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WILEY
The Safety and Efficacy of Transnasal Humidified Rapid-Insufflation Ventilatory Exchange for Laryngologic Surgery

Vladimir Nekhendzy, MD, FASA; Amit Saxena, MD; Brita Mittal, MD; Eric Sun, MD, PhD; Kwang Sung, MD; Karuna Dewan, MD; Edward J. Damrose, MD, FACS

INTRODUCTION

Since its introduction to clinical anesthesia practice by Patel and Nouraei in 2015,1 transnasal humidified rapid-insufflation ventilatory exchange (THRIVE) has been rapidly gaining popularity as the sole ventilatory technique for adult laryngologic surgery. With patients anesthetized and apneic, THRIVE delivers fully conditioned oxygen (O2) through a specialized nasal cannula at or above 70 L/minute, which leads to flow-dependent flushing of anatomical dead space, decreased airway resistance, generation of positive airway pressure and lung recruitment, and enhanced oxygenation and gas exchange due to interactions between the highly turbulent oxygen vortices and cardiogenic oscillations.1-9 Intraoperatively, a combination of THRIVE-induced apneic oxygenation and apneic ventilation may alleviate the need for tracheal intubation (TI) or jet ventilation (JV) and may afford the surgeon with a fully exposed, unobstructed, and highly stable surgical field (Fig. 1).10-15

A number of small prospective observational trials and case reports demonstrated the feasibility of THRIVE as an alternative to conventional ventilation during adult laryngologic surgery. Gustafsson et al.10 studied 30 nonobese patients and recorded only one episode of peripheral oxygen desaturation (SpO2) to 91% during 22.5 (±4.5) minutes of apnea. Lyons and Callaghan11 reported a series of 28 patients with a median apnea time of 19 minutes (interquartile range [IQR] 9 through 37 minutes), with only four patients desaturating briefly to SpO2 85% to 90%. To et al.12 reported successful use of THRIVE in 17 cases of endoscopic treatment of subglottic stenosis, with the median apnea time of 18 minutes (IQR 10 to 27 minutes)
and two instances of desaturation to 80% and 83%. In both Lyons and Callaghan and To et al.’s studies,\textsuperscript{11,12} intraoperative hypoxemia was quickly corrected with increased oxygen flow rate, institution of bag-mask, or supraglottic airway ventilation, or following deflation of the subglottic balloon dilation device. As satisfying as these reports are, no THRIVE studies to date have attempted to assess anesthesia-related, surgical, and patient outcomes in an interventional trial setting. We therefore embarked on a prospective, randomized, patient-blinded, 2-arm parallel pilot trial to investigate both the safety and the efficacy of THRIVE use for adult nonlaser laryngologic surgery. We sought to explore the effects of THRIVE on patients’ intraoperative oxygenation and anesthesia awakening/extubation time (primary anesthesia outcomes); on surgical interventions, such as suspension time, number of suspension adjustments, surgical duration (primary surgical outcomes); and on patients’ immediate and postdischarge recovery profile (secondary outcomes).

**MATERIALS AND METHODS**

The study was prospectively registered at ClinicalTrials.gov (NCT03091179, principal investigator Vladimir Nekhendzy, MD) and conducted at the Stanford University Medical Center (SUMC) (Stanford, CA) according to Good Clinical Practice and the Consolidated Standards of Reporting Trials (CONSORT) guidelines between March 2017 and July 2018.

**Study subjects**

With SUMC Institutional Review Board approval and informed written patient consent, we prospectively studied 20 American society of anesthesiologists (ASA) physical status 1 to 3 patients aged 18 to 80 years presenting for elective nonlaser
laryngologic surgical procedures. The patient exclusion criteria are listed in Appendix S1. There were no restrictions imposed on the subjects' ethnic background, race, or gender.

