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Revolutionizing Anesthesia Using Esketamine for Congenital Diaphragmatic Hernia: A Case Report

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Abstract: Congenital diaphragmatic hernia (CDH) is a rare developmental abnormality involving the partial formation of the diaphragm, which creates an opening that allows abdominal organs to extend into the chest cavity. Children with congenital diaphragmatic hernia often face complications such as lung infection, hypoxia, acid-base imbalance, and electrolyte disorders, due to the occurrence of abdominal organs within the chest cavity and underdeveloped lungs. The standard treatment for children with CDH involves reducing the herniated organs and repairing the diaphragmatic hernia following their birth. Anesthetic management during surgery can be challenging, particularly when addressing large hernias coupled with lung hypoplasia and congenital heart disease. Positive pressure ventilation with a mask during anesthesia induction may cause gastric distension, exacerbating the child's hypoxemia and further worsening circulation. Therefore, preserving spontaneous breathing during anesthesia induction is the ideal choice. We present a case involving the preservation of spontaneous breathing during the induction of anesthesia in a one-year-old child diagnosed with CDH. In this case, a novel approach using a combination of sevoflurane and esketamine is proposed to maintain stable hemodynamics without significant respiratory depression. The combination of sevoflurane and esketamine offers a promising solution for maintaining stable hemodynamics and preserving spontaneous breathing during anesthesia induction. Further research is required to validate the effectiveness of this approach and provide optimal dosing guidelines for different clinical scenarios.

Keywords: Congenital Diaphragmatic Hernia (CDH), Esketamine, Anesthesia Induction

1. Introduction

Congenital diaphragmatic hernia (CDH) is a rare developmental abnormality of the diaphragm, marked by the protrusion of abdominal organs into the chest cavity, leading to varying degrees of pulmonary hypoplasia and pulmonary hypertension (PH). The occurrence of CDH ranges from 1: 2000 to 1: 4000, with an equal male-to-female ratio [1-4]. The etiology of CDH remains unclear and is multifactorial [5]. CDH patients exhibit different extents of lung underdevelopment, altered surfactant system, and pulmonary vasculature with or without pulmonary hypertension. They typically present with breathing difficulties during the neonatal period, and in some cases cyanosis, however, 10% manifest symptoms later in life [6, 7]. More than half of these instances are associated with other congenital abnormalities, such as cleft lip, cleft palate, and congenital heart disease, which independently predict outcome [8, 9]. Based on anatomical location, CDH can be classified into esophageal hiatal hernia, thoracoabdominal hernia, and parasternal hernia.

The safe anesthesia choice for diaphragmatic hernia patients involves preserving spontaneous respiration during general anesthesia induction without using muscle relaxants and avoiding positive pressure oxygenation to prevent gas from being forced into the stomach and intestines leading to increased intrathoracic and pulmonary hypertension. In this case, we present a successful case of laparoscopic esophageal hiatal hernia repair performed under anesthesia induction with esketamine, while maintaining spontaneous respiration and stable hemodynamics, offering an interesting and potentially promising approach for anesthesia induction in CDH cases.

2. Case Report

A child, aged one year and weighing 9 kg, exhibited symptoms of periodic milk regurgitation and vomiting, along with a recurring cough and chest infection. Upon examination, the child appeared underweight and frail. The respiratory system assessment revealed slightly reduced movement on the left side of the chest. During auscultation, diminished airflow was observed in the left rear section of the chest, and peristaltic noises were audible in the left half of the thoracic cavity. The esophagography showed that the cardia and part of the stomach herniated into the diaphragm. The abdominal and thoracic computed tomography (CT) confirmed the diagnosis of a left esophageal hiatal hernia (figure 1). Upon visual examination, the abdomen appears normal in shape. The abdomen is soft on palpation, with no tenderness or rebound pain. Echocardiography and electrocardiogram examinations did not show any significant abnormalities before the operation and hematologic investigations were within normal range.

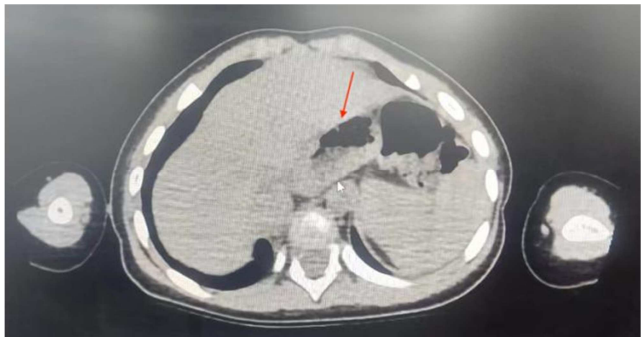

Figure 1. *The abdominal computed tomography showed the cardia and part of the stomach herniated into the diaphragm.*

After fasting for 8 hours, the patient was transported to the operating room. Informed consent regarding anesthetic risk was obtained. After administering 0.75mg of midazolam intravenously, the patient became calm. Vital signs were monitored with blood pressure at 90/56 mmHg, heart rate measured at 120 beats per minute, respiratory rate at 30 breaths per minute, and blood oxygen saturation level at 100%. Subsequently, 0.1mg of atropine was administered intravenously to inhibit secretions. Then, the patient received an intravenous injection of 10mg esketamine, followed by inhalation of 3% sevoflurane. Once unresponsive to painful stimuli, an orotracheal intubation was performed. Throughout the induction process, spontaneous breathing was maintained with tidal volumes of 70-80ml and a breathing rate ranging from 25 to 30 breaths per minute. Simultaneously, the hemodynamics of the patient was stable. Anesthesia was then maintained with 0. 2ug/kg*min remifentanil and 3% sevoflurane throughout the surgery. Measures were taken to maintain regular body temperature, adequate interior vascular volume, and the balance between acidic and basic substances. As the procedure started, 1mg of cisatracurium was administered intravenously, along with 20ug fentanyl. The patient underwent laparoscopic repair of the esophageal hiatus hernia and fundoplication, with an uneventful intraoperative course. Following the surgery, the patient was transferred to the recovery room, where the endotracheal tube was removed after 15 minutes. Subsequently, she was taken back to the general ward and discharged on the 6th day following the operation.

