TYPE Case Report
PUBLISHED 21 November 2023
DOI 10.3389/fanes.2023.1226132

OPEN ACCESS

EDITED BY
Bahadir Ciftci,
Istanbul Medipol University, Türkiye

REVIEWED BY
Ahmet Murat Yayik,
Atatürk University, Türkiye
Muhammed Enes Aydin,
Atatürk University, Türkiye

*CORRESPONDENCE
Hua Xu
pshhuaxu@163.com

RECEIVED 20 May 2023
ACCEPTED 31 October 2023
PUBLISHED 21 November 2023

CITATION
Shi H, Zhou Z and Xu H (2023) Transnasal humidified rapid insufflation ventilatory exchange combined with intravenous anesthesia and nerve block without endotracheal intubation for atrial septal defect repair: a case report.
Front. Anesthesiol. 2:1226132.
doi: 10.3389/fanes.2023.1226132

Transnasal humidified rapid insufflation ventilatory exchange combined with intravenous anesthesia and nerve block without endotracheal intubation for atrial septal defect repair: a case report

Haifeng Shi, Zhengqing Zhou and Hua Xu*

Department of Anesthesiology, Yueyang Hospital of Integrated Traditional Chinese and Western Medicine, Shanghai University of Traditional Medicine, Shanghai, China

This brief case report describes a new anesthesia method without endotracheal intubation in open heart surgery. The patient was a 41 years old female. Because the location of the atrial septal defect was not suitable for interventional minimally invasive surgery, she could only undergo open heart surgery under cardiopulmonary bypass. Due to news reports about anesthesia without tracheal intubation, the patient refused to undergo tracheal intubation anesthesia; therefore, we innovatively adopted an anesthesia method of transnasal humidified rapid insufflation ventilatory exchange (THRIVE) combined with intravenous anesthesia and nerve block without endotracheal intubation, and achieved success. The whole operation process was very smooth; the patient was quiet and motionless, and her respiration and circulation were stable. After the operation, the patient opened her eyes without any complaints and was safely sent to the CICU (cardiac intensive care unit).

KEYWORDS
THRIVE, hfno, non-intubated open-heart surgery, ultrasound guided, nerve block

Introduction

Open heart surgery is generally performed under general anesthesia with endotracheal intubation. Although the anesthesia method of retaining spontaneous breathing without endotracheal intubation is conducive to the rapid recovery of patients, it has not been widely applied due to its immature technology, disunity, and safety problems. In this case, the anesthesia method of transnasal humidified rapid insufflation ventilatory exchange combined with intravenous anesthesia and nerve block without endotracheal intubation was successfully applied in the repair of an atrial septal defect via median sternotomy. During the whole operation, the patient's respiratory, circulatory, and oxygen saturation were stable and satisfied, and she immediately opened her eyes after the operation without complaints.

Case report

A 41 years old woman, height 156 cm, weight 47.5 kg, and BMI 19.5 kg/m^2, was hospitalized due to "cough with fatigue for more than 2 weeks". Two weeks prior, the patient had a cough with fatigue without obvious inducement, with a maximum temperature of 39.1°C. There was a small amount of blood in the sputum, occasionally purulent sputum, no asthma, suffocation, cyanosis, and no lower limb edema. After anti-infection treatment in the local hospital, the fever was relieved but the fatigue was the same as before. Echocardiography showed that there was an interruption in the middle of the atrial septum, with a range of 10.1 mm. Color Doppler flow imaging (CDFI) showed a left-to-right shunt in the diastolic phase. After admission, the patient's cardiac ultrasound showed that there was a defect in the middle and upper part of the atrial septum, about 18 × 26 mm in size, with a left-to-right shunt, multiple stumps less than 5 mm in length, a right enlarged heart, widened pulmonary artery, slight tricuspid regurgitation, estimated pulmonary artery systolic pressure of 35 mmhg, and an echo-free area in front of the anterior wall of the right ventricle with a depth of 6 mm. Left ventricular function was FS 37%, LVEF 67%, SV 42 ml/stroke, and Co 2.5 L/min. Preoperative examination showed the level of B-type natriuretic peptide precursor was 157.8 pg/ml and the myocardial enzyme spectrum, blood routine, blood gas analysis, and liver and kidney function were normal. Diagnosis was atrial septal defect, cardiac function class II. Because the defect location was close to the superior vena cava and multiple defect stumps were less than 5 mm, it was not suitable for interventional closure. After multidisciplinary discussion before operation, it was proposed to perform median sternotomy and extracorporeal circulation for atrial septal defect repair. The anesthesia method was intravenous anesthesia combined with nerve block anesthesia without endotracheal intubation. Transnasal humidified rapid insufflation ventilation exchange (THRIVE) was used during the operation.

