Southern African Journal of Anaesthesia and Analgesia 2017; 23(2)(Supplement 1)

South Afr J Anaesth Analg
ISSN 2220-1181 EISSN 2220-1173

Mediastinoscopy in paediatric patients

S Spijkerman

Department of Anaesthesiology, Steve Biko Academic Hospital, University of Pretoria
Correspondence to: sandra.spijkerman@up.ac.za

Mediastinal pathology presents a diagnostic and therapeutic dilemma that requires management from a multidisciplinary team, often consisting of members of various specialties, including an anaesthetist, surgeon, radiologist, oncologist and intensivist.[1] Discourse and planning are paramount.

Anatomy of the mediastinum

The mediastinum is divided into a superior and inferior part, the division being an imaginary line extending from the sternomanubrial junction to the T4 vertebra. The inferior part is further divided into three parts. Of these three parts, the anterior mediastinum lies posterior to the sternum, anterior to the pericardium, superior to the diaphragm, inferior to the superior mediastinum and medial to the parietal pleurae. The middle mediastinum is bordered anteriorly by the anterior margin of the pericardium, posteriorly by the posterior border of the pericardium, laterally by the mediastinal pleura (parietal pleura) of the lungs, superiorly by the superior mediastinum and inferior by the diaphragm, whereas the posterior mediastinum is situated posterior to the pericardium and great vessels, anterior to the T4–T12 vertebrae, superior to the diaphragm, inferior to the superior mediastinum and lateral to the parietal pleurae.[1]

Presentation of mediastinal tumours

In children under the age of two years, most tumours are benign and the incidence of malignancies increases above this age.[1] Different types of malignant tumours are found in the three different parts of the inferior mediastinum. In children, the most common anterior mediastinal tumours are lymphoma (Hodgkin and non-Hodgkin), thymoma and teratoma.[1] In the middle mediastinum lymphoma is the most common with tumours of neuronal tissue most frequently found in the posterior mediastinum. The clinical presentation depends on where the tumour is situated and which structures are compressed (see Table I).

Table I. Clinical presentation of mediastinal tumours[1]

Involved structures	Symptoms and signs
Airways and lungs	Cough Dysponea Orthopnoea (exacerbated in supine position) Stridor Cyanosis Wheezing Decreased breath sounds Haemoptysis Hoarseness
Heart and great arteries	Fatigue Headache Syncope Orthopnoea Hypotension (tamponade or cardiac compression) Pulsus paradoxus
Superior vena cava	Headache Oedema of the head and neck Distended neck and chest veins Plethora Cyanosis of the face, neck and arms Proptosis Horner syndrome (sympathetic chain involvement)
Other symptoms	Pain Dysphagia

Techniques of mediastinoscopy

Mediastinoscopy was first described by Harken[2] in 1954, followed by the development of the suprasternal approach by Carlens[3] and his colleagues in 1959 and the anterior mediastinotomy approach by Chamberlain[4] in 1966. By permitting minimally invasive access to the mediastinum, mediastinoscopy is utilised to obtain biopsies of mediastinal lymph nodes and masses in order to facilitate tissue diagnosis for staging and treatment purposes.[5] It is therefore mainly a diagnostic procedure.

Superior (cervical) mediastinoscopy is not commonly used in children,[6] although its safe use has been reported in children older than one year.[7,8] The technique utilises a small transvers incision in the suprasternal notch, with advancement of the scope through the pretracheal fascia into the mediastinum and down towards the carina. The scope is therefore inserted

anterior to the trachea and posterior to the aortic arch and lies in close proximity to several major vessels in the mediastinum.[9] Although this technique is advantageous due to its minimally invasive nature, it affords the surgeon only limited access to lymph nodes in the superior mediastinum up to the level of the carina (anterior and lateral para-mainstem bronchial, anterior subcarinal, anterior and lateral paratracheal lymph nodes)[9] and allows poor access to the aorticopulmonary window.[5] Successful biopsy of the thymus has been done through this route.[10]

The anterior mediastinotomy (also called anterior mediastinoscopy), of which the Chamberlain's procedure is one example, is a surgical technique where the second or third intercostal space is incised lateral to the sternum to allow access to the anterior mediastinum, right paratracheal area and aorticopulmonary window,[1] where biopsies of lymph nodes and anterior mediastinal masses can be obtained.

Middle and posterior mediastinal masses are biopsied through thoracoscopy or thoracotomy.

Contraindications to superior mediastinoscopy

Absolute contraindications to superior mediastinoscopy are listed as anterior mediastinal masses, inoperable tumours, previous recurrent laryngeal nerve injury, severely debilitated patients, ascending aortic aneurisms and previous mediastinoscopy (due to adhesions) while relative contraindications mentioned include severe tracheal deviation, cerebrovascular disease, superior vena cava syndrome and descending thoracic aortic aneurism.[9,11]

Anaesthetic implications of mediastinal masses

Patients booked for superior mediastinoscopy usually present with mediastinal lymph nodes but no anterior mediastinal masses (as these are contraindications to the procedure).[11] Those for Chamberlain's procedure may present with a range of symptoms from asymptomatic to severe respiratory or cardiovascular compromise. Patients with mediastinal masses may present with superior vena cava (SVC) syndrome and are at risk of compression of the heart, the great vessels or the tracheobronchial tree (often below the level of an endotracheