Review Article

Trans-nasal humidified rapid insufflation ventilatory exchange (THRIVE) in neuroanesthesia practice: A review

Balaji Vaithialingam, Kamath Sriganesh

Department of Neuroanaesthesia and Neurocritical Care, National Institute of Mental Health and Neurosciences (NIMHANS), Bengaluru, Karnataka, India

Abstract

Respiratory management is an important aspect of care in neuroanesthesia practice for neurosurgical patients. A wide variety of procedures are performed under sedation in the neurosurgical population, and maintaining oxygenation is of paramount importance during these procedures. The high-flow oxygen devices improve arterial oxygenation by providing higher inspiratory oxygen concentration and maintaining higher dynamic positive airway pressure. These devices have gained importance during the recent years with regard to enhancing patient safety. This narrative review focuses on the role of trans-nasal humidified rapid insufflation ventilatory exchange (THRIVE) and high-flow nasal oxygenation (HFNO) techniques in the neuroanesthesia practice and electroconvulsive therapy.

Keywords: High-flow nasal oxygenation, neuroanesthesia, review, THRIVE

Introduction

Trans-nasal humidified rapid insufflation ventilatory exchange (THRIVE) is a novel high-flow nasal oxygenation (HFNO) technique employed in both spontaneously breathing and apneic patients. Since its introduction, it has rapidly gained acceptance in anesthesia practice during the past 6 years. THRIVE has quickly established itself as a pre-oxygenation tool in a difficult airway scenario and also as a sole insufflation technique during the conduct of tubeless surgeries of a short duration.[1,2] The provision of 100% humidified oxygen with a maximum flow of 70 L/min is the key feature of THRIVE. The utility of this novel device in the field of neuroanesthesia is yet to be fully explored. This review highlights the possible applications and feasibility of THRIVE in the neuroanesthesia practice.

Address for correspondence: Dr. Balaji Vaithialingam, Second Floor, Skandha Nivas, Second Cross End, Gundappa Gowda Garden, Ejipura Main Road, Viveknagar, Bengaluru - 560 047, Karnataka, India.
E-mail: balamedicine04@gmail.com

Access this article online

Quick Response Code:

Website: https://journals.lww.com/joacp

DOI: 10.4103/joacp.joacp_92_22

Methods

The PUBMED, Web of Science, and PROQUEST were searched in January 2022 using the keywords "Transnasal Humidified Rapid Insufflation Ventilatory Exchange" OR "High Flow Nasal Oxygen" AND "Neurosurgery" OR "Neuroanesthesia" OR "Neuroanaesthesia" AND "electroconvulsive therapy" in the title, abstract, or keywords. The search strategy was developed with the support of our university library. A manual search was also performed to retrieve any additional articles not obtained with the electronic search strategy. No restriction was applied with regard to study design, and case series/reports were also included. A total of 230 articles were obtained using the above search strategy, and seven articles (with additional keywords "Awake craniotomy" and "Pregnancy") were obtained by manual search [Figure 1]. A full-text review was performed, and

How to cite this article: Vaithialingam B, Sriganesh K. Trans-nasal humidified rapid insufflation ventilatory exchange (THRIVE) in neuroanesthesia practice: A review. J Anaesthesiol Clin Pharmacol 2023;39:521-7.

Submitted: 09-Mar-2022 **Revised:** 16-May-2022
Accepted: 02-Jul-2022 **Published:** 19-Apr-2023

