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Narrative Review and Consensus Recommendations for the Use of Transnasal Humidified Rapid-Insufflation Ventilatory Exchange in Modified Electroconvulsive Therapy

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ABSTRACT

Transnasal humidified rapid-insufflation ventilatory exchange (THRIVE) is a safe, effective, and novel technique that is currently being used in electroconvulsive therapy (ECT). This study aimed to summarize the clinical practices of THRIVE use in ECT to aid physicians and institutions in implementing the best practice guidelines for ECT. Thus, we reviewed the current literature and presented our consensus on the application of THRIVE in ECT in daily clinical practice. This consensus provides information regarding THRIVE use in ECT, including its safety, effectiveness, procedures, precautions, special case management, and application in special populations. Moreover, it guides the standardized use of THRIVE in ECT.

Keywords: Transnasal humidified rapid-insufflation ventilatory exchange, apneic oxygenation, electroconvulsive therapy, expert consensus

Introduction

Electroconvulsive therapy (ECT) has been widely acknowledged as a highly effective physical intervention for a diverse range of severe mental disorders.[1,2] General anesthesia should be induced in patients to lower the risk of injuries that may arise from generalized epileptic seizures occurring during the ECT procedure.[3,4] Conventional ventilation methods, such as high-frequency jet ventilation, laryngeal mask airway, and facemask ventilation, have been widely used during general anesthesia in ECT. However, these ventilation methods have certain disadvantages. First, high-frequency jet ventilation may increase airway pressure and cause airway barotrauma-related complications, which are manifested as pneumothorax, hypoxemia, or hypercapnia.[5] Additionally, it requires specific equipment and is difficult to perform. Second, the use of lidocaine jelly during laryngeal mask placement may cause oral discomfort. Moreover, tooth occlusion can easily damage the laryngeal mask during electrical stimulation.[6] Third, patients may experience mask fear and claustrophobia when undergoing facemask ventilation, and the oral-bite placement reduces the ventilatory effect of facemask ventilation.[3] Therefore, optimized ventilation methods (e.g., apneic oxygenation) have been used in patients undergoing general anesthesia during ECT.

In apneic oxygenation, patients are supplied with high concentrations of O_2 at a high flow rate through the nasal or oral cavity to promote apneic oxygenation and prolong safe apnea time, i.e., when the peripheral oxygen saturation (SpO_2) levels reach 90% after the onset of apnea,[7,8] during general anesthesia. Supplying O_2 at a flow rate <15 L/min through a double-lumen nasal cannula during asphyxia can prolong safe apnea time.[9-11] However, ideal humidification cannot be achieved at a flow rate >6 L/min, and patients who receive dry and cold O_2 will experience frontal sinus pain, nasal mucosal dryness, and bleeding, in addition to a shortened safe apnea time.[12] Therefore, transnasal humidified rapid-insufflation ventilatory exchange (THRIVE), a novel method of apneic oxygenation, has been employed to overcome these limitations in patients receiving ECT in clinical practice.

Transnasal humidified rapid-insufflation ventilatory exchange delivers high-flow O_2 at a constant temperature and humidity to patients to extend the safe apnea time under general anesthesia. High patient comfort and a safe apnea time of up to 65 minutes[13] can be achieved using THRIVE. Compared with other ventilation methods, THRIVE has several advantages. Anesthesiologists can quickly master instrument handling after simple training and assessment, with strong generalizability. Use of the THRIVE instrument involves a simple procedure, thus saving procedure time. THRIVE keeps O_2 at a constant temperature and humidity, which protects the tracheal ciliary functions and improves the respiratory comfort of patients.[14,15] The O_2 supply through a high-flow nasal cannula (HFNC) throughout the process, without any interruption due to suction or electrical stimulation, reduces the risk of hypoxemia. THRIVE facilitates the exchange of O_2 and carbon dioxide (CO_2) by generating low airway pressure,[16] thereby reducing the risk of gastric insufflation.[17,18] Compared with facemask ventilation, a HFNC with CO_2 monitoring probes continuously monitors the end-tidal CO_2 ($ETCO_2$) levels, which improves treatment safety. Thus, THRIVE has been widely used in rapid sequential induction,[19,20] laryngeal surgeries,[13,21,22] thyroplasty,[23] and other general anesthesia scenarios.[24-28]

