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Anesthetic Management with High Frequency Jet Ventilation for Laryngotracheal Procedures: A Retrospective Study

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Background: Good surgical exposure and unhindered laryngeal area are an ideal component in tracheolaryngeal surgery. High frequency jet ventilation (HFJV) has been developed over decades for these procedures. The safety of this technique was proved. The aim of this study was to report the success rate and safety of anesthesia with HFJV technique in a tertiary university hospital in Thailand.

Methods: We reviewed both elective and emergency cases of laryngotracheal procedures which were under general anesthesia with HFJV technique at the Ear-Nose-Throat operating theater of King Chulalongkorn Memorial Hospital between August 2013 to March 2016. The characteristics, details of anesthesia technique, and surgery immediate outcomes were examined.

Results: A total of 45 cases in 43 patients were included to the case series. There were 31 male and 14 female patients. The mean age was 45 years old (range 11 to 84 years old). Common symptoms were dyspnea (40%) and hoarseness (32.6%). The common diagnosis was subglottic stenosis which needed reduction of stenosis with or without laser assistance. All of the cases received total intravenous anesthesia (TIVA) during HFJV. Mean operation time was 38.7 minutes (range 15 to 115 minutes). Complications were hypoxia (4.4%), failed HFJV (2.2%) due to outflow obstruction and airway fire (2.2%). No death or barotrauma was reported.

Conclusion: Anesthesia with HFJV in most of patients who underwent laryngotracheal procedures was safe and successful with a small amount of minor adverse outcomes.

Keywords: Anesthetic Management, High Frequency Jet Ventilation, Laryngotracheal Procedures

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Introduction

Airway surgery, especially endoscopic surgical interventions in the larynx and the trachea, is a challenge for both anesthesiologists and surgeons. Rigid laryngoscopes and/or surgical suspension laryngoscopes need to be positioned but intubation with conventional tracheal tubes is occasionally impractical. There are several alternative methods to solve this problem. Apnea technique is one of the most common ways to perform but it is associated with hypoxia.[1] Spontaneous ventilation under intravenous sedation is reported in adults and children but limits some operations.[2] Ventilation via a small microlaryngeal tube is also a common method although it can interfere in the surgical field and also has a flame risk.[3] Manual jet ventilation at a normal respiratory rate risks serious complications including death.[4] An appropriate anesthetic technique depends on varying degrees of obstruction and possible procedures.

Sanders et al. reported high pressure ventilation via a small bore cannula during bronchoscopy in an experimental study.[5] During 1970s, there were several

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high pressure ventilation clinical studies in humans especially in bronchoscopy, interventional laryngoscopy and thoracic surgery.[6-9]

Compared to conventional positive pressure technique, HFJV offers several advantages such as excellent surgical exposure of the larynx especially the posterior part of the glottis, adequate oxygenation in most cases and maintained ventilation.[10] Moreover, a positive end-expiratory pressure is usually present during HFJV and results in lower mean and peak airway pressures when compared to conventional ventilation. This benefit results in smaller gas leak, prevents low resistance airway pathology such as bronco-pleural fistula and less hemodynamic compromise.[11] Possible undesirable complications of HFJV are barotrauma (pneumothorax, pneumomediastinum, subcutaneous emphysema), inadequate gas exchange (hypoxia, hypercarbia), delayed discharge and high dependency on unit admission. However, low frequency or manual jet ventilation was related to higher rate of adverse outcomes including death.[4-12] In addition, minor complications of low frequency or manual jet ventilation were failure of cannula insertion, mucosal damage laryngospasm and hemodynamic instability.[13]

In Thailand, anesthesiologists are familiar with manual jet ventilation in emergency airway situations but less in laryngeal surgery. Anesthesia for laryngotracheal procedures with HFJV is a worldwide standard technique and needs experienced staff. The aim of this study was to report the success rate and adverse outcomes related to HFJV from a university hospital in Thailand.

Methods

A retrospective descriptive study was conducted after institutional ethical approval (IRB no. 783/62). The electronic search was performed in the hospital information system database covering August 2013 to March 2016. The inclusion criteria were patients who underwent laryngeal and tracheal surgery and received anesthesia with HFJV as a part of anesthetic technique in Ear-Nose-Throat operating theaters, King Chulalongkorn Memorial Hospital. Both of elective and emergency cases were included. The details of cases were collected from pre-anesthetic evaluation, anesthetic record, operating notes and other related documents. Patients' demographic data, anesthetic techniques and details such as medication, anesthetic time, etc., details of operations, and complications within 24 hours were retrieved. Fifteen year old and younger patients were considered as pediatric group.

