 60 min            |
|-------------------------------------------------------|--------|-------------------|-------------------|-------------------|
| $V_T$ (ml)                                            | $NV_T$ | 400 [340-467]     | 440 [380-478]     | 397 [362-428]     |
|                                                       | $IV_T$ | 777 [708-812]*    | 750 [703-808]*    | 717 [692-807]*    |
| $V_T (\text{ml kg}^{-1})$                             | $NV_T$ | 4.6 [4.3-5.3]     | 4.9 [4.5-5.2]     | 5.0 [4.5-5.1]     |
|                                                       | $IV_T$ | 9.3 [8.6-10]*     | 9.2 [8.7-9.7]*    | 9.0 [8.7-9.8]*    |
| P-Peak ( $\text{cmH}_2\text{O}$ )                     | $NV_T$ | 16.5 [12.0-23.3]  | 16.0 [13.0-22.3]  | 15.5 [14.0-22.5]  |
|                                                       | $IV_T$ | 24.5 [21.5-26.5]* | 25.0 [23.0-25.5]* | 25.5 [22.8-27.8]* |
| P-Plateau ( $\text{cmH}_2\text{O}$ )                  | $NV_T$ | 15.0 [11.8-20.3]  | 14.5 [11.8-17.8]  | 15.0 [12.8-19.8]  |
|                                                       | $IV_T$ | 18.5 [15.0-20.0]  | 16.0 [11.8-17.8]  | 17.5 [15.0-21.5]  |
| P-Mean ( $\text{cmH}_2\text{O}$ )                     | $NV_T$ | 6.0 [4.0-7.0]     | 5.0 [4.0-6.3]     | 4.0 [4.0-6.3]     |
|                                                       | $IV_T$ | 7.0 [6.0-9.0]*    | 7.0 [6.0-8.3]*    | 7.0 [6.8-9.0]*    |
| Lung Compliance<br>( $\text{ml cmH}_2\text{O}^{-1}$ ) | $NV_T$ | 28 [23-34]        | 29 [21-33]        | 27 [21-31]        |
|                                                       | $IV_T$ | 41 [37-53]*       | 48 [36-58]*       | 41 [31-52]*       |

**Table 3**

Comparison of the values for the expiratory carbon dioxide ( $P_{ET}CO_2$ ), carbon dioxide pressures in arterial blood ( $P_aCO_2$ ) and  $P_aCO_2 - P_{ET}CO_2$  difference ( $P_a - P_{ET}CO_2$ ) between normal tidal volume group ( $NV_T$ ) and increased tidal volume group ( $IV_T$ ). Values are mean  $\pm$  SD ( $n = 10$  in each group).  $P_{ET}CO_2$  values were similar in the two groups. The values of  $P_aCO_2$  and  $P_a - P_{ET}CO_2$  were statistically significantly lower in the  $IV_T$  group compared to the  $NV_T$  group. Independent two-tailed t-test (\*,  $P < 0.05$ ).

|                          |        | 5 min             | 30 min            | 60 min            |
|--------------------------|--------|-------------------|-------------------|-------------------|
| $P_{ET}CO_2$ (kPa)       | $NV_T$ | $4.3 \pm 0.28$    | $4.4 \pm 0.27$    | $4.4 \pm 0.22$    |
|                          | $IV_T$ | $4.6 \pm 0.32$    | $4.6 \pm 0.33$    | $4.5 \pm 0.07$    |
| $P_aCO_2$ (kPa)          | $NV_T$ | $5.2 \pm 0.36$    | $5.5 \pm 0.25$    | $5.5 \pm 0.31$    |
|                          | $IV_T$ | $5.0 \pm 0.32^*$  | $5.2 \pm 0.36^*$  | $5.0 \pm 0.20^*$  |
| $P_a - P_{ET}CO_2$ (kPa) | $NV_T$ | $0.92 \pm 0.32$   | $1.1 \pm 0.21$    | $1.1 \pm 0.30$    |
|                          | $IV_T$ | $0.42 \pm 0.22^*$ | $0.57 \pm 0.36^*$ | $0.53 \pm 0.21^*$ |

