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Adequacy of Ventilation With Low and Conventional Tidal Volumes in Overweight and Obese Patients Undergoing Elective General Surgical Procedures- A Prospective, Single-Blinded, Randomised Controlled Trial

KEYWORDS: Allelopathic, Trianthema portulacastrum L., Gossypium hirustum L., Arachis hypogaea L., Decreases, Increases.

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ABSTRACT *INTRODUCTION: Low tidal volume (TV) ventilation has become popular due to its benefits in patients with lung injury. The effects of low TV in patients with normal lung function are unclear.*

METHODOLOGY: 36 patients with BMI of 25 or more with normal lung function were randomised to receive TV of either 6 mL/kg or 10 mL/kg of ideal body weight for 2 hours during elective general anaesthesia. Primary outcome was End-tidal Carbon Dioxide (ETCO2)going beyond defined limits of 24-40 mm Hg. A suggested starting TV was also derived, such that the ETCO2 was likely to have remained within the defined limits if that TV had been used from the start.

RESULTS: 74% of patients receiving 6 mL/kg and 6% of patients receiving 10 mL/kg TV had inadequate ventilation. None of the patients receiving 6 mL/kg but 90% of patients receiving 10 mL/kg TV had excessive ventilation. The difference were statistically significant. In both groups, a TV of 8 mL/kg was derived as most likely to maintain ETCO2 within accepted limits.

Introduction:
Volume-controlled ventilation is probably the commonest mode of controlled ventilation, especially in resource-poor areas where older stand-alone ventilators are used, but even in developed countries(1). Traditionally, tidal volumes (TV) of 10 mL/kg of ideal body weight or more have been used(2)(3).

In May 2000, a landmark study(4) was published which showed that lower TV decreased mortality and duration of mechanical ventilation in patients with Acute Respiratory Distress Syndrome. Subsequently, there has been a change in ventilation strategies in intensive care units, where a significant proportion of patients have compromised lung function(5). Such practices are extending into the peri-operative setting. However, most patients in anaesthesiology have normal lung function. The effect of lower TV on such patients is unclear(6).

The role of Positive End-Expiratory Pressure (PEEP) should be considered in this context. In lung injury patients, it is the combination of low TV and PEEP which seems beneficial. However, the use of PEEP in patients with normal respiratory function undergoing anaesthesia is much less common because older stand-alone ventilators often did not have in-built PEEP valves, it was traditionally considered unnecessary(7), and is not without adverse effects (decreased cardiac output and systemic oxygen delivery)(8). Even a recent multi-centric study from France showed that 81% of patients receiving mechanical ventilation received no PEEP(1).

Many different ventilation strategies have been used in overweight and obese patients but no consensus has been established on the ideal strategy(9).

Accordingly, we wanted to compare the adequacy of low TV (6 mL/kg) with conventional TV (10 mL/kg) in overweight and obese patients with normal lung function. As End-Tidal Carbon Dioxide (ETCO2) monitoring is now standard for all general anaesthetics, we decided to use it as a simple means of assessing adequacy of ventilation along broadly accepted lines.

Methodology:
The study was commenced after obtaining permission from the Institutional Review Board.

American Society of Anesthesiology (ASA) Physical Status 1 & 2 adult patients with a body mass index (BMI) of 25 or more undergoing general surgical procedures under general anaesthesia with controlled ventilation were recruited. Patients were excluded if they had a pre-existing respiratory pathology or acid-base abnormality; or were undergoing laparoscopy, thoracotomy, or any procedure requiring alteration of ventilatory parameters; or any procedures likely to be completed in less than 2 hours.

After obtaining informed consent, a standard general anaesthetic was administered and standard monitoring established. Thirty-six patients were recruited and randomly allocated to receive TV of either 6 mL/kg (Group I) or 10 mL/kg (Group II) by picking sealed envelopes from a bag. 19 patients were randomised to Group I and 17 to Group II. The TV's were based on ideal body weight (IBW) of the patient, determined by the formula:

IBW = 22 x [Height (in metres)]2 (10)

The TV was then calculated and rounded off to the nearest 25 mL based on the group to which the patient was randomised. The respiratory rate was set at 12 breaths per minute (bpm) initially, the upper pressure limit at 35 cm H2O, and the fractional inspired oxygen concentration (FiO2) at 0.6.

Continuous ETCO2 monitoring was performed from induction. After induction and intubation, volume-controlled

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ventilation was provided with the anaesthesia ventilator (Datex Ohmeda 7100TM or 7900TM) built into a Datex Ohmeda Aestiva/5TM (GE Healthcare) workstation via a circle system using the settings previously mentioned.

If the ETCO2 went beyond the pre-defined acceptable limits (24-40 mm Hg), the incident was noted and the ventilator settings changed to bring the ETCO2 back to acceptable range. The rate was increased by 2 bpm at a time if the ETCO2 rose and decreased at the same rate if the ETCO2 fell. If the ETCO2 did not come back to the acceptable range despite changing the respiratory rate to 18 bpm or 6 bpm, the TV was changed similarly by 50 mL at a time. At the end of two hours, ventilator management was handed over to the attending anaesthesiologist to readjust as they saw fit.

The primary outcome measured was ETCO2 surpassing allowable limits and requiring a change in ventilator settings. We also looked at the final ventilator settings needed to maintain ETCO2 within the pre-determined limits. The final minute ventilation was calculated by multiplying the final respiratory rate and tidal volume settings at which ETCO2 stayed between 24-40 mm Hg.

Final Minute Ventilation (total) = (Final Tidal Volume) x (Final Respiratory Rate).