Transnasal humidified rapid-insufflation ventilatory exchange has also been effectively utilized in patients receiving ECT. For example, Zhu et al[29] found that the SpO_2 levels of patients undergoing ECT remained above 95% when they were ventilated using THRIVE, and adverse reactions such as hypoxemia, gastric insufflation, prolonged seizure time, and postoperative delirium were not observed. Jonker et al[30] reported that patients undergoing THRIVE had SpO_2 levels >95% and that THRIVE did not shorten seizure duration. Vaithialingam et al[31] reported a case of a patient with bipolar disorder who underwent ECT with THRIVE during the 6th month of pregnancy. The hemodynamic parameters of the patient remained stable throughout the ECT procedure, and the SpO_2 levels remained above 95%. Overall, these findings suggest the effective utilization of THRIVE in ECT, maintaining SpO_2 levels within the normal range and ensuring hemodynamic stability. However, due to mixed conclusions regarding the O_2 concentration, flow rate, and use in special populations, many clinicians may not be able to formulate appropriate oxygen delivery parameters. It is necessary to establish a consensus among clinical treatment experts to standardize the use of THRIVE in ECT. This study aimed to summarize the clinical practices of THRIVE use in ECT to aid physicians and institutions in implementing the best practice guidelines for ECT. Hence, we reviewed the current literature and presented our consensus on the application of THRIVE in ECT in daily clinical practice.

We searched all studies related to apneic oxygenation in the databases, including PubMed, Cochrane Library, Medline, China National Knowledge Infrastructure, and EMBASE, from inception to October 2023. The following keywords were used: "High-flow nasal oxygen", "HFNO", "High-flow nasal cannula", "HFNC", "High-flow humidified nasal oxygen", "Transnasal humidified rapid-insufflation ventilatory exchange", "THRIVE", "Anesthesia induction", "Apnoeic oxygenation", and "Apneic oxygenation". In total, 713 articles were obtained. After evaluating the relevance of the abstracts, 161 articles were investigated for the effect of THRIVE on patients under general anesthesia. Five of these articles were on the use of THRIVE in ECT.[29-33] Since there are few studies on the use of THRIVE in ECT, we organized experts to reach a consensus through discussion. A formal consensus process, such as the Delphi method, was not used in this study.[34]

MAIN POINTS

- *THRIVE used in ECT is a safe, effective and novel technique.*
- *This consensus provides detailed information on the use of THRIVE in ECT.*
- *This consensus aims to guide the standardized use of THRIVE in ECT.*

Indications and Contraindications of Transnasal Humidified Rapid-Insufflation Ventilatory Exchange Application in Electroconvulsive Therapy

Indications

Transnasal humidified rapid-insufflation ventilatory exchange is recommended in ECT for diverse patient populations, including those classified as American Society of Anesthesiologists grade I-III and Mallampati airway grade ≤ III, adult patients (aged 18-91 years), pregnant individuals, and patients with morbid obesity (body mass index (BMI) ≥40.0 kg/m^2).

Contraindications

Contraindications of THRIVE are as follows: (i) upper airway obstruction (e.g., tumor and snoring); (ii) anticipated difficult tracheal intubation; (iii) lung diseases affecting normal oxygenation (e.g., post-lobectomy, pneumonia, asthma, chronic obstructive pulmonary disease, bronchiectasis, and asthma); (iv) abnormal nasopharyngeal cavity (e.g., nasopharyngeal malformation, turbinate hypertrophy, deviated nasal septum, and nasopharyngeal carcinoma); (v) active airway bleeding; and (vi) skull base fracture.

Procedures, Precautions, and Handling of Special Cases of Transnasal Humidified Rapid-Insufflation Ventilatory Exchange Application in Electroconvulsive Therapy

Procedures

Assess the Patient: Thoroughly evaluate the patient's physical condition before using THRIVE to ensure that it is appropriate and safe for the patient. Parameters such as age, BMI, the American Society of Anesthesiologists grade, respiratory functions, and nasal cavity should be assessed.