**Table 4**

Comparison of the values for the inspiratory oxygen concentrations ( $F_iO_2$ ), oxygen saturation, as measured by pulse oximeter ( $SpO_2$ ), oxygen tension ( $P_aO_2$ ), between normal tidal volume group ( $NV_T$ ) and increased tidal volume group ( $IV_T$ ). Values of  $SpO_2$  are median [inter quartile range] and values of  $F_iO_2$  and  $P_aO_2$  are mean  $\pm$  SD, ( $n = 10$  in each group).  $F_iO_2$  values were similar in the two groups.  $SpO_2$  and  $P_aO_2$  were statistically significantly higher in the  $IV_T$  group compared to the  $NV_T$  group. Mann-Whitney test and independent two-tailed t-test, respectively, (\*,  $P < 0.05$ ).

|                |        | 5 min          | 30 min         | 60 min         |
|----------------|--------|----------------|----------------|----------------|
| $F_iO_2$ (%)   | $NV_T$ | $35 \pm 2.1$   | $37 \pm 2.3$   | $37 \pm 5.5$   |
|                | $IV_T$ | $35 \pm 1.0$   | $35 \pm 1.0$   | $35 \pm 0.5$   |
| $SpO_2$ (%)    | $NV_T$ | 96 [92-98]     | 96 [93-97]     | 94 [91-98]     |
|                | $IV_T$ | 100 [99-100]*  | 100 [99-100]*  | 99 [98-100]*   |
| $P_aO_2$ (kPa) | $NV_T$ | $11 \pm 3.8$   | $11 \pm 2.9$   | $10 \pm 2.7$   |
|                | $IV_T$ | $16 \pm 3.0^*$ | $17 \pm 3.8^*$ | $15 \pm 4.3^*$ |

**Table 5**

Comparison of the values for the inspiratory sevoflurane concentrations ( $F_{i\text{sevo}}$ ), expiratory sevoflurane concentrations ( $P_{\text{ETsevo}}$ ), arterial sevoflurane tensions ( $P_{\text{asevo}}$ ) and  $P_{\text{ETsevo}}-P_{\text{asevo}}$  difference ( $P_{\text{ET}}-P_{\text{asevo}}$ ) between normal tidal volume group ( $\text{NV}_T$ ) and increased tidal volume group ( $\text{IV}_T$ ). Values of  $F_{i\text{sevo}}$ ,  $P_{\text{ETsevo}}$ ,  $P_{\text{asevo}}$  and  $P_{\text{ET}}-P_{\text{asevo}}$  are mean  $\pm$  SD ( $n = 10$  in each group).  $F_{i\text{sevo}}$  and  $P_{\text{ETsevo}}$  values were not significantly different between the groups except  $P_{\text{ETsevo}}$  which was statistically significantly lower in the  $\text{IV}_T$  group before and at 5 min. Arterial sevoflurane tensions were statistically significantly higher in the  $\text{IV}_T$  group compared to the  $\text{NV}_T$  group.  $P_{\text{ETsevo}}-P_{\text{asevo}}$  differences were statistically significantly lower in the  $\text{IV}_T$  group compared to the  $\text{NV}_T$  group. Two-Way repeated measurement ANOVA followed by Greenhouse-Geisser *post hoc* test (\*,  $P < 0.05$ ).

|                                        |               | 5 min             | 30 min            | 60 min            |
|----------------------------------------|---------------|-------------------|-------------------|-------------------|
| $F_{i\text{sevo}}$ (kPa)               | $\text{NV}_T$ | $2.80 \pm 0.28$   | $2.24 \pm 0.20$   | $2.30 \pm 0.24$   |
|                                        | $\text{IV}_T$ | $2.64 \pm 0.19$   | $2.18 \pm 0.20$   | $2.24 \pm 0.17$   |
| $P_{\text{ETsevo}}$ (kPa)              | $\text{NV}_T$ | $2.10 \pm 0.15$   | $1.82 \pm 0.18$   | $1.89 \pm 0.22$   |
|                                        | $\text{IV}_T$ | $1.88 \pm 0.15^*$ | $1.76 \pm 0.21$   | $1.85 \pm 0.19$   |
| $P_{\text{asevo}}$ (kPa)               | $\text{NV}_T$ | $1.43 \pm 0.20$   | $1.37 \pm 0.21$   | $1.43 \pm 0.19$   |
|                                        | $\text{IV}_T$ | $1.60 \pm 0.17^*$ | $1.65 \pm 0.19^*$ | $1.74 \pm 0.18^*$ |
| $P_{\text{ET}}-P_{\text{asevo}}$ (kPa) | $\text{NV}_T$ | $0.68 \pm 0.29$   | $0.46 \pm 0.19$   | $0.46 \pm 0.23$   |
|                                        | $\text{IV}_T$ | $0.28 \pm 0.17^*$ | $0.11 \pm 0.12^*$ | $0.11 \pm 0.13^*$ |

