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Cardiovascular Collapse During Thoracoscopic Tracheoesophageal Fistula Repair

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Stem Case and Key Questions Content

A 3 day old, 2.5 kg neonate is scheduled for tracheoesophageal fistula (TEF) repair. The new pediatric surgical attending who is experienced in laparoscopic surgery, calls you the night before to discuss the case. The new surgical attending usually performs TEF repair via thoracotomy, but this time would like to attempt a thoracoscopic approach and asks for your opinion.

KEY QUESTION 1. What factors would you take into consideration before deciding if it would be appropriate to attempt the surgery via a thoracoscopic approach? What if the patient had congenital heart disease?

KEY QUESTION 2. What are the possible advantages of thoracoscopic surgery over open procedures? Are these advantages supported by evidence?

After a productive discussion, you both decide that this neonate would be an ideal candidate for a thoracoscopic repair. You put the phone down and make a call to the Neonatal Intensive Care Unit (NICU) Fellow.

KEY QUESTION 3. What pre-operative information would you request? Are there any special investigations you would like to request?

KEY QUESTION 4. If echocardiogram revealed a right-sided aortic arch would this alter the surgical and/or anesthetic plan?

You are assigned with a senior anesthesia resident to provide care for the neonate. The neonate is transported from the NICU down to the preoperative area. Preoperatively, SpO2 is 94% on room air and the neonate is tachypneic. Physical examination reveals a non-dysmorphic neonate with a sacral dimple. On auscultation you hear coarse breath sounds bilaterally. CXR reveals a coiled feeding tube in the esophagus. The echocardiogram note mentions the presence of a moderate sized patent ductus arteriosus with predominantly left to right shunt.

The surgeon would like to start the procedure by performing rigid bronchoscopy to assess the position of the fistula.

KEY QUESTION 5. What is your anesthesia plan with regard to induction and maintenance? Is spontaneous ventilation necessary, or will you use muscle relaxation? Would nitrous oxide be appropriate?

Your resident connects the standard ASA monitors. When she attempts to flush the 24 gauge intravenous catheter, she notices a large subcutaneous bleb forming at the IV site.

KEY QUESTION 6. Would you choose to induce the neonate without intravenous access? Is an arterial line important? Essential? If so, would you place it before or after induction?
Induction proceeds uneventfully and the child is breathing spontaneously with stable vital signs. The surgeon places a rigid bronchoscope into the trachea. He sees the fistula on the posterior wall and successfully inserts a fogarty balloon catheter into the fistula. He inflates the balloon and pulls back on the catheter to isolate the fistula. He removes the bronchoscope and says he would like lung isolation for the surgery.

KEY QUESTION 7. How will you isolate the lung? Would a fistula at the carina alter your management?

KEY QUESTION 8. Is lung isolation required for the thoracoscopic approach?
Your resident successfully inserts a 2.5 cuffed endotracheal tube into the left mainstem bronchus and lung isolation is achieved. Before surgery commences there is sudden loss of end-tidal carbon dioxide and the high airway pressure alarm sounds.

KEY QUESTION 9. What could be the cause of this sudden loss of end-tidal and high airway pressures?
You resolve the issue and surgery commences. After insufflation end tidal CO2 steadily increases and is now 62mmHg.

KEY QUESTION 10. What are the likely causes of this increase in CO2? What would you consider doing to improve the situation?
Surgery continues but the patient's blood pressure starts to decline and becomes progressively more tachycardic. Suddenly the arterial waveform is lost. End tidal carbon dioxide is 16mmHg. EKG shows a sinus tachycardia of 170. The pulse oximeter waveform is flat.

KEY QUESTION 11. What would explain the clinical picture? What are the possible causes of arrest in this situation?
Surgery proceeds and the TEF is successfully repaired after 3 hours. The child has stable vital signs.

KEY QUESTION 12. What considerations do you have for conversion to open?

KEY QUESTION 13. Would you attempt to extubate at the end of the procedure? If you were planning to extubate, how would you have altered your anesthetic technique?

KEY QUESTION 14. What options are there for post-operative pain management? Pharmacological therapy? What is the role of regional?

