Original Article

The use of transnasal humidified rapid insufflation ventilatory exchange in laryngeal and pharyngeal surgery: Flinders case series

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Background: Transnasal humidified rapid insufflation ventilatory exchange (THRIVE) is a new anaesthetic technique that allows for prolonged apnoeic oxygenation without intubation. THRIVE is often conducted in patients with a normal body mass index (BMI) and mild systemic disease. However, it is unclear if patients with an increased BMI or significant co-morbidities are able to safely undergo laryngeal and pharyngeal surgery with THRIVE.

Methods: A 14-month retrospective case note review was conducted in patients who underwent THRIVE for ear, nose, and throat (ENT) upper airway surgery. Factors were analysed to identify relationships with the requirement for rescue ventilation: age, BMI, American Society of Anaesthesiologists (ASA) physical status, smoking status, medical history and procedure type. An analysis was performed using non-parametric tests and odds ratios.

Results: THRIVE was used with the following upper airway procedures (n=56): microlaryngoscopy with injection laryngoplasty (n=7), microlaryngoscopy with biopsy (n=14), microlaryngoscopy with potassium titanyl phosphate (KTP) laser use (n=11), panendoscopy with biopsy (n=10), oesophageal dilatation (n=3), subglottic stenosis dilatation (n=10), and stapling of a pharyngeal pouch (n=1). Rescue bag and mask ventilation or intubation were required in 21% of cases (n=12). A weight of more than 80 kg or BMI more than 30 were 5.2 and 5.7 times respectively more likely to require rescue ventilation (Fisher Exact Test P=0.023 and P=0.021).

Conclusions: THRIVE can be safely used for a variety of laryngeal and pharyngeal procedures. However, there is a higher likelihood of rescue ventilation if the patient is over 80 kg or has a BMI over 30. Prospective investigation with a larger dataset of patients is required to validate these results.

Keywords: Transnasal humidified rapid insufflation ventilatory exchange (THRIVE); Optiflow™; apnoea time; ear, nose, and throat (ENT); upper airway surgery

Received: 30 November 2018; Accepted: 06 May 2019; Published: 29 May 2019.

doi: 10.21037/ajo.2019.05.02

View this article at: http://dx.doi.org/10.21037/ajo.2019.05.02

Introduction

Transnasal humidified rapid insufflation ventilatory exchange (THRIVE) allows for prolonged apnoeic oxygenation and ventilation during general anaesthesia (1). This technique is a recent adoption in upper airway surgery (1). Current literature demonstrates that THRIVE reduces the risks of barotrauma and soft tissue injury compared to other methods, such as jet ventilation and intubation (2,3). Additionally, THRIVE improves access to the surgical field and reduces interruptions to laryngeal procedures compared to general anaesthesia with an endotracheal tube or supraglottic jet ventilation, potentially shortening operation and total anaesthetic time (2-6).

Patel and Nouraei first described, in 2015, the use

of THRIVE in prolonging apnoea in preparation for intubation of patients with a difficult airway (1). Several studies have now demonstrated that THRIVE allows enough time for short procedures such as panendoscopy and subglottic stenosis dilatation with reported apnoea time ranging from 18–65 minutes (1,2,4). This has extended the application of THRIVE beyond simply using it for pre-oxygenation. However, numerous authors have raised concerns about using THRIVE in overweight patients. It is theorised that obese patients have reduced functional residual capacity which may decrease the apnoeic window (1,7). The aim of this study is to analyse the use of THRIVE in a range of laryngeal or pharyngeal surgeries. The secondary aim is to explore patient characteristics that may contribute to the success or failure with the use of THRIVE.

Methods

We conducted a retrospective review of all patients who underwent elective pharyngeal and laryngeal surgery using THRIVE as primary airway support for general anaesthesia at Flinders Medical Centre and Flinders Private Hospital between March 2017 to May 2018. The primary outcomes were the successful completion of the operation with the use of THRIVE alone, and the need for alternative rescue ventilation or intubation during the operation. Failure of THRIVE was defined as patients requiring alternate airway management such as bag and mask ventilation, jet ventilation or intubation with an endotracheal tube. Other details collected were patient demographics and medical history. These were used to determine whether specific patient characteristics predicted the successful use of THRIVE in upper airway surgery.

