Workshop C6: Anesthesia for Thoracic Surgery in Children

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Techniques For Single Lung Ventilation (SLV) In Infants And Children

Prior to the 1990s, nearly all thoracic surgery in children was performed by thoracotomy. In the majority of cases, anesthesiologists ventilated both lungs with a conventional tracheal tube and the surgeons retracted the operative lung in order to gain exposure to the surgical field. During the past decade, the use of video-assisted thoracoscopic surgery (VATS) has dramatically increased in both adults and children. Recent advances in surgical technique as well as technology, including high-resolution microchip cameras and smaller endoscopic instruments, have facilitated the application of VATS in smaller patients. VATS is being used extensively for pleural debridement in patients with empyema, lung biopsy and wedge resections for ILD, mediastinal masses, and metastatic lesions. More extensive pulmonary resections, including segmentectomy and lobectomy, have been performed for lung abscess, bullous disease, sequestrations, lobar emphysema, CAM, and neoplasms. In addition, closure of PDA, repair of hiatal hernias, and anterior spinal fusion are performed with VATS. Although VATS can be performed while both lungs are being ventilated, using CO_2 insufflation and placement of a retractor to displace lung tissue in the operative field, single lung ventilation (SLV) is extremely desirable during VATS. There are several different techniques that can be used for SLV in children.

A. Single-lumen endotracheal tube

The simplest means of providing SLV is to intentionally intubate the ipsilateral mainstem bronchus with a conventional single lumen endotracheal tube (ETT). When the left bronchus is to be intubated, the bevel of the ETT should be rotated 180° and the head turned to the right. The ETT is advanced into the bronchus until breath sounds on the operative side disappear. A fiberoptic bronchoscope (FOB) may be passed through or alongside the ETT to confirm or guide placement. When a cuffed ETT is used, the distance from the tip of the tube to the proximal cuff must be shorter than the length of the bronchus so that the trachea and bronchial orifice are not obstructed.

This technique is simple and requires no special equipment other than a FOB. This may be the preferred technique of SLV in emergency situations such as airway hemorrhage or contralateral tension pneumothorax.

Problems include failure to provide an adequate seal of the bronchus, especially if a smaller, uncuffed ETT is used. This may prevent the operative lung from collapsing or fail to protect the healthy, ventilated lung from contamination by purulent material from the contralateral lung. One is unable to suction the operative lung using this technique. Hypoxemia may occur due to obstruction of the upper lobe bronchus, especially when the short right mainstem bronchus is intubated.

Variations of this technique have been described, including intubation of both bronchi independently with small ETTs**.** One mainstem bronchus is initially intubated with an ETT, after which another ETT is advanced over a FOB into the opposite bronchus.

B. Balloon tipped bronchial blockers

Recently, the use of an end-hole, balloon wedge catheter (Arrow International Corp., Redding, PA) as a bronchial blocker has been described. The bronchus on the operative side is initially intubated with an ETT. A guidewire is then advanced into that bronchus through the ETT. The ETT is removed and the blocker is advanced over the guidewire into the bronchus. An ETT is then reinserted into the trachea alongside the blocker catheter. Alternatively, a Fogarty embolectomy catheter may be placed with or without bronchoscopic guidance. A FOB may be used to confirm position of the blocker. With an inflated blocker balloon the airway is completely sealed, providing more predictable lung collapse and better operating conditions than with an uncuffed ETT in the bronchus.

A potential problem with this technique is dislodgement of the blocker balloon into the trachea. The inflated ballon will then block ventilation to both lungs and/or prevent collapse of the operative lung. The balloons of most catheters currently used for bronchial blockade have low volume, high pressure properties and overdistension can damage or even rupture the airway. A recent study, however, reported that bronchial blocker cuffs produced lower "cuff-to-tracheal" pressures than double lumen tubes. When closed tip bronchial blockers are used, the operative lung cannot be suctioned and continuous positive airway pressure (CPAP) cannot be provided to the operated lung if needed.

C. The Univent tube

The Univent tube (Fuji Systems Corporation, Tokyo, Japan) is a conventional ETT with a second lumen containing a small tube that can be advanced into a bronchus. A balloon located at the distal end of this small tube, when inflated, serves as a blocker. Univent tubes require FOB for successful placement. Pediatric size Univent tubes are now available in sizes as small as a 3.5 and 4.5 mm internal diameter (ID).

Because the blocker tube is firmly attached to the main ETT, displacement of the Univent blocker balloon is is less likely than when other blocker techniques are used. The blocker tube has a small lumen which allows egress of gas and can be used to insufflate oxygen or suction the operative lung.

