ANESTHETIC MANAGEMENT OF PEDIATRIC THORACOSCOPIC CONGENITAL DIAPHRAGMATIC HERNIA REPAIR: INITIAL EXPERIENCE OF FIVE CASES AND REVIEW OF THE LITERATURE

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Abstract

Background: Thoracoscopic repair of congenital diaphragmatic hernia is emerging progressively over past few decades in pediatric population.

Aims: To study perioperative anaesthetic management of children posted for thoracoscopic congenital hernia repair.

Methods: we prospectively collected data of consecutive five children posted for thoracoscopic congenital diaphragmatic hernia repair performed during July 2015 to December 2015. Demographic parameters, preoperative and postoperative clinical and investigations data, review of intraoperative anaesthesia details, hemodynamics,ventilatory strategy, postoperative analgesia, surgical details and complications were recorded.

Results: All the children were optimised preoperatively. All the cases were done under general anaesthesia. Low tidal volume ventilation with pressure limitation and permissive hypercapnia was maintained throughout the surgery. Stable haemodynamics was achieved in all the cases. Intraoperative and postoperative analgesia was maintained with epidural bupivacaine infusion which was later replaced with intravenous paracetamol and fentanyl in most of the cases. There was no surgery or anaesthesia related adverse event or serious complication reported either in intraoperative or in postoperative period.

Conclusions: successful anaesthetic management of thoracoscopic congenital diaphragmatic hernia repair were safely performed in all the cases. Adherence to the basics of pediatric and thoracic anaesthesia and knowledge of intricate surgical details can prevent untoward perioperative complications.

Keywords: congenital diaphragmatic hernia, thoracoscopy, anaesthetic management.

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Introduction

Thoracoscopic surgical procedures and examinations are emerging in the pediatric population.[1] Thoracoscopic repair of congenital diaphragmatic hernia (CDH) has been shown to be more efficient and safer than other procedures.[3] Clinical data, anesthesia management and perioperative complications for thoracoscopic CDH repair is sparse in the anesthesia literature. Here we describe perioperative anesthetic management of consecutive 5 children posted for thoracoscopic CDH repair in a tertiary healthcare hospital in India.

Material and Methods

After obtaining informed written consent from the guardians of the children, we prospectively collected data of consecutive five children posted for thoracoscopic CDH repair performed from July 2016 to December 2016. Demographic parameters, preoperative and postoperative clinical data, intraoperative anaesthesia details, hemodynamics and ventilatory strategy, postoperative analgesia, surgical details and complications were recorded.

Demographic data

All 5 children were of infant age group. Among them two were neonates. Pre-operative weight ranged from 2.4kg to 7kg. Apart from their primary congenital anomaly, two children had ano-rectal anomaly and pulmonary artery hypertension respectively. Total duration of surgery and total blood loss ranged from 2 to 4 hours and 25 to 80 ml respectively. Baseline demographic parameters are presented in table 1.

Preoperative optimisation

Detailed history of antenatal diagnosis, fetal surgery, birth weight, age of onset and progression of symptoms, presence of other congenital anomaly and pre-operative medical treatment were taken from parents and records were scrutinised. In our series, one child was diagnosed antenatally. All the children had low birth weight. Presenting symptoms were dyspnea, cyanosis, cough and fever. On examination, there was scaphoid abdomen, decreased breath sound in the affected site, bulging chest and bowel sound in the chest. Congenital heart disease (CHD) was present in 3 patients; one with moderate pulmonary hypertension (PHTN), one with ventricular septal defect (VSD) and one with atrial septal defect (ASD). The patient with PTHN was intubated and ventilated preoperatively for not being able to maintain adequate oxygen saturation. The other 4 patients were maintaining adequate oxygen saturation either by hood or on room air. Preoperatively routine investigations such as pulse oxymetry (SpO2), hemogram, liver function test, kidney function test, serum electrolytes, Chest X-ray (CxR), electrocardiography (ECG), echocardiography (ECHO) and arterial blood gas (ABG) were obtained.

