Auris Nasus Larynx xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Auris Nasus Larynx

journal homepage: www.elsevier.com/locate/anl

High frequency jet ventilation during endolaryngeal surgery: Risk factors for complications☆

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ARTICLE INFO

Article history:
Received 26 September 2017
Accepted 27 December 2017
Available online xxx

Keywords:
Anesthesia
High frequency jet ventilation
Laryngoscopic surgery

1. Introduction

Microlaryngeal surgery requires teamwork between surgeons and anesthesiologists. Two main components required for this surgery are the maximal exposure of the surgical area and adequate gas exchange for safe anesthesia. Other requirements include an immobile larynx and the protection of the airway against surgical debris.

High-frequency jet ventilation (HFJV) is an artificial breathing technique, preferred during endolaryngeal interventions, which offers a good solution for the requirements stated above [1,2]. However, as a survey study in the United Kingdom has revealed, HFJV may be associated with serious complications, such as hypoxia, hypercarbia, and barotrauma [3], and yet, patient or surgical characteristics related to intraoperative complications remain to be elucidated. Most studies investigating the independent risk factors for intraoperative complications during HFJV in endolaryngeal surgery (ELS) are retrospective and not standardized and the anesthetic approach is not standardized.

This prospective observational study aims to identify factors associated with intraoperative complications during ELS with infraglottic HFJV under a standardized anesthesia regimen.

2. Materials and methods

2.1. Study population and setting

After obtaining Institutional Ethics Committee approval (2013/1247) and written consent from the patients, 243 patients who underwent ELS with infraglottic HFJV were investigated between October 2013 and June 2015. Patients with severe tracheal stenosis (tracheal diameter < 4.0 mm) were excluded

☆ Presented in part at 2nd European Airway Congress, 5–7th December 2013, Istanbul, Turkey.

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https://doi.org/10.1016/j.anl.2017.12.003

and underwent surgery with conventional mechanical ventilation via tracheostomy or thin tracheal tubes.

2.2. Anesthetic management

After standard anesthesia induction (midazolam 0.05 mg/kg, remifentanil 1.5 μg/kg propofol 2–2.5 mg/kg, mivacurium 0.25 mg/kg) a 4-mm-diameter 40-cm-long infraglottic HFJV catheter (Acutronic Medical Systems AG, Hirzel, Switzerland) was advanced with the aid of a laryngoscope, and infraglottic HFJV was started (Acutronic Medical Systems AG, Hirzel, Switzerland). Jet ventilation parameters were adjusted as follows: heated and humidified gas composition with a driving pressure (DP) of 1.3 bar, an inspiration time (IT) of 50%, FiO_2 of 0.8, and a frequency of 130/min. The automatic shutdown trigger level of the ventilator was set at 30 cmH_2O to reduce the risk of barotrauma. When carbon dioxide laser treatment was planned, several precautions were employed to prevent airway fires, including reducing FiO_2 to 0.35 and placing wet pads around the surrounding tissue. In patients with a body mass index (BMI) exceeding 30 kg/m^2, ventilation parameters were modified (DP: 1.4–1.5 bar, IT: 60%, and frequency: 140/min) to prevent encountering gas exchange difficulties.

Anesthesia was maintained intravenously with an infusion of propofol and remifentanil. Propofol infusion was started as 6 mg/kg/h, and the rate was adjusted to maintain a BIS level of 45–55. Infusion rate was changed in 0.5 mg/kg/h steps if the bispectral index (BIS) value was out of the targeted range for more than 30 s. Likewise, a remifentanil infusion was started at 0.1 μg/kg/min, and the rate was changed by 0.05 μg/kg/min to achieve a mean arterial pressure (MAP) within 20% of the baseline mean arterial pressure in two-minute intervals. The total doses of propofol and remifentanil for the maintenance of each patient were recorded. Additional mivacurium was planned to be administered if requested by the surgeon. All patients received standard doses of ranitidine 50 mg, granisetron 3 mg, and dexamethasone 8 mg. The vocal cords were sprayed with lidocaine 4% at the end of the surgery just before the removal of the catheter to avoid coughing and laryngospasm.