Model Discussion Content
Minimally invasive thoracoscopic surgical techniques are being used increasingly for repair of tracheoesophageal fistula (TEF) in neonates. In 2000, the first successful thoracoscopic repair of a TEF was preformed. (1) Over the past decade, thoracoscopic repair has been rapidly

spreading beyond just a few major academic centers. Anesthesiologists need to have an understanding of the considerations for thoracoscopic repair, in order to provide optimal anesthetic management.

By itself, TEF repair presents many challenges for the anesthesiologist, but thoracoscopic repair has multiple unique considerations. This approach requires isolation of the TEF and sometimes isolation of the mainstem bronchus with single lung ventilation (SLV). An understanding of the various TEF types and how the anatomical differences present unique challenges for thoracoscopic repair is required. Knowledge of the surgical technique, including surgical challenges and complications of thoracoscopic repair can prepare the anesthesiologist. Additionally, there are unique positioning considerations and understanding the physiologic consequences of thoracoscopic approach can assist in management.

There are multiple potential benefits of the thoracoscopic approach. The greatest advantage of the thoracoscopic approach is avoidance of the postero-lateral thoracotomy. This approach potentially decreases pain, time to extubation and ICU stay. Additionally, the thoracoscopic approach improves the surgeon's view because the fistula is seen perpendicular to its' connection to the trachea. (1) Long-term benefits may include a decreased risk of thoracic scoliosis, winging of the scapula, rib deformities, hemithorax hypoplasia and shoulder girdle weakness later in development. Also, there is a cosmetic benefit of 3-4 small surgical port insertion sites versus the larger scar of an open procedure. (2) Greater experience and larger case volumes are needed to determine the long-term benefits and see if there is any reduction in complications. Initial experience with limited numbers of patients, has shown a decrease in time to extubation for thoracoscopic versus open technique (37 hours vs 54 hours) and duration of ICU stay (2.75 days vs 3.4 days). (2) Additional benefits may include shorter duration of narcotic use and earlier return to full feeds but the numbers are limited and there are no randomized control trials. Disadvantages of the thoracoscopic approach include longer operative times and higher intra-operative arterial CO2 levels. (3) Recognized complications of open TEF repair include esophageal stricture, gastroesophageal reflux, anastomotic leak and recurrence of the fistula. Precise data does not yet exist for comparison of the incidence of these complications with thoracoscopic repair, due to a limited number of cases. Initial evidence had suggested possibly a higher rate of anastomotic narrowing but advances in surgical technique have seemed to have resolved this concern. (1) Current data supports thoracoscopic TEF approach is a safe and efficient procedure with at least similar short-term outcomes to open repair. (1-3)

There is not yet an established criterion for which patients should undergo thoracoscopic repair. Those with significant congenital heart disease and/or very low birth weight may be unable to tolerate the hemodynamic and ventilation changes of the thoracoscopic approach. Additionally, neonates with significant lung disease and/or high oxygen requirements may be better served by an open procedure. There is a case report describing successful thoracoscopic repair in a neonate with single ventricle physiology. (4) In one case series, 52 neonates underwent thoracoscopic TEF repair ranging from 1.2 to 3.8kg and 22 patients had congenital heart disease. A neonate weighing 800 g at birth was excluded as well as a 1100 g neonate with Tetralogy of Fallot. (1) Additionally, those neonates with surgical challenges such as with a long gap esophageal atresia may not be good candidates for thoracoscopic repair.

Tracheoesophageal fistulas and/or esophageal atresia occurs in approximately 1 in 3000 live