3. Discussion

CDH is a potentially fatal condition, with a severity that is predominantly determined by the size of the hernia sac and the degree of lung hypoplasia [10-12]. When a large hernia sac enters the chest cavity, it can increase intrathoracic pressure, leading to compression of the heart, lungs, and major blood vessels. This results in hypoxia, hypotension, exacerbated pulmonary hypertension, and significant impairment of respiration and circulation in the child. The presence of cardiac defects has been demonstrated to negatively impact the outcome, irrespective of the severity of the hernia [13], making anesthesia highly risky.

Anesthetic considerations for CDH patients include the patient's age, underdeveloped physiological organ systems, pulmonary hypoplasia, limited lung function, high blood pressure in the pulmonary arteries, and accompanying congenital abnormalities. Pulmonary complications like hypoxemia, hypercapnia, weakened hypoxic pulmonary vasoconstriction, atelectasis, re-expansion lung edema, and pneumonia are commonly encountered during the perioperative phase. Heart abnormalities, a preoperative alveolar-to-arterial oxygen difference exceeding 500 mmHg, or intense hypercarbia despite aggressive respiratory support may be indicators of a poor outcome.

When patients present for surgical repair of diaphragmatic hernias, it is essential to conduct a thorough preoperative evaluation, focusing on the extent of lung and heart malfunction. Typically, this involves obtaining a comprehensive history, performing a physical examination, and assessing hemoglobin levels, blood electrolyte levels, arterial blood gas analysis, and chest radiographs. A consultation with a pediatric specialist should also be conducted to exclude the possibility of other congenital abnormalities. Before surgery, measures such as chest physiotherapy, proper nutrition, bronchodilator or antibiotic treatment, and steroid supplementation can contribute to improving the patient's overall health.

Considering that muscle relaxants can easily cause enlargement of the hernia ring in such patients, leading to more abdominal organs entering the thorax, and positive pressure ventilation may cause gastric dilation, which further worsens lung compression and affects ventilation. Moreover, these children often have underdeveloped lungs, even combined with lung infections, resulting in poor respiratory reservation, making it difficult for them to tolerate rapid sequence induction with a ventilation gap. During awake intubation, the child's crying and struggling make cooperation impossible. Therefore, preserving spontaneous breathing during anesthesia induction is the safest option for such

patients, especially those with a large hernia sac accompanied by compression on the heart, lungs, and major blood vessels [10]. However, 1% to 3% of sevoflurane alone cannot suppress the irritation of endotracheal intubation, and fentanyl can easily cause respiratory depression and hypotension, aggravating the child's respiratory and circulatory disorders. The combination of esketamine and sevoflurane can maintain the child's spontaneous breathing while providing the needed anesthesia depth for endotracheal intubation.

Esketamine is an isomer of ketamine that functions as an antagonist to the N-methyl-D-aspartate receptor (NMDAR), providing analgesic and anesthetic effects similar to the classic pharmacological properties of ketamine. Compared to ketamine, it has faster onset and elimination, fewer side effects, and stronger sedative and analgesic capabilities. It can be used for anesthesia and analgesia in various clinical surgeries and short examinations. In a study conducted by Van and colleagues the effectiveness of esketamine and morphine as procedural sedation agents for children undergoing intussusception reduction was compared, The findings revealed that the group treated with esketamine experienced a greater success rate of reduction than the group treated with morphine [14]. Dhawal provided an analysis of 151 children with forearm fractures who underwent reduction using esketamine for procedural sedation, and showed that esketamine's performance is similar to other documented methods in attaining satisfactory results, and no adverse events occurred in the study [15].

In this case, the child was admitted to the hospital with recurrent vomiting of milk and intermittent cough accompanied by lung infection. A preoperative echocardiogram revealed no significant abnormalities, and the child had a relatively small hernia sac with no severe lung compression symptoms or additional malformations, making anesthesia administration less challenging. However, through this case, we provide a novel approach for inducing anesthesia while preserving spontaneous breathing in children with CDH. The combination of sevoflurane and esketamine provides more stable hemodynamics without significant respiratory depression, making this approach worth further promotion. However, it is important to note that esketamine may increase secretions, so it is recommended that esketamine should be used in combination with secretion-suppressing medications like atropine or glycopyrrolate. Additionally, there is a significant age difference among children undergoing CDH surgery, ranging from newborns to 1-2 years old, and they often present with different congenital abnormalities with significant individual differences. Therefore, further investigation with larger sample sizes is essential to assess the usefulness of this approach.

4. Conclusion

Children with congenital diaphragmatic hernia often experience complications such as lung infection, acid-base imbalance, and electrolyte disorders due to abdominal organs protruding into the thoracic cavity and underdeveloped lungs. Positive pressure ventilation with a mask during anesthesia induction may cause gastric distension, exacerbating the child's hypoxemia and further worsening circulation. Therefore, preserving spontaneous breathing during anesthesia induction is the ideal choice. The combination of sevoflurane and esketamine can maintain stable hemodynamics without significant respiratory depression. However, further research involving larger sample sizes and controlled studies would be necessary to validate the effectiveness of this method and determine the optimal dosage for various clinical situations, providing further guidance and experience for anesthesia in such patients.

Conflict of Interests

All the authors do not have any possible conflicts of interest.

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