The enrolled subjects were scheduled to undergo general anesthesia for operative microdirect laryngoscopy (MDL) with either vocal cord surgery (e.g., excision, biopsy, injection laryngoplasty) or endoscopic treatment of subglottic stenosis. Procedure duration was expected not to exceed 30 minutes. Subjects were distributed in a 1:1 ratio to two intraoperative ventilation groups by a randomly assigned study envelope. Intraoperative gas exchange in the experimental group was managed with THRIVE and in the active comparator group with either TI and mechanical ventilation or with supraglottic high-frequency JV (SHFJV) administered via operating laryngoscope. Patients were blinded to the intraoperative ventilatory modality that was used.

Sample size estimation
A priori sample size estimation (effect size) was not performed due to the overwhelmingly observational nature of previous THRIVE-MDL studies, which left the variability in the comparator group and a clinically meaningful difference for the investigated outcomes between the groups unknown. Although we initially aimed at enrolling 40 patients, the interim analysis of the results for the first 20 subjects demonstrated adequate power for some of the primary outcomes. It also showed that even with the full planned patient enrollment, the study would be underpowered to detect other possible outcome differences. The study was terminated at 20 patients, and our results should be considered largely exploratory.

Study protocol
Anesthetic management for all patients was standardized and conducted by the members of the SUMC head and neck anesthesia group (V.N., A.S., B.M.). The surgeries were performed by the SUMC laryngologists (E.D., K.S., K.D.). After premedication with intravenous (IV) midazolam (0.5 to 2 mg) and application of standard operating room monitors, general anesthesia was induced with IV remifentanil 1 μg/kg and IV propofol 2 mg/kg, and muscle relaxation was facilitated with IV rocuronium 0.6 mg/kg. Anesthesia was maintained with IV infusions of propofol and remifentanil, manually titrated to maintain patient’s adequate hypnotic state (SedLine Brain Function Monitor, Masimo Co., Irvine, CA) and intraoperative hemodynamic stability (mean arterial pressure [MAP] within 20 mm Hg from preoperative baseline).

THRIVE was administered using the OptiFlow system (Fischer & Paykel Healthcare, Auckland, New Zealand) according to the protocol established in our institution (Appendix S2) (Fig. S1). Our modified THRIVE discontinuation criteria\textsuperscript{10,16} included surgical duration over 40 minutes (current rate of rise of PaCO\textsubscript{2} estimate: 1.1 mm Hg/minute [0.15 kPa/minute]\textsuperscript{10} to 1.8 mm Hg/minute [0.24 kPa/minute]\textsuperscript{10}); intraoperative hypoxemia manifested as SpO\textsubscript{2} < 90% and declining, not relieved by increased oxygen flow and/or correction of possible equipment-related and/or surgical iatrogenic causes (Appendix S2); and/or occurrence of malignant cardiac arrhythmias. In the TI/SHFJV group, patients were either orotracheally intubated with a 5.0 mm ID microlaryngeal tracheal (MLT) tube and mechanically ventilated with a mixture of O\textsubscript{2} and air (FI\textsubscript{O2} = 0.5) to maintain intraoperative normocapnia (EtCO\textsubscript{2} 35 to

![Fig. 2. CONSORT flow diagram. CONSORT = Consolidated Standards of Reporting Trials; QoR15 = quality of recovery questionnaire; VHI-10 = voice handicap index questionnaire.](image-url)
40 mm Hg), or they were jet-ventilated. TI was preferred for vocal fold procedures and SHFJV for subglottic procedures. SHFJV was administered using the Monsoon III automated jet ventilator (Acutronic Medical Systems, Hirzel, Switzerland) at a rate of 150 cycles per minute, FiO2 1.0, inspiratory time 40%, and driving pressure calculated according to the formula: lean body weight (kg) × 0.4. Transcutaneous CO2 was not monitored in THRIVE and SHFJV groups because such monitoring is not available in our institution.

At the conclusion of surgery, patients received routine antiemetic prophylaxis with IV ondansetron; neuromuscular blockade was reversed with IV sugammadex; and patients were transferred to the postanesthesia care unit (PACU) upon emergence from anesthesia. The PACU orders and discharge-ready criteria were standardized.