Ventilator settings and approach: According to our center practice, we set an electronic jet ventilator (Monsoon3 Jet Ventilator®, Acutronic Medical System, Hirzel, Switzerland) with the following protocol: driving pressure 1-4 Bar (until adequate chest rise visibility), frequency of 100-200 cycles/minute, inspiration duration of 30% to 50% and oxygen fraction starting from 100%. If laser surgery was planned, we decreased oxygen fraction to as low as possible or less than 30% for at least 2 minutes before the laser was initiated, in order to avoid airway fire. If supraglottic approach was used, the jet nozzle connected with small metallic suction was inserted through a side port of the surgical direct laryngoscope by the surgeons. No airway pressure was monitored. In cases of infraglottic approach, we used a 4-mm. double lumen laser-resistant tube (LaserJet®), 40 cm. in length. The airway pressure could be continuously measured by the second lumen. The jet tube was placed at the subglottic area by the anesthesiologist just before the surgeon inserted instruments. If the patient had a tracheostomy in situ, a jet tube was inserted transtracheally.

Lack of clear details in some critical points would be addressed by conducting interviews with involving anesthesiologists to complete the information as much as possible. Hypoxemia was defined as oxygen saturation declined less than 90%. Descriptive statistics were analyzed with SPSS version 17.0 for Windows.

Results

From the electronic search, 48 cases met the inclusion criteria but we excluded 3 cases due to irrelevance. Patient mean age was 44.5 (range 11-84)

years. Three pediatric patients were included. Average body mass index was 23.2 (range 21-76) kg/m^2. There were 32 (69.6%) male patients and 14 (30.4%) female patients. Operation and anesthetic mean time was 40 (15-115) and 61.1 (25-135) minutes, respectively. The American Society of Anesthesiologists (ASA) physical status and Mallampati classification are shown in table 1.

Table 1 Demographic data

Demographic data	N = 45(N = 45)
Sex	
Male/Female	31 (68.9)/14 (31.1)
Mean age (years)	45 (11-84)
Body mass index (kg/m^2)	23.2 (21-76)
ASA class	
Class I	9 (20.00)
Class II	31 (68.88)
Class III	5 (11.11)
Mallampati	
Grade I	26 (57.77)
Grade II	11 (24.44)
Grade III	0
Grade IV	0
N/A	8 (17.77)
Operation time (minute)	
Mean operation time	37.8 (15-115)
Anesthetic time (minute)	
Mean anesthetic time	59.1 (25-135)
Elective VS Emergency	
Elective/Emergency	44 (97.8)/1 (2.2)
Clinical presentation	
Dyspnea	18 (40.0)
Hoarseness	15 (33.3)
Stridor	5 (11.1)
Dysphagia	4 (8.8)
Other (follow up)	13 (28.8)

Data were presented in n (%) or mean (range)

Clinical presentation cases at day of surgery were dyspnea 18 (39.1%), hoarseness 14 (30.4%), stridor 6 (13.0%), dysphagia 4 (8.7%) and others 12 (26.1%). The diagnosis and surgical procedures were divided into the following groups: stenotic lesion, peri-laryngeal mass, voice diseases, laryngeal papillomatosis and malignant diseases as shown in table 2

Table 2 Diagnosis and operations

Diagnosis	Operation	n (%)
Stenosis lesion		
Subglottic	Reduction of stenosis	12 (26.7)
Tracheal	Reduction of stenosis	5 (11.1)
Tracheal and laryngeal	Reduction of stenosis	2 (4.4)
Glottic	Reduction of stenosis	2 (4.4)
Supraglottic	Reduction of stenosis	1 (2.2)
Mass		
Laryngeal cyst	Cyst excision	3 (6.7)
Epiglottic cyst	Cyst excision	2 (4.4)
Vocal cord mass	Laser transection	3 (6.67)
Vocal cord hyperplasia	CO2 laser stripping	2 (4.4)
Unilateral vocal cord palsy	Posterior cordectomy	2 (4.4)
Bilateral vocal cord palsy	Micro DL+CO2	5 (11.1)
Cricoarytenoid subluxation	laser+cordectomy	2 (4.4)
Laryngeal papilloma	DL with joint reduction	2 (4.4)
Supraglottic Cancer	Micro DL with Co2 laser	2 (4.4)
	Laser transection	