Table 1

Demographic characteristics of the patients

	AGE	SEX (M/F)	WEIGHT (Kg)	Co Morbidities	Blood loss (ml)	Duration of Surgery(Hr)
CDH1	3 Months	M	4.8	Nil	40	2.5
CDH2	11Days	F	2.4	Ano-rectal malformation	30	2
CDH3	2 Days	M	2.5	Pulmonary artery hypertension	25	3.5
CDH4	2Months	F	2.6	Nil	50	4
CDH5	9 Months	M	7	Nil	80	3

CHD- Congenital diaphragmatic hernia.

Table 2
Pre-operative baseline investigations

	ECHO	Chest X-ray	SpO2 (%)	Ventilation	ABG
CDH 1	Normal	1. Left lower lobe absent 2. No infective changes 3. Mid gut in hernia content	94-96	O_2 by hood @ 5l/min	pH-7.29 PO2-98 PCO2-45
CDH2	Small VSD	1. Absent lung tissue in left side 2. No infective changes 3. Mid gut in hernia content	99	O_2 by hood @ 6l/min	pH-7.39 PO2-110 PCO2-48.9
CDH3	PAP 32 mm Hg	1. only Small upper lobe in left side present 2. Mediastinal shifting to right 3. Stomach in hernia content	95-96	Intubated & ventilated with PSIMV mode, FIO_2-0.5	pH-7.29 PO2-95 PCO2-52
CDH4	Normal	1. Near complete absence of left lung 2. Colon in hernia content 3.Right upper lobe infective changes	92-94	O2 by hood @ 5l/min	pH-7.38 PO2-82.5 PCO2-38.7
CDH5	Small ASD	1. Left upper lobe present 2. Midgut in hernia content	95-96	Room air	pH-7.36 PO2-135 PCO2-41

CDH- Congenital diaphragmatic hernia, ECHO-Echocardiography, ABG- Arterial blood gas, VSD- Ventricular septal defect, PAP- Pulmonary artery pressure, PSIMV- Pressure synchronised intermittent mandatory ventilation. FIO_2- Fraction of inspired oxygen.

Computed tomography (CT) scan was done in selected patients upon surgeons' discretion. Physiotherapy, antibiotics, bronchodilators were used where necessary. Good hydration and nutrition was maintained in all patients. Preoperative patients' characteristics, CxR finding, ventilatory status and preoperative ABG are summarised in the table 2.

Conduction of general anesthesia

All patients were induced with intravenous fentanyl, thiopentone and atracurium since all of the children had in situ intravenous line. Standard monitoring (ECG, NIBP, SpO_2, temperature and urine output) with invasive arterial pressure (IAP) and central venous pressure (CVP) monitoring was done in all cases. Anesthesia was maintained with 50% oxygen in air, sevoflurane and atracurium boluses. Caudal catheter was put and tunnelled in 4 patients with no anorectal anomaly and intraoperative infusion of 0.125% bupivacaine at a rate of 0.1ml/kg was initiated and titrated according to hemodynamic response. In one patient with ano-rectal malformation (ARM), intraoperative fentanyl infusion was used for analgesia and was stopped 30 min before end of surgery.

Airway management and creation of capnothorax

Intrathoracic bowel content was deflated with nasogastric tube. High airway pressure with bag and mask ventilation was avoided. Endotracheal intubation was done in all children. None of the patients required lung isolation. All the patients were put in right lateral position. Eyes were padded, pressure points were secured and air entry rechecked. Our surgeons usually use a three port systems of one 5mm and two 3mm, inserted in anterior, middle and posterior axillary line respectively in either 7^{th} or 8^{th} intercostal space. CO2 insufflated through middle port at a rate of (1-2)L/min and a pressure of (4-6) mm Hg was maintained throughout the surgery. All surgeries were done by video assisted thoracoscopic surgery (VATS) and no conversion to open technique was required.