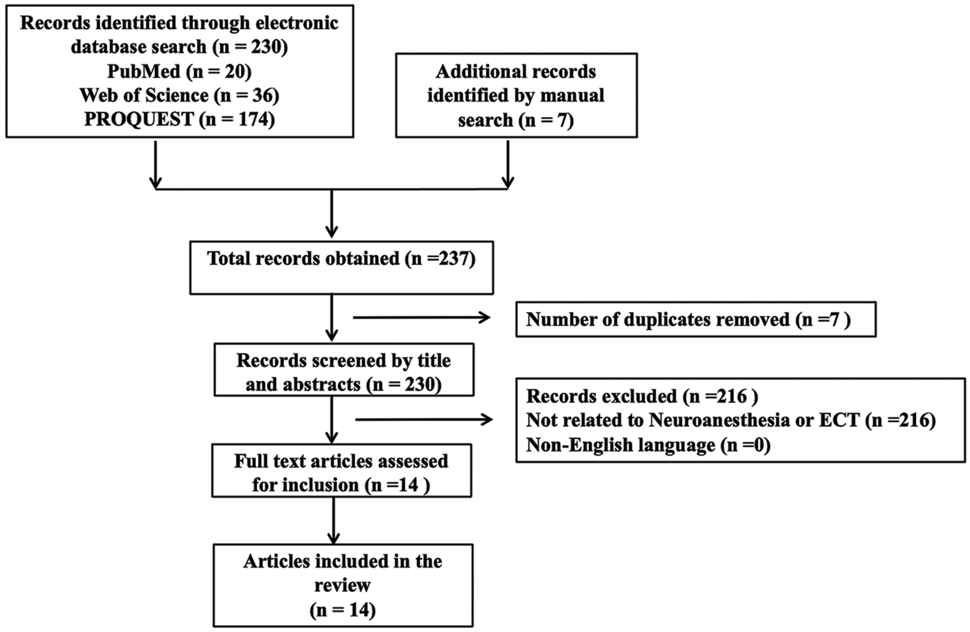

Figure 1: Flow diagram showing selection of studies in this review

only the articles reporting human subjects in the English language were included. A total of 14 articles that were relevant to the neuroanesthesia practice were included in the final review [Table 1].

Anatomy of THRIVE

The THRIVE system consists of the following components:

- A flexible hose with a probe that is compatible with an oxygen wall outlet
- A flowmeter capable of delivering a maximum of 70 L/min of oxygen
- Humidification unit
- Specialized wide bore inspiratory tubing assembly with a filter
- Custom-built soft nasal cannula.

All these components are mounted over a portable stand, making it easier for emergency use. A contrasting difference between THRIVE and other high-flow oxygen devices (AIRVO-2) is the lack of an air/oxygen blender in THRIVE, making it capable of delivering only 100% oxygen. The humidification unit is another key component of the Optiflow THRIVE™ (Fisher and Paykel Healthcare, Auckland, New Zealand) with three levels of humidification settings that can be adjusted according to the patient's comfort.

Physiology of THRIVE

The physiological basis of THRIVE is because of the underlying factors

- Aventilatory mass flow and apneic oxygenation
- Reduction of dead space
- Airway hydration
- Dynamic positive airway pressure.

"*Aventilatory mass flow*" forms the main physiologic basis of all apneic oxygenation techniques including THRIVE.[17] Turbulent "primary supraglottic vortex" is created when HFNO loops around the soft palate and exits through the mouth, thereby constantly replacing the pharynx with oxygen and preventing room air entrainment. The supraglottic vortex bypasses the upper airway and reduces the resistance of the respiratory system to air flow by 50%.[18] THRIVE also prolongs the apnea time by continuous flushing of the dead space and by providing continuous positive airway pressure (CPAP).[19] The cardiac oscillations during apnea might contribute to alveolar gas exchange during THRIVE.[20]

THRIVE could effectively decrease the dead space gas in a flow-dependent manner. Möller *et al.*[21] studied the clearance of tracer gas ^{81m}Kr from the upper airway as a surrogate of dead space gas and demonstrated a linear relationship between dead space clearance and the THRIVE flows.

The humidification unit allows for a comfortable delivery of very high flows to the patient. The optimal humidity provided by THRIVE simulates the natural balance between heat and moisture occurring in a healthy lung.[22]

THRIVE generates a flow-dependent dynamic positive airway pressure, thereby decreasing the work of breathing and