Establish O_2 Administration Protocol: Determine the following parameters for O_2 administration: flow rate, O_2 administration time, and O_2 concentration. It is recommended to follow the following procedures and O_2 parameters: (i) adjust the flow rate to 30 L/min (this flow rate should be appropriately increased for patients with higher BMI), 100% O_2 pre-oxygenation for 3 minutes, and ETO_2 >90% or end-tidal nitrogen concentration (ETN_2) <5%,[35] (ii) when Ramsay sedation score reaches 3 points after administering anesthetics, adjust the flow rate to 70 L/min,[36] lift the jaws with both hands and close the patient's mouth (this step can be omitted for patients without reduced SpO_2 levels), and (iii) decrease the flow rate to 30 L/min after the recovery of spontaneous breathing, and perform O_2 inhalation in the observation area for at least 30 minutes.

Instrument Preparation: Ensure that the THRIVE unit is working properly and connect the device tubing correctly. Preheat the humidification liquid thoroughly and maintain it at 37°C. Select a

HFNC of the appropriate size. The cannula should generally be <50% of the inner diameter of the nostril, and there should be a visible gap between the nasal obstruction catheter and the patient's nostril.

Patient Preparation: Once the patient completes the necessary preoperative examinations, it should be checked whether all results are normal. Following this, it should be confirmed that the patient has fasted and abstained from food and drink for more than 8 hours on the day of treatment. If there is gastrointestinal dysfunction (gastroesophageal reflux, gastrointestinal obstruction, or gastroparesis) and morbid obesity, then fasting and abstinence from food and drink should be appropriately prolonged. The patient should be asked to remove their dentures, jewelry, and nail polish. It should be ensured that the patient's bowels are empty. The patients should have thoroughly understood the THRIVE treatment process and mastered the key points of cooperation, such as using nose inspiration and mouth expiration. The patient should be placed in the supine position with the head at an angle of 20°-25°. The electrocardiogram monitor should be connected to monitor the pulse, respiration, and blood pressure.

O_2 Administration Initiation: O_2 administration should be performed according to the established protocol.

Monitor the Patient: The patient should be closely monitored for SpO_2 levels, heart rate, and blood pressure throughout the treatment course. If the SpO_2 levels appear to be low, the O_2 parameters should be adjusted immediately, or THRIVE should be suspended, and alternative active ventilation should be adopted.

End of the Treatment: After removing the HFNC, the patients should be instructed to breathe deeply.

Follow-up: The patient should be followed up within 24 hours after the end of the treatment to assess airway-related complications, including epistaxis, dryness, pain, and itching. These should be recorded, and the O_2 regimen should be appropriately adjusted.

Considerations for Transnasal Humidified Rapid-Insufflation Ventilatory Exchange Application in Electroconvulsive Therapy

The following points should be considered to ensure the safe and effective application of THRIVE in ECT:

General Consideration of Transnasal Humidified Rapid-Insufflation Ventilatory Exchange Application in Electroconvulsive Therapy:

1. Anesthesiologists should undergo standardized training before treatment and must pass the assessment before applying THRIVE in their practice.
2. Anesthesiologists should inform the patient of the treatment process and cooperation essentials before the treatment. Additionally, anesthesiologists should select a HFNC of appropriate size (generally <50% of the inner diameter of the nostril) and headbands of appropriate tightness.
3. The vital signs of the patient should be closely monitored during THRIVE, and ventilation strategies should be adjusted or changed at the right time.
4. Close attention should be paid to the patient's oral cavity, and airway secretions and sputum should be suctioned when necessary to prevent airway blockage.
5. Sterilized water should be used for injection in the humidification tank, and the water level should be in the range of the labeled water level line. The humidification solution should be sufficiently preheated before use to achieve "optimal humidification".
6. Medical staff should closely monitor the patient's vital signs and pay attention to any adverse reactions during the treatment. Additionally, anesthesia-, treatment-, and ventilation-related records should be maintained.