The patient underwent routine fasting and drinking restrictions before the operation and also underwent routine vital signs monitoring and BIS (Bispectral index) monitoring after entering the operating room. After opening the peripheral vein, she was given 1 ug/kg dexmedetomidine for sedation within 15 min. Under local anesthesia, left radial artery catheterization was completed to monitor the arterial blood pressure and cardiac output, and right internal jugular vein catheterization was performed to monitor the central venous pressure (CVP). When the patient fell asleep and the BIS value was less than 60, the nasal catheter was put into the patient's nostrils and THRIVE was started after confirming that the airflow was unobstructed. The parameter settings were: temperature 37°C, flow rate 70 L/min, and FiO2 100%. Under ultrasound guidance, a bilateral T4-5 Deep parasternal intercostal plane (PIP) block (15 ml 0.33% ropivacaine each side), and bilateral superficial cervical plexus block (5 ml 0.33% ropivacaine each side) were performed. Because the patient was sedated, the block scope was not tested. During the operation, the anesthesia depth was maintained by target-controlled infusion of propofol and remifentanil in Marsh and Minto modes, respectively. The anesthesia was deepened before sternotomy to inhibit the patient's breathing and reduce the probability of pleural injury during sternotomy. The target concentration of propofol was adjusted to 3 ug/ml and remifentanil to 4 ng/ml. THRIVE was suspended during the sternotomy. The anesthesia was lightened immediately after sternotomy. The target concentration of propofol was adjusted to 1–2 ug/ml and remifentanil to 1–2 ng/ml. Spontaneous breathing was resumed as soon as possible and THRIVE was continued. THRIVE was stopped after full flow perfusion of the cardiopulmonary bypass. When the rewarming started after the completion of intracardiac operation, all anesthetics were stopped, before the aorta was opened, mask pressure ventilation was used for lung enlargement, the intrapulmonary pressure was increased, and the blood was pushed to leave the pulmonary vein and enter the left atrium, so as to remove the possible residual air in the pulmonary vein, left atrium, left ventricle, and aortic root. After opening the aorta, THRIVE was continued with the same parameters as before. Dopamine was routinely pumped at 5–6 ug/kg/min, and magnesium sulfate was injected at 2.5 g. The patient's heart automatically began beating, the flow of the cardiopulmonary bypass was gradually reduced, and the auxiliary circulation time was 1/3 of the blocking time until shutdown. After shutdown, the vital signs of the patient were closely observed. Protamine antagonistic heparin was given under the condition of stable volume, normal heart beat rhythm, stable blood pressure, and normal oxygen saturation, and propofol and remifentanil were given to maintain the depth of anesthesia. During chest closure, the patient had abnormal respiration, and the right pleura was found to be ruptured by exploration. The sternum was closed after rapid packing with wet gauze and the right pleural puncture was performed for closed drainage. After the operation, all anesthetics were stopped. The patient's respiration and circulation were stable, and she opened her eyes without complaints. She was safely sent to the Cardiac Surgery ICU.

The operation time of this case was 230 min, and the cardiopulmonary bypass time was 71 min. During the off-pump period, the oxygen saturation was maintained at 97%–100%, and there was no significant decrease. Blood gas analysis before skin incision was: PH7.347, $PaCO_2$45.9 mmhg, and $PaO_2$404 mmhg; blood gas analysis after splitting the sternum was: PH7.203, $PaCO_2$67.6 mmhg, and $PaO_2$354 mmhg, and $PaCO_2$ increased significantly, which was caused by deepening anesthesia before sternotomy to inhibit respiration. After sternotomy, the blood gas analysis was performed again after 22 min of shallow anesthesia and was: PH7.36, $PaCO_2$43 mmhg, and $PaO_2$457 mmhg. Blood gas analysis 20 min after cardiopulmonary bypass was: PH7.293, $PaCO_2$52 mmhg, and $PaO_2$92 mmhg. Blood gas analysis after 50 min was: PH7.31, $PaCO_2$498 mmhg, and $PaO_2$121 mmhg, and PaO_2 was lower than those before cardiopulmonary bypass. Later, it was found that this was related to pneumothorax caused by pleural rupture, but the oxygen saturation was still maintained at 97%–99%, and the oxygen saturation was maintained at 100% after thoracic closed drainage of thoracentesis.