Table 1: Details of the final articles included for the review

Author	Year	Study type	No of patients	Application	Conclusion
Banik *et al.*[3]	2019	Case report	1	Super obese patients undergoing awake craniotomy	HFNC is a safe technique for carrying out an awake craniotomy in a super obese patient
Gook *et al.*[4]	2021	Case report	2	HFNC in awake craniotomy with oxygen reserve index monitoring	Combined HFNC with oxygen reserve index monitoring is an effective technique during awake craniotomy
Ng *et al.*[5]	2018	Randomized controlled trial	50	Pre-oxygenation in neurosurgical patients	THRIVE is not very effective in maintaining oxygenation and ventilation as compared to the bag and mask technique following the neuromuscular blockade
Jonker *et al.*[6]	2019	Feasibility study	13	Electroconvulsive therapy	THRIVE is a novel tool for safe oxygenation in patients during electroconvulsive therapy
Kumar *et al.*[7]	2017	Case report	1	HFNC in awake craniotomy	OPTIFLOW THRIVE is pivotal in airway management in a complex neurosurgical procedure
Land *et al.*[8]	2019	Case series	8	Electroconvulsive therapy	THRIVE is a unique and effective technique in maintaining oxygenation in patients undergoing electroconvulsive therapy
Lin *et al.*[9]	2019	Case report	1	Awake craniotomy	Awake craniotomy with HFNC is an effective technique for airway management
Reese *et al.*[10]	2018	Case report	1	HNFC in a patient with obstructive sleep apnea with transcutaneous carbon dioxide monitoring in awake craniotomy	Transcutaneous carbon dioxide monitoring increases the safety of the HFNC technique in high-risk patients
Smith *et al.*[11]	2018	Case report	1	Awake craniotomy in morbidly obese patients	HFNC should be considered for airway management in morbidly obese patients undergoing awake craniotomy
Vaithialingam *et al.*[12]	2021	Case report	2	Awake craniotomy	THRIVE is a useful technique to prevent adverse respiratory events during awake craniotomy
Vaithialingam *et al.*[13]	2022	Case report	1	Pregnant patients undergoing electroconvulsive therapy	THRIVE can effectively maintain arterial oxygen saturation in pregnant patients undergoing electroconvulsive therapy
Wong *et al.*[14]	2017	Case report	1	Patients with obstructive sleep apnea undergoing awake craniotomy	HFNC is a beneficial in providing ventilatory support for patients with obstructive sleep apnea during intra-operative sedation
Yi Zhu *et al.*[15]	2019	Randomized controlled trial	150	Electroconvulsive therapy	Use of HFNC in non-obese patients is beneficial during electroconvulsive therapy
Yi P *et al.*[16]	2020	Randomized controlled trial	65	Awake craniotomy	HFNC is safe and effective for patients undergoing awake craniotomy

making inspiration easier. The HFNO therapy also promotes deep slow breathing during expiration, which eventually increases the end-expiratory lung volume (EELV).[23] Optiflow THRIVE can generate approximately a pressure of 1 cm H_2O for every 10 liters of gas insufflated.[24,25]

THRIVE and Flow Requirements

THRIVE flow needs to be titrated on an individual basis. The main advantage of THRIVE is that it meets the patient's inspiratory demand. A normal healthy patient usually requires a flow of 30 L/min to sustain oxygenation during procedural sedation.[26] Higher flows (up to 70 L/min) may be needed when muscle relaxants are used because of the development of basal atelectasis.[27] Similarly, obese patients with a poor respiratory reserve because of their lower vital capacity, functional residual capacity, and lung compliance also benefit from higher flows.[28]

Applications in Neuroanesthesia Practice

The utility of THRIVE in neuroanesthesia practice can be broadly classified into the following

1. During rapid sequence anesthetic induction and intubation
2. During fiber-optic intubation
3. For respiratory support during procedural sedation without an artificial airway
4. During electroconvulsive therapy (ECT)
5. To prevent and/or overcome peri-operative adverse respiratory events.

Anesthetic Induction and THRIVE

THRIVE has a beneficial role in prolonging apnea and maintaining oxygenation during the conduct of rapid sequence induction (RSI).[29,30] Based on the evidence of utility of THRIVE during RSI in non-neurosurgical emergency surgeries,[31,32] THRIVE oxygenation may be preferable during RSI and intubation for emergency neurosurgical procedures too, such as in patients with low Glasgow Coma Scale scores following traumatic brain injury, arterial or venous stroke, malignant brain tumors, neuro-radiological intervention for acute stroke, and so on. These patients with acute brain injury are likely to have a poor respiratory reserve and are at increased risk of pulmonary aspiration of gastric contents. Pre-oxygenation with 30 L/min of 100% humidified oxygen followed by the administration of a rapidly acting anesthetic drug and muscle relaxant and the application of cricoid pressure would be a preferred approach. Increasing THRIVE flow up to 70 L/min after anesthesia induction will help sustain the apneic oxygenation and avoid positive pressure mask ventilation till the tracheal tube is secured.