The PACU recovery outcomes included the time to full patient’s alertness and orientation, discharge-ready time, patients’ pain scores, and total opioid consumption calculated in oral morphine milligram equivalents. The pain scores were assessed on a standard 11-point numerical rating scale (range 0 to 10: 0, no pain; 10, worst pain imaginable). The postoperative functional patient outcomes were evaluated through self-reported questionnaires: Voice Handicap Index (VHI-10) and Quality of Recovery profile (QoR-15). The VHI-10 reproducibly assesses patient’s quality of life related to voice handicap in 10 questions, each scored on a 5-point scale from 0 (never) to 4 (always), with the lowest scores corresponding to the better outcomes. The VHI-10 was recorded by patients preoperatively and during the first postoperative visit 4 weeks after surgery. The QoR-15 is a validated multidimensional assessment of a patient’s physical and mental well-being during recovery after a broad range of surgical procedures. It is evaluated on an 11-point numerical rating scale (0 to 10), with a higher total score corresponding to improved recovery. The QoR-15 was reported by patients preoperatively and at the end of the first week after surgery.

**Statistical analysis**

Data are presented as means (±standard deviations) or numbers (%). The statistical significance of differences between the THRIVE and the TI/SHFJV groups was assessed using an unpaired two-sample t test for all patient characteristics except gender, for which a chi-square test was used. Due to the exploratory nature of the study, we did not adjust the statistical significance threshold for multiple comparisons. All analyses were conducted using STATA 14.0 (StataCorp, College Station, TX).

**RESULTS**

A total of 20 patients were recruited and completed the study protocol in full, with the exception for two patients in each group who did not submit postoperative questionnaires (CONSORT flow diagram; Fig. 2). The collected data set was successfully analyzed for primary and secondary outcomes.

Both patient groups were comparable with respect to baseline characteristics, although more patients with subglottic stenosis were allocated to the THRIVE group, and all patients for injection laryngoplasty were assigned to the TI/SHFJV group (Table I). Intraoperatively, there were no differences between the groups with regard to hemodynamic stability (MAP, heart rate), hypnotic state, or IV fluid administration (data not shown). There were no intraoperative or postoperative anesthesia-related or surgical complications in any group.

**Primary anesthesia outcomes**

All surgeries in the experimental group were completed successfully only using THRIVE (Table II), and none of the patients required airway support beyond basic airway maneuvers (e.g., jaw thrust, oral airway insertion) during anesthesia induction and emergence. A statistically significant lower intraoperative oxygenation was observed in the THRIVE group over mean apnea time of 29.9 (±10.4) minutes: SpO2 93.0 ±5.6% versus 98.7 ±1.6%, mean difference 5.7% with 95% confidence interval (CI) 1.80 to 9.60; P = 0.0066 (Table II).

Figure 3 presents the lowest SpO2 value for each individual THRIVE patient during the period of apnea. In three instances, SpO2 briefly decreased to 84%, 85%, and 88% secondary to dilation catheter balloon inflation and tight packing of the surgical area with epinephrine-soaked cottonoids (two patients) and to a displaced Optiflow cannula (Fischer & Paykel Healthcare) (one patient). All three deoxygenation episodes were promptly corrected by addressing the underlying cause, and none of the patients met THRIVE discontinuation criteria. In the remaining