Discussion

In this case, the method of intravenous anesthesia and nerve block without endotracheal intubation was used. The difficulty with this method lies in ensuring that the patient is in a quiet and painless state, and they must be able to maintain normal oxygenation and acceptable $PaCO_2$. Firstly, on the basis of sedation, we performed ultrasound-guided bilateral deep parasternal intercostal plane block and bilateral cervical nerve pathway block to cover the surgical incision area and reduce the stress response to the thoracotomy. Secondly, when splitting the sternum, it was necessary to increase the dose of remifentanil to temporarily inhibit respiration and reduce the risk of pleural injury. At this time, the application of THRIVE ensured the oxygenation of the patient during the period when respiration almost stopped. Although $PaCO_2$ had a slight rise, it quickly returned to normal after spontaneous breathing recovered. Thirdly, after cardiopulmonary bypass stopped and the circulation was stable, it still took some time for the patients' spontaneous breathing to fully recover. At this time, THRIVE plays a very good supporting role and effectively avoids the occurrence of hypoxia. In this case, a pleural rupture was found after cardiopulmonary bypass was stopped. Although the patient had pneumothorax and decreased PaO_2, it was still within the normal range, and SpO_2 remained between 97% and 99%. Fourthly, the patient's breathing range should not be too large during the whole operation. Because non-endotracheal intubation cardiac surgery is different from conventional endotracheal intubation surgery under general anesthesia, muscle relaxants cannot be used, and the range of chest expansion should not be too large to reduce pain stimulation, which limits the operating space and vision of surgeons. If the breathing range is too large, it will seriously affect the operation of surgeons. Therefore, opioids should be used to inhibit the patient's breathing. Keeping weak and slow breathing is conducive to the operator's operation, but it will lead to a decrease in PaO_2 and increase in $PaCO_2$. While THRIVE maintains oxygenation, it slows down the increase of $PaCO_2$. Furthermore, different from the state of complete no breathing, weak breathing at this time is conducive to the discharge of carbon dioxide (1). In this case, it took 70 min from sternal splitting to the establishment of the cardiopulmonary bypass, and no significant increase in $PaCO_2$ was observed. Artificial ventilation was not given during the whole operation process.

Anesthesia without endotracheal intubation cannot fully control the patient's breathing; there are risks of hypoxia and carbon dioxide accumulation after anesthesia and excessive spontaneous breathing affects the operation. The THRIVE used in this case is a new technology based on high flow nasal oxygen therapy (hfno). It mainly refers to the fact that the patient carries out hfno without spontaneous breathing and mechanical ventilation to maintain oxygenation and remove carbon dioxide. The study found that the patient with THRIVE had a no spontaneous breathing time of 16–65 min and SpO_2 was greater than 90% without hypercapnia. $PaCO_2$ was 7.8 kpa (4.9–15.3 kpa). With the extension of time, PaCO2 increased, and the rate of increase was 0.15 kpa/min (2). Although in theory, THRIVE can increase CO_2 clearance by producing supraglottic gas vortices and strong turbulence through high-flow airflow and cardiogenic oscillation (3), there are still controversies in clinical application. With the extension of time, an increase in $PaCO_2$ is inevitable. Although permissive hypercapnia has certain benefits for the nervous system, cardiovascular system, respiratory system, and immune system (4), excessive $PaCO_2$ will lead to intractable hypotension, myocardial depression, etc., which will threaten the life safety of patients. How to remove CO_2 more effectively is the focus of THRIVE's future application and research. After cardiopulmonary bypass in cardiac surgery, patients will have varying degrees of pulmonary edema and atelectasis, which can lead to a certain degree of hypoxemia. Hfno has the advantages of producing peep, reducing anatomic dead space, providing sustainable FiO_2, increasing PaO_2/FiO_2, improving ciliary movement, promoting sputum excretion, reducing upper respiratory tract resistance and respiratory work, and increasing the coordination of thoracoabdominal movements (5). The application of THRIVE in patients undergoing cardiac surgery after extubation can significantly increase the patient's oxygen partial pressure and reduce $PaCO_2$ (6). When stopping cardiopulmonary bypass and experiencing pneumothorax, this case can still maintain satisfactory oxygen saturation and PaO_2, ensured the patient's safety. THRIVE has been used more and more in clinical anesthesia, such as awake intubation, airway related examination or surgery, non-endotracheal intubation thoracoscopic surgery, painless gastrointestinal endoscopy, obstetric anesthesia, and pediatric anesthesia, but it has not been reported in non-endotracheal intubation cardiac surgery. The application of THRIVE in this case has solved the problem of patients having no spontaneous breathing or weak spontaneous breathing during anesthesia without endotracheal intubation, which can easily lead to hypoxia. It provides sufficient time for patients to resume spontaneous breathing after cardiopulmonary bypass shutdown and maintains satisfactory oxygen before the recovery of spontaneous breathing, ensuring the safety of patients. It makes up for the lack of oxygen in patients with anesthesia without endotracheal intubation.