2.2.1. Data collection

Demographic (age, gender, comorbidities including respiratory and cardiovascular disease) and operative (type of surgery, operation time, previous laryngeal operations) data were noted. Hemodynamics (heart rate [HR], MAP, SpO_2, and end-tidal CO_2 ($ETCO_2$)) were monitored via a catheter adapted to a Y-connector to ensure the adequacy of ventilation and were recorded at regular intervals (after catheter insertion, 5th min, 10th min, 15th min, and at the end of surgery) throughout the operation. Any respiratory complications (hypoxia, hypercarbia, presence of laryngospasm or bronchospasm, barotrauma [presence of pneumothorax shown by chest X-rays or real time ultrasonographic evaluation in suspected cases], equipment failure, and requirement of conventional ventilation due to ineffective gas exchange or surgical preference) as well as hemodynamic complications (bradycardia, tachycardia, hyper/hypotension, and arrhythmia) were documented. Hypoxia was defined as a drop of oxygen saturation to 90%; hypercarbia was defined as an $ETCO_2$ that exceeded 50 mmHg, in which case an arterial blood sampling was performed to verify simultaneously. In the event of a hypoxic episode, DP was augmented to 1.4 bar, and IT was increased to 60%. If refractory arterial desaturation and/or CO_2 retention lasted more than 5 min, HFJV was terminated, and conventional ventilation with tracheal intubation was initiated. Bradycardia (heart rate less than 50 beats/min) was planned to be treated with atropine 0.5 mg. Tachycardia (heart rate $>$ 100 beats/min for more than two minutes) and/or hypertension despite a remifentanil infusion rate of $>$0.3 μg/kg/min was planned to be treated with a 0.01 mg/kg/min esmolol infusion. Hypotension despite a remifentanil infusion rate of $<$0.05 μg/kg/min and BIS within the targeted range was planned to be treated with a 200-mL fluid bolus, followed by a 5-mg ephedrine bolus.

At the end of the surgery, all anesthetic infusions were stopped. The oro-pharynx was cleared by suction, and the HFJV parameters were changed for one minute (DP: 0.8 bar, frequency: 300/min), as described by Biro [4] to accumulate the CO_2 to stimulate spontaneous breathing before stopping HFJV and removing the catheter. Following this maneuver, patients who started breathing spontaneously were supported using a mask, whereas respiratory support was provided for the patients with insufficient effort with a laryngeal mask airway. The time required for awakening (eye opening) and the time required to get ready for discharge to the ward were recorded. Patients were discharged to the ward once they fulfilled a modified Aldrete score = 10 [5].

All patients were assessed for their recall of intraoperative events using the modified Brice scale [6] in the postoperative care unit before discharge.

2.2.2. Statistical analyses

A priori two-tailed sample size calculation with an effect size of $\geq$0.1, alpha and beta errors of 0.05 and 0.2, respectively, revealed that 172 patients would be needed to test a maximum of 10 factors.

The results are expressed as mean $\pm$ standard deviation (SD), median [minimum–maximum], or number of patients (% incidence). ANOVA, Mann–Whitney U test, and Student's t-test were used to compare the quantitative variants. The qualitative variants were compared using chi-square tests. $P < 0.05$ was considered statistically significant. Binary logistic regression analysis was used for the risk analysis for age, gender, BMI, type of previous airway surgery, and operation duration. The odds ratio (OR) and 95% confidence intervals (CI) were stated for independent risk factors detected.

3. Results

In this study, 243 patients undergoing minor laryngotracheal surgery were screened. Thirteen patients refused to participate in the study, and 230 consenting patients were enrolled. During the anesthetic induction phase, eight patients were excluded from the study due to severe laryngeal stenosis. Data from the remaining 222 patients were included in the statistical analysis (Fig. 1).

Please cite this article in press as: Altun D, et al. High frequency jet ventilation during endolaryngeal surgery: Risk factors for complications. Auris Nasus Larynx (2018), https://doi.org/10.1016/j.anl.2017.12.003