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ORIGINAL RESEARCH

Impact of body mass index (BMI) on ventilation during low-frequency jet ventilation

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OBJECTIVE: Percutaneous trans-tracheal jet ventilation (PTJV) is an alternative ventilatory approach in airway surgery. We evaluated the effects of body mass index (BMI) on ventilation during low-frequency jet ventilation.

STUDY DESIGN AND SETTING: Forty-two patients undergoing micro-laryngeal surgery under total anesthesia were studied. Low-frequency jet ventilation was applied through an injector inserted into the trachea via cricothyroid membrane; ventilation was assessed during the operation by arterial blood gas sampling.

RESULT: The age range of the patients was 43.54 ± 12.04 years, weight was 69.97 ± 11.66 kg, and BMI 24.80 ± 2.78 (mean ± SD). There was a strong correlation ($P < 0.05$) and a good correspondence between the BMI and mean $PaCO_2$, and arterial pH.

CONCLUSION AND SIGNIFICANCE: This method was effective in maintaining gas exchange in the presence of micro-laryngeal surgery for low-BMI patients. It provided a nice visible surgical field, avoiding the use of combustible material inside the larynx or trachea.

Laryngeal surgery requires an anesthetic method that exposes the larynx, provides continuous control of airway, and immobilizes the vocal cords.[1,2] Suggested techniques include: spontaneous ventilation under light anesthesia in adults or deep anesthesia in children; an apneic technique, especially in children; intermittent positive-pressure ventilation via a small micro-laryngeal tube; manual jet ventilation at a normal ventilatory frequency; or high-frequency percutaneous trans-tracheal jet ventilation (PTJV).[1-3] The laryngeal structures should be freely accessible, and the application of a laser beam should be possible without endangering patients or personnel in the operatory. In addition, patients undergoing micro-laryngeal surgery may suffer from severe obstruction in the upper airways caused by laryngeal masses, which inhibit gas exchange and the insertion of ventilation tube.[1-3]

The most promising development that may solve these problems is jet ventilation.[2] Jet ventilation was first described by Sanders for use during rigid bronchoscopy and was later modified by Olton and Donald to provide ventilation during laryngoscopy.[1] Different types of jet ventilation have been investigated with regard to the ventilatory mode (ie, respiratory frequency, driving pressure, timing of ventilatory bursts, or ventilator technologies) and the access route (eg, laser-resistant endotracheal tubes, jet ventilator catheters, or nozzles that are integrated in the wall of the laryngoscope).[2] Jet ventilation permits an unobstructed view of the larynx while providing adequate ventilation[1]; it also plays a role in providing ventilation under emergency conditions.[4,5]

In all of these situations, the presence and adequacy of ventilation are usually assessed by observation of chest wall movement or arterial blood gas analysis. It contrasts the situation in which the airway is maintained by continuous endotracheal tube capnography, which indicates the presence of patent airway and the adequacy of ventilation.[1]

There are several recent studies that measured end tidal CO_2 concentrations during jet ventilation and compared to mechanical ventilation.[1-4,6] Obesity can affect the thorax and diaphragm, and cause hypertonicity in the abdominal muscles. Lung function in obesity is characterized by reduced expiratory reserve volume (ERV) and functional residual capacity (FRC) increased closing volume. These factors are suggestive of small airway closure and air trapping.

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Table 1
Comparison of patients' arterial pH, $PaCO_2$, PaO_2, SaO_2, at time 0 (initiation of the jet ventilation) and their changes at 15 and 30 minutes later

Arterial	pH	$PaCO_2$ (mm Hg)	PaO_2 (mm Hg)	SaO_2 (%)
Time 0 (mean ± SD)	7.404 ± 0.011	36.55 ± 0.94	260 ± 53.4	99.79 ± 0.12
Statistical significance	$P = 0.386$	$P = 0.058$	$P = 0.085$	$P = 0.73$
After 15 min (mean ± SD)	7.368 ± 0.030	40.55 ± 3.22	244.4 ± 52.4	99.74 ± 0.18
Statistical significance	$P = 0.000$*	$P = 0.000$*	$P = 0.004$*	$P = 0.001$*
After 30 min (mean ± SD)	7.345 ± 0.037	42.90 ± 3.99	236.1 ± 58.7	99.66 ± 0.32
Statistical significance	$P = 0.000$*	$P = 0.000$*	$P = 0.006$*	$P = 0.005$*

*$P < 0.05$.