Specific Consideration of Transnasal Humidified Rapid-Insufflation Ventilatory Exchange Application in Electroconvulsive Therapy:

1. We need to be alert to the potential for delivery of ECT stimulus to cause fires when oxygen is administered at high flow rates. If necessary, oxygen flow should be turned down properly during the delivery of ECT stimulus.[37]
2. If prolonged seizures occur, ventilation modification should be considered to avoid hypercapnia.[30]
3. It is advised for patients with poor seizure duration to prolong preoxygenation.[38]
4. The oral bite should be removed from the patient's mouth until the patient resumes spontaneous respiration, which is conducive to increasing airway pressure.[39,40]

Special Case Processing of Transnasal Humidified Rapid-Insufflation Ventilatory Exchange Application in Electroconvulsive Therapy

Anesthesiologists should develop emergency plans for airway management before the surgery. If the SpO_2 levels are >90% and <95%, the airway should be opened using a jaw-support instrument, and vacuum suction of the oral cavity and airway secretions should be performed. When the SpO_2 levels are <90%, the oropharyngeal airway and facemask ventilation should be used to supply oxygen. If an airway spasm occurs, appropriate drugs should be administered to relieve the spasm, airway patency should be maintained, and endotracheal intubation performed if necessary. If these measures fail to increase the SpO_2 levels, the patient should be handled according to the guidelines for the management of unanticipated difficult airways established by the British Difficult Airway Association, 2015.[7] If the patient develops any of the following, THRIVE should be terminated and an emergency plan for airway management should be initiated to ensure patient safety: (i) partial pressure of CO_2 ($PaCO_2$) >82.5 mm Hg; (ii) pH <7.15; (iii) malignant arrhythmia; and (iv) hypotension (mean arterial pressure <20% of the baseline) or bradycardia.

Tolerability and Safety of Transnasal Humidified Rapid-Insufflation Ventilatory Exchange

Tolerability

Many factors, such as the magnitude of the initial pre-oxygenation flow rate, O_2 temperature and humidity, and the breathing method, can affect a patient's tolerance toward THRIVE. A previous study showed that the technique was well-tolerated, and no patient complained of intolerance or refused to continue THRIVE.[41] Although adverse events directly caused by THRIVE are rare, pneumothorax and pneumomediastinum may occur due to high flow rates.[42] Epistaxis, an undesirable effect associated with THRIVE,[43,44] can be avoided with effective O_2 humidification. Overall, THRIVE is well tolerated and well accepted by patients.

Safety

Gastric Insufflation: Transnasal humidified rapid-insufflation ventilatory exchange produces low-pressure levels during its use and theoretically carries a risk of gastric reflux due to O_2 entering the stomach. The lower esophageal sphincter is a high-pressure area at the lower esophagus and stomach junction and serves as a barrier to prevent gastric reflux into the esophagus.[45] The normal range of the lower esophageal sphincter pressure is 13.0-30.0 mm Hg, and THRIVE produces an airway pressure in the range of 2.7-7.4 cm H_2O, which is consistently below 13.0 mm Hg.[16] Moderate positive airway pressure produced by THRIVE increases thoracic pressure, compresses the esophagus, and increases esophageal resistance.[46] Relevant studies have also confirmed the above findings.[17,18] Patients with obesity undergoing THRIVE during anesthesia induction maintained good SpO_2 levels and did not develop intragastric insufflation.[17] Healthy volunteers who were breathing spontaneously underwent THRIVE with continuous ventilation at a flow rate of 70 L/min for 30 minutes, and no significant changes were observed in their gastric volumes.[18] Thus, the use of THRIVE in ECT not only reduces the risk of intragastric insufflation, aspiration pneumonia, and asphyxia but also improves treatment safety.

Absorptive Atelectasis: O_2 mainly shares the alveolar space with N_2, which is poorly soluble in blood, accounting for a large proportion of the alveolar space. During breathing, slow N_2 diffusion limits the emptying of the lungs. Rapid N_2 replacement by O_2 promotes O_2 transfer from the lungs to the bloodstream, causing alveolar collapse, which leads to absorptive atelectasis. Thus, the most common side effect of pure O_2 administration is absorptive atelectasis.[47] The supine position and anesthesia reduce lung volumes, and changes in the shapes of the chest wall, spine, and diaphragm increase intra-abdominal pressure, thoracic compression, and airway closure, thereby accelerating atelectasis. However, no studies have reported absorptive atelectasis caused by THRIVE. When discontinuing THRIVE postoperatively, the flow rate should be gradually reduced, airway pressure should be maintained, and N_2 content in alveoli should be increased to avoid absorptive atelectasis. Simultaneously, anesthesiologists should comprehensively examine the patient to ensure that the patient's physical condition meets the conditions recommended for applying THRIVE to avoid absorptive atelectasis.