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<table>
<thead>
<tr>
<th>Study Endpoints</th>
<th>THRIVE (N = 10)</th>
<th>ETT/SHFJV (N = 10)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary anesthesia outcomes</strong></td>
<td></td>
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</tr>
<tr>
<td>Lowest intraoperative SpO₂ (%)</td>
<td>93.0 (±5.6)</td>
<td>98.7 (±1.6)</td>
<td>.0066</td>
</tr>
<tr>
<td>Mean difference 5.7, 95% CI [1.80, 9.60]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awakening/extubation time (min)</td>
<td>10.3 (±4.0)</td>
<td>9.4 (±3.4)</td>
<td>.59</td>
</tr>
<tr>
<td>Mean difference −0.9, 95% CI [−4.39, 2.59]</td>
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<td></td>
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<tr>
<td><strong>Other anesthesia outcomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jet ventilation/tracheal intubations</td>
<td>0/0</td>
<td>4/6</td>
<td></td>
</tr>
<tr>
<td>Spontaneous ventilation (min)</td>
<td>5.7 (±3.50)</td>
<td>8.3 (±3.9)</td>
<td>.11</td>
</tr>
<tr>
<td>Mean difference 2.6, 95% CI [−6.22, 7.04]</td>
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<td></td>
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<tr>
<td>Apnea time (min)</td>
<td>29.9 (±10.4)</td>
<td>39.2 (±12.7)</td>
<td>.10</td>
</tr>
<tr>
<td>Mean difference 9.3, 95% CI [−0.56, 19.16]</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Duration of anesthesia (min)</td>
<td>34.6 (±11.8)</td>
<td>40.7 (±12.9)</td>
<td>.28</td>
</tr>
<tr>
<td>Mean difference 6.1, 95% CI [−5.51, 17.71]</td>
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<td></td>
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<tr>
<td>Total propofol dose (mg)</td>
<td>366.5 (±77.3)</td>
<td>420.4 (±259.3)</td>
<td>.54</td>
</tr>
<tr>
<td>Mean difference 53.9, 95% CI [−125.84, 233.64]</td>
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</tr>
<tr>
<td>Total remifentanil dose (μg)</td>
<td>374.6 (±151.9)</td>
<td>438.8 (±247.2)</td>
<td>.49</td>
</tr>
<tr>
<td>Mean difference 64.2, 95% CI [−128.58, 256.98]</td>
<td></td>
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<tr>
<td><strong>Primary surgical outcomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to suspension (min)</td>
<td>1.8 (±1.1)</td>
<td>4.3 (±2.1)</td>
<td>.0040</td>
</tr>
<tr>
<td>Mean difference 2.6, 95% CI [0.91, 4.09]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of suspension adjustments</td>
<td>0.4 (±0.5)</td>
<td>1.7 (±0.9)</td>
<td>.0013</td>
</tr>
<tr>
<td>Mean difference 1.3, 95% CI [0.58, 2.02]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of surgery (min)</td>
<td>19.1 (±10.8)</td>
<td>20.9 (±8.8)</td>
<td>.69</td>
</tr>
<tr>
<td>Mean difference 1.8, 95% CI [−7.48, 11.08]</td>
<td></td>
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<tr>
<td><strong>Secondary patient outcomes: PACU</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alert, oriented × 4 (min)</td>
<td>4.3 (±6.3)</td>
<td>4.8 (±7.4)</td>
<td>.87</td>
</tr>
<tr>
<td>Mean difference 0.5, 95% CI [−5.92, 6.92]</td>
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<td></td>
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<tr>
<td>Discharge-ready time (min)</td>
<td>65.7 (±43.4)</td>
<td>77.7 (±42.8)</td>
<td>.54</td>
</tr>
<tr>
<td>Mean difference 12.0, 95% CI [−28.52, 52.52]</td>
<td></td>
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<tr>
<td>First pain score</td>
<td>1.3 (±1.9)</td>
<td>3.7 (±2.9)</td>
<td>.044</td>
</tr>
<tr>
<td>Mean difference 2.4, 95% CI [0.07, 4.72]</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Discharge-ready pain score</td>
<td>0.9 (±1.3)</td>
<td>2.7 (±1.8)</td>
<td>.018</td>
</tr>
<tr>
<td>Mean difference 1.8, 95% CI [0.35, 3.25]</td>
<td></td>
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<tr>
<td>Analgesic consumption (oral morphine milligram equivalents, MME)</td>
<td>8.7 (±11.0)</td>
<td>22.5 (±22.1)</td>
<td>.09</td>
</tr>
<tr>
<td>Mean difference 13.75, 95% CI [−2.69, 30.18]</td>
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<tr>
<td><strong>Secondary patient outcomes: Functional</strong></td>
<td></td>
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<tr>
<td>VHI-10 score preoperative</td>
<td>12.8 (±12.6)</td>
<td>22.7 (±12.1)</td>
<td>.09</td>
</tr>
<tr>
<td>Mean difference 9.9, 95% CI [−1.70, 21.50]</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>VHI-10 score postoperative</td>
<td>7.6 (±12.2)</td>
<td>13.6 (±13.2)</td>
<td>.30</td>
</tr>
<tr>
<td>Mean difference 6.0, 95% CI [5.95, 17.95]</td>
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<td></td>
<td></td>
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<tr>
<td>QoR15 score preoperative</td>
<td>132.3 (±16.2)</td>
<td>119.5 (±22.9)</td>
<td>.17</td>
</tr>
<tr>
<td>Mean difference −12.7, 95% CI [31.37, 5.97]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QoR15 score postoperative</td>
<td>142.5 (±15.7)</td>
<td>131.2 (±17.9)</td>
<td>.19</td>
</tr>
<tr>
<td>Mean difference −11.3, 95% CI [−28.80, 6.24]</td>
<td></td>
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</table>