In clinical practice, body fat (obesity) is most commonly and simply estimated by using a formula that combines weight and height (weight/height^2). The underlying assumption is that most variation in weight for persons of the same height is due to fat mass, and the formula most frequently used in epidemiological studies is body mass index (BMI). A graded classification of overweight and obesity using BMI values provides valuable information about increasing body fatness. It allows meaningful comparisons of weight status within and between populations and the identification of individuals and groups at risk of morbidity and mortality. It also permits identification of priorities for intervention at an individual or community level and for evaluating the effectiveness of such interventions.[7]

No previous literature was found suggesting a relation between BMI and gas exchange during jet ventilation. Hence, it is the subject of this study.

METHODS

All patients were informed of the research conditions and consent was obtained from each patient. The study was approved and conducted under close observation by Baqiyatallah University Review Board. Forty-two ASA class I-II patients aged between 16 and 70 years undergoing elective micro-laryngeal surgery were studied. Patients with morbid obesity (BMI > 35) and Chronic Obstructive Pulmonary Disease (COPD) were excluded from the study.

Electrocardiogram, Non Invasive Blood Pressure (NIBP), and arterial oxygen saturation were monitored, and the patients were given 100% oxygen. After skin preparation with local anesthesia, a radial artery catheter was established and the first sample of Arterial Blood Gas (ABG) obtained.

Intravenous Ringer's lactate solution (10 mL/kg) was administered. Anesthesia was induced with midazolam (30 μg/kg), fentanyl (2 μg/kg), and propofol (2.5 mg/kg) followed by atracurium (0.5 mg/kg), propofol infusion (150 μg/kg/min), and the patient's lungs were ventilated with oxygen, using a face mask attached to a circle system, then the plastic cannula (13G) was inserted through the cricothyroid membrane. Entry into the trachea was confirmed by aspiration of air with a syringe containing fluid and the catheter was secured with a ribbon.

The tube was connected to the canula and low-frequency jet ventilation, 24-30 times/min with 40 PSI pressure, was applied by manually activating the system. Manu Jet III system introduced by VBM Medizintechnik GmbH, Germany (tel:4907454-95960) was used. I/E ratio was 1/3. Once the jet flow stopped, expiration occurred as a result of the elastic recoil of the thorax. Adequacy of ventilation was confirmed by the presence of chest wall movement and adequate pulse oxymeter readings. Following anesthesia, vital signs were recorded and repeated measurement of blood gas was obtained every 15 minutes.

Statistical analysis of data was performed with the SPSS/PC, χ^2 test, ANOVA, and *t* tests, and correlations between

Table 2
Comparison of patients' arterial pH, $PaCO_2$, PaO_2, SaO_2, changes at time 0, and 15 and 30 minutes after the initiation of the operation

Patients	Time 0 (mean ± SD)	After 15 min (mean ± SD)	After 30 min (mean ± SD)	Friedman χ^2 test
pH	7.404 ± 0.011	7.368 ± 0.030	7.345 ± 0.037	$P = 0.000$*
$PaCO_2$ (mm Hg)	36.55 ± 0.94	40.55 ± 3.22	42.90 ± 3.99	$P = 0.000$*
PaO_2 (mm Hg)	260 ± 53.4	244.4 ± 52.4	236.1 ± 58.7	$P = 0.000$*
SaO_2 (%)	99.79 ± 0.12	99.74 ± 0.18	99.66 ± 0.32	$P = 0.001$*

*$P < 0.05$.

