The Laryngoscope

Utility of Transnasal Humidified Rapid Insufflation Ventilatory Exchange for Microlaryngeal Surgery

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Objective: Microlaryngeal surgery typically requires oxygenation and ventilation via either an endotracheal tube (ETT), jet ventilation (JV), or intermittent apnea with an ETT. Transnasal Humidified Rapid Insufflation Ventilatory Exchange (THRIVE) delivered by high flow nasal cannula has been reported as an alternative technique. This method of apneic oxygenation and ventilation allows for stable, unobstructed visualization of immobile laryngeal structures. We aim to describe the technique and characterize intraoperative parameters related to its safety.

Study Design: Case Series.

Methods: The electronic medical record was reviewed for patients who underwent microlaryngoscopy using THRIVE technique. Patient demographics, procedural details, operative parameters, and anesthesia records were reviewed. Descriptive statistics were reported.

Results: A total of 53 patients underwent microlaryngoscopy using THRIVE as the sole method of ventilation, with 62% female. Median age was 51 years, and median BMI was 25 kg/m^2. Most patients were ASA class 2, and most had a Mallampati score of 2. The most common surgical indications were subglottic stenosis, vocal fold lesions, and vocal fold paralysis. Median apnea time was 16 minutes. At the end of case, median end tidal CO_2 was 50 mmHg, and median minimum SpO_2 was 95. Six cases required supplementation of THRIVE with JV or tracheal intubation for sustained oxygen desaturation. There was an increase in end tidal CO_2 of 0.844 mmHg/min of apneic time.

Conclusions: THRIVE is a safe and effective technique for oxygenation and ventilation in microlaryngeal, non-laser surgery in appropriately selected patients. To ensure safety, back-up plans such as jet ventilation and microlaryngeal ETT should be available.

Key Words: THRIVE, microlaryngeal surgery, high-flow nasal oxygen, otolaryngology, apneic oxygenation.

Level of Evidence: 4

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INTRODUCTION

Microlaryngeal surgery typically requires oxygenation and ventilation via either an endotracheal tube (ETT), jet ventilation (JV), or intermittent apnea with an ETT. Each of these methods has its own disadvantages—ETT often obscures the posterior glottis, JV often causes movement in the delicate structures of the larynx, and intermittent apnea introduces frequent interruptions. Transnasal humidified rapid insufflation ventilatory exchange (THRIVE), or also termed High Flow Nasal Oxygenation (HFNO), is an apneic oxygenation and ventilation technique that addresses these challenges. THRIVE utilizes a special device (Fig. 1) capable of delivering continuous, warmed, and humidified oxygen of varying FiO_2 up to 100% at a high flow rate of up to 70 L/min via a nasal cannula. This method was first introduced in the perioperative literature in 2015 as a way to avoid hypoxemia in sedated, spontaneously breathing patients during difficult airway management, but has evolved into a way of providing apneic oxygenation and ventilation during laryngopharyngeal surgery (Fig. 2) even when the patient is paralyzed and apneic.[1] Although high flow oxygen has been used in other settings, such as the intensive care unit, and for preoperative pre-oxygenation, this report focuses on its use as the only method of oxygenation and ventilation during microlaryngoscopy.

The concept of aventilatory mass flow demonstrated in the late 1950s[2] allows for oxygenation to occur in the absence of ventilation due to the pressure gradient generated from the difference between alveolar rates of oxygen removal and carbon dioxide excretion.[3,4] As long as airway patency is maintained, apneic oxygenation can occur. Apneic oxygenation alone, however, does not account for the lower than expected rise of carbon dioxide during THRIVE, which additionally provides apneic ventilation. Although the mechanism of this apneic ventilation is poorly understood, some propose that it is due to continuous high flow insufflation creating turbulent flow, thereby allowing for carbon dioxide clearance through gaseous mixing and dead space flushing.[1] In

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Fig. 1. An Optiflow device (Fisher and Paykel Healthcare, Auckland, New Zealand) capable of delivering humidified and warmed high flow oxygen up to 70 L/min with an FiO2 up to 100% through a specialized nasal cannula.

addition, there seems to be a role for cardiogenic oscillations in assisting in ventilation.[5] Given the ability of THRIVE to oxygenate as well as clear carbon dioxide in an otherwise apneic patient, it is particularly suited for microlaryngeal surgery given the patent airway provided by suspension laryngoscopy, relatively short operative times, and the advantage of a stable and completely unobstructed operative field. Here, we aim to describe the utility and safety of the THRIVE technique in a cohort of patients undergoing microlaryngeal procedures.