CI = confidence interval; min = minutes; ETT = endotracheal tube; MME = morphine milligram equivalents; PACU = postanesthesia care unit; THRIVE = transnasal humidified rapid-insufflation ventilatory exchange; QoR-15 = Quality of Recovery profile-15 Item; SHFJV = supraglottic high-frequency jet ventilation; SpO₂ = peripheral oxygen desaturation; VHI-10 = Voice Handicap Index-10.

Awakening/Extubation time = recorded from the end of surgery until the return of patient’s protective airway reflexes and patient opening eyes to command.

Time to spontaneous ventilation = recorded from the discontinuation of anesthetic drugs to the return of patient’s spontaneous ventilation.

Apnea time = recorded from induction of anesthesia to the return of spontaneous ventilation.

Duration of anesthesia = recorded from induction of anesthesia to patient’s awakening/extubation.

Time to suspension = recorded from the moment of the introduction of the operating laryngoscope in patient’s mouth to full surgical suspension.

Duration of surgery = recorded from the moment of the introduction of the operating laryngoscope in patient’s mouth to withdrawing the laryngoscope at the completion of surgery.

Alert, oriented × 4 = recorded from patient’s admission to the postanesthesia care unit (PACU) to patient’s orientation to person, place, time, and situation.

PACU discharge-ready time = recorded from patient’s PACU admission to fulfilling PACU discharge criteria.

VHI-10 = Voice handicap index questionnaire.

QoR15 = Quality of recovery questionnaire.
seven THRIVE patients, SpO₂ had never decreased below 91% (Fig. 3), similar to the findings by Gustaffson et al.¹⁰

The time to return of patients’ spontaneous ventilation, anesthesia awakening/extubation time, apnea time, anesthesia duration, and total dose of anesthetic drugs were not different between the study groups (Table II).

**Primary surgical outcomes**

Compared to the TI/SHFJV group, the use of THRIVE was associated with significantly shorter time to surgical suspension (1.8 ± 1.1 minutes vs. 4.3 ± 2.1 minutes, mean difference 2.5 minutes with 95% CI 0.91 to 4.09; P = .0040); fewer suspension adjustments (0.4 ± 0.5 vs. 1.7 ± 0.9, mean difference 1.3 with 95% CI 0.58 to 2.02; P = .0013) (Table II); and superior surgical visualization, as subjectively reported by the surgeons. These positive findings, however, did not translate to faster surgery [19.1 (±10.8) vs. 20.9 (±8.8), mean difference 1.8 with 95% CI between −7.48 and 11.08, P = .69] (Table II).

**Secondary outcomes**

The PACU discharge-ready times were comparable between the groups (Table II). There was a significant effect of THRIVE on lower PACU admission pain scores (1.3 ± 1.9 vs. 3.7 ± 2.9, mean difference 2.4 with 95% CI 0.07 to 4.72; P value = .044) (Table II). Although a reduction in total opioid consumption in the THRIVE group was statistically nonsignificant (8.7 ± 11.0 vs. 22.5 ± 22.1, mean difference 13.75 with 95% CI −2.69 to 30.18; P value = .09) (Table II), overall pain relief continued to be significantly better for these patients on PACU discharge (pain score 0.9 ± 1.3 vs. 2.7 ± 1.8, mean difference 1.8 with 95% CI 0.35 to 3.25; P value = .018) (Table II).