Table 3
Changes in arterial pH and paCO$_2$, in the two extreme groups of patients (BMI < 25, BMI > 25)

	BMI < 25		BMI > 25	
Patients	(mean ± SD)	*P* value	(mean ± SD)	*P* value
pH at time 0	7.400 ± 0.008	*P* = 0.152	7.401 ± 0.010	*P* = 0.683
pH after 15 min	7.383 ± 0.009	*P* = 0.304	7.342 ± 0.022	*P* = 0.003*
pH after 30 min	7.370 ± 0.009	*P* = 0.704	7.311 ± 0.023	*P* = 0.000*
PaCO$_2$ at time 0	36.318 ± 0.83	*P* = 0.786	37.05 ± 0.68	*P* = 0.627
PaCO$_2$ after 15 min	37.90 ± 1.30	*P* = 0.281	43.45 ± 1.87	*P* = 0.031*
PaCO$_2$ after 30 min	39.50 ± 1.89	*P* = 0.01*	46.65 ± 1.33	*P* = 0.015*

*$P < 0.05$.

age, BMI, duration of surgery, and PaCO$_2$, pH, PaO$_2$ were calculated. $P < 0.05$ was considered statistically significant.

RESULTS

Patient findings (mean ± SD) were: sex (male 28, female 14), average age (43.54 ± 12.04 y), weight (69.97 ± 11.66 kg), BMI (24.80 ± 2.78). Duration of operation was 34.19 ± 5.81 minutes (mean ± SD).

In the conducted study, there was no significant statistical difference in the arterial pH, pCO$_2$, pO$_2$, and SaO$_2$ at the (time 0) initiation of the ventilation, but a significant change ($P < 0.05$) was seen in the above data 15 and 30 minutes after the initiation of jet ventilation and operation (Tables 1 and 2).

Due to higher difficulty with ventilation in obese subjects than in nonobese, the 20 heavy patients (BMI greater than 25) were compared with the 22 light patients (BMI less than 25). There was a statistically significant difference between the light and heavy patients in the arterial pH at 15 and 30 minutes and pCO$_2$ at 30 minutes (Table 3). No anesthetic complications occurred during the study.

DISCUSSION

Jet ventilation is an important tool for airway management during surgery of the airway; it can provide an unobstructed view of the airway and eliminate the need for a potentially flammable endotracheal tube.[1] However, a significant disadvantage of jet ventilation, as currently practiced, is im-

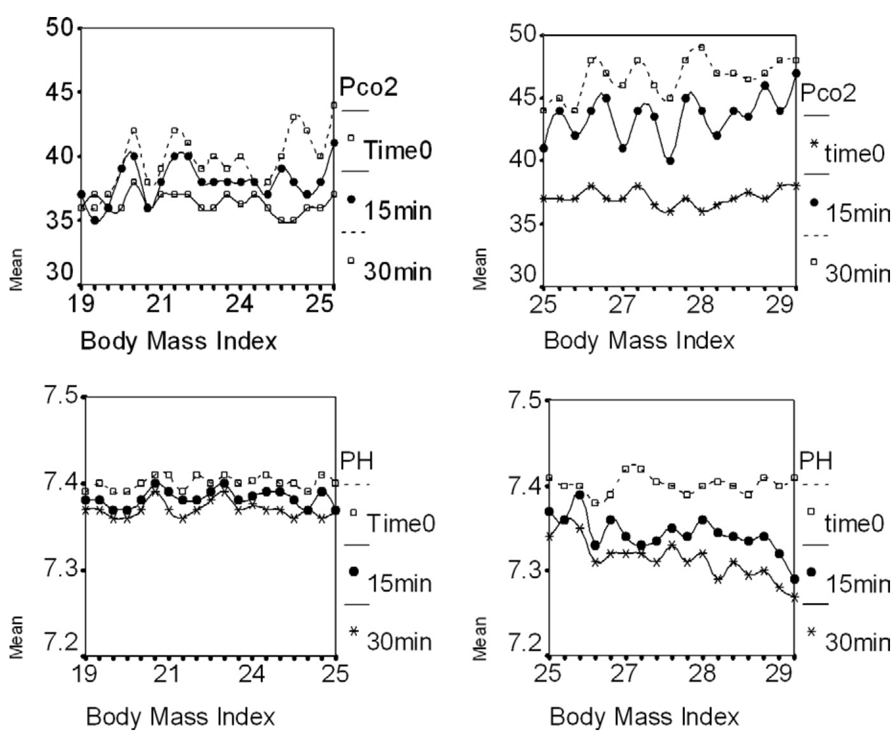

Figure 1 Mean ± SD PCO$_2$ and pH during the study.