THRIVE may also be beneficial during conventional induction and intubation in elective neurosurgical patients with a decreased functional residual capacity such as morbid obesity, obstructive sleep apnea (OSA), post-coronavirus disease 19 infection status, acromegaly, Parkinson's disease, kyphoscoliosis, chronic cervical compressive myelopathy, and brainstem and cervico-dorsal spine pathologies where oxygenation can be maintained hands-free during anesthesia induction and airway management, especially when expert help is limited. However, a study in neurosurgical patients undergoing non-RSI observed a lower partial pressure of oxygen and a higher partial pressure of carbon dioxide after intubation with HFNO as compared to bag-mask ventilation when used for pre-oxygenation and apneic oxygenation.[5]

Fiber-optic Intubation and THRIVE

Conventional oxygen delivery techniques may not provide adequate 100% oxygen to prevent desaturation during awake or anesthetized fiber-optic intubation. THRIVE has been shown to reduce the risk of desaturation and optimize the condition for awake fiber-optic intubation in patients with anticipated difficult airways by allowing continuous oxygenation and simultaneous passage of a fiberscope and tracheal tube.[33] The patients can be oxygenated with 30–70 L/min of THRIVE flows using a custom-built nasal cannula during the conduct of awake fibreoptic intubation [Figure 2]. THRIVE may be useful in elective neurosurgical patients during awake fiber-optic intubation for cervical spine instability, where it is the most preferred technique for airway management,[34] or during anticipated difficult airway management in neurosurgical pathologies.[35] In anesthetized and apneic patients also, THRIVE can be beneficial in extending the apneic window during fiber-optic intubation as shown in an earlier study where oxygen insufflation through the working channel resulted in better post-intubation oxygen levels than without oxygen insufflation.[36]

Figure 2: THRIVE use during fiber-optic intubation

Respiratory Support During a Procedural Sedation

Use of anesthetic agents during sedation can result in reduction of oropharyngeal muscle tone and desaturation. HFNO reduces desaturation events and rescue airway interventions during sedation as compared to conventional oxygenation techniques.[37] Moreover, THRIVE is better tolerated despite high flows because of humidification, provides 100% inspired concentration of oxygen, facilitates washout of nasopharyngeal dead space, reduces nasopharyngeal resistance, increases alveolar recruitment, decreases work of breathing, and prevents development of atelectasis.[38] Many neurosurgical patients undergo a variety of procedures under sedation without the placement of an artificial airway. These include interventional pain procedures such as radiofrequency ablation for trigeminal neuralgia, functional neurosurgery such as deep brain stimulation, burr hole evacuation of chronic subdural hematoma,[39] stereotactic neurosurgery,[40] and awake craniotomies.[41] HFNO can be beneficial during procedural sedation for these procedures [Figure 3]. The use of THRIVE maintained oxygenation and prevented the occurrence of desaturation during awake craniotomy in obese patients with OSA[3,10,11,14] and during the intra-operative seizure.[12] The utility of HFNO as a sole insufflation technique of airway management during the conduct of awake craniotomy has been demonstrated in several reports in recent years.[4,7,9,16]

Similarly, diagnostic cerebral angiography and therapeutic interventions are routinely performed in the neuroradiology suite under sedation while maintaining spontaneous respiration in patients with subarachnoid hemorrhage and acute stroke. These patients are at risk of adverse respiratory events such as airway obstruction, apnea, and desaturation despite administration of oxygen by face masks.[42] When these complications occur, they prolong the procedure duration, necessitate airway interventions and repeat imaging, and increase radiation hazards to patients and health care workers. Moreover, neurosurgical patients with subarachnoid hemorrhage or ischemic stroke have a high risk of pulmonary complications of acute brain injury, and a further decrease in respiratory function can occur with sedation. THRIVE can help overcome the limitations of conventional oxygenation techniques such as flow rates <15 L/min, unpredictable FiO_2, impairment of mucociliary functions, and bronchospasm from dry cold air flow[38] and provide sustained oxygenation during these procedures.