Postoperatively, patients in both groups demonstrated comparable functional improvement as assessed by total and individual domain scores in VHI-10 and QoR-15 questionnaires (Table II; individual domain scores are not shown).

**DISCUSSION**

This study represents the first focused attempt to assess anesthesia-related, surgical, and functional outcomes for patients undergoing nonlaser laryngologic surgery in an interventional THRIVE trial setting. Our results confirm a favorable THRIVE oxygenation profile for ASA 1 to 3 class patients with body mass index < 35 kg/m² undergoing common laryngologic surgical procedures of short-to-intermediate duration and provide insight into the efficacy of THRIVE use for these patients.

The mean THRIVE apnea time recorded in our study (Table II) is comparable to previous reports.¹⁰⁻¹⁵ All three episodes of moderate oxygen desaturation were iatrogenic in nature and highlight the need for constant intraoperative vigilance and close communication between the anesthesia and surgical teams. Although none of the THRIVE patients required a conversion to TI or SHFJV (Table II), intraoperative hypoxemia during THRIVE can occur due to the formation of atelectasis.¹⁹ Parke et al. have shown that administration of high-flow nasal oxygen in spontaneously breathing patients increases mean airway pressure in a flow-dependent manner (0.69 to 1.16 cm H₂O for every 10 L/minute of O₂ flow), which leads to lung recruitment.²⁻⁴ However, with the patient’s mouth open during suspension laryngoscopy, such pressure is approximately halved²⁻⁶ and therefore insufficient to recruit atelectasis and reduce shunting.²¹ In the setting of increased venous admixture, THRIVE-associated hypercapnia and ensuing acute respiratory acidosis¹,¹⁰,¹⁵ may precipitate rapid oxygen desaturation due to a rightward shift of the oxyhemoglobin dissociation curve. Appropriate backup ventilation strategies should be discussed with the surgeon, and the corresponding airway equipment should be readily available prior to anesthesia induction (Appendix S2).

Mild-to-moderate hypercapnia facilitates a return of spontaneous ventilation and increases cerebral blood flow and cardiac output, which may promote a decrease in propofol effect-site concentration and enhance propofol clearance.²²⁻²⁵ However, we did not observe this effect on time to return of spontaneous ventilation (5.7 ± 3.5 vs. 8.3 ± 3.9 minutes, mean difference 2.6 with 95% CI −6.22 to 7.04; P value = .11) (Table II) or time to patients’ awakening from anesthesia (10.3 ± 4.0 vs. 9.4 ± 3.4 minutes, mean difference −0.9 with 95% CI −4.39 to 2.59; P value = .59) (Table II). Our findings (Table II) are in agreement with Kwon et al.,²² who observed no difference between the apnea, awakening, and extubation times for hypercapnic and hypocapnic patients anesthetized with IV propofol and remifentanil.

Unimpeded surgical access to all parts of the glottis afforded by THRIVE may lead to better surgical precision, decreased surgical time, and potentially improved patient outcomes. Predictably, we found significantly shorter suspension time, fewer intraoperative suspension adjustments, and subjectively reported superior operating conditions with THRIVE; yet, surgical time was similar between the groups (Table II). Comparable surgical duration may reflect the pragmatic nature of our study, which included patients with the spectrum of laryngologic diseases, as well as the use of SHFJV in 40% of patients,
which facilitated surgery in the TI/SHFJV group (Table II). In addition, the absent need for TI likely made the total anesthesia time for this group more comparable to THRIVE. Due to the small sample size, we were unable to do a meaningful subgroup analysis for only TI cases.

