American Journal of Otolaryngology–Head and Neck Medicine and Surgery 43 (2022) 103605

Contents lists available at ScienceDirect

American Journal of Otolaryngology–Head and Neck Medicine and Surgery

journal homepage: www.elsevier.com/locate/amjoto

# Feasibility and safety of THRIVE in transoral laser microsurgery

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ARTICLE INFO

*Keywords:*
Apneic oxygenation
High flow nasal oxygen
THRIVE
Transoral laryngeal microsurgery
Otorhinolaryngology
Laser

ABSTRACT

*Objective:* Transnasal Humidified Rapid Insufflation Ventilatory Exchange (THRIVE) presents obvious advantage in laryngeal surgery and Transoral Laser Microsurgery (TLM). Airway fire represents a rare complication of TLM and may be the most important limitation in the use of THRIVE. The objective was to evaluate the different operating conditions of the TLM with THRIVE with regard to fire risk.

*Experiment:* In this report, we assessed the risk of fire by varying the Fraction of Inspired Oxygen (FiO2), the Laser Energy, and the placement of endolaryngeal surgical and ventilatory equipment in a porcine model for TLM.

*Results:* Fire, sparks and smoke were reported. No combustion occurred with THRIVE in the absence of an endolaryngeal material. Fire occurred systematically while delivering between 3 and 5 W Carbon dioxide (CO2) Laser direct shot on a dry laryngeal cotton. Conclusion

THRIVE-TLM should never be performed using a dry cotton or a plastic endolaryngeal material.

## 1. Introduction/background

Transoral Laser Microsurgery (TLM) is the surgical gold standard for early -Tis-T1-T2- Larynx Squamous Cell Carcinomas with excellent oncological and functional results [1]. A large vision on the surgical site is essential for oncologic and pathologic outcomes. The use of Transnasal Humidified Rapid Insufflation Ventilatory Exchange (THRIVE) is a compelling approach in laryngeal surgery allowing a better laryngeal exposure in the lack of endotracheal tubes. THRIVE delivers nasal oxygen at a high flow rate of up to 70 L/min with a Fraction of Inspired Oxygen (FiO2) up to 100 % [2].

Although rare, airway fires are described and remain a potentially serious TLM complication [3]. Ignition may occur in the combined presence of a combustible (oxygen-rich environment), an oxidizer (e.g. plastic, tissue) and an energy source (CO2-Laser) [4]. Only two studies reported the use of THRIVE in TLM and the authors did not report any adverse events in their 10 [5] and 11 [6] inpatients, respectively.

In the present study, we reported the use of a porcine laryngeal model in TLM with THRIVE in order to assess the risk of airway fires in different surgical and anesthetic conditions.

## 2. Experiment protocol

A non-randomized protocol (local ethical and research registration number: IRB000123437) was established. Conditions were gradually modified: -THRIVE parameters $FiO_2$: 21 % 30 % and 100 % under a constant flow rate of 60 L per minute; -CO2-Laser (Digital Acublade®, Lumenis Be Ltd., Yokneam, Isreal) energy of 1, 3 and 5 W in continuous laser pulsation mode for 30 consecutive seconds in a porcine laryngeal simulator for TLM.

TLM surgeries included both vestibulectomy (ventricular band resection) and cordectomy. Porcine larynxes and tracheas were consecutively used. The dimensions of the larynxes were similar in all specimens. The mean length of the membranous vocal fold was 25 mm, while the mean length of the cartilaginous vocal fold was 7 mm. The mean length of the true vocal fold was 5 mm. A system of continuous air suction was adapted to the suspension microlaryngoscopy.