A disadvantage of the Univent tube is the large amount of cross sectional area occupied by the blocker channel, especially in the smaller size tubes. Smaller Univent tubes have a disproportionately high resistance to gas flow. The Univent tube's blocker balloon has low volume, high pressure characteristics so mucosal injury can occur during normal inflation.

D. Double-lumen tubes (DLTs)

All DLTs are essentially two tubes of unequal length molded together. The shorter tube ends in the trachea and the longer tube in the bronchus. DLTs for older children and adults have cuffs located on the tracheal and bronchial lumens. The tracheal cuff, when inflated, allows positive pressure ventilation. The inflated bronchial cuff allows ventilation to be diverted to either or both lungs, and protects each lung from contamination from the contralateral side.

Conventional plastic DLTs, once only available in adults sizes (35, 37, 39, and 41 Fr), are now available in smaller sizes. The smallest cuffed DLT is a 26 Fr (Rusch, Duluth, GA) which may be used in children as young as 8 years old. DLTs are also available in sizes

28 and 32 Fr (Mallinckrodt Medical, Inc., St. Louis, MO) and are suitable for children 10 years of age and older.

In children the DLT is inserted using the same technique as in adults. The tip of the tube tube is inserted just past the vocal cords and the stylet is withdrawn. The tube is rotated through 90 degrees to the appropriate side and then advanced into the bronchus. In the adult population the depth of insertion is directly related to the height of the patient. No equivalent measurements are yet available in children. If FOB is to be used to confirm tube placement, a bronchoscope with a small diameter and sufficient length must be available.

A DLT offers the advantage of ease of insertion, ability to suction and oxygenate the operative lung with CPAP, and the ability to visualize the operative lung. Left tubes are preferred to right DLTs because of the shorter length of the right main bronchus**.** Right DLTs are more difficult to accurately position because of the greater risk of right upper lobe obstruction.

DLTs are relatively safe and easy to use. There are very few reports of airway damage from DLTs in adults, and none in children**.** Their cuffs high volume, low pressure cuffs should not damage the airway if they are not overinflated with air or distended with nitrous oxide while in place.

Use of these techniques for providing SLV in infants and children is summarized in Table 1.

V. Monitoring And Anesthetic Techniques

A thorough preoperative evaluation is essential in caring for pediatric patients scheduled for thoracic surgery. As discussed above, imaging and laboratory studies will have been performed preoperatively according to the lesion involved. Guidelines for fasting, choice of premedication, and preparation of the OR are invoked as for other infants and children scheduled for major surgery. Following induction of anesthesia, arterial catheterization should be performed for most patients undergoing thoracotomy as well as those with severe lung disease having VATS. This facilitates close monitoring of arterial blood pressure during manipulation of the lungs and mediastinum as well as arterial blood gas tensions during SLV. For thoracoscopic procedures of relatively short duration in patients without severe lung disease, insertion of an arterial catheter is not mandatory. Placement of a central venous catheter is not generally indicated if peripheral intravenous access is adequate for projected fluid and blood administration.

Inhalational anesthetic agents are commonly administered in 100% O_2. Isoflurane may be preferred due to its lesser effect on HPV compared with other inhalational agents, although this has not been studied in children. Nitrous oxide is avoided. Isoflurane is commonly supplemented with intravenous opioids in order to limit its concentration and impairment of HPV. Alternatively, total intravenous anesthesia may be used with a variety of agents. The combination of regional anesthesia with genereal anesthesia is particularly desirable for thoracotomies, but may also be beneficial for VATS, especially when chest tube drainage is used following surgery. A variety of regional anesthetic techniques have been described, including intercostal blocks, intrapleural infusions, spinal anesthesia, and epidural anesthesia. Of these, epidural anesthesia best facilitates excellent intraoperative anesthesia and postoperative analgesia.

In order to attenuate the stress response associated with thoracic surgery, minimize the inhaled anesthetic concentration, and provide optimal postoperative analgesia, a combination of epidural opioids and local anesthetic agents should be used. Although local anesthetic agents may spread to thoracic dermatomes when administered via the caudal epidural space, potentially toxic doses of local anesthetics may be required to achieve thoracic analgesia. Thoracic epidural blockade may be achieved with greater safety and efficacy by placing the epidural catheter tip in proximity to the spinal segment associated with surgical incision. Segmental anesthesia may then be achieved with lower doses of local anesthetic than those needed when the catheter tip is distant from the surgical site. In infants, a catheter can reliably be advanced from the caudal to the thoracic epidural space. For example, with the infant in the lateral decubitus position, a 20-gauge epidural catheter may be inserted via an epidural needle or an 18-gauge intravenous catheter placed through the sacrococcygeal membrane, and then advanced 16-18 cm to the mid-thoracic epidural space. Minor resistance to passage of the catheter may be overcome by simple flexion or extension of the spine. If continued resistance is encountered, no attempt should be made to advance the catheter further, as the catheter may become coiled within or exit the epidural space. In older children, a thoracic epidural catheter may be inserted directly between T6 and T8 to provide intraoperative anesthesia and postoperative analgesia. In our practice, an initial dose of hydromorphone 7-8µg/kg and 0.25% bupivacaine 0.5 ml/kg is administered. Subsequent doses of 0.25% bupivacaine 0.3 ml/kg are administered intraoperatively at approximately 90 minute intervals. No intravenous opioids are given during surgery. Postoperatively, a continuous infusion of 0.10% bupivacaine and hydromorphone 3 µg/ml is administered at a rate of 0.3 ml/kg/hr. Clonidine may be added to the initial bolus of epidural agents and/or to the subsequent continuous infusion (eg, 1 µg/kg bolus, 0.25 – 1.0 µg/ml of infusate).