births. (5) Approximately 80-85% of cases involved esophageal atresia with a distal esophageal pouch and a proximal TEF. Most commonly this fistula is located one to two tracheal rings above the carina. Thirty percent of TEF patients are preterm and associated anomalies occur in 30-50% of neonates. (1) A poor prognosis has been associated with the coexistence of other congenital anomalies, prematurity and the presence of underlying lung disease. TEF often occurs with the VACTERL complex (vertebral, anorectal, cardiac, TEF, renal and/or limb defects). It is important to have a thorough preoperative evaluation for any associated cardiac, renal, musculoskeletal and gastrointestinal defects. Preoperative evaluation should include an echocardiogram and renal ultrasound. Cardiac defects occur as frequently as 15-25% of cases. It is important to identify presence of a right aortic arch, as this will preclude anastomosis of the upper and lower esophageal pouches from the right-sided approach. (2) If known preoperatively, the surgical technique can be modified to a left sided surgical approach. (1) Blood results should be checked for electrolyte abnormalities, glucose level, hemoglobin and platelet counts. Additionally, a type and cross match should be preformed. The chest x-ray should be reviewed and most commonly reveals a nasogastric or oral-gastric tube coiled in the esophagus and may reveal evidence of aspiration pneumonia. The child should be examined for signs of vertebral anomalies especially if any neuraxial techniques are planned. Discussion with the ICU team should take place regarding pre-operative oxygen requirements and hemodynamic stability. (2)

Positioning, access and monitors: As with open repair, thoracoscopic cases necessitate a second venous line after induction (either peripheral or central). However, there has not been significant blood loss during these cases to date. (1,2) A series of 8 neonates reported < 10ml of blood loss during thoracoscopic repair. (2) An arterial line is warranted for hemodynamic monitoring and for arterial blood gas measurement. In neonates, especially those undergoing single lung ventilation (SLV), end tidal CO2 reading will be falsely low and arterial CO2 measurements can guide management. The neonates are placed in a semi-prone position with the right side elevated. This allows access to the posterior sites needed for trocar placement while allowing gravity to assist in retraction of the right lung from the posterior pleural wall optimizing views of surgical structures. (2) Careful attention to positioning is required. It can be challenging to manipulate the fiberoptic bronchoscope in the semi-prone position and therefore is important to verify endotracheal tube (ETT) position prior to placement of surgical drapes. Airway management: Airway management and ventilation can be extremely difficult in neonates for TEF repair. The goal of maintaining spontaneous ventilation while achieving a deep plane of anesthesia for bronchoscopy and fistula isolation is challenging to achieve in small neonates. This goal can be accomplished with either an inhalation induction and/or careful titration of propofol. Positive pressure ventilation may increase gastric distention and ventilation may be compromised. Ventilation can be particularly difficult in those with poor lung compliance and also is more challenging with larger sized fistulas (>3 mm in size). Traditionally, muscle relaxation was avoided until after intubation distal to the fistula, but now many centers give relaxation after ventilation is successful and there is not significant gastric distention.(5) The surgical team may request single lung ventilation (SLV), as lung deflation will allow for better visualization during thoracoscopy. Fistulas that have a take off near the carina may also require SLV. Otherwise, it may be preferable to achieve lung collapse from CO2 insufflation of 4-6 mmHg and avoid lung isolation.(1) Flexible fiberoptic bronchoscopes should be used to guide ETT placement and check placement of fogarty catheters used for either fistula or lung isolation.(6) With a right thoracotomy, isolation of the left mainstem bronchus can cause post-operative edema of the left mainstem with post-operative atelectasis.(1) In neonates, small

movements can result in migration of the ETT. The ETT can migrate into the under-ventilated right lung and may cause a sudden increase in pressure and decrease in tidal volume. Migration of the ETT into fistula can also occur. Additionally, fogarty dislodgement can lead to sudden airway occlusion with loss of end-tidal CO2 and high pressure. (5) Any ventilation changes should be immediately assessed and a fiberoptic bronchoscope.