Trials were gradually conducted without endolaryngeal material then with successively wet, dry cottons (Cottonoid®, Codman, Johnson and Johnson, New Brunswick, NJ, USA) and a sample of endotracheal tube. In each trial, the CO2-laser beam was focused on the material. In the final trial, a conventional endotracheal tube (Polyethylane, not laser

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https://doi.org/10.1016/j.amjoto.2022.103605
Received 6 August 2022;
Available online 11 August 2022

compatible) was placed between the vocal cords for ventilation. FiO2 and external laryngeal material conditions schema was investigated as previously described. A water syringe was available in case of combustion.

Investigators assessed the following outcomes: 1-dense smoke, 2-sparks and 3-airway fire that led to the immediate interruption of the experiment. Each trial was conducted under the same conditions, i.e. [Ventilation parameters (Thrive/Endotracheal tube ventilation parameters); CO2-Laser power (Watts); Endolaryngeal material], having a corresponding larynx. A new Larynx was used after each fire. Situations were repeated at least 3 times. No statistical analyses applied.

## 3. Results

Results are presented in Table 1. Eighteen porcine larynxes and tracheas were successively used. Fire occurred in the following situations: [Thrive: 30 % $FiO_2$, 60 L/min; CO2-Laser: 5 W; with a dry cotton], [Thrive: 100 % $FiO_2$, 60 L/min; CO2-Laser: 3–5 W; with a dry cotton], [Thrive: 100 % $FiO_2$, 60 L/min; CO2-Laser: 3–5 W; with a plastic tube] and [Endotracheal tube ventilation; CO2-Laser: 3–5 W]. No fire occurred with THRIVE in the absence of endolaryngeal material, even with 100 % $FiO_2$. No fire occurred with THRIVE while using wet cotton. However, sparks occurred in [Thrive: 30 % $FiO_2$, 60 L/min; CO2-Laser: 5 W] and in [Thrive: 100 % $FiO_2$, 60 L/min; CO2-Laser: 3–5 W].

## 4. Discussion

Finally, THRIVE-TLM with up to 5 W laser energy and even 100 % FiO2 concentration is feasible with extremely low risk of airway fires due to lack of combustion material. The endolaryngeal material placement (cotton to protect the vocal cords) is avoided. Our study is a valuable contribution to the evaluation of the feasibility and safety for the use of THRIVE in TLM.

The limitations are evident: the non-randomized uncontrolled design (which might have been difficult to achieve), the impossibility of carrying out a statistical analysis (as we thought that an open assessment of the time to cause a fire would not be relevant information as all conditions under which a fire occurred are unacceptable) and the small sample size.

**Table 1**
Incidents occurred according to THRIVE and CO2-Laser parameters.

| | 60 L/min THRIVE | | | | Intubation |
|---|---|---|---|---|---|
| 21 % $FiO_2$ | No material | Wet cotton | Dry cotton | Plastic tube | |
| 1 W | None | None | None | None | None |
| 3 W | None | Dense smoke | Sparks | None | None |
| 5 W | Dense smoke | Sparks | Sparks | Dense smoke | Dense smoke |
| 30 % $FiO_2$ | No material | Wet cotton | Dry cotton | Plastic tube | |
| 1 W | None | None | Dense smoke | None | None |
| 3 W | None | Smoke | Sparks | Dense smoke | Dense smoke |
| 5 W | Dense smoke | Sparks | Fire | Dense smoke | Dense smoke |
| 100 % $FiO_2$ | No material | Wet cotton | Dry cotton | Plastic tube | |
| 1 W | None | Dense smoke | Sparks | Sparks | Sparks |
| 3 W | Dense smoke | Sparks | Fire | Fire | Fire |
| 5 W | Dense smoke | Sparks | Fire | Fire | Fire |

Incidents assessed during 30-s continuous CO2-Laser firing in a porcine laryngeal simulator: None, Smoke, Sparks, Fire that led to interrupt the experiment. Each situation with the same conditions was repeated at least 3 times. A new Larynx was used after each fire. Eighteen larynxes were consecutively used. No live animal experimentation was performed. Cotton: Cottonoid® (Codman, Johnson and Johnson, New Brunswick, NJ, USA). CO2-Laser: Digital Acublade® (Lumenis Be Ltd., Yokneam, Isreal). THRIVE 60 L/min.