However, the application of THRIVE still has certain limitations, such as: the risk of reflux aspiration caused by intragastric air intake; patients with severe nasal diseases and severe nasal congestion may not achieve the expected effect; excessive oxygen flow will lead to patient discomfort; long-term application still cannot avoid carbon dioxide accumulation; and $PetCO_2$ cannot be monitored. Continuous percutaneous carbon dioxide monitoring or intermittent blood gas analysis after arterial catheterization can be used. However, on the basis of mastering the application indications, the depth management of anesthesia, and emergency plan, the safety and effect of this technology can be greatly improved and widely recognized.

Endotracheal intubation general anesthesia is still the main anesthesia method for median sternotomy because of its safety and controllability, but it is not without complications. Although the anesthesia method without endotracheal intubation is generally considered inconceivable. However, in order to achieve faster recovery for patients and the benefits of autonomous breathing on pulmonary circulation, exploration and attempts for this anesthesia method have never stopped. Epidural anesthesia was once the most important method of this anesthesia method, including valve replacement surgery under cardiopulmonary bypass (7) and off-pump coronary artery bypass surgery (8), and for valve replacement surgery in high-risk patients, the postoperative mortality of patients under epidural anesthesia seems to be lower (9). However, epidural anesthesia is difficult to manage, as it is easy to inhibit the sympathetic nerve, resulting in a high probability of slow heart rate and low blood pressure. The most important thing is the risk of epidural hematoma after heparinization. Most clinicians are not willing to use epidural anesthesia widely in heart surgery because paraplegia caused by epidural hematoma is catastrophic. Hematoma will occur not only during epidural puncture but also when the epidural catheter is pulled out. The method of deep parasternal intercostal plane block was used in this case, also known as the transverse thoracic muscle plane block (10). The blocking range of the transverse thoracic muscle plane block is the anterior cutaneous branch of the intercostal nerve T2–T6 in the central region of the anterior chest. In order to avoid incomplete blocking from T2 to the supraclavicular fossa area, the bilateral superficial cervical plexus block was also used in this case. The application of the bilateral deep parasternal intercostal plane block in open heart surgery can reduce postoperative pain and opioid consumption and promote the recovery of patients (11, 12). Although it has been used for sternum revision surgery in conscious patients without tracheal intubation after COVID-19 (13) there are still no reports of its application in non-endotracheal intubation anesthesia in cardiac surgery. Although this nerve block method can cover the surgical incision, it only blocks the cutaneous branch of the intercostal nerve, which can only provide analgesia for the surgical incision, and cannot completely block the discomfort reaction of sternal distraction and intrathoracic operation. It needs to be used in cooperation with intravenous anesthesia to achieve satisfactory results.

Conclusion

In this case, bilateral deep parasternal intercostal plane combined with bilateral superficial cervical plexus block was used to cover the incision position of median sternotomy to reduce the pain and stimulation during thoracotomy. At the same time, intravenous sedatives and analgesics were used to make the patients fall asleep quietly, reduce the adverse stimulation and body movement of the external environment, and weaken the patient's breathing amplitude to facilitate the needs of the operator. Furthermore, THRIVE technology was used to ensure the oxygen supply of the patient and slow down the rising speed of $PaCO_2$. Whether the anesthesia method of non-endotracheal intubation cardiac surgery can be applied to more complex operations, make patients safer and anesthesia management simpler, help patients recover more quickly, and whether it can be further promoted still needs to be further confirmed and improved by large sample research.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the patient for the publication of this case report and any accompanying images/data.