We extracted the following information from patients' case notes: patient age, gender, height, weight, BMI, American Society of Anaesthesiologists (ASA) status, smoking history, respiratory or cardiac diseases, and gastro-oesophageal reflux history requiring medication, anaesthetic details, type of laryngeal and pharyngeal procedures, oxygen flow rate, duration of apnoea, lowest oxygen saturation recorded with pulse oximeter, need for rescue ventilation, and details of rescue ventilation.

It was a joint decision between the anaesthetist and the surgeon to use THRIVE in these patients. All patients received pre-oxygenation prior to their procedure. Patients were placed on Optiflow^{TM} (Fisher & Paykel, New Zealand) at lower flow rates of 30–40 L min^{-1} as pre-oxygenation. The duration of pre-oxygenation was often poorly documented in the case notes. The rationale for lower flow rate during pre-oxygenation was for patient comfort. All patients received total intravenous anaesthesia with opioid analgesia and propofol infusion. Neuromuscular blockade (rocuronium, vecuronium or mivacurium) was used in 84% (n=37) of patients in those without rescue ventilation, and 92% (n=11) in those with rescue ventilation. Sugammadex was used for reversal for those who received neuromuscular blockade. Flow rate was increased to 70 L min^{-1} once the patient was anaesthetised. Potassium titanyl phosphate (KTP) laser was used with THRIVE in 11 cases. As there is a potential risk of airway fire when using laser with 100% oxygen, THRIVE was turned off for 30 seconds prior to using the laser and resumed afterwards. Patients were grouped into those that successfully completed the operation with THRIVE and those who required rescue ventilation.

Normality of data were assessed using the Shapiro-Wilk test and were not found to be normally distributed. Therefore, the descriptive data is presented as median with interquartile range. Non-parametric statistical tests (Mann-Whitney U test, Pearson correlation coefficient) were used for hypothesis testing. Fisher Exact Test with odds ratios were used to analyse the association between weight and BMI with rescue ventilations.

Results

A total of 56 patients were included in this case note review. Optiflow^{TM} was the device used to deliver THRIVE in all patients. Patient demographics and medical history are presented in *Tables 1,2*. THRIVE was used with the following upper airway procedures (*Table 3*): microlaryngoscopy with injection laryngoplasty, microlaryngoscopy with biopsy, microlaryngoscopy with KTP laser use, panendoscopy with biopsy, oesophageal dilatation, subglottic stenosis dilatation, and stapling of a pharyngeal pouch. Median apnoea time [range (IQR)] was 23 [5–40 (20 to 28)] minutes.

Seventy-nine percent (n=44) patients completed their operation with the use of THRIVE alone; 21% (n=12) of patients desaturated and required rescue ventilation with bag-mask ventilation (n=1) or insertion of a microlaryngoscopy tube (n=11). In those that required rescue ventilation, the lowest oxygen saturations recorded just before successful rescue ventilation ranged from 60–94%. One patient desaturated to 94% prior to the

Table 1 Patient demographics presented as median (IQR)

Patient demographics	No rescue ventilation	Rescue ventilation
Number	44	12
Age (years)	60 (39 to 70)	57 (45 to 66)
Gender (male: female)	4:7	3:1
Weight (kg)	75 (65 to 86)	92 (78 to 102)
Height (cm)	165 (159 to 172)	171 (167 to 176)
BMI (kg/m^2)	26 (23 to 30)	31 (29 to 33)
ASA physical status	2	3
Duration of apnoea (min)	25 (20 to 28)	10 (5 to 25)

BMI, body mass index; ASA, American Society of Anaesthesiologists.

Table 2 Patient's co-morbidities presented as percentages within their group (%)

Medical history	No rescue ventilation	Rescue ventilation
Non-smoker	75	67
Active smoker	15	25
Ex-smoker	9	8
Obstructive sleep apnoea	2.3	16.6
Cardiac disease	25	25
Respiratory disease	22.7	25
Gastroesophageal reflux disease	20.4	33.3

Table 3 Types of ENT procedures presented as numbers

Procedures	Total	No rescue ventilation	Rescue ventilation
Microlaryngoscopy + biopsy	14	10	4
Microlaryngoscopy + KTP laser	11	7	4
Panendoscopy + biopsy	10	8	2
Subglottic stenosis dilatation	10	10	0
Microlaryngoscopy + injection laryngoplasty	7	5	2
Oesophageal dilatation	3	3	0
Stapling of pharyngeal pouch	1	1	0

KTP laser, potassium titanyl phosphate laser; ENT, ear, nose, and throat.

procedure being performed and therefore this patient required intubation. Duration of apnoea was not recorded in six patients (with three requiring rescue ventilation and three not requiring rescue ventilation). The lowest oxygen saturation was not recorded in three patients who required rescue ventilation. No standard saturation threshold was identified to trigger rescue ventilation. One patient with bilateral vocal fold immobility required intubation with a microlaryngoscopy tube after 25 minutes, with the lowest oxygen saturation recorded being 93%. No patients experienced long-term complications from desaturation or the implementation of rescue ventilation.