O_2 Poisoning: Pulmonary edema, acute respiratory distress syndrome, retinal detachment, and seizures are the clinical manifestations of O_2 poisoning. O_2 poisoning is related to O_2 inhalation duration, with signs of early lung injury beginning to appear after 12 hours of constant exposure to high O_2 concentrations.[48] A study reported that patients receiving ECT showed a short apnea time of average 4.2 ± 0.4 minutes;[29] thus, the risk of O_2 poisoning caused by the transient application of THRIVE in ECT may be low. The inhalation of high O_2 concentrations may result in oxidative stress, and existing studies have shown no alterations in the cardiac, inflammatory, or renal biomarkers in asphyxiated patients undergoing THRIVE for 17.9 ± 4.8 minutes.[49]

Thus, THRIVE is safe and has a low risk of adverse effects when used in ECT because of its association with low airway pressure, short apnea time, and scientific THRIVE O_2 regimen.

Transnasal Humidified Rapid-Insufflation Ventilatory Exchange Usage in Special Populations

Currently, only a few studies on THRIVE usage in special populations are available. Thus, this consensus discusses THRIVE usage in older adults, pregnant individuals, and patients with obesity.

Transnasal Humidified Rapid-Insufflation Ventilatory Exchange in Older Adults

Transnasal humidified rapid-insufflation ventilatory exchange effectively prolongs the safe apnea time in older adults. Hua et al[28] reported that patients aged 65-80 years were pre-oxygenated at a flow rate of 30 L/min for 5 minutes, and the flow rate was adjusted to 70 L/min after inducing anesthesia. The SpO_2 levels remained >90% within 10 minutes in 83.8% of the patients, with a safe apnea time of 600 seconds and a mean $PaCO_2$ of 72.00 ± 9.23 mm Hg. No complications, such as hemodynamic instability, intractable arrhythmia, or nasal discomfort, were observed. Jung et al[50] reported a case of a 91-year-old patient with hypertension and diabetes, who was treated with the rigid bronchoscopic removal of a foreign body in the left mainstem bronchus, and O_2 was continuously supplied to the patient using THRIVE at a flow rate of 70 L/min. The patient did not receive any airway intervention during the 22 minutes of the treatment, and the vital signs were stable without any adverse events, such as hypoxemia. Blood gas analysis revealed a pH of 7.44, partial pressure of O_2 (PaO_2) of 120 mm Hg, $PaCO_2$ of 40 mm Hg, and a bicarbonate level of 27.2 mmol/L. Thus, THRIVE is likely to be an effective option for older adults receiving ECT.

Transnasal Humidified Rapid-Insufflation Ventilatory Exchange for Pregnant Individuals

Pregnant people with mental disorders, who do not respond to medical treatments or are at high risk of suicide, can undergo ECT. The risks to pregnant individuals and children, including teratogenicity, toxicity, and withdrawal symptoms, are lower with ECT administered during pregnancy than with antipsychotic drugs.[51] Diaphragmatic elevation, acute pulmonary edema, and decreased functional residual capacity (FRC) in pregnant individuals can lead to weakened respiratory systems, which are additionally affected by increased O_2 consumption, thereby increasing the risk of hypoxemia during apnea time. Consequently, airway management in pregnant people is more challenging. Due to hormonal fluctuations, gastric retention is better in pregnant individuals, and they generally require endotracheal intubation to protect the airways after the 16th week of pregnancy.[52] Nevertheless, endotracheal intubation in pregnant individuals has some operational disadvantages.[53] Notably, THRIVE can overcome limitations such as difficult intubation due to pregnancy-induced airway edema, bleeding, and prolonged anesthesia.[3,53,54] Compared with conventional facemask ventilation, THRIVE supplies O_2 to the airway at a higher flow rate without causing significant flatulence.[29]