MATERIALS AND METHODS

This case series was approved by our institutional review board. The electronic medical record was reviewed for patients who underwent microlaryngeal surgery with the THRIVE technique between December 2018 and January 2020. Data collected included patient's age, sex, body mass index (BMI), American Society of Anesthesiologists Physical Status Class (ASA Class),

Fig. 2. High Flow Nasal Oxygenation, the so-called Transnasal Humidified Rapid Insufflation Ventilatory Exchange (THRIVE) during suspension laryngoscopy and balloon dilation procedure.

Mallampati score, procedure indication, total apneic time, end tidal carbon dioxide (CO_2) at end of case, heart rate, blood pressure, and oxygen saturation (SpO_2) at end of case when available, minimum SpO_2, and adverse events or need for intubation. Apneic time was considered from the time of anesthetic induction to resumption of ventilation. End tidal CO_2 was measured by capnography. All statistical analysis was performed in SPSS v.25 (IBM, Armonk, USA). Two-tailed significance levels were prespecified at $\alpha = 0.05$.

The analyzed patients underwent relatively uniform anesthetic management. Patients were premedicated with intravenous (IV) midazolam. After adequate pre-oxygenation, IV induction of anesthesia was performed with propofol, lidocaine, and fentanyl, along with rocuronium for neuromuscular paralysis. Once the patient was apneic, mask ventilation was instituted for approximately 2 minutes until the muscle relaxant took effect. At this point, the mask was removed and replaced with the high flow cannula, and suspension laryngoscopy was performed. Anesthesia was then maintained with IV infusion of propofol, as well as remifentanil. THRIVE was maintained at 70 L/minutes at 100% FiO_2. Once the procedure was completed and the laryngoscope removed, an oral airway was applied to keep the airway open while THRIVE was continued. Muscle relaxant was then reversed, and the propofol and remifentanil infusions were stopped, allowing the patient to emerge from anesthesia. As ventilatory efforts were observed, the oxygen flow rate was gradually decreased until the patient was fully awake, and the high flow cannula was replaced with a standard nasal cannula at a rate of 2–4 L/minutes. In obese patients or those with residual deep neuromuscular blockade, a supraglottic airway was inserted upon removal of the suspension laryngoscope for ventilation during emergence from anesthesia at the anesthesiologist's discretion. The first $EtCO_2$ value obtained after insertion of the supraglottic airway was reported. In all cases, we had available jet ventilation equipment as well as variable sizes of microlaryngeal tubes (MLT) to supplement or replace THRIVE if it proved to be inadequate. Descriptive statistics are reported as median (range) or percentage as appropriate. Given the lack of parametric testing, a normality test was not performed.

RESULTS

A total of 53 patients underwent THRIVE as the sole method of ventilation during microlaryngeal surgery between December 2018 and January 2020, with 62% females (see Table I). Median age was 51 years (19–75), and median BMI was 25 kg/m^2 (19–50). Most patients were ASA class 2 (45%) and had a Mallampati score of 2 (49%). The most common surgical indications were subglottic stenosis, vocal fold lesions, and vocal fold paralysis. Performed procedures included use of cold instruments, steroid injection, vocal fold augmentation, and balloon dilation.

TABLE I.
Patient Characteristics of Cohort.

Patient Characteristics (n = 53)	Median/Count (range/percent)
Age (years)	51 (19–75)
Female	33 (62%)
BMI (kg/m^2)	25 (19–50)
ASA	
Class I	3 (6%)
Class II	24 (45%)
Class III	21 (40%)
Class IV	5 (9%)
Mallampati	
Score I	20 (38%)
Score II	26 (49%)
Score III	7 (13%)
Indication for Surgery	
Subglottic stenosis	16 (30%)
Vocal fold lesion	17 (32%)
Polyp	2 (4%)
Nodules	5 (9%)
Cyst	1 (2%)
Papillomatosis	3 (6%)
Unspecified	6 (11%)
Vocal fold paralysis	10 (19%)
Laryngeal web	2 (4%)
Spasmodic dysphonia	1 (2%)
Vocal fold scar	2 (4%)
Vocal fold atrophy	1 (2%)
Chronic laryngitis	1 (2%)
Laryngeal spasm	1 (2%)
Infraglottic mass	2 (4%)

TABLE II.
Intraoperative Parameters.