Our finding that patients undergoing THRIVE had a nearly threefold reduction in mean pain scores on both PACU admission and discharge (Table II) is intriguing, especially because the intensity of postoperative pain after outpatient laryngologic surgery is usually mild.26,27 Better pain control observed in the THRIVE group could be a reflection of improved surgical precision and/or absent need for TI. Theoretically, THRIVE-associated hypercapnia and hyperoxia may reduce the incisional pain through enhanced tissue perfusion and oxygenation, counteracting local tissue acidosis, although the analgesic effect of supplemental intraoperative oxygen for other surgical patient populations has not been demonstrated to date.19

Our study was underpowered to detect a statistically significant difference in PACU opioid consumption between the groups, as indicated by a wide 95% CI (Table II). It is also possible that a lack of difference reflects, at least in part, a common nursing practice for liberal administration of postoperative opioids in order to facilitate PACU discharge.19 Our study sample was too small to reliably investigate patients’ satisfaction with pain control or to scrutinize other pain outcomes, such as maximum pain scores, pain scores preceding analgesic administration, or a proportion of patients requiring rescue analgesic medications, which were utilized in other PACU pain outcome studies.29

Notwithstanding comparable opioid consumption in both groups, superior pain control may increase patient’s satisfaction, improve functional recovery, and decrease healthcare costs.27,29 However, we did not observe any difference between the study groups with regard to patients’ postoperative functional outcomes, as assessed by VHI-10 and QoR-15 (Table II). A lower postoperative VHI-10 score can be viewed as a surrogate outcome measure for improved surgical exposure and technique; however, VHI-10 score reduction in THRIVE group was statistically nonsignificant: 7.6 (±12.2) versus 13.6 (±13.2), mean difference 6.0 with 95% CI from 5.95 to 17.95 (Table II).

**Limitations and future directions**

The limitations of our study are reflected in its pragmatic nature and small sample size, which may have increased the probability of a type II error for many studied clinical endpoints. A spectrum of laryngologic diseases, unbalanced distribution of the surgical procedures between the study groups (Table I), and a combined use of TI/SHFJV could have skewed the outcomes data.

Although THRIVE does offer certain advantages over SHFJV, such as the completely still surgical field and absent need to interrupt JV during the most delicate parts of the procedure, future THRIVE trials may wish to compare THRIVE only to TI to better reflect conventional practice of using the 5.0 ID MLT tube for either dedicated TI or apneic intermittent ventilation.30–32 Such adequately powered trials may be able to demonstrate putative advantages of THRIVE due to a higher incidence of the difficult airway observed in laryngologic surgery patients and hindered surgical visualization and access, especially for lesions involving the posterior glottis (Fig. 1).33

**CONCLUSION**

We conducted a prospective, randomized, patient-blinded, pilot trial comparing the safety and efficacy of THRIVE with conventional ventilation techniques for nonobese, adult ASA 1 to 3 patients undergoing outpatient nonlaser laryngologic surgical procedures of short-to-intermediate duration. The results of our study confirm the safe intraoperative oxygenation profile of THRIVE while highlighting the need for constant intraoperative vigilance and close communication between the surgical and anesthesia teams. THRIVE facilitated surgical exposure and improved early patient recovery by significantly reducing postoperative pain, suggesting its potential economic benefit in outpatient laryngologic procedures.

It is conceivable that THRIVE may become the ventilatory technique of choice for selected laryngologic surgical procedures, pending the results of future larger studies addressing its clinical efficacy and safety. Our exploratory results shall provide a framework for designing adequately powered THRIVE trials in a more homogenous surgical population. These trials may further benefit from comparing THRIVE only with TI, which will better reflect mainstream anesthesia and surgical practice.

Finally, we provide a protocol for safe intraoperative THRIVE use, which was developed and adopted at our institution. Anesthesiologists and surgeons need to know the advantages, disadvantages, and limitations of this technique for laryngologic surgery; this protocol helps to establish a framework within which THRIVE can be performed safely and effectively.

**BIBLIOGRAPHY**


Nekhendzy et al.: THRIVE and Laryngologic Surgery