The conventional practice of providing sedation for diagnostic and certain therapeutic procedures in neurosurgical patients includes administration of intravenous anesthetic agents such as dexmedetomidine or propofol with oxygen supplementation through a simple face mask.[42] This technique carries certain important drawbacks. The face mask may not be tolerated well; there can be a mismatch between the patient's peak inspiratory flow and flows that can be provided by conventional oxygen delivery devices (a maximum of 15 L/min), air entrainment and dilution of inspired gas can result in a lower fraction of inspired oxygen concentration (FiO_2), and high flows cannot be delivered if needed.[43] In contrast, THRIVE can provide inspired flows up to 70 L/min, which is well beyond the patient's inspiratory demand. This ensures a wider safety margin for upward titration of the doses of intravenous anesthetic agents without the fear of oxygen desaturation and patient movement during the critical stages of neurosurgical procedures.

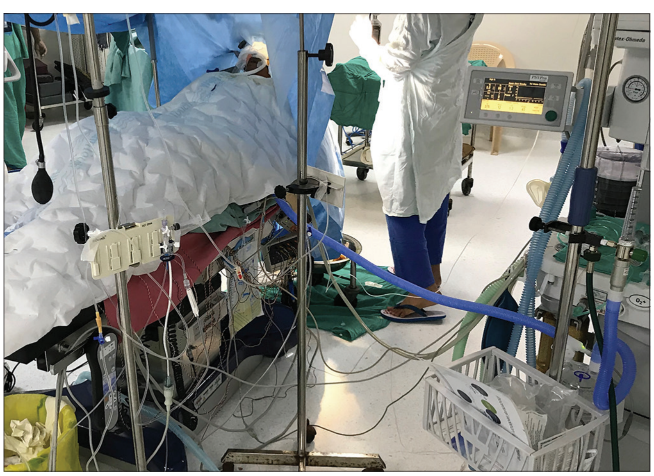

Figure 3: THRIVE use during awake craniotomy

Electroconvulsive Therapy and THRIVE

The anesthetic technique for ECT involves the administration of a short-acting intravenous anesthetic agent and muscle relaxant. The breathing is supported by bag and mask ventilation that is interrupted briefly during the application of an electrical stimulus and during the ictal phase. The incidence of oxygen desaturation is noted to be as high as 29% with this technique and is more when induced seizure duration is prolonged and in patients with a higher body mass index (BMI).[44] In this background, the utility of HFNO using THRIVE during the conduct of ECT appears promising. This hands-free technique can facilitate better patient monitoring and performance of other necessary tasks during anesthesia. Moreover, oxygenation will be continued without interruption even during the application of electrical shock and during the period of motor seizures. Thus, THRIVE can be beneficial during ECT, especially in pregnant patients, morbidly obese patients, and those at increased aspiration risk as there is no gastric insufflation that is seen with the conventional bag and mask technique.[13] The patients are pre-oxygenated with a THRIVE flow of 30 L/min through a custom-built nasal cannula [Figure 4] that can be escalated to 50–70 L/min following the administration of short-acting intravenous anesthetic agents and muscle relaxants.

There are limited data regarding the use of THRIVE for ECT. Land GRM and Jonker *et al*. have demonstrated the feasibility of using THRIVE in a small set of populations undergoing ECT.[6,8] A recent trial demonstrated that HFNO (Optiflow) is non-inferior to conventional facemask ventilation with regard to desaturation, gastric insufflation, seizure quality, and recovery in patients undergoing modified ECT.[15]

Figure 4: THRIVE use during ECT

THRIVE and Peri-operative Adverse Respiratory Events

The common adverse respiratory events that can occur after extubation following surgery include desaturation, hypercarbia, laryngo- or bronchospasm, airway obstruction, and atelectasis, leading to re-intubation. Application of high inspiratory flows and dynamic positive airway pressure with THRIVE along with a manual jaw thrust can avert (and/or rescue from) post-operative airway complications and prevent re-intubation. In neurosurgical patients, post-operative seizures and respiratory depression may also necessitate re-intubation. THRIVE can prolong apnea duration, prevent oxygen desaturation in these emergent respiratory scenarios, and provide a longer time for the anesthesiologist to identify the cause and implement a definitive solution. THRIVE can also act as a bridge during cannot ventilate and cannot oxygenate scenarios until a surgical airway is established after extubation following high cervical spine fusion surgeries.[45]

THRIVE and Neurointensive Care

The utility of THRIVE extends beyond neuroanesthesia into the neurointensive care unit (NICU) as well. Use of HFNO has shown to reduce mechanical ventilation requirement, lower phlegm viscosity, and shorten the duration of NICU and hospital stay.[46] However, more evidence is needed regarding its potential application in this setting.

