Superimposed High-Frequency Jet Ventilation for Laryngeal and Tracheal Surgery

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Objective: To describe our experience with superimposed high-frequency jet ventilation (SHFJV), which does not require any endotracheal tubes or catheters, for performing laryngeal and tracheal surgery.

Design: A case series of 500 patients.

Setting: A university medical center.

Patients: Four hundred sixty adult patients and 40 children in a consecutive sample who required laryngeal or tracheal surgery under SHFJV.

Interventions: The SHFJV uses 2 jet streams with different frequencies simultaneously and is applied using a jet laryngoscope. Ventilation was performed with an air-oxygen mixture, and intravenous agents were used for anesthesia. Arterial blood gas values were analyzed.

Main Outcome Measures: Reported values of oxygenation and ventilation during the application of SHFJV and laryngotracheal surgery.

Results: In 497 patients, adequate oxygenation with a mean ± SD PaO₂ of 91.8 ± 22.9 mm Hg and ventilation with a PaCO₂ of 29.7 ± 5.5 mm Hg were achieved using SHFJV. The average duration of the application of ventilation was 27 minutes, and the longest duration was 118 minutes. No complications due to the ventilation technique were observed. Laser surgery was performed in 150 patients.

Conclusions: The use of SHFJV in combination with the jet laryngoscope provides patients with sufficient ventilation during laryngotracheal surgery. Even in patients at high risk because of pulmonary or cardiac disease, this technique can be applied safely. In patients with stenosis, the ventilation is applied from above the stenosis, reducing the risk of barotrauma. The SHFJV can be used for tracheobronchial stent insertion, and laser can be used without any additional protective measures.

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PATIENTS AND METHODS

PATIENTS

Starting in 1990, we analyzed the outcomes of the first 500 patients in whom SHFJV was applied. Of the 500 patients, 193 were female, 307 were male, and 40 were children ranging from neonate to 14 years of age. The age of the patients (mean ± SD) was 48.3 ± 19.4 years, the oldest being 92 years. The body weight ranged from 2.5 kg in a neonate to 123 kg in an obese adult (70.2 ± 21.7 kg). The patients' diagnoses are listed in the Table. One hundred eighty-eight patients (37.6%) were considered at high risk for the following reasons: chronic obstructive pulmonary disease or emphysema (n = 36 [7.2%]), bronchial asthma (n = 14 [2.8%]), pulmonary metastases (n = 6 [1.2%]), extreme obesity (body mass index, > 35) (n = 42 [8.4%]), cardiac disease (American Society of Anesthesiology classification, 3-4) (n = 52 [10.4%]), and laryngeal stenosis (degree II and III of obstruction according to Cotton) (n = 38 [7.6%]). In 12 patients with increasing hypoxemia and peripheral oxygen saturation of less than 90%, emergency surgical procedures were performed using SHFJV.

MONITORING

In all patients, electrocardiography, arterial oxygen saturation (SaO2) using a pulse oximeter, and arterial blood pressure using an arterial catheter were monitored simultaneously each datum by an automated device (Merlin, model 685; Hewlett-Packard Co, Waltham, Mass). The ventilation pressure was measured continuously at the tip of the jet laryngoscope, and arterial blood gas analysis was performed every 5 minutes. The applied oxygen concentration was monitored by an anesthesia monitoring system (Datex Devision Instrumentarium Corp; Helsinki, Finland). The fraction of inspired oxygen (FiO2) values are those adjusted at the respirator, but the actual FiO2 concentrations are lower because of the Venturi effect.

ANESTHESIA TECHNIQUE

Intravenous anesthesia was used in all patients because SHFJV using the jet laryngoscope is an open system. As premedication, all adult patients received oral diazepam (0.15 mg/kg of body weight), and children received midazolam hydrochloride (1 mg/kg of body weight) given rectally. Preoxygenation was performed by mask ventilation with 100% oxygen. Anesthesia induction consisted of the administration of propofol (2 mg/kg) and sufentanil citrate (0.3 µg/kg), with vecuronium bromide (0.08 mg/kg) given for a muscle relaxant. For anesthesia maintenance, propofol (4-7 mg/kg per hour) was administered as a continuous intravenous infusion. Sufentanil and vecuronium were given as needed.

The administration of mask ventilation with 100% oxygen was continued during induction. After 2 minutes, the jet laryngoscope was inserted using a protection for the teeth. The tubing for both jet streams and the pressure monitor were connected to the jet laryngoscope, and SHFJV was started.

At the end of the surgical procedure and after the patient regained protective reflexes, the jet laryngoscope was removed. Mask ventilation was administered until the patient emerged from anesthesia. Neuromuscular blockade was reversed by administering neostigmine methylsulfate and atropine sulfate.

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For endoscopic procedures of the larynx and the trachea, different jet ventilation techniques can be applied. These methods, however, are limited for 1 or more reasons: an increased risk of barotrauma, insufficient carbon dioxide elimination, the risk of catheter dislocation or kinking, or impaired visibility.

Subglottic jet techniques applied through the larynx or percutaneously through the trachea with thin
Ventilation Technique

With the SHFJV technique, 2 jet streams with different frequencies are applied simultaneously. The low-frequency jet stream provides 8 to 20 breaths per minute and serves primarily to remove carbon dioxide. The high-frequency jet stream, which provides 400 to 800 breaths per minute, causes a delay of the expiration of gas and prevents the lungs from being totally exhausted at the end of respiration. The inspiratory-expiratory ratio is 1:1 in both frequency settings. Because of this gas dynamic property, it is possible to achieve larger tidal volumes than with single-frequency jet ventilation techniques and to build up a positive end-expiratory pressure in an open system.