possible routine measurement of the CO_2 concentration of expiratory gas. In spontaneous breathing of healthy subjects, the relationship between end-tidal CO_2 tensions is only 1 to 4 mm Hg less than those of arterial blood.[1] General anesthesia, which increases physiologic dead space, would be expected to cause an increase in this arterial to end-tidal CO_2 difference. During conventional mechanical ventilation under general anesthesia, however, this relationship is not substantially different from that in the awake state and varies from 1 to 8 mm Hg.[1]

Recently, a small-bore double-lumen tube designed for monitoring $EtCO_2$ has been used in jet ventilation (mono-jet catheter).[2-4] The mono-jet catheter is composed of two parallel tubes and is made of polytetrafluoroethylene. The second lumen allows continuous $EtCO_2$ and PEO_2 measurement during jet ventilation.[2,3] This lumen can also be used for airway pressure monitoring. Measurement of end-tidal CO_2 is not reliable during high-frequency jet ventilation via a mono-jet catheter because the ventilation gas delivered by jet ventilator would be mixed with environmental and expiratory air, a phenomenon that is generally known as environmental air entrainment.[2,8,9]

As shown in Tables 1 and 2, SaO_2, PaO_2, $PaCO_2$, and pH do not remain consistently stable during the study. Total operating time was always less than 40 minutes. Arterial blood sampling and evaluation at 0, 15, and 30 minutes showed significant *P* values for pH, $PaCO_2$, PaO_2, and SaO_2. This means the above method of jet ventilation is not capable of maintaining good ventilation for all of the patients. Meanwhile, correlating the patients BMI with their arterial blood data revealed the efficiency of this method in cases with BMI less than 25.

Figure 1 shows that PCO_2 increased and pH decreased significantly between times 0 and 15 in cases of BMI greater than 25. These could be strong indicators that low-frequency jet ventilation is as effective as conventional intubation anesthesia. Further, PTJV maintains adequate pulmonary gas exchange during surgery for low-BMI patients. A visible, accessible way for application of laser beam and low airway pressure are the other priorities.

With increasing operating time, $PaCO_2$ and pH progress (Table 3), and this may be a limiting factor for employing this route. The authors recommend combined or other ways for high-BMI patients and prolonged surgeries.

REFERENCES

1. Gottschalk A, Mirza N, Weinstein GS, et al. Capnography during jet ventilation for laryngoscopy. Anesth Analg 1997;85:155–9.
2. Bacher A, Pichler K, Aloy A. Supraglottic combined frequency jet ventilation versus subglottic mono frequent jet ventilation in patients undergoing micro laryngeal surgery. Anesth Analg 2000;90:460.
3. Klein U, Karzai W, Gottschall R, et al. Respiratory gas monitoring during high-frequency jet ventilation for tracheal resection using a double-lumen jet catheter. Anesth Analg 1999;88:224–6.
4. Bacher A, Lang T, Weber J, et al. Respiratory efficacy of sub glottic low-frequency, sub glottic combined-frequency, and supra glottic combined-frequency jet ventilation during micro laryngeal surgery. Anesth Analg 2000;91:1506–12.
5. David I, Marel M, Pipkova R, et al. Jet ventilation for fiber optic bronchoscopy. Anesthesiology 2001;94:930–2.
6. Hautmann H, Gamarra F, Henke M, et al. High frequency jet ventilation in interventional fiber optic bronchoscopy. Anesth Analg 2000;90:1436–40.
7. Rasslan Z, Junior RS, Stirbulov R. Evaluation of pulmonary function in Class I and II obesity. J Bras Pneumol 2004;30:508–14.
8. Unzueta MC, Casas I, Merten A, et al. Endo bronchial high-frequency jet ventilation for endo bronchial laser surgery: an alternative approach. Anesth Analg 2003;96:298–300.
9. Cairo JM, Susan P. Respiratory care equipment. 6th ed. Baltimore: Mosby; 1999. p. 310–1.