Concerns During use of THRIVE

Even though some amount of CO_2 elimination can occur with THRIVE by cardiac oscillation mechanism, CO_2 accumulation is still a concern. This can be challenging in patients with altered intra-cranial dynamics. Second, the use of very high flows can be non-economical because of the wastage of oxygen. The third concern with THRIVE is the inability to titrate FiO_2 and provision of only 100% oxygen, which limits its utility in the NICUs and for prolonged surgeries. The use of other HFNO devices can help overcome some of these limitations and should be considered in these specific situations.

Conclusions

THRIVE is a novel oxygenation technique that delivers continuous, warm, humidified, and 100% oxygen at a high flow rate. THRIVE increases the apnoeic period, enhances patient safety, averts potential airway complications, and reduces the need for artificial airways. The several advantages of THRIVE will increase its wider use in neuroanesthesia and neurocritical care practice in the future.

Declaration of patient consent

The authors declare that written and informed consents are not applicable for this publication.

Authors'contributions

Structure/outline: BV. Literature review: BV, KS. Current evidence synthesis: KS. Writing first draft: BV. Critical revision: BV, KS. All authors read and approved the final manuscript.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Benninger MS, Zhang ES, Chen B, Tierney WS, Abdelmalak B, Bryson PC. Utility of transnasal humidified rapid insufflation ventilatory exchange for microlaryngeal surgery. Laryngoscope 2021;131:587-91.
2. Patel A, Nouraei SA. Transnasal humidified rapid-insufflation ventilatory exchange (THRIVE): A physiological method of increasing apnoea time in patients with difficult airways. Anaesthesia 2015;70:323-9.
3. Banik S, Parrent AG, Noppens RR. Awake craniotomy in a super obese patient using high flow nasal cannula oxygen therapy (HFNC). Anaesthesist 2019;68:780-3.
4. Gook J, Kwon JH, Kim K, Choi JW, Chung IS, Lee J. Awake craniotomy using a high-flow nasal cannula with oxygen reserve index monitoring - A report of two cases. Anesth Pain Med (Seoul) 2021;16:338-43.
5. Ng I, Krieser R, Mezzavia P, Lee K, Tseng C, Douglas N, *et al*. The use of transnasal humidified rapid-insufflation ventilatory exchange (THRIVE) for pre-oxygenation in neurosurgical patients: A randomised controlled trial. Anaesth Intensive Care 2018;46:360-7.
6. Jonker Y, Rutten DJ, van Exel ER, Stek ML, de Bruin PE, Huitink JM. Transnasal humidified rapid-insufflation ventilatory exchange during electroconvulsive therapy: A feasibility study. J ECT 2019;35:110-4.
7. Kumar P, McGinlay M, Kelly C, Farling PA, Mullan B. High-flow nasal oxygenation: A new tool to increase patient safety during awake craniotomy. J Neurosurg Anesthesiol 2017;29:368-9.
8. Land GM. Use of transnasal humidified rapid-insufflation ventilatory exchange in Electroconvulsive therapy, a tool to increase patient safety in a remote area: A case series. Trends Anaesth Crit Care 2019;28:36-8.
9. Lin YC, Liu YT, Wu ZF, Chan SM. The successful application of high flow nasal cannula for awake craniotomy. J Clin Anesth 2019;55:140-1.
10. Reese A, Deruyter M. High flow nasal oxygen therapy and transcutaneous carbon dioxide monitoring for awake craniotomy. Turk J Anaesthesiol Reanim 2018;46:326-7.
11. Smith SC, Burbridge M, Jaffe R. High flow nasal cannula, a novel approach to airway management in awake craniotomies. J Neurosurg Anesthesiol 2018;30:382. doi: 10.1097/ANA.0000000000000447.
12. Vaithialingam B, Sriganesh K. Clinical utility of trans-nasal humidified rapid insufflation ventilatory exchange (THRIVE)