Intraoperative Parameters	Median (range)
Apnea Time (min)	16 (4–42)
HR at end case (bpm)	80 (53–120)
Systolic BP at end case (mmHg)	138 (103–186)
Diastolic BP at end case (mmHg)	76 (51–101)
End tidal CO_2 at end case (mmHg)	50 (23–76)
SpO_2 at end case (%)	98 (90–100)
SpO_2 nadir (%)	95 (75–100)

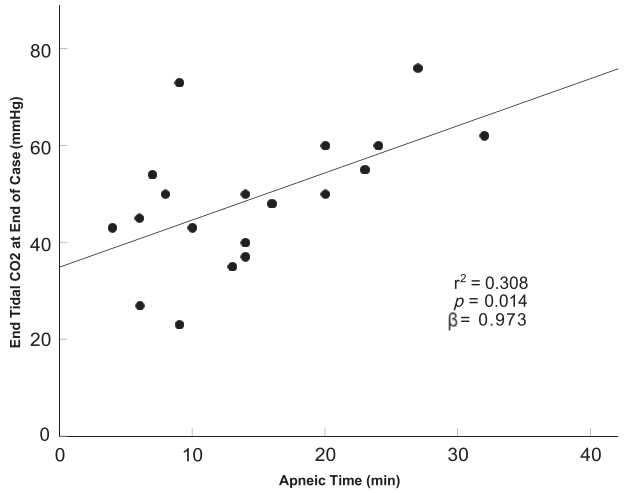

Fig. 3. Correlation between end tidal CO2 at the end of case and apnea time for 23 patients.

Median apnea time was 16 minutes (4–42), and median minimum SpO_2 was 95% (see Table II). Of the 23 patients who had end tidal CO_2 recorded at the end of case, the median was 50 mmHg (23–76). A total of 12 patients had oxygen saturations decrease below 90%. While six patients quickly recovered normal oxygen saturations with supplementation of a few breaths utilizing jet ventilation equipment, six required intermittent endotracheal intubation for sustained oxygen desaturation. It was noted, however, that the number of ETT insertions to accomplish the procedure was much lower than previous experience without the THRIVE technique, indicating marked prolongation of the apnea period. One patient with a BMI of 42 undergoing surgery for chronic laryngitis desaturated into the high 80s after insertion of the laryngoscope. Another patient with laryngeal papillomatosis had bronchospasm and bleeding, and he desaturated to 88% after 20 minutes of THRIVE. Two patients were intubated due to difficulty visualizing the inferior aspect of a large mass and bleeding. A patient with a BMI of 40 was intubated after 14 minutes due to oxygen saturation dropping below 90%. One patient with a BMI of 31 undergoing surgery for removal of vocal fold nodules desaturated to 75% after 8 minutes of THRIVE and was intubated.

When looking at correlations between intraoperative parameters, there was a statistically significant positive correlation between end tidal CO_2 at the end of the case and apneic time (Fig. 3; $P < .02$). There was a 0.844-mmHg increase in end tidal CO_2 for every minute of apneic time ($r^2 = 0.25$). There were not any statistically significant correlations between BMI and any other intraoperative parameter.

DISCUSSION

THRIVE is a safe alternative ventilatory technique that addresses the drawbacks of other methods during microlaryngeal surgery, such as vocal fold movement with jet ventilation, obscured posterior view with ETT, and the trauma and interruptions of intermittent intubations. Our study is the first to demonstrate safety in a large cohort of US adults.

The results of other reports corroborate the data presented here. A 2018 study of 19 patients in France[6] had similar indications for the use of THRIVE in laryngeal surgery. The most common limitation requiring termination of THRIVE was related to obesity. However, they also had a longer mean apnea time at 27 minutes.[6] Gustafsson et al. found that patients with an ASA class of 2 or below and BMI <30 remained well-oxygenated for up to 30 minutes.[7] High BMI seems to be one of the more limiting patient characteristics in the use of THRIVE given its association with lower functional residual capacity. Huang et al. found that patients with a BMI >30 or weight >80 kg had more than five times the odds of needing rescue ventilation.[8] In contrast, To et al. showed that patients with subglottic stenosis had good success even with BMI >30.[9] Of the 13 patients in our cohort who had a BMI >30, four required rescue intubation. Waters et al. found that patients with a BMI >25 desaturated sooner, although most patients maintained high oxygen saturations up to 20 minutes.[10] In our cohort, only one case of the aforementioned 12 patients exceeded 20 minutes of apneic time, which may explain the relative paucity of adverse events. Of note, prior to the start date of this study, we had an experience with a patient of normal BMI who tolerated the technique for 90 minutes without any desaturation for a prolonged complex laryngeal procedure. This demonstrates the ability of THRIVE to extend the apneic time significantly more than expected in select patients.