Intraoperative ventilation strategy and hemodynamics

All children were ventilated with pressure control ventilation. Low tidal volume (TV) ventilation with permissive hypercapnia was allowed. Peak inspiratory

Table 3
Intra-operative management and post-operative variables

NAME	Vent Setting (intraop)	ABG (Pre-extubation)	Ex-tubation	Chest X ray (postop)	Analgesia (Postop)
CDH1	PCV PIP-25 RR-25	pH-7.29 PO2-124 PCO2-48	On table	Fully inflated lung	Caudal infusion, Intravenous PCM and Fentanyl
CDH2	PCV PIP-20 RR-21	pH-7.12 PO2-116 PCO2-79.4	POD5	Partially inflated lung	Caudal infusion, Intravenous PCM and Fentanyl
CDH3	PCV PIP-30 RR-28	pH-7.15 PO2-120 PCO2-75	POD7	Enlarge pulmonary artery, Infective changes left lower lobe	Caudal infusion, Intravenous PCM and Fentanyl
CDH4	PCV PIP-18 RR-23	pH-7.23 PO2-156 PCO2-43	On table	Mild effusion in right side	Intravenous PCM and Fentanyl
CDH5	PCV PIP-22 RR-25	pH-7.32 PO2-164 PCO2-51	On table	Clear lung field	Caudal infusion, Intravenous PCM and Fentanyl

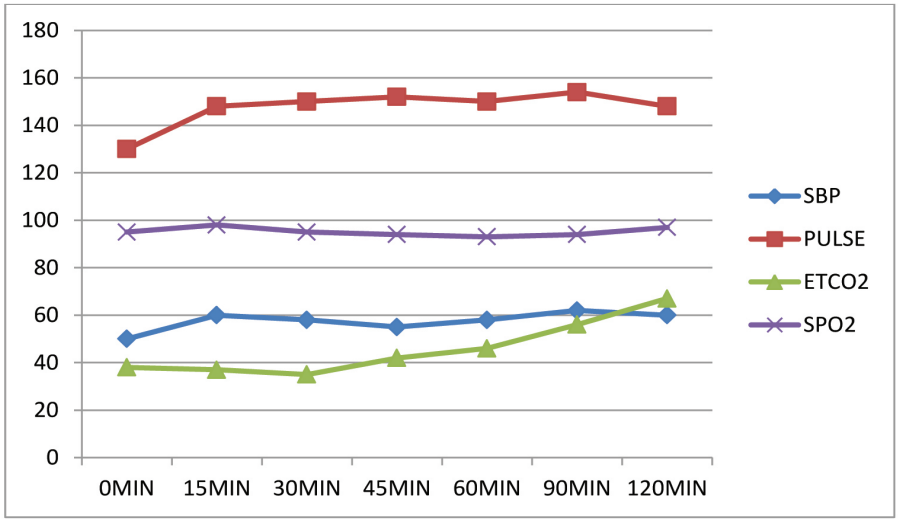
CDH- Congenital diaphragmatic hernia, Intraop- Intra- operative, ABG- Arterial blood gas, Postop- Post-operative, PCV- Pressure control ventilation, PIP- Peak inspiratory pressure, RR-Respiratory rate, POD- Post operative day, PCM- Paracetamol.

pressure (PIP) was adjusted to deliver a tidal volume of 4-6ml/kg TV. After creation of capnothorax, PIP was increased to deliver set TV. Respiratory rate and PIP were adjusted to achieve an end tidal carbon dioxide (ETCO2) maximum of 50 mm of Hg. In spite of adjusting ventilation parameter, $ETCO_2$ was more than 60mm Hg in two patients. Inspired oxygen concentration (FIO_2) was adjusted to keep SpO_2 around 91-92 %, ABGs were done in all patients at 1hr post capnothorax and before extubation. Ventilatory

Fig. 1
Intra-operative haemodynamics

SBP- Systolic blood pressure, ETCO2- End tidal CO2

Figure 1: Intra-operative haemodynamics



SBP- Systolic blood pressure, ETCO2- End tidal CO2

strategy was modified as per ABG results. All children were hemodynamically stable intraoperatively (Figure 1). In all patients, mild hypotension and tachycardia and ventricular ectopics in one patient were noticed during CO2 insufflation, but didn't require any treatment. Intra-operative lung isolation technique, ventilator settings, pre-extubation ABGs are summarized in Table 3.

Extubation

Most of the patients were extubated after surgery. Inter costal drain was inserted in all cases in the operating side. Two children were electively ventilated postoperatively due to acidosis and hypercarbia.

Post-operative pain control

Postoperatively 0.1% bupivacaine with morphine 50mcg/kg was infused for 2 days at a rate of 0.1ml/kg. The caudal catheter was removed on the second postoperative day and replaced with intravenous paracetamol 7.5mg/kg three times daily and fentanyl boluses when required. In one patient the caudal catheter could not be inserted because of anorectal malformation. Fentanyl infusion was started postoperatively at a rate of 0.5mcg/kg/hr. Post-operative analgesia technique is presented in Table 3.

