A prospective randomized study comparing respiratory efficacy of percutaneous transtracheal and endotracheal, low-frequency jet ventilation during microlaryngeal surgery

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Abstract

Background: Transtracheal jet ventilation is an alternative ventilatory approach in airway surgery. The purpose of this study was to compare respiratory efficacy of percutaneous transtracheal with endotracheal, low frequency jet ventilation during microlaryngeal surgery.

Methods: Ninety ASA class I-II patients aged between 16 and 70 years undergoing elective microlaryngeal surgery were prospectively studied and randomly assigned to one of two groups: Percutaneous Transtracheal Jet Ventilation (PTJV) group or subglottic Endotracheal Jet Ventilation ETJV via the Benjet tube group.

Results: No significant differences in demographic data between the two study groups were observed. The understudy population included; ETJV=42 (total) 25 men, 17 women; PTJV= 48 (total) 34 men, 14 women. Age ranges were: ETJV: 43.83±11.52 yr, PTJV: 44.92±12.08 yr; weight ranges were ETJV: 69.62±11.66 kg, PTJV: 71.33±11.57 kg; BMI ranges were ETJV: 24.97±2.58, PTJV: 25.06±2.71. There were no significant differences between the measured pHa, PaO₂, PaCO₂ in two study groups at the initiation of operation. Significant differences were observed between measured pHa, PaO₂ and PaCO₂ during operation in ETJV group as compared with PTJV group.

Conclusion: We conclude that ETJV procedure provides regular pulmonary gas exchange during microlaryngeal surgery and carbon dioxide elimination can be better maintained in this group compared to the PTJV group.

Keywords: endotracheal, transtracheal, jet ventilation, microlaryngeal surgery

Introduction

Microlaryngeal surgery is associated with difficulty in providing adequate mechanical ventilation during laryngoscopy because the view of the operating field should not be hindered [1,2]. The laryngeal structures should be freely accessible with surgical instruments and the application of a laser should be possible without endangering patients or personnel in the operating room. Patients undergoing microlaryngeal surgery may additionally suffer from severe obstruction in the upper airway, caused by laryngeal pathologies which inhibit gas exchange and the insertion of ventilation tubes [1,2,3].

Choosing a suitable ventilation method is a major consideration when providing anesthesia in a patient undergoing laryngotraheal surgery. Airway management using a conventional tracheal tube may not be possible and may obscure the surgical field. Alternatively the technique of ventilation without a tracheal tube
with total IV anesthesia may be preferable \[1,2\]. One of the promising developments that may solve these problems is jet ventilation \[2,3,4\].

Jet ventilation was first described by Sanders for use during rigid bronchoscopy\[5\] and was later modified by Outlon and Donald to provide ventilation during microlaryngeal surgery \[5,6\]. Jet ventilation has been an established and safe anesthetic technique for ventilation in microlaryngeal surgery \[7\]. Jet ventilation permits an unobstructed view of the larynx while providing adequate ventilation and can eliminate flammable material from the airway. It also plays a significant role in providing ventilation under emergency conditions \[1,2,3,4,7,8\].

Several different types of jet ventilation have been investigated regarding the ventilatory mode (i.e. respiratory frequency, driving pressure, timing of ventilatory bursts, or ventilatory technology) and to the access route \[1,2,3,4,7,8,9,10\].

Several different types of endotracheal catheter have been used in jet ventilation (ETJV) safely and routinely.

Percutaneous transtracheal jet ventilation (PTJV) using a large bore catheter at the cricothyroid membrane is a life saving, relatively safe and simple procedure that requires little experience \[11,12,13,14\]. Although the transtracheal method is a suitable procedure, it is invasive and cannot be the choice.

There are several studies that measured end tidal CO\(_2\) concentrations during jet ventilation in comparison with conventional ventilation, but we did not find any report in the literature comparing PTJV and ETJV concerning BMI and gas exchange, which is the main aim of this study.