Author contributions

HX contributed to the idea and HS and ZZ wrote the manuscript. All authors contributed to the article and approved the submitted version.

Funding

Supported by Research Project of Yueyang Hospital of Integrated Traditional Chinese and Western Medicine, Shanghai University of Traditional Chinese Medicine (2019YYQ13).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Gustafsson IM, lodeniu A, Tunelli J, Ullman J, Jonsson Fagerlund M. Apnoeic oxidation in adults under general anaesthesia using transnasal humanized rapid inventory venture exchange (thrive)—a physiologic study. *Br J Anaesth.* (2017) 118:610–7. doi: 10.1093/bja/aex036

2. Patel A. Nouraei saTransnasal humanized rapid - inventory utility exchange (thrive): a physiologic method of increasing apnoea time in patients with difficult airways. *Anaesthesia.* (2015) 70(3):323–9. doi: 10.1111/anae.12923

3. Hermez LA, Spence CJ, Payton MJ, Nouraei SAR, Patel A, Barnes TH. A physical study to determine the mechanism of carbon dioxide clearance during apnoea when using transnasal humanized rapid inventory ventilation exchange (thrive). *Anaesthesia.* (2019) 74(4):441–9. doi: 10.1111/anae.14541

4. Contreras M, Masterson C, Laffey JG. Permissive hypercapnia: what to remember. *Curr Opin Anesthesiology.* (2015) 28(1):26–37. doi: 10.1097/ACO.0000000000000151

5. Cuquemelle E, Pham T, Papon JF, Louis B, Danin PE, Brochard L, et al. Heated and humanized high-flow oxygen thermal reduction discomfort during hypoxic respiratory failure. *Res Care.* (2012) 57(10):1571–7. doi: 10.4187/respcare.01681

6. Burra V, Putta G, Prasad SR, Manjunath V. A prospective study on use of thrive (transnasal humified rapid insufflation venture exchange) versus conventional nasal oxidation following extension of adult cardiac surgical patients. *Ann Card Anaesth.* (2021) 24(3):353–7. doi: 10.4103/aca.ACA_16_20

7. Thomas S, Johannes B, Doris B, Josef M, Peter M, Günther L, et al. Aartic valve replacement in the chronic patient under regional anesthesia without endogenous introduction. *J Tradit Cardiovasc Surg.* (2003) 125(6):1526–7. doi: 10.1016/s0022-5223 (02) 73416-8.

8. Chakravarthy M, Jawali V, Patil TA, Jayaprakash K, Shivananda NV. High thoracic epidural anesthesia as the sole anesthesia for performing multiple grafts in off-pump royal artery bypass surgery. *J Automot Vas Anal.* (2003) 17(2):160–4. doi: 10.1053/jcan2003.40

9. Bottio T, Bisleri G, Piccoli P, Negri A, Manzato A, Muneretto C. Heart valve surgery in a very high-risk population: a preliminary experience in awake patients. *J Heart Valve Dis.* (2007) 16(2):187–94.

10. El-Boghdadly K, Wolmarans M, Stengel AD, Albrecht E, Chin KJ, Elsharkawy H, et al. Standardizing nomenclature in regional anesthesia: an ASRA-ESRA Delphi consensus study of abdominal wall, paraspinal, and chest wall blocks. *Reg Anesth Pain Med.* (2021) 46(7):571–80. doi: 10.1136/rapm-2020-102451

11. Hamed MA, Boules ML, Sobhy MM, Abdelhady MA. The analytical efficiency of ultrasound guided bilateral transversus thoracic muscle plane block after open heart surgeries: a randomized controlled study. *J Pain Res.* (2022) 15:675–82. doi: 10.2147/jprS355231

12. Aydin ME, Ahiskalioglu A, Ates I, Tor IH, Borulu F, Erguney OD, et al. Efficacy of ultrasound-guided transversus thoracic muscle plane block on postoperative opioid consumption after cardiac surgery: a prospective, randomized, double-blind study. *J Cardiothorac Vasc Anesth.* (2020) 34(11):2996–3003. doi: 10.1053/j.jvca.2020.06.044

13. Karapinar YE, Medetoglu EN, Ozkal MS, Aydin ME, Ahiskalioglu A. Ultrasound-guided transverse thoracic muscle plane block for awake sternum revision in a post-COVID patient. *JARSS.* (2022) 30(2):143–5. doi: 10.54875/jarss.2022.60465