THRIVE was originally developed to provide pre-oxygenation, but has proven to be of great value in patients with difficult airways [7]. THRIVE is not simply an "apneic oxygenation" but acts as ventilation without respiratory movements: carbon dioxide is removed by continuous positive pressure induced by continuous insufflation [8]. Situations with hazardous airway management could be encountered in laryngeal and pharyngeal carcinomas. Definitive airway intubation could be challenged by anatomical deformity or bleeding. THRIVE could preventively provide a high level of oxygenation during sleep before any intubation attempt. In this regard, THRIVE has emerged as a safety technique for ENT airway management [7]. This, and the freeing up of the surgical field give THRIVE a compelling role in the management of laryngeal cancer.

The question of the safety of using of THRIVE arises. There are very few publications dealing about TLM and THRIVE [5,6]. The risk of fire is the reason for this. Several cases of ignition with High Flow Oxygen, cauterization, monopolar diathermy or Laser have been reported [9–11]. Surgeons and anesthesiologists are reluctant to use CO2-Laser without the safety of an endotracheal intubation. To date, data scientifically evaluating the possibility of fire in TLM with THRIVE or High-Flow nasal Oxygen are scarce [12–14]. Stuermer et al. [13] defined a safety zone for the use of the CO2-Laser with THRIVE: [Lasing time less than 5 s; FiO2 less than 50 %]. Our study brings some supplementary data to precise the perimeter of this safety zone. With the (potassium-titanyl-phosphate) KTP-Laser, Huang et al. [14] found a 2.3 increase in fire risk for each 10 % increase in oxygen concentration above 60 %. According to them, the continuous setting of the laser appeared statistically more dangerous that the pulsed setting [14]. A self-sustained fire could occur even in the absence of any combustible material by high level of FiO2 and energy on the contrary to the data reported in our experiment [12]. Difficult to conduct from an ethical and practical standpoint, no studies have been performed comparing the KTP and the CO2 Laser in the safety of Laser-TLM under THRIVE. Further studies should be conducted to statistically evaluate the risk of fire using CO2-Laser with THRIVE. Our porcine model could be used in the manner of Huang et al.'s study [14].

## Presentation

The present study has not been presented anywhere.

## Funding

The authors have no funding to declare in regard to this study.

## Ethical rules

The authors declare that this manuscript complies with the Declaration of Helsinki.

## Additional contributions

Additional Contributions: The authors thank Charlotte LOUBIERES, MD, Jeremy MAMAN, MD, Luigi STRINGA, MD from the Department of Otolaryngology - Head & Neck Surgery, Foch Hospital, School of Medicine, UFR Simone Veil, Université Versailles Saint-Quentin-en-Yvelines (Université Paris Saclay), France for their help with data collection.

## CRediT authorship contribution statement

Dr. Baudouin had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Baudouin, Circiu, Le Guen, Hans.

Acquisition, analysis, or interpretation of data: Baudouin, Rigal, Lechien, Couineau, Le Guen, Hans.

Drafting of the manuscript: Baudouin, Rigal, Lechien.

Critical revision of the manuscript for important intellectual content: All authors.

Administrative, technical, or material support: Circiu, Couineau, Le Guen, Hans.

Supervision: Le Guen, Hans.

## Declaration of competing interest

The authors have no conflicts of interest to declare in regard to this study.

## Acknoledgements

Assistance with the study: The authors thank Charlotte LOUBIERES, MD, Jérémy MAMAN, MD, Luigi STRINGA, MD from the Department of Otolaryngology - Head & Neck Surgery, Foch Hospital, School of Medicine, UFR Simone Veil, Université Versailles Saint-Quentin-en-Yvelines (Université Paris Saclay), France for their help with data collection.

Financial support and sponsorship: None.

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