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CASE REPORT

Use of jet ventilation in thoracoscopic tracheo-esophageal fistula repair—can both surgeons and anesthesiologists be happy?

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Summary

Laparoscopic and open thoracic surgery in the neonate typically results in hypercapnea and low cardiac output with often poor surgical visualization as the anesthesiologist attempts to correct the respiratory derangements usually seen. We describe three cases in which jet ventilation provided not only superior ventilation with a return to normocapnea but also ideal operating conditions. In addition, jet ventilation utilizes lower mean airway pressures which typically results in improved cardiac output.

Introduction

Thoracic surgery in the neonate presents many difficult challenges to both the anesthesiologist and the surgeon. Insufflation of carbon dioxide increases ventilatory requirements and decreases venous return. Increased ventilation can impair surgical visualization and prolong the operation. Hypercapnea and low cardiac output can compromise patient outcomes due to prolonged ventilation postoperatively and hemodynamic instability resulting in hypotension. Use of high-frequency ventilation during these cases can significantly improve surgical visualization as well as patient ventilation and oxygenation (1). We describe three cases in which jet ventilation was used successfully in neonatal thoracic surgery to improve surgical visualization, ventilation, and oxygenation.

Case descriptions

Case #1

A 3-day-old, 2.2-kg term neonate presented for thoracoscopic repair of her tracheo-esophageal fistula. Her history was significant for Trisomy 21, a large patent ductus arteriosus with bidirectional flow, a large patent foramen ovale vs secundum atrial septal defect with a left to right shunt, and a preoperative oxygen requirement via nasal cannula. After induction and bronchoscopic confirmation of the fistula, the patient was placed in a modified prone position (i.e., right side elevated ~30°, facilitates right lung falling away from the mediastinum) and the surgeons commenced operating. The initial ventilation strategy was pressure controlled. Efforts were made to adjust ventilation to different modes (i.e., volume controlled, pressure controlled with volume guarantee) while maintaining a high respiratory rate and low tidal volume technique. Upon entering the thorax, visualization of structures was poor and despite further attempts at optimization, ventilation and oxygenation deteriorated. The patient developed an increased gap between the pre- and postductal oxygen saturations which was felt to indicate flow reversal through the intracardiac shunts. Despite conversion into an open repair, ventilation and oxygenation continued to be difficult (P_aCO_2 > 100 mmHg, P_aO_2 40 mmHg) and surgical visualization remained inadequate. The initiation of

high-frequency jet ventilation (HFJV) (420 breaths per minute, peak inspiratory pressure (PIP) 24 cm H_2O, positive end-expiratory pressure (PEEP) 9 cm H_2O with the Bunnell High Frequency Jet Ventilator, Salt Lake City, UT, USA) resulted in immediate improvement in surgical operating conditions as the right lung was held in a partially inflated state (secondary to the CO_2 insufflation pressure) with minimal movements which would obscure surgical visualization of relevant structures. Significant improvements in both oxygenation and ventilation were apparent within 20 min of the ventilation change probably secondary to improved recruitment of alveoli despite surgical compression of the right lung. By the end of the procedure, the infant was normocapnic (P_aCO_2 36 mmHG) and well oxygenated (P_aO_2 87 mmHg on 0.4 FiO_2). The patient was returned to the neonatal intensive care unit (NICU) on jet ventilation. She was transitioned to conventional ventilation on postoperative day 5 and was extubated the following day.

Case #2

A full-term female presented at 2 months of age weighing 4 kg for repair of her long gap esophageal atresia. She had undergone daily esophageal stretching and two gap studies via her g-tube to demonstrate appropriate elongation of the esophageal pouch prior to repair. In this case, HFJV was planned from the outset and was initiated (500 breaths per minute, PIP 30–42 cm H_2O, PEEP 8 cm H_2O) after positioning in the left lateral decubitus 75% prone position. Intermittent blood gas samples as well as transcutaneous CO_2 readings confirmed excellent ventilation and oxygenation throughout the operation, and the surgeons reported ideal operating conditions with this mode of ventilation. The operation was not completed thoracoscopically due to a surgical breach of the membranous portion of the trachea. However, it should be emphasized that jet ventilation continued to provide both excellent ventilation and operating conditions despite the large tracheal leak while an attempt was made to close the 'breach' thoracoscopically. Upon delivery to the NICU, the patient was placed on conventional ventilation and extubated on postoperative day 4.

Case #3

A 3-day-old, 2.1-kg female with an atrioventricular canal defect, born at 34 weeks gestational age, presented for open repair of her tracheo-esophageal fistula. Initially, conventional ventilation was used, but the patient developed hemodynamic and respiratory instability during dissection around the aorta. Jet ventilation was initiated (420 breaths per minute, PIP 26-42 cm H_2O, PEEP 12 cm H_2O) and greatly improved the P_aCO_2 from 70 mmHg to 44 mmHg while maintaining excellent operating conditions. Upon delivery to the NICU, the patient was placed on conventional ventilation and was extubated on postoperative day 5.

Discussion

High-frequency ventilation utilizes high respiratory rates, generally >150 breaths per minute, to deliver tidal volumes that are typically less then anatomical dead space (2). It has been used successfully to treat severe respiratory distress syndrome, air leaks, bronchopleural fistula, pulmonary interstitial emphysema, and other complications associated with air leaks (3).

There are two common ways that high-frequency ventilation can be provided. The first is high-frequency oscillation (HFO), in which inspiratory flow begins slowly, accelerates rapidly, and then slows down at the end of inspiration. The oscillator uses active expiration, which requires a high mean airway pressure throughout the respiratory cycle to prevent airway collapse during expiration (4). In contrast, HFJV, in which exhalation is passive, generates lower mean airway pressure than HFO, thereby reducing the potential of gas trapping (4). Hemodynamic functions may be better for patients who are on HFJV, because the lower mean airway pressure utilized for this style of ventilation allows for better cardiac output and venous return (5).

At our institution, we use the Bunnell High Frequency Jet Ventilator which uses the *in situ* endotracheal tube and does not require placement of a special HFJV catheter. Whenever this mode of ventilation is used in the OR, a respiratory therapist is assigned to assist us during the case. A change in anesthetic technique is also required for these cases as it would be difficult to deliver volatile agents; typically a total intravenous anesthetic (TIVA) technique is used with muscle relaxant, high-dose narcotic infusion +/− hypnotic. We are pleased to report that this technique has worked well for all of our patients undergoing thoracoscopic repair, and we have even used it as a rescue maneuver (similar to case 3) during open repair when conventional ventilation is not adequate. It should be briefly mentioned that many institutions favor a technique where the endotracheal tube is deliberately main-stemmed on the left side to allow for one lung ventilation. We have found this technique to have a high failure rate (typically due to movement of the mediastinum during dissection which allows

the tube to 'pop out' of the left side and then be inherently difficult to replace back into the left side) and to also contribute to potential injury of the left main bronchus.

Learning points

1 Jet ventilation is an excellent alternative to conventional ventilation because it provides a relatively quiet surgical field while thoracoscopic procedures are being performed on small patients.
2 The three cases presented demonstrate that jet ventilation can substantially improve ventilation and oxygenation in neonates especially during CO_2 pneumothorax.
3 Cardiac output and venous return may be markedly improved during jet ventilation as a result of lower mean airway pressures. As demonstrated above, this can be especially important in the small neonate with congenital heart disease who requires tracheo-esophageal fistula repair.

Ethics approval

This manuscript does not require any ethical approval.

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Conflict of interest

No conflicts of interest declared.

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