**Methods**

All the patients have been informed of the research conditions and a letter of consent was obtained from each patient. Eighty-two ASA class I-II patients aged between 16 and 70 years undergoing elective microlaryngeal surgery were prospectively studied and randomly assigned to one of two groups, percutaneous transtracheal jet ventilation (PTJV) group via the plastic catheter (G 13) or subglottic endotracheal jet ventilation (ETJV) via the Ben-jet tube group. Patients with morbid obesity (Body Mass Index>35) and COPD were excluded from the study. Electrocardiogram, NIBP and
arterial oxygen saturation were monitored, and the patients were given 100% oxygen. After skin preparation and under local anesthesia, a radial artery catheter was established and the first sample of ABG was obtained. Intravenous Ringer’s lactate solution (10ml/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), and the patient’s lungs were ventilated with oxygen, using a facemask attached to a circle system. After anesthetic induction, in the PTJV group, the plastic cannula (13G) (Fig. 1(A)) was inserted through the cricothyroid membrane. Entrance into the trachea was confirmed by aspiration of air with a syringe containing fluid and the catheter was secured with a ribbon. In contrast in the ETJV group endotracheal intubation was performed via Ben-Jet tube (Fig. 1 (B)). The Ben-jet is a polytetrafluoroethylene, self-centering, fine bore tube that can be inserted via the mouth through the subglottic region that allows the application of either high or low frequency jet ventilation. The tube was equipped with a basket on its tip to avoid direct contact of the jet nozzle with the tracheal wall and aligns the catheter with the trachea. The tube or catheter was connected to the cannula and low frequency jet ventilation, 24-30 times/min with 45 PSI pressure was applied by activating the system manually. Manu Jet III system introduced by VBM Medizintechnik GmbH Company was used. I/E ratio was 1/3. Once the jet flow stops, expiration will occur 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. Anesthesia was maintained with an intravenous infusion of (propofol, fentanyl, atracurium) technique (TIVA). Following anesthesia, vital signs were recorded and repeated measurements of blood gas were obtained every 15 minutes. Statistical analysis of data was performed with SPSS/version 14. Chi-square test, ANOVA, t-tests, and correlations between variables were used as statistical analysis to compare ages, BMI; duration of surgery and PaCO₂, pH, PaO₂ in the two groups. A significant level was set as P<0.05.

Results

No significant differences in demographic data between the two study groups (ETJV=42, 25 men, 17 women; PTJV=48, 34 men, 14 women) were observed. Age ranges were: ETJV: 43.83±11.52 yr, PTJV: 44.92±12.08 yr; weight ranges were ETJV: 69.62±11.66 kg, PTJV: 71.33± 11.57 kg; BMI ranges were ETJV: 24.97±2.58, PTJV: 25.06±2.71). There were no significant differences between the

<table>
<thead>
<tr>
<th>Subject</th>
<th>Time</th>
<th>PTJV</th>
<th>ETJV</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (mean±SD)</td>
<td>Time 0</td>
<td>7.406±0.009</td>
<td>7.407±0.009</td>
<td>0.905</td>
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<tr>
<td></td>
<td>After 15 min</td>
<td>7.361±0.025</td>
<td>7.400±0.016</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>After 30 min</td>
<td>7.339±0.034</td>
<td>7.404±0.020</td>
<td>0.000*</td>
</tr>
<tr>
<td>PaCO₂ (mmHg)</td>
<td>Time 0</td>
<td>36.6±8.0</td>
<td>36.5±8.9</td>
<td>0.549</td>
</tr>
<tr>
<td>(mean±SD.)</td>
<td>After 15 min</td>
<td>40.9±3.2</td>
<td>34.5±2.4</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>After 30 min</td>
<td>43.4±4.0</td>
<td>34.1±3.4</td>
<td>0.000*</td>
</tr>
<tr>
<td>PaO₂ (mmHg)</td>
<td>Time 0</td>
<td>263.5±47.5</td>
<td>276.7±43.0</td>
<td>0.196</td>
</tr>
<tr>
<td>(mean±SD.)</td>
<td>After 15 min</td>
<td>244.1±51.4</td>
<td>199.4±36.3</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>After 30 min</td>
<td>235.4±58.3</td>
<td>196.3±34.5</td>
<td>0.001*</td>
</tr>
<tr>
<td>SaO₂ (%)</td>
<td>Time 0</td>
<td>99.80±12</td>
<td>99.81±12</td>
<td>0.625</td>
</tr>
<tr>
<td>(mean±SD.)</td>
<td>After 15 min</td>
<td>99.74±17</td>
<td>99.76±15</td>
<td>0.619</td>
</tr>
<tr>
<td></td>
<td>After 30 min</td>
<td>99.65±32</td>
<td>99.66±34</td>
<td>0.769</td>
</tr>
</tbody>
</table>