Transnasal humidified rapid-insufflation ventilatory exchange effectively prolongs the safe apnea time in pregnant individuals. Vaithialingam et al[31] reported a case of ECT in a 23-year-old patient with bipolar disorder during the 6th month of pregnancy. The patient was pre-oxygenated using the THRIVE device at a flow rate of 30 L/min for 3 minutes. The rate was increased to 50 L/min after administering a muscle relaxant. After seizure cessation, the flow was gradually decreased at a rate of 1 L/min. The patient's hemodynamic parameters were stable throughout the ECT procedure, and

the SpO_2 levels remained above 95%. Bourn et al[26] reported a case of a patient with subglottic stenosis during the 23rd week of gestation, who was pre-oxygenated at a flow rate of 50 L/min (100% pure O_2) for 5 minutes during THRIVE. During anesthesia induction, the flow rate was adjusted to 70 L/min, and airway patency was maintained by the jaw thrust maneuver. The patient's SpO_2 levels remained above 98% over 13 minutes of apnea time, and the $ETCO_2$ was 7.8 kPa (assuming a baseline $ETCO_2$ of 4.6 kPa, it increased at a rate of 0.25 kPa/min). Preoperative and postoperative fetal monitoring was satisfactory with no adverse events. Thus, preliminary results have demonstrated the safety and efficacy of THRIVE in pregnant individuals receiving ECT.

Preston et al[55] determined the time required for pre-oxygenation in pregnant people by performing a "dose-finding" up-and-down study. Patients were positioned supine and instructed to breathe through the nose with their mouths closed, and a pelvic wedge pad was placed on the right side to decrease aortic lumen compression. Patients undergoing THRIVE were pre-oxygenated at 45 L/min to achieve an ETO_2 of over 85%. The results indicated that the median effective dose of pre-oxygenation was 225 seconds, while the 95% effective dose was 354 seconds. A significant correlation was found between pre-oxygenation time and ETO_2. Eight pregnant people, who were pre-oxygenated for 30 minutes, showed a median ETO_2 of 67.5% (42%-92%). Thus, based on this pre-oxygenation regimen, ETO_2 >85% was not achieved by pre-oxygenation for 3 minutes. Pre-oxygenation for 3 minutes through a facemask is the time limit for pregnant individuals clinically recommended for pre-oxygenation.[56] Byrne et al[57] concluded that due to the decrease in the FRC during pregnancy, it takes less time for pregnant people to denitrify completely (2% ETN_2) than younger people of similar age and weight. Pregnant individuals at 13-26 gestational weeks received a flow rate of 8 L/min via a close-fitting mask to achieve complete N_2 removal and required 104 ± 30 seconds to denitrify completely, whereas those at 26-42 gestational weeks required 80 ± 20 seconds, and non-pregnant individuals required 130 ± 30 seconds.

The increase in maternal $PaCO_2$ during pregnancy should be taken seriously because it may pose a potential risk to the fetus.[58] Guidelines for laparoscopy in pregnancy recommend monitoring the $ETCO_2$ levels[59] in pregnant individuals during treatment and maintaining them between 4.0 and 4.6 kPa (30-34 mm Hg).[60] No study has reported the target ETO_2 values, safety conditions, and the maximum safe level of $PaCO_2$ in pregnant individuals undergoing THRIVE. Hence, it is uncertain whether THRIVE is safe and beneficial in pregnant individuals receiving ECT.

Transnasal Humidified Rapid-Insufflation Ventilatory Exchange in Patients with Obesity

