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Original contribution

Technical description of a modified jet ventilation injector for airway laser surgery in neonates and infants: retrospective analysis of 20 cases☆

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Abstract
Introduction: The authors modified an adult jet ventilation injector (Hunsaker Mon-Jet Ventilation Tube®) to be able to provide transglottal high-frequency jet ventilation (HFJV) in small children undergoing laryngeal procedures with CO_2 laser.
Methods and material: Retrospective review of the anesthetic records of all children younger than 2 years undergoing transglottal HFJV for CO_2 laser laryngeal procedures using this modified adult injector between 2006 and 2013.
Results: Nine children (5 boys, 4 girls) were identified who underwent a total of 20 procedures. Mean age was 7.4 ± 6.9 months, and mean weight was 6 ± 2.8 kg. No complications were observed with the use of HFJV or this modified injector.
Conclusion: In experienced hands, this modified injector ensures excellent visibility and field access to the surgeon as well as adequate ventilation during laryngeal laser surgery in infants.

1. Introduction

Laryngeal procedures are sometimes necessary to relieve laryngeal obstruction in very young children, for example, papillomatosis or resection of cysts. Many of them need the use of a CO_2 laser [1]. In this population, laryngeal procedures are very demanding for ENT surgeons and anesthesiologists because they share a narrow and critical airway. There are several different ventilation techniques that can be used for that purpose. The first is **spontaneous ventilation** without tracheal intubation, which avoids altogether a source of combustible material and restriction

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of the surgeon's view [2]. However, the vocal cords are not immobile, and there is concern regarding respiratory depression and laser fumes inhalation. The second is **apneic anesthesia/ventilation** with intermittent ventilation and oxygenation, which gives the surgeon only short periods of access to the larynx and carries a risk of hypoxemia because infants have higher O_2 consumption. In addition, unless mask ventilation is provided in between the periods of apnea, this technique exposes the patient to multiple intubations/extubations with their own risks [3,4]. The third is standard **ventilation with a laser-compatible endotracheal tube**, but it limits the surgeon's vision of the larynx. Moreover, tube size for small infants remains an issue [2,3]. Last, **jet ventilation (JV)** provides excellent surgical conditions but is not commonly used in infants. Unsatisfied with the above-described methods, our team made the choice of using transglottic high-frequency JV (HFJV) with a modified adult injector, the Hunsaker Mon-Jet Ventilation Tube® (Medtronic Xomed, Jacksonville, FL). This injector proved to be easy to use, safe, flexible (yet sufficiently rigid), resistant to high pressures, and nonflammable in adults [5]. We report hereafter the description of our technical modification and our clinical experience with it in a series of infants to show the safety of this modified device in this population.

2. Materials and methods

This retrospective review includes all patients younger than 2 years who underwent laryngeal procedures where the use of CO_2 laser was required and HFJV was chosen as ventilation method from August 2006 to August 2013. All the procedures took place at Cliniques universitaires Saint-Luc (Brussels, Belgium). Our review received prior approval by the hospital's Institutional Review Board, and parental consent requirement was waived in November 2014.

The patients were retrieved using our electronic anesthesia records database (Mexys, by Exacto, Mons, Belgium) and cross-checked with the surgeons' database.

As this was an observational study, only descriptive statistics are provided which were calculated using the Microsoft Excel file in which the data were recorded. All values are expressed as mean and standard deviation, and their range is given when necessary.

Patient monitoring followed standard American Society of Anesthesiologists recommendations: electrocardiogram, pulse oximetry (Spo_2), non-invasive blood pressure (NIBP), temperature, and end-tidal CO2 (EtCO2). However, EtCO2 cannot be measured during HFJV: ideally, transcutaneous Pco_2 should be monitored instead, but this device was not available at the time of the study in our department. HFJV was initially performed using the AMS 1000® and more recently the Mistral® jet ventilator (Acutronic Medical Systems AG, CH-6342 Baar, Switzerland). Both allow control of the following parameters: fraction of inspired oxygen (Fio_2), frequency, inspiratory time, driving pressure. Most importantly, to prevent barotrauma, their jet systems are equipped with an adjustable alarm system for airway pressures that stops inflation as soon the preset end-expiratory pressure (EEP) threshold is reached [6–8]. The initial ventilation settings were as follows: 150 cycles per minute, driving pressure 0.8-1.2 bar, inspiratory-to-expiratory time ratio (I:E) <30%, Fio_2 <30%, and EEP 4 mbar. They were adapted according to the child's response as evaluated with Spo_2 and thoracic movements. The following data were retrieved from the anesthetic records: epidemiologic data, lowest Spo_2, lowest blood pressure and heart rate, duration of HFJV, and any anesthetic or surgical complications.

The patients did not receive any premedication. Sevoflurane/O_2 was used for inhalation induction unless an intravenous line was already present. Anesthesia was maintained with a continuous intravenous propofol infusion (between 6 and 10 mg kg^{-1} h^{-1}, Diprivan®, AstraZeneca, Belgium). Sufentanil (0.1-0.2 μg kg^{-1}, Sufenta®, Janssen Pharmaceutica, Belgium) was added to provide analgesia. Atracurium (0.3 mg kg^{-1}, Tracrium®, Glaxosmithkline Pharmaceuticals, Belgium) was used as neuromuscular-blocking agent to ensure a motionless surgical field. Sufentanil and atracurium injections were repeated if necessary. The vocal cords and glottic area were sprayed with lidocaine (3 mg kg^{-1}, Linisol 1%®, Braun, Belgium) before starting the procedure.

A Hunsaker Mon-Jet Ventilation Tube® was used. This fluroplastic device is compatible with laser use. It has a 4.3-mm outside diameter (OD) tube with 2 lumens: oxygen is delivered through the largest lumen (OD 3 mm, inside diameter [ID] 2.7 mm), whereas peak airway pressures can be monitored through the smallest one (ID 1 mm, opening 3.2 cm proximal to the jet port). The EEP is monitored through the largest lumen between 2 insufflations. It contains a stainless steel wire to facilitate extubation in case of tube damage. The device is 35.5 cm long and includes a basket-like stabilizing structure at its distal end to avoid whip-like movements and submucosal injection during JV [5,9].

It was modified as follows to allow its use in small infants (Fig. 1).

The small lumen was carefully removed to decrease the external diameter of the injector and limit the risk of airway obstruction. Its external connector is left however it has no utility.

As the basket-like structure is too large and the remaining catheter too long, the distal part of the catheter was cut halfway to make sure its distal end was approximately at midtrachea when in place for ventilation.

Moreover, to avoid any airway mucosal trauma, the wire contained in the remaining tube was also removed by pulling it with mosquito forceps. Finally, the external surface and the distal end of the remaining part of the injector were carefully inspected to avoid any trauma to the pharyngeal and laryngeal mucosa.

The injector was introduced in the trachea under direct laryngoscopy by the anesthesiologist. The HFJV ventilator was immediately started using the ventilation settings