during awake craniotomy. Indian J Anaesth 2021;65:262-3.
13. Vaithialingam B, Bansal S, Ramesh VJ, Muthuchellappan R. Trans-nasal humidified rapid insufflation ventilatory exchange (THRIVE) ventilation during electroconvulsive therapy (ECT) for a pregnant patient- A novel technique. Asian J Psychiatr 2022;70:103023. doi: 10.1016/j.ajp.2022.103023.
14. Wong JWM, Kong AHS, Lam SY, Woo PYM. High-flow nasal oxygen in patient with obstructive sleep apnea undergoing awake craniotomy: A case report. A A Case Rep 2017;9:353-6.
15. Zhu Y, Kang Y, Wei J, Hu J, Wang C, Wang S. Effect of high-flow nasal cannula versus conventional facemask ventilation for patients undergoing modified electroconvulsive therapy: A randomised controlled, noninferiority trial. Eur J Anaesthesiol 2019;36:309-10.
16. Yi P, Li Q, Yang Z, Cao L, Hu X, Gu H. High-flow nasal cannula improves clinical efficacy of airway management in patients undergoing awake craniotomy. BMC Anesthesiol 2020;20:156.
17. Bartlett RG Jr, Brubach HF, Specht H. Demonstration of aventilatory mass flow during ventilation and apnea in man. J Appl Physiol 1959;14:97-101.
18. Delorme M, Bouchard PA, Simon M, Simard S, Lellouche F. Effects of high-flow nasal cannula on the work of breathing in patients recovering from acute respiratory failure. Crit Care Med 2017;45:1981-8.
19. Spoletini G, Alotaibi M, Blasi F, Hill NS. Heated humidified high-flow nasal oxygen in adults: Mechanisms of action and clinical implications. Chest 2015;148:253-61.
20. Slutsky AS. Gas mixing by cardiogenic oscillations: A theoretical quantitative analysis. J Appl Physiol Respir Environ Exerc Physiol 1981;51:1287-93.
21. Möller W, Feng S, Domanski U, Franke KJ, Celik G, Bartenstein P, *et al*. Nasal high flow reduces dead space. J Appl Physiol (1985) 2017;122:191-7.
22. Fischer & Paykel Healthcare. Available from: https://www.fphcare.com/in/hospital/adult-respiratory/optiflow/mechanisms-of-action/#airwayhydration. [Last accessed on 2022 May 14].
23. Corley A, Caruana LR, Barnett AG, Tronstad O, Fraser JF. Oxygen delivery through high-flow nasal cannulae increase end-expiratory lung volume and reduce respiratory rate in post-cardiac surgical patients. Br J Anaesth 2011;107:998-1004.
24. Ritchie JE, Williams AB, Gerard C, Hockey H. Evaluation of a humidified nasal high-flow oxygen system, using oxygraphy, capnography and measurement of upper airway pressures. Anaesth Intensive Care 2011;39:1103-10.
25. Parke RL, Eccleston ML, McGuinness SP. The effects of flow on airway pressure during nasal high-flow oxygen therapy. Respir Care 2011;56:1151-5.
26. Mishima G, Sanuki T, Revie J, Pinkham M, Watanabe T, Kurata S, *et al*. Nasal high flow improves ventilation during propofol sedation: A randomized cross-over study in healthy volunteers. Respir Physiol Neurobiol 2020;277:103429. doi: 10.1016/j.resp.2020.103429.
27. Piosik ZM, Dirks J, Rasmussen LS, Kristensen CM, Kristensen MS. Exploring the limits of prolonged apnoea with high-flow nasal oxygen: An observational study. Anaesthesia 2021;76:798-804.
28. Kuo HC, Liu WC, Li CC, Cherng YG, Chen JT, Wu HL, *et al*. A comparison of high-flow nasal cannula and standard facemask as pre-oxygenation technique for general anesthesia: A PRISMA-compliant systemic review and meta-analysis. Medicine (Baltimore) 2022;101:e28903. doi: 10.1097/MD.0000000000028903.
29. Lodenius Å, Piehl J, Östlund A, Ullman J, Jonsson Fagerlund M. Transnasal humidified rapid-insufflation ventilatory exchange (THRIVE) vs. facemask breathing pre-oxygenation for rapid sequence induction in adults: A prospective randomised non-blinded clinical trial. Anaesthesia 2018;73:564-71.