All of the cases received total intravenous anesthesia (TIVA) during HFJV. However, 6 cases (13.0%) started with tracheal tube and conventional positive pressure ventilation before HFJV conduction. One case (2.2%) was induced by light sedation until HFJV started. Anesthesia with HFJV was performed in 43 (93.5%) paralyzed and in 2 (4.3%) non-paralyzed patients. Propofol was the main medication on all cases but there were, also, 31 (67.4%) cases which received fentanyl and 15 (32.6%) cases which received midazolam combination. During the emergence phase, there was a variety of techniques in transitional periods from HFJV to patients' awakening. The 3 different approaches of HFJV are shown in table 3. The driving pressure ranged 0.8-2.0 bar. The frequency of jet ventilation was 100-200 cycles per minute.

Table 3 Anesthetic management and medications

Anesthetic management	n (%)
Airway management technique	
Tubeless/Tracheal tube combination	38 (84.4)/7 (15.6)
Paralysed/Non-paralysed	42 (93.3)/3 (6.7)
Medication	
Propofol	45 (100)
Fentanyl	31 (68.9)
Midazolam	15 (33.3)
Dexmeditomidine	3 (6.7)
Route of HFJV	
Transtracheal	7 (15.6)
Infraglottic	5 (11.1)
Supraglotic	34 (75.6)
Emergence	
Laryngeal mask airway	9 (20.0)
Tracheal tube	5 (11.1)
Bag-mask ventilation	31 (68.9)

HFJV; High frequency jet ventilation

Anesthesia with HFJV was successful in 43 (95.6%) cases. Adverse events and complications were accounted for 3 cases (8.7%). Minor complications were reported: resolved desaturation without sequelae (6.5%), self-limited cardiac arrhythmia (4.4%), failed HFJV and need change to a tracheal tube (2.2%). There was 1 case of airway fire (2.2%). Major and minor adverse events are shown in table 4.

Table 4 Outcomes and complications

Outcome	n (%)
Airway obstruction and failed HFJV	1 (2.2)
Hypoxia (oxygen saturation <90%)	2 (4.4)
Arrhythmia	2 (4.4)
Airway fire	1 (2.2)

Discussion

In the present case series, anesthesia with HFJV in most of the patients who underwent tracheolaryngeal surgery was safe and successful with a small amount of minor adverse or undesirable outcomes. Similar to the previous studies, HFJV is claimed to be an excellent method to ventilation during the surgery or interventional fiberoptic bronchoscopy.[14-15] Among 45 cases, we included 3 pediatric patients in the present the case series. All of them were successful without significant complications. Safety of Anesthesia with HFJV in pediatrics had been reported for a long time.[16-17]

Anesthetic management: All of the cases in this report received TIVA with propofol and/or additional adjuvants such as fentanyl, midazolam or dexmedetomidine. However, there was a retrospective review success with inhalation technique combined with remifentanil infusion to maintain spontaneous breathing during HFJV for tracheobronchial foreign body removal.[18] From the present case series, we report 2 successful cases which performed HFJV without neuromuscular blocking agents. Both cases presented severe tracheal stenosis and the attending anesthesiologists needed to maintain spontaneous ventilation. The non-paralyzed technique had to be combined with reliable topical anesthesia and was done cautiously, with patients moving or coughing. HFJV with spontaneous ventilation technique has been demonstrated in the previous reports as well.[19]

During emergence, the most common method from this case series was bag-mask ventilation after all instruments were removed and waiting for spontaneous ventilation until awakening. No laryngospasm was noticed. In some cases which, where a possible difficult bag mask ventilation was present, the anesthesiologists inserted a laryngeal mask instead of using manual bag-mask technique. The tracheal tube was used only in the indication of possible uncertainty of airway. However, no adverse event was reported in emergence phase.

Ventilator settings and approach: The most common method in the present study was supraglottic approach (73.9%) which does not allow monitoring the airway pressure throughout the procedure. However, at the early study phase, surgeons felt comfortable and familiar with this technique. The different approach allowed a slightly different surgical exposure and vocal fold movement in microscopic procedures because the airway pressure and air entrainment during HFJV depends on the position of nozzles relative to the

stenosis as an experimental study.[20] However, the incidence of complications between different approaches was controversial.[4,13] Moreover, HFJV allows controlled humidified high flow oxygen which is superior to manual jet ventilation especially for longer operation times.