Weight and BMI were statistically significant when associated with patients requiring rescue ventilation (weight P=0.031, BMI P=0.045). Further analysis with Fisher Exact Test and odds ratio showed a weight of 80 kg or more was associated with the need for rescue ventilation (P=0.023, OR =5.2). BMI of more than 30 kg/m^2 was associated with rescue ventilation (P=0.021, OR =5.7). Gender was also associated with rescue ventilation (Pearson correlation r=–0.319, P=0.017), with 75% of those failing THRIVE being male. Gender was not associated with weight or BMI (Pearson Chi-square; weight: r=–0.241 P=0.074; BMI: r=0.122, P=0.374). No other factors reported a statistically significant association with rescue ventilation.

Discussion

THRIVE has been used in the critical care and the peri-operative environment since it was first described in 2000 (8,9). Despite being available since 2000, its use for apnoeic oxygenation during general anaesthesia is a relatively new concept. The published literature consisting of several case series is supportive of apnoeic oxygenation in a small group of patients requiring upper airway surgery (1-4). The high flow rate allows flow-dependent clearance of carbon dioxide and anatomical dead space (8,10). It has been demonstrated to reduce the rate of carbon dioxide accumulation compared to low flow oxygen therapy, allowing prolonged use as an apnoeic ventilation technique (2-4,11). THRIVE allows excellent access to the surgical field without the vibrational movement and interruptions of jet ventilation or obstruction from an endotracheal tube, thus potentially reducing the operation time (1,8).

In our study, we report a median [range (IQR)] apnoea time of 23 [5–40 (20 to 28)] minutes which is comparable to what has been previously reported in the literature (1-4).

Gustafsson *et al.* conducted a study using THRIVE with 31 patients who had an ASA score of I–II, and a BMI of less than 30 kg/m^2. The mean (SD) apnoea time was 22.5 (4.5) minutes (4). Patel and Nouraei utilised THRIVE as a pre-oxygenation technique in 25 patients with known difficult airways until definitive airways were secured and with two patients using THRIVE as their primary airway support. Their median (range) apnoea time was 14 minutes (range, 5 to 65 minutes), though one patient had an apnoea time as long as 65 minutes (1). To *et al.* utilised THRIVE in 17 cases of subglottic stenosis dilatation with a mean (range) age of 52 years (range, 20–74 years), a weight of 69 kg (range, 53–103.2 kg), and BMI of 27 kg/m^2 (range, 20–36 kg/m^2). THRIVE was discontinued in one patient due to desaturation. The median (range) reported apnoea time is 18 minutes (range, 10–27 minutes) (2). Lyons also reported a case series of 28 patients with upper airway surgeries similar to those in our study (microlaryngoscopy with biopsy, tumour excision, subglottic stenosis dilatation, rigid bronchoscopy, cordotomy and injection thyroplasty) (3). They had a mean [SD] age of 56.6 [18], BMI of 24.8 (4.5) kg/m^2, resulting in median apnoea time (range) of 19 (range, 9–37) (3). The rate of rescue ventilation at our institution was 21%. Even though no patients had long-term complications from requiring alternate airway support, there is a theoretical risk of hypoxaemia or hypercapnoea. It is therefore essential to ensure there are patient-specific rescue plans in place if THRIVE is unsuccessful.