The final minute ventilation was divided by the patient's IBW and then by 12 (assuming 12 bpm) to derive a possible best TV to start with, such that the ETCO2 would have stayed within defined limits from the beginning.

Final Minute Ventilation (per kg IBW) = Final Minute Ventilation (total) / Ideal Body Weight.

Suggested Tidal Volume (per kg IBW) = Final Minute Ventilation (per kg IBW) / 12.

Descriptive statistics like mean, standard, deviation, and confidence intervals were calculated for the variables. Outcome variables in the two groups were compared using appropriate statistical tests which are specified with the results. Data analysis was performed using SPSS 14.0.

Results:
Baseline Variables: Table 1 shows that there was a significant difference in the tidal volumes delivered in the two groups, but not in any of the baseline characteristics. Thus, any significant difference in outcomes can be reasonable assumed to be due to the intervention.

Table 1: Baseline Variables.

VARIABLE	GROUP I (6 mL/kg) (n=19)	GROUP II (10 mL/kg) (n=17)	**p Value** (difference between Group I & Group II)
DEMOGRAPHIC VARIABLES			
Age (Years)	43.16 ± 8.95*	46 ± 12.25*	0.429#
Sex (Male: Female)	4:15	3:14	1.000†
Weight (Kg)	72.79 ± 10.97*	69.58 ± 10.52*	0.379#
Height (Metres)	1.58 ± 0.07*	1.56 ± 0.07*	0.285#
Body Mass Index (B.M.I.)	28.90 ± 3.28*	28.59 ± 3.24*	0.705#
Number Of Obese Patients	6/19 (31.58%)	5/17 (29.41%)	1.000†
INTERVENTION			
Tidal Volume (mL)	331.84 ± 31.63	536.76 ± 50.87	**<0.001**#

* Values are mean ± standard deviation

2-tailed significance from T-Test for Independent Samples

† 2-sided exact significance from Fischer's Exact Test

Primary Outcome: The incidence of ETCO2 going beyond the acceptable range is displayed in Table 2, which shows that a statistically significant proportion of patients in Group I had inadequate ventilation, and in Group II, had excessive ventilation.

Table 2: Primary Outcome.

$ETCO_2$ EXCEEDING SET LIMITS	GROUP I (6 mL/kg) (n=19)	GROUP II (10 mL/kg) (n=17)	**p Value*** (difference between Group I & Group II)
> 40 mm Hg	14/19 (73.7%)	1/17 (5.9%)	<0.001
< 24 mm Hg	0/19 (0%)	15/17 (88.2%)	<0.001

* from Fischer's Exact Test

Deriving a Suggested Tidal Volume: This issue becomes relevant because ETCO2 exceeded acceptable limits in both groups. The results are given in Table 3, which shows that there was no significant difference between the two groups in the final minute ventilation required to maintain ETCO2 within the accepted range. Further, based on the ideal body weight, 8 mL/kg is our suggested starting tidal volume in both groups.

Table 3: Suggested Starting Tidal Volume.

	GROUP I* (6 mL/kg) (n=19)	GROUP II* (10 mL/kg) (n=17)	**p Value**†
Final Minute Ventilation (mL/min)	5316.32 ± 605.60	5250 ± 583.35	0.879
Suggested Tidal Volume (per kg IBW) (assuming 12 bpm)	8.02 ± 0.89 mL/kg	8.25 ± 1.15 mL/kg	0.747

* Values are mean ± 95% confidence intervals

† 2-tailed significance from T-Test for Independent Samples

Discussion:
This study attempts to evaluate the effects of low TV ventilation in patients with normal lung function. We hypothetised that low TV would be ineffective in adequately washing out carbon dioxide (CO2) and that there would be a need to raise the minute ventilation.

Using a uniform respiratory rate of 12 bpm, 74% of patients in Group I (6 mL/kg) and only 6% of patients in Group II (10 mL/kg) had inadequate ventilation ($p < 0.001$) as defined by ETCO2 exceeding the upper limit of 40 mm Hg.

On the other hand, almost 90% of patients in Group II (10 mL/kg) but none of the patients in Group I (6 mL/kg) had excessive ventilation ($p < 0.001$).

Resting tidal volumes in awake normal adults are 7-8 mL/kg(8). Supra-physiological volumes of 10 mL/kg or more were recommended to counter the almost invariable reduction in Functional Residual Capacity (FRC) seen under general anaesthesia(11). It is interesting to note that the suggested tidal volume derived from this study is very similar to the resting physiological tidal volume. However, it should be remembered that this suggested tidal volume is only calculated with regard to adequate CO2 elimination. The effect of tidal volumes of 6, 8, and 10 mL/kg of IBW on FRC reduction or oxygenation parameters cannot be definitely commented upon from this data except to observe that none of the patients in this study had any clinically significant drop in oxygen saturation or required an increase in FiO2 during the study.

Our study suffers from the limitation of not assessing the effects of PEEP. However, PEEP is not used very commonly under anaesthesia in patients with normal lung function for reasons mentioned previously, and we wanted to assess the effects of ventilation under usual conditions.

Conclusions:

In this study comparing adequacy of ventilation with tidal volumes of 6 mL/kg and 10 mL/kg of ideal body weight in overweight and obese patients, we reached the following conclusions:

1. Controlled ventilation with TV of 6 mL/kg IBW is likely to be inadequate for CO2 elimination;
2. Controlled ventilation with TV of 10 mL/kg IBW is likely to be excessive in terms of CO2 elimination; and
3. A starting TV of around 8 mL/kg IBW may provide optimum ventilation (with a respiratory rate of 12 bpm) for CO2 elimination.

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