## Legends to figures

### Figure 1

Patient flow of the study.

### Figure 2

Comparison of the values for arterial sevoflurane ( $P_a\text{sevo}$ ) and end-tidal sevoflurane tension ( $P_{ET}\text{sevo}$ ) between the increased tidal volume group ( $IV_T$ ) and normal tidal volume group ( $NV_T$ ). Values are mean  $\pm$  SD ( $n = 10$  in each group). The expiratory sevoflurane concentration was similar in the two groups except before and at 5 min when it was statistically significantly lower in the  $IV_T$  group. Arterial sevoflurane tensions were statistically significantly higher in the  $IV_T$  group compared to the  $NV_T$  group and the differences increased with time. Two-Way repeated measurement ANOVA followed by Greenhouse-Geisser *post hoc* test ( $P < 0.05$ ).

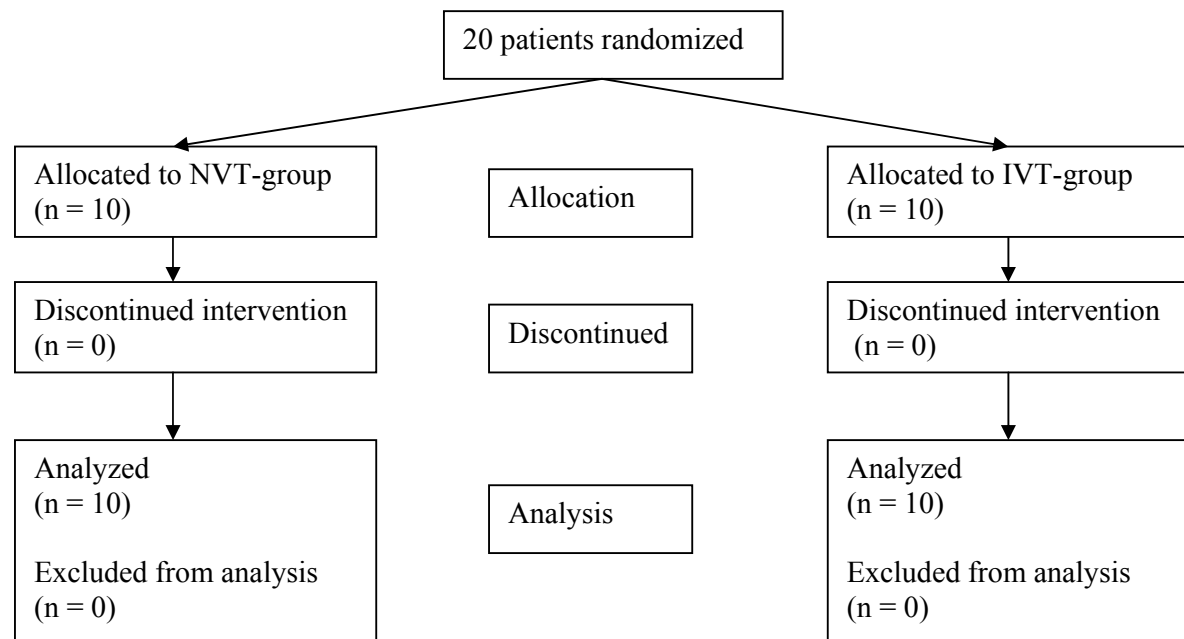
**Figure 1**

Figure 2