In addition to BMI, certain characteristics and complications of vocal fold lesions could predispose to inadequacy of THRIVE. Two of our patients required rescue intubation due to bleeding of the mass or poor visualization of a large tumor. Similarly, a case series out of Taiwan that evaluated 23 patients undergoing THRIVE for microlaryngeal surgery found it to be relatively safe, with only one patient experiencing desaturation due to a large mass that was prone to bleeding.[11]

Our rate of rise in end tidal CO_2 at 0.844 mmHg per minute or 0.11 kPa per minute is very similar to that found in other studies.[1,9,10] Using capnography measurements, however, is limited to only beginning and end of case measurements. Conversely, transcutaneous CO_2 (Fig. 4A,B) is a continuous measure that seems to correspond well with arterial levels.[7] Its use intraoperatively, however, may be impractical due to the time needed for the subcutaneous CO_2 monitor to set up and begin functioning given the short duration of these surgeries in addition to the issue of a noted delay (lag period) between device readings and the arterial $PaCO_2$.

Although none of the cases presented here used laser, some studies have reported the use of THRIVE during potassium titanyl phosphate (KTP) as well as CO_2 laser cases without adverse events or airway fire.[12] Huang et al[8] used KTP laser with THRIVE in 11 cases without any adverse events by turning THRIVE off for 40 seconds prior to laser use. Lau et al was able to use CO_2 laser by decreasing fraction of inspired oxygen to 30% and suctioning airway gases.[13]

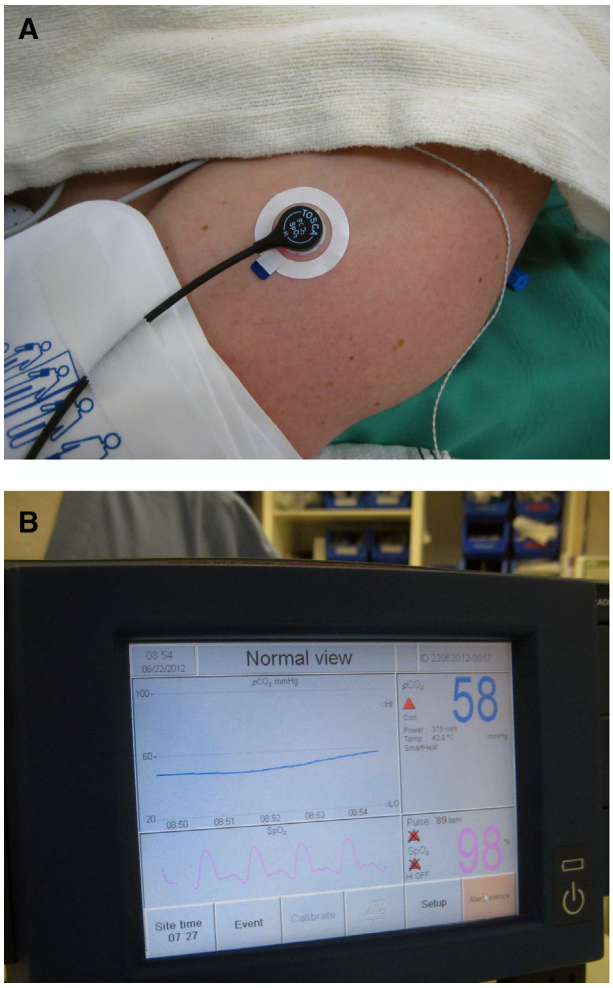

Fig. 4. (A) A trancutaneous CO_2 sensor, and (B) a transcutaneous CO_2 monitor.

However, there is one report of ignition of the monopolar diathermy grip during palate surgery using THRIVE when an arc arose from the diathermy tip to a titanium implant.[14] Due to such concerns and the paucity of data confirming this technique's safety regarding the risk of airway fires, lasers, cautery and Coblation were not used in any of our cases utilizing THRIVE.

CONCLUSION

THRIVE is a safe and effective oxygenation and ventilation technique that addresses the disadvantages of other methods during microlaryngeal surgery. The failure rate of 11% seen in our cohort demonstrates the

importance of careful patient selection for optimal outcomes. When possible, higher success is anticipated with patients with BMI <30. Back-up equipment and plans, such as jet ventilation and intermittent ventilation through an ETT should be readily available to supplement inadequate oxygenation and ventilation with THRIVE.

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