Table 1. Arterial pH, PaCO₂, PaO₂, at initiation of operation and their changes, 15 and 30 minutes later in the two study groups (P<0.05).
measured pH, PaO₂, PaCO₂ in the two study
groups at the initiation of operation. Significant
differences between measured PaO₂, at min 15
and min 30 in ETJV group were detected. In ad-
dition, there were significant differences be-
tween the measured pH, PaCO₂ in these
groups during the operation.

The light patient in ETJV group hyperventi-
lated and heavy patient was in normal range,
but the heavy patient in PTJV group hypoventi-
lated and PaCO₂ raised.

Conclusion
The present study demonstrates that arterial
oxygenation was lower and carbon dioxide
elimination can be maintained better with sub-
glottic endotracheal jet ventilation (ETJV) per-
cutaneous transtracheal jet ventilation (PTJV)
during microlaryngeal surgery. The physiolog-
ic backgrounds of these findings which were
clarified by this study showed that the tidal vol-
umes that could be administrated were greater
with subglottic endotracheal jet ventilation
(ETJV) than percutaneous transtracheal jet
ventilation (PTJV). This hypothesis is based on
the observation that the measured PaCO₂ and
PaO₂ in the ETJV group was lower than PTJV
group. It means that, the FiO₂ which was re-
ceived by patients in the ETJV group was lower
than the PTJV group. Thus, the ventilation gas
which was delivered by the jet ventilator (FiO₂
≈ 80%) in the two groups must have been mixed
with environmental air (FiO₂ =21%), a phe-
nomenon that is generally known as environ-
mental air entrainment which is generated as a
result of the Venturi effect; in the ETJV group it
was more than the PTJV group. It has been
shown that a greater amount of environmental
air entrainment results in greater tidal volumes,
a fact that could, at least in part, have con-
tributed to the more efficient CO₂ elimination
and lower FiO₂ results, lower PaO₂ and PaCO₂.
The respiratory rate, Jet ventilator pressure, I/E
ratio, internal diameter of the catheter and dis-
tance of distal end of catheters in the trachea
were same in the two groups, still the cause of
better ventilation with Ben-jet catheter which
was observed by fiberoptic, is due to the fact
that the Ben-jet catheter is situated in the center
of the trachea after insertion and the air flow is
laminar, not turbulent (conclusively, no back-
ward flow exists during operation). In contrast
the PTJV catheter is not situated in the center.
Adjacent to the posterior wall of the trachea the
air flow becomes turbulent and has back ward
flow due to lateral holes on the sides of the
PTJV plastic catheter leading to prevention of
the Venturi effect.

We concluded that ETJV provides regular
pulmonary gas exchange during microlaryn-
geal surgery and carbon dioxide elimination can be maintained better in this group in comparison with the PTJV group. The view of the glottis and surgical access are not hindered by an endotracheal catheter in the PTJV group. No clinically relevant differences were observed with regard to surgical acceptance of either technique.

References