An advantage of epidural catheter compared with "single shot" techniques is that adjustments can be made in dosing postoperatively according to the patient's level of comfort. For example, a "bolus" of epidural anesthetic agents may be given and the infusion rate increased if the patient is experiencing pain. Alternatively, the infusion may be decreased if the patient becomes somnolent. Our dosing regimen for thoracic epidural anesthesia and analgesia is summarized in Table 2.

Side Effects of Neuraxial Opioids

Side effects related to neuraxial opioids include nausea and vomiting (N/V), pruritus, somnolence, respiratory depression, and urinary retention. Nausea and vomiting as well as pruritus appear to be relatively uncommon in infants and are primarily seen in children over the age of 3 years. These side effects are more common with morphine compared with hydromorphone and fentanyl. Treatment includes metoclopromide 0.1-0.2 mg/kg IV and ondansetron 0.1-0.2 mg/kg IV Q6 hrs. Pruritus may be treated with diphenhydramine 0.5-1.0 mg/kg IV Q6hrs or nalbuphine 0.1 mg/kg IV Q6hrs. Both of these therapies are also efficacious in the treatment of N/V. Due to greater rostral spread, respiratory depression is more common when morphine is used compared with hydromorphone. Respiratory depression with oxygen desaturation should be treated with 100% O_2 and, if necessary, repeated doses of naloxone 0.5-1.0 µg/kg IV administered incrementally. Persistent N/V, pruritus, and respiratory depression can be treated with a continuous infusion of naloxone 1-5 µg/kg/hr IV. Urinary retention is seen most commonly during the initial 24 hours of therapy, during which time patients may benefit from having a urinary catheter in place.

VI. Conclusion

Perioperative care of infants and children undergoing thoracic surgery presents a great challenge to the anesthesiologist. To meet this challenge, the practitioner benefits from a review of congenital and acquired "surgical" diseases of the chest in this age group. Equally important are an understanding of the physiology of lung ventilation and perfusion during surgery, monitoring requirements, appropriate anesthetic techniques, and methods of providing single lung ventialtion safely and effectively. Skill in performing regional anesthetic techniques in infants and chidlren, including thoracic epidural anesthesia and postoperative analgesia, are also important in managing pediatric patients undergoing thoracic surgery.

Table 1.Tube selection for single lung ventilation in children.

AGE (yrs)	ETT (ID) @	BB (Fr)	Univent®***	DLT (Fr)
0.5-1	3.5-4.0	2*		
1-2	4.0-4.5	3*		
2-4	4.5-5.0	5**		
4-6	5.0-5.5	5**		
6-8	5.5-6	5**	3.5	
8-10	6.0 cuffed	5-7**	3.5	26#
10-12	6.5 cuffed	7**	4.5	26#-28##
12-14	6.5-7.0 cuffed	7**	4.5	32##
14-16	7.0 cuffed	7-9**	6.0	35##
16-18	7.0-8.0 cuffed	9**	7.0	35##

@ Sheridan® Tracheal Tubes, Kendall Healthcare, Mansfield, MA.
* Edwards Lifesciences LLC, Irvine, CA.
** Cook Critical Care, Inc, Bloomington, IN.
*** Fuji Systems Corporation, Tokyo, Japan.
# Rusch, Duluth, GA
Mallinckrodt Medical, Inc., St. Louis, MO.
ID = internal diameter, Fr = French size, DLT = double-lumen tube.

Table 2. Dosing regimens for epidural anesthesia.

Intraoperative Dose Bupiv. 0.25% (ml/kg)	HM (µg/kg)	Clonidine (µg/kg)	Postoperative Infusion (ml/kg/hr)
0.5 initially, then 0.3 q 90 min.	7-8	1	Bupiv 0.1% + HM 3µg/ml + Clonidine 0.25-1.0 µg/ml @ 0.3 ml/kg/hr

Bupiv. = bupivacaine; HM = hydromorphone

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