Previous studies and meta-analyses have revealed a significant positive association between depression and obesity.[61,62] Therefore, the number of patients with obesity receiving ECT is increasing.[63] The FRC in patients with healthy weight decreases by approximately 20% after anesthesia induction,[64] whereas it decreases by approximately 50% in patients with obesity.[65] Intrapulmonary shunt rates in patients with obesity range from 10% to 20% compared with 2% to 5% in non-obese patients,[66] leading to a higher risk of desaturation in the former than in the latter. Anesthesiologists face severe challenges during the airway management of patients with obesity.[67,68] Transnasal humidified rapid-insufflation ventilatory exchange is a novel and effective ventilation modality for patients with obesity undergoing ECT. Schutzer et al[27] reported that patients with morbid obesity (BMI >40 kg/m^2) took deep breaths during pre-oxygenation and received a flow rate of 35 L/min during the first minute. The flow rate was adjusted to 50-70 L/min for the subsequent 2 minutes and maintained at 70 L/min thereafter. Patients were asked to keep their mouths tightly closed throughout the procedure. Anesthesiologists used oropharyngeal ventilation tubes and jaw support to maintain airway patency. The SpO_2 levels were maintained above 92% during 18 minutes of apnea time in 36 (87.8%) patients, and the mean $PaCO_2$ was 10.7 ± 1.1 kPa. The SpO_2 levels remained above 92% during 9 min of apnea time in 38 (92.7%) patients, with a mean $PaCO_2$ of 9.0 ± 0.9 kPa. Lee et al[24] reported a case of THRIVE use in a patient with morbid obesity (BMI, 40 kg/m^2) who underwent total endoscopy and biopsy of a left vocal cord lesion. The pre-oxygenation regimen was 15 minutes of pure O_2 with a gradual increase in the flow rate from 20 to 60 L/min. The SpO_2 levels of the patient remained above 98% during 14 minutes of apnea. Arterial blood gas analysis during 10 minutes of apnea showed $PaCO_2$ of 65 mm Hg and PaO_2 of 183 mm Hg. The hemodynamics of the patient were stable throughout the treatment, with systolic blood pressure between 120 and 170 mm Hg and heart rate between 60 and 90 beats/min. David et al[25] reported a study of THRIVE in patients with morbid obesity (BMI ≥40 kg/m^2) undergoing elective surgery with a pre-oxygenation regimen of 40 L/min flow rate for 3 minutes and 60 L/min during apnea. Outcome measures were decreased when the SpO_2 levels were <95% or during a maximum apnea period of 6 minutes. The safe apnea time was 261.4 ± 77.7 s, and the lowest SpO_2 level was 91.0 ± 3.5%. In a randomized clinical trial,[69] 40 patients with morbid obesity (BMI >40 kg/m^2) received pre-oxygenation at a flow rate of 10 L/min for 3 minutes. Apneic oxygenation was performed using standard nasal prongs (10 L/min) or high-flow nasal insufflation (HFNI) (120 L/min). The median duration of safe apnea was 601 s (268-900 s) in the standard nasal prongs group and 537 s (399-808 s) in the HFNI group (P = .698). The results are not completely consistent due to inconsistencies in outcome measures, patient positioning, and oxygen regimen. These results indicate that the safe apnea time may be maintained for at least 6 minutes. Thus, THRIVE may be safe and effective in patients with obesity and mental disorders undergoing ECT.

Limitations and Prospects

Transnasal humidified rapid-insufflation ventilatory exchange supplies O_2 and possesses the characteristics of easy operation, constant temperature, and constant humidity, which decreases the risk of gastric reflux and prolongs the safe apnea time. Patients have reported a good experience, and THRIVE has been widely used in general anesthesia in recent years.

Although THRIVE is considered safe and effective for use in ECT, it has certain limitations. Transnasal humidified rapid-insufflation ventilatory exchange pre-oxygenation regimen for patients with mental disorders undergoing ECT should be developed, including pre-oxygenation time, initial flow rate, and O_2 concentration. The target values of ETO_2 or ETN_2 pre-oxygenation should be clearly defined. The treatment position of THRIVE when applied in patients undergoing ECT should be clearly defined. Whether the duration of THRIVE pre-oxygenation is associated with changes in the seizure duration and whether hyperventilation with pre-oxygenation

can increase the seizure duration and improve the efficacy of ECT should be further investigated. The essentials of respiratory cooperation for patients undergoing THRIVE should be standardized. Future relevant studies are warranted to clarify the aforementioned issues and further standardize the procedure of THRIVE in patients with mental disorders undergoing ECT. There are two main limitations to this article. First, more information is not provided on the specific nature of anesthesia for ECT. Second, this consensus only describes the process of applying THRIVE in ECT. The grade of evidence recommendations for the use of THRIVE in ECT is not conducted in this consensus. Therefore, a formal consensus process, such as the Delphi method, was not used.

Availability of Data and Materials: *This narrative review and consensus recommendations are classified as a qualitative study with no available data.*

Peer-review: *Externally peer-reviewed.*

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