Jet Laryngoscope

The jet laryngoscope (C. Reiner Corp, Vienna, Austria), a diagram of which is shown in Figure 1, is a conical endoscopy tube used by otorhinolaryngology surgeons for laryngeal procedures that has been modified by Aloy et al. Two metal cannulas with 1.5-mm internal diameters are welded to the proximal third of the jet laryngoscope. The openings of the cannulas into the jet laryngoscope have an 18° angle but do not protrude into the lumen of the jet laryngoscope. The 2 jet nozzles are placed apart, one beside the other toward the distal end of the jet laryngoscope. The low-frequency jet stream goes through the distal cannula, and the high-frequency jet stream passes through the proximal cannula, maximizing the air entrainment (Venturi effect). As a result of the design of the angle of insertion of the cannulas, the entering gas streams do not hit the opposite wall of the jet laryngoscope but are directed toward the center of the distal end of the jet laryngoscope. A third cannula for continuous measurement of the ventilation pressure is inserted at the tip of the jet laryngoscope. Distinctive connectors prevent incorrect line connections to the jet respirator. The jet laryngoscope is available in 3 sizes for adults and 2 sizes for children.

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respirator. Passing through the jet nozzles, the gas stream undergoes changes. It changes from a high pressure (1-2 millibar) and a low flow (20 L/min) to a low pressure (6-10 millibar) and a high flow (up to 200 L/min, depending on the working pressures). This pressure drop and the placement of the jet nozzles in the proximal part of the endoscope ensure that no high pressures occur in the distal part of the endoscopy tube. Therefore, the risk of damage to the mucosa of the larynx or the trachea due to the jet streams is unlikely.

Although the pressures are low (6-10 millibar), the possibility of barotrauma cannot be eliminated entirely, but none of our patients experienced barotrauma due to SHFJV with the jet laryngoscope.

LARYNGEAL AND TRACHEAL STENOSIS

In patients with laryngeal stenosis (Cotton II and III), respiration might be impaired to such a degree that even surgical procedures using local anesthesia might not be possible. Attempts to improve oxygenation in these patients by applying high-frequency jet ventilation have been made using small translaryngeal or transtracheal cath-
nary artery disease, and extreme obesity—that were re-
pulmonary disease, restrictive pulmonary disease, coro-
tients with disease states—such as chronic obstructive
tion techniques. The SHFJV has even been used in pa-
ers a larger tidal volume than single-frequency ventila-
with pulmonary diseases. This is because SHFJV deliv-
ering pressure, it is possible to overcome the high inspira-
respirator and using long inspiration times and a high work-
sis (Cotton II and III) that, with proper adjustment of the
by manipulating the instruments.

With the use of the SHFJV technique with the jet la-
ryngoscope, patients with a laryngeal stenosis of even 90% can be provided ventilation from above the stenosis. Aloy
et al13 demonstrated in 23 patients with laryngeal steno-
sis (Cotton II and III) that, with proper adjustment of the
ator and using long inspiration times and a high working
pressure, it is possible to overcome the high inspira-
respiratory resistance and to provide adequate ventilation.

HIGH-RISK PATIENTS AND JET VENTILATION

The SHFJV is superior to the single-frequency jet venti-
lation techniques for use in obese patients and patients
with pulmonary diseases. This is because SHFJV deliv-
ers a larger tidal volume than single-frequency ventila-
tion techniques. The SHFJV has even been used in pa-
ients with disease states—such as chronic obstructive
pulmonary disease, restrictive pulmonary disease, coro-
ary artery disease, and extreme obesity—that were reg-
arded as relative or even absolute contraindications to
single-frequency jet ventilation.12

LARYNGOTRACHEAL SURGERY IN CHILDREN

Because of the development of pediatric jet laryngo-
sopes, SHFJV is also applicable for laryngeal proce-
dures in children.13 This ventilation technique is suit-
for removing aspirated intratracheal or intrabronchial
foreign bodies because ventilation is not a handicap in the
operating area.

TRACHEOBRONCHIAL STENT INSERTION

The experience acquired with SHFJV using the jet laryn-
goscope in otolaryngology surgery has led to the use
of the SHFJV for tracheobronchial stent insertion.14
Aloy et al13 demonstrated in 15 patients with high anes-
thesia risk of 4 to 5 (the American Society of Anesthesi-
ology scale) that continuous ventilation of a patient dur-
ing stent insertion is possible. If the jet laryngoscope is
inserted correctly, the carina can be seen. Even large sili-
con or metal stents can be inserted without any prob-
lems. With the use of the SHFJV and the jet laryngo-
scope, the procedure time is distinctly shorter because
of the good visibility and because multiple switches be-
tween an endotracheal tube and bronchoscope are not
necessary. A patient can be given ventilation up to when
the stent is placed in its final position. At this point, ven-
tilation of the patient is not possible with any current
ventilation technique. This ensures that the patient is well
oxygenated throughout the procedure.

Contraindications for SHFJV using the jet laryngo-
scope are acute bleeding in the tracheobronchial system
and inability of the patient to hyperextend the neck. Hy-
pertension of the neck is necessary to correctly place
the jet laryngoscope to direct the gas stream into the tra-
chea. In patients in whom the glottis cannot be visual-
ized through the jet laryngoscope, transtracheal high-
frequency ventilation is the technique of choice.13

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