This study demonstrates that THRIVE can be safely used in a wide range of laryngeal and pharyngeal procedures. Microlaryngoscopy and biopsy was the most common procedure performed in our institution when using THRIVE. It was the main procedure performed by Gustafsson *et al.* (4). Their study demonstrated no patients desaturated below 91%, however, their patient population differed from this study—with an ASA physical status of less than two, and BMI of less than 30 kg/m^2. The use of THRIVE with subglottic stenosis balloon dilatation has also been described in several case series (2,3). No patients in our study who received subglottic stenosis balloon dilatation required rescue ventilation. This is the first description in the literature of using THRIVE in proximal oesophageal stricture dilatation and stapling of a pharyngeal pouch. All three patients completed their surgery using THRIVE alone. Lyons *et al.* and Tam *et al.* demonstrated the successful use of THRIVE in other laryngeal and airway procedures not included in our study—cordotomy, rigid bronchoscopy and supraglottic stenosis dilatation (3,12). A patent airway is essential for the success of THRIVE, which is provided by suspension laryngoscopy or direct laryngoscopy in the cases described above. Flow dependent flushing of carbon dioxide from dead-space and denitrogenation appears to allow sufficient oxygen reservoir. Therefore, these patients were still able to maintain oxygen saturation without oxygen flow for short durations. The types of procedures were not shown to be significantly associated with rescue ventilation in this study, keeping in mind that our sample size was small.

The main findings from this study indicated that weight and BMI were significantly associated with the need for rescue ventilation. Patel and Nouraei encountered two cases of desaturation—one patient with severe obesity and the other had obesity and tracheobronchomalacia (1). In To *et al.*'s study, one of the two patients of which they had to discontinue THRIVE use had a BMI of 35 and known difficult subglottic access (2). Both studies recommended caution when using THRIVE in this patient population. Obesity is associated with reduced lung compliance and increased airway resistance due to excess adipose tissue (13). As functional residual capacity and expiratory reserve volume are also reduced in obesity due to mass effect, there is increased intra-pulmonary shunt (7,13-15). The small continuous positive airway pressure of 7 cmH_2O provided by the continuous high flow of oxygen in THRIVE may not be enough to prevent atelectasis in this group of patients (1,16).

In this study, rescue ventilation was carried out at the discretion of the anaesthetist. We did not control for the anaesthetist dependent variability in instigating rescue ventilation. Therefore, these rescue ventilations were commenced at different levels of desaturations. The implemented rescue airway (bag-mask, jaw thrust, microlaryngoscopy tube, laryngeal mask airway) was also dependent on the progress of the operation. If the patient desaturated early in the operation then a microlaryngoscopy tube was inserted to complete the operation.

Theoretically, patients with poor lung function, a smoking history and obstructive sleep apnoea have a higher likelihood of desaturation. The mechanism of THRIVE surrounds the concept of apnoeic oxygenation and flow-dependent flushing of dead space (1,17). Therefore, those with low diffusion capacity and low functional residual capacity could result in a higher chance of failure. Our study does not demonstrate statistical significance for patients with respiratory disease, obstructive sleep apnoea, cardiac disease or gastro-oesophageal reflux. However, our findings

are limited by the small number of patients in this study.

Caution should be taken when using laser or electrosurgery with THRIVE. The combination of oxygen rich airflow and electrical heat have the potential to cause an airway fire (18). These incidents have been documented when using diathermy while performing a tracheostomy (19). The only case of fire when using THRIVE has been reported by Onwochei *et al.* where non-sustained ignition occurred while using monopolar diathermy in the oral cavity (20). High oxygen concentration has been demonstrated to be a major contributor of ignition (21,22).

The retrospective nature of the study, small sample size, heterogeneity of procedures and incomplete documentation were the main limitations of this study. Missing data values due to poor documentation potentially introduces bias in the analysis. In response to these limitations we are designing a future prospective study to address these concerns and limitations.

Conclusions

In summary, this retrospective Australian study demonstrates that THRIVE is safe to be used in a range of laryngeal and pharyngeal procedures. Male patients, patients with a weight more than 80kg regardless of gender, or patients with a BMI more than 30 kg/m^2 regardless of gender are more likely to desaturate when using THRIVE, requiring further airway intervention. A larger sample size is needed to validate these findings and determine the significance of other comorbidities when using THRIVE.

Acknowledgments

Funding: None.

Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/ajo.2019.05.02). TA serves as an unpaid editorial board member of *Australian Journal of Otolaryngology*. EHO serves as an unpaid editorial board member of *Australian Journal of Otolaryngology*. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Ethics approval was obtained from Southern Adelaide Clinical Human Research Ethics Committee for research of this study as a retrospective clinical audit (OFR number: 11.18). Informed consent was waived due to the retrospective nature of the study.

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doi: 10.21037/ajo.2019.05.02
Cite this article as: Huang L, Athanasiadis T, Woods C, Dharmawardana N, Ooi EH. The use of transnasal humidified rapid insufflation ventilatory exchange in laryngeal and pharyngeal surgery: Flinders case series. Aust J Otolaryngol 2019;2:17.