Single Lung Ventilation Physiology of the Neonate: Video-assisted thoracoscopic surgery (VATS) for the neonate presents multiple challenges for the anesthesiologist. Ventilation/perfusion (V/Q) mismatch is increased by several factors during thoracoscopic surgery. General anesthesia, neuromuscular blockade and mechanical ventilation will all cause a dramatic decrease in functional residual capacity (FRC). Mechanical compression from the surgically induced pneumothorax and manipulation leads to atelectasis of the dependent lung. In neonates and infants, the FRC is already closer to the residual volume creating earlier airway closure. In the lateral position, the neonates compliant and easily compressible rib cage does not support the dependent lung and causing atelectasis. Hypoxic pulmonary vasoconstriction (HPV), which normally can divert blood flow from poorly ventilated areas of the lungs to areas of ventilation, helps decrease the V/Q mismatch but is blunted by inhalational agents. Due to all of these factors challenges with oxygenation/ventilation are common. Careful attention and continuous communication with the surgical team will allow for optimization of care. Increasing the FiO2 (often 100% FiO2 is necessary) and/or hand ventilation is often required to maintain oxygen saturation and adequate ventilation. Arterial blood gas samples can guide management of ventilation with pH and CO2 assessment. Typically there is a large arterial to end-tidal CO2 gradient in neonates and this is further widened with SLV. A fiberoptic bronchoscope (FOB) is extremely useful to guide endotracheal tube placement and assess positioning. It is prudent to check after any positioning changes. Hemodynamic changes of the surgical induced pneumothorax: Hemodynamic changes with thoracoscopy, especially right-sided thoracoscopy result in decreased venous return, cardiac output and mean arterial pressure from compression of the right atrium and inferior vena cava. If a fogarty catheter is used to achieve lung isolation, high pressure may cause impingement on smaller pulmonary vessels impairing pulmonary blood flow. Increases in pulmonary vascular resistance from thoracoscopy put the neonate at risk for return to fetal circulation from reopening of the patent foramen ovale and reversal of flow via the PDA. Those neonates with congenital heart disease are especially at risk and significant hemodynamic changes may be extremely detrimental. (7,8)

Cardiac arrest: There are multiple potential causes of cardiovascular collapse during thoracoscopic procedures in the neonate. Excessive intrathoracic pressure may result in further reduction in venous return with mediastinal shift, and therefore compromised cardiac output. Surgical manipulation of lung tissue and inadvertent pressure on the right atrium impacts right ventricular output and blood pressure. Injury to major intrathoracic vessels will cause life threatening blood loss and necessitate conversion to open. Surgical dissection of the azygos vein is often performed during the procedure. During initial insufflation, bradycardia may result in the context of high vagal tone in the neonate. Carbon dioxide embolism may also occur during thoracoscopic procedures resulting in collapse. If a Fogarty catheter is used to achieve lung isolation, high pressure may cause impingement on smaller pulmonary vessels impairing pulmonary blood flow. There is a case report of near arrest from a left mainstem bronchial tear during a thorascopic TEF. The bronchial tear presented itself with a sudden increase in CO2 as a result of creating a connection of the airway and the pleural place insufflated with CO2.(9) Post-operative management: Currently, a majority of patients undergoing thoracoscopic TEF

repair remain intubated post-operatively. TEF repair is performed typically on day 2-4 of life, with many being premature neonates and/or low birth weight. These patients carry a risk of having apnea postoperatively from a case that warrants opiate usage unless regional is used in conjunction with general anesthesia. It is a major operation, with airway inflammation, the possibly of SLV, intraoperative acidosis and therefore many suggest a short duration of mechanical ventilation postoperatively.(2) However, there are some neonates appropriate for early extubation. Those patients who are full term would be optimal candidates for early wake up and extubation. Anesthetic technique could be altered to include, remifentanil infusions intra-operative to avoid postoperative respiratory depressants effects of longer acting opiates. While it is thought that minimally invasive surgery in neonates has less pain postoperatively this has not yet been proven, regional techniques may be beneficial. (10) Multiple regional techniques are available for use such as paravertebral blocks, thoracic epidurals, continuous threaded caudal catheters and intercostal nerve blocks. It is important to note location of the port insertion sites as well as discuss the planned location of the chest tube or drain if regional is performed at the start of the case. Additionally, it is essential to keep in mind the vertebral anomalies that may coexist as part of VACTERL when considering neuraxial techniques.

Conclusion:
Thoracoscopic repair of tracheo-esophageal fistula in the neonate adds significant new challenges to an already complex procedure. Increased thoracic pressure impacts both cardiovascular and pulmonary physiology in the newborn, and it is imperative that the anesthesiologist providing care for these procedures is familiar with this unique set of challenges.

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