Postoperative outcome

All children were shifted to the pediatric surgery intensive care unit (ICU). The patient with pulmonary hypertension was extubated on 7th postoperative day. Two children had occational supraventricular tachycardia which responded to conservative management. No child required re-do surgery. Three children had fully expanded lung and only one patient had minor effusion which did not required treatment.

Discussion

Thoracoscopy allows the surgeon to look inside the thoracic cavity and perform operative procedures without breaching the thoracic wall. This avoids extensive incision over the thoracic wall, excessive blood loss from the wound, severe postoperative pain leading to compromised respiration, post-thoracotomy syndrome and longer hospital stay.[4] It also reduces the musculoskeletal sequel like scoliosis, development of asymmetrical thoracic cage and winging of scapula compared to conventional thoracotomy in children.[2] Development of advanced thoracoscopic instruments and improvement in the finer aspects of surgical steps has widened the scope for more complicated procedures, leading to increased challenge for the anesthesiologist to manage these cases successfully.

Initial studies had strict selection criteria for thoracoscopic CDH repair since preoparative respiratory instability, hypercarbia, children on ECMO, stomach in the hernia content were considered bad prognostic factors and the chances of conversion to open surgery were high.[5] Lao OB et al analysed thoracoscopic versus open CDH repair and found favourable outcome in thoracoscopic group with a broad selection criteria including presence of pulmonary hypertension and stomach as hernia content.[6] Children stabilised with preoperative ECMO were successfully operated with minimally invasive procedure.[3] In the present series, we did not include children with these complications due to newer setup and limited experience.

Thoracoscopic CDH repair does not require lung isolation. Hypoplastic lung does not inflate and does not hinder surgeon's view. Isolation is required when the lung is healthy or when the surgeon requires more space for plication or patch repair for larger defects. Inspite of numerous options for lung isolation, considering our patient profile only three options would have been suitable. These includes selective main stem bronchus intubation either with Fogarty embolectomy or swan-ganz catheter and Arned endobroncial blocker (AEB). All our patients were infants and 3Fr size Fogarty catheter is recommended for male or female unless they are more than 1 year of age. The catheter can be inserted blindly and confirmed by either fibreoptic bronchoscopy (FOB) or fluoroscopy. Alternatively it can be put via rigid bronchoscope under direct visualisation and kept alongside the ETT.[7] Smallest size of AEB (5Fr) can be used even in 2days old neonate weighing 2.5kg.

It is passed through the vocal cord extraluminally to ETT and the position reconfirmed by FOB through the ETT.[8] But our surgeons did not asked for one lung ventilation (OLV) in any of the cases.

CO_2 insufflation facilitates thoracic surgery by collapsing the lung; however its effects on hemodynamic instability has not been investigated in details. High insufflation pressure is deleterious in patients with poor cardiac functions or hypovolemia.[9] Hill RC et al showed decreases in mean arterial pressure, cardiac index and left ventricular stroke work index with significant increase in CVP and PA pressure when capnothorax insufflation pressure reaches10mm Hg.[10] These effects can be minimised by limiting the CO_2 flow rate insufflation to 1L/min and inflating pressures up to 4-6 mm Hg[7] as done in all our cases. In the present series, our intraoperative goals were low tidal volume lung protective ventilation, permissive hypercapnia, maintenance of stable cardiovascular parameter, good analgesia and optimal muscle relaxation for good surgical outcome.

Complications with thoracoscopy include hypercapnia and respiratory acidosis. Greater solubility of CO_2 increases $PaCO_2$, $etCO_2$ and leads to respiratory acidosis. Bishay M et al reported prolonged and severe hypercarbia and acidosis in thoracoscopic TEF repair compared to open surgery and questioned about its safety.[11] In contrast, Mukhtar AM et al considered it safe and concluded that hypercapnia with 50-70 mm Hg target $PaCO_2$ in children undergoing thoracoscopic surgery using OLV is without any deleterious cardiopulmonary effects.[12] Our goal was to allow permissive hypercapnia upto 50 mm Hg of $etCO_2$. In two children in spite of adjusting the ventilatory parameter, $etCO_2$ increased more than 60mm Hg.

Post-operative pain control is essential since it prevents postoperative hypoxia, atelectasis and retention of secretions. Multiple modalities have been described like NSAID, paracetamol, opioid, intercostal nerve block, and epidural analgesia.[13] In all our patients caudal epidural catheter was put preoperatively and bupivacaine morphine combination was infused upto 2nd postoperative day and then replaced by intravenous paracetamol and fentanyl boluses when required. In one patient caudal catheter could not be put because of anorectal malformation and fentanyl infusion was started instead. Though epidural analgesia was not considered necessary in thoracoscopy by some author but considering the possibility of conversion to open thoracotomy and better pain relief, we inserted caudal catheter wherever it was feasible.[7] Several complications can adversely affect the outcome of the surgery such as persistent air leak, pneumothorax, subcutaneous emphysema, infective changes such as pneumonia, empyema, abscess, lung herniation, gas embolism etc.[7,13] None of our patients had any major postoperative complication. In one case, mild infective change was found in left lower lobe chest x-ray and in another case mild pleural effusion was detected, which did not require drainage.

Conclusion

Anesthetic management of pediatric thoracoscopic CDH repair was safely managed without any serious complications in our case series of five children. However proper patient selection, invasive monitoring, lung isolation, ventilation strategy with permissive hypercapnia, limiting insufflations pressure and perioperative pain management are keys to success.

References

1. Shah R, Reddy AS, Dhende NP. Video assisted thoracic surgery in children. *J Minimal Access Surg* 2007;3:161–7.
2. Taussig LM, Landau LI. Pediatric Respiratory Medicine. Elsevier Health Sciences; 2008. p. 940.
3. Kim AC, Bryner BS, Akay B, Geiger JD, Hirschl RB, Mychaliska GB. Thoracoscopic repair of congenital diaphragmatic hernia in neonates: lessons learned. *J Laparoendosc Adv Surg Tech A* 2009;19:575–80.
4. Hau T, Förster E. Thoracoscopic pulmonary surgery. 2001 [cited 2015 Aug 1];
5. Yang EY, Allmendinger N, Johnson SM, Chen C, Wilson JM, Fishman SJ. Neonatal thoracoscopic repair of congenital diaphragmatic hernia: selection criteria for successful outcome. *J Pediatr Surg* 2005;40:1369–75.
6. Lao OB, Crouthamel MR, Goldin AB, Sawin RS, Waldhausen JH, Kim SS. Thoracoscopic repair of congenital diaphragmatic hernia in infancy. *J Laparoendosc Adv Surg Tech A* 2010;20:271–6.
7. Dave N, Fernandes S. Anaesthetic implications of paediatric thoracoscopy. *J Minimal Access Surg* 2005;1:8–14.
8. Sutton CJ, Naguib A, Puri S, Sprenker CJ, Camporesi EM. One-lung ventilation in infants and small children: blood gas values. *J Anesth* 2012;26:670–4.
9. Tran DTT, Badner NH, Nicolaou G, Sischek W. Arterial pCO2 changes during thoracoscopic surgery with CO2 insufflation and one lung ventilation. *HSR Proc Intensive Care Cardiovasc Anesth* 2010;2:191–7.
10. Hill RC, Jones DR, Vance RA, Kalantarian B. Selective lung ventilation during thoracoscopy: effects of insufflation on hemodynamics. *Ann Thorac Surg* 1996;61:945-8.
11. Bishay M, Giacomello L, Retrosi G, Thyoka M, Garriboli M, Brierley J, et al. Hypercapnia and acidosis during open and thoracoscopic repair of congenital diaphragmatic hernia and esophageal atresia: results of a pilot randomized controlled trial. *Ann Surg* 2013;258:895–900.
12. Mukhtar AM, Obayah GM, Elmasry A, Dessouky NM. The therapeutic potential of intraoperative hypercapnia during video-assisted thoracoscopy in pediatric patients. *Anesth Analg* 2008;106:84-8.
13. Kumar K, Basker S, Jeslin L, Karthikeyan C, Matthias A. Anaesthesia for pediatric video assisted thoracoscopic surgery. *J Anaesthesiol Clin Pharmacol* 2011;27:12-6.