30. Mir F, Patel A, Iqbal R, Cecconi M, Nouraei SA. A randomised controlled trial comparing transnasal humidified rapid insufflation ventilatory exchange (THRIVE) pre-oxygenation with facemask pre-oxygenation in patients undergoing rapid sequence induction of anaesthesia. Anaesthesia 2017;72:439-43.
31. Sjöblom A, Broms J, Hedberg M, Lodenius Å, Furubacke A, Henningsson R, *et al*. Pre-oxygenation using high-flow nasal oxygen vs. tight facemask during rapid sequence induction. Anaesthesia 2021;76:1176-83.
32. Raineri SM, Cortegiani A, Accurso G, Procaccianti C, Vitale F, Caruso S, *et al*. Efficacy and safety of using high-flow nasal oxygenation in patients undergoing rapid sequence intubation. Turk J Anaesthesiol Reanim 2017;45:335-9.
33. Badiger S, John M, Fearnley RA, Ahmad I. Optimizing oxygenation and intubation conditions during awake fibre-optic intubation using a high-flow nasal oxygen-delivery system. Br J Anaesth 2015;115:629-32.
34. Sriganesh K, Busse JW, Shanthanna H, Ramesh VJ. Airway management in the presence of cervical spine instability: A cross-sectional survey of the members of the Indian Society of Neuroanaesthesiology and Critical Care. Indian J Anaesth 2018;62:115-20.
35. Gopalakrishna KN, Prajwal S, Sriganesh K, Reddy BS. Fixed cervical flexion deformity: Difficult airway. Saudi J Anaesth 2018;12:362-3.
36. Roh GU, Kang JG, Han JY, Chang CH. Utility of oxygen insufflation through working channel during fiberoptic intubation in apneic patients: A prospective randomized controlled study. BMC Anesthesiol 2020;20:282.
37. Vijitpavan A, Kooncharoensuk Y. High flow versus conventional nasal cannula for oxygenation and ventilation maintenance during surgery with intravenous deep sedation by propofol: A randomized controlled study. BMC Anesthesiol 20214;21:214.
38. Kim HJ, Asai T. High-flow nasal oxygenation for anesthetic management. Korean J Anesthesiol 2019;72:527-47.
39. Surve RM, Bansal S, Reddy M, Philip M. Use of dexmedetomidine along with local infiltration versus general anesthesia for burr hole and evacuation of chronic subdural hematoma (CSDH). J Neurosurg Anesthesiol 2017;29:274-80.
40. Sriganesh K, Deora H, Tejaswi GM. Anaesthesia for frameless stereotactic neurosurgery in a patient with Cheyne-Stokes respiration. Indian J Anaesth 2020;64:913-5.
41. Sriganesh K, Sabina B, Reddy M. Apnea during awake epilepsy surgery: An unusual cause for a rare complication. J Neurosurg Anesthesiol 2015;27:75-6.
42. Sriganesh K, Reddy M, Jena S, Mittal M, Umamaheswara Rao GS. A comparative study of dexmedetomidine and propofol as sole sedative agents for patients with aneurysmal subarachnoid hemorrhage undergoing diagnostic cerebral angiography. J Anesth 2015;29:409-15.
43. Nishimura M. High-flow nasal cannula oxygen therapy in adults. J Intensive Care 2015;3:15. doi: 10.1186/s40560-015-0084-5.
44. Surve R, Bansal S, Sriganesh K, Subbakrishna DK, Thirthalli J, Umamaheswara Rao GS. Incidence and risk factors for oxygen desaturation during recovery from modified electroconvulsive therapy: A prospective observational study. J Anaesthesiol Clin Pharmacol 2015;31:99-103.
45. Shallik N, Karmakar A. Is it time for high flow nasal oxygen to be included in the difficult airway algorithm? Br J Anaesth 2018;121:511-2.
46. Wang S, Yang J, Xu Y, Yin H, Yang B, Zhao Y, *et al*. High flow nasal cannula decreased pulmonary complications in neurologically critically ill patients. Front Hum Neurosci 2022;15:801918. doi: 10.3389/fnhum.2021.801918.