Monitoring: In the present study, standard monitoring was applied in all cases except capnometer. Arterial blood gas analysis is the standard measurement during HFJV in some institutions. However, transcutaneous carbon dioxide monitoring and intermittent sampling end tidal capnography were shown to be correlated with arterial blood gas in some studies.[21-22] Continuous airway pressure monitoring is essential for barotrauma detection because this is a common complication of HFJV. The risk may increase in the presence of outflow obstruction.[23]

Outcomes and complications: In our case series, anesthesia with HFJV was successful in 43 cases (95.5%). We did not find the incident of barotrauma - which is one of the major complications in previous studies.[4,10,24] Neither laryngospasm nor mucosal damage was found in the present report. In aspects of hemodynamic complications, we observed 2 cases (4.4%) of self–limited and non-malignant cardiac arrhythmia whereas the recent retrospective study reported hypotension (10.8%), bradycardia (2.7%) and cardiac arrhythmia (1.8%).[25] Moreover, procedure duration and history of previous airway surgery increased the risk of hemodynamic instability.[25]

We found 1 incident of HFJV failure (2.2%). This incident was more common than barotrauma or oxygen desaturation found in a previous study.[13] The patient presented dyspnea due to recurrent subglottic laryngeal papillomatosis. The emergency laser surgery was initiated with HFJV but severe oxygen desaturation occurred. The operation was finished with tracheostomy after emergency intubation. However, the need for intubation described in the previous study was 4.5%.[25] Although body mass index (BMI) was associated with respiratory complications[25], there was a high success rate for jet ventilation in a case series among obese and morbidly obese patients who underwent airway surgery for subglottic and tracheal stenosis.[26]

In addition, 1 case reported “airway fire” - a rare complication in HFJV. The patient underwent microscopy with carbon dioxide laser surgery. Anesthesia with HFJV was conducted using a tubeless supraglottic approach via rigid bronchoscope, but lack of communication occurred between the anesthesia resident and the case unfamiliar surgeon. The anesthesia resident did not reduce the oxygen fraction before the laser started. Ignition and superficial burn around perioral small area occurred within 5 minutes after the laser was started. No intraoral and laryngeal burn was found after rigid bronchoscopic examination. The surgery finished with conventional tracheal tube intubation. Delayed discharge from the hospital occurred. Airway fire is one of the most frequent complications during laser surgery for laryngotracheal procedures but is rarely reported in HFJV, especially in the supraglottic approach.[27] The contributing factors were the oxygen-enriched atmosphere from lack of experience and coordination with the team. Moreover, types of irradiated tissue (fat, cartilage, muscle) and laser power were contributing factors as well.[28] This incident was preventable with more supervision, additional training and adherence to the guidelines of airway fire prevention in laser surgery.

Additional roles of anesthesia with HFJV: HFJV was successful not only for the laryngotracheal and ENT procedures, but also for bronchial procedures or thoracic surgery as reported in other studies.[26] Another novel advantage is minimizing surgical field movement in many necessary motionless interventions such as thermal ablation of solid tumors, extracorporeal shock wave lithotripsy and some cardiologic interventions.[26,29] Furthermore, combination of HFJV and transnasal high flow oxygen cannula showed benefits, such as maintaining oxygenation in a recent case report.[30]

There were some limitations in the present study. First, some information was missing due to the nature of this being a retrospective study. Second, the sample size was not calculated. Third, no comparison in terms of outcome of safety to other common techniques such

as low frequency jet ventilation or apneic method was conducted.

Conclusion

Among a variety of possible anesthetic techniques for laryngotracheal procedures, anesthesia with HFJV is an excellent choice of anesthesia because the surgeons can operate the surgical fields using microlaryngoscopy or a bronchoscope with unhindered and moveless surgical field. In Thailand, safety and complication was within the acceptable rate under experienced hands.

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What is already known on this topic?

Anesthesia with HFJV for laryngotracheal procedures has been reported the safe and having low complications for decades. This technique requires experienced anesthesiologists, surgeons who are familiar with it, and also appropriate equipment.

What this study adds?

We report a case series including data on safety and adverse events from a tertiary university hospital. This report provides the anesthetic management for this technique under a limited resource context.

Keywords: High frequency jet ventilation, tracheolaryngeal procedures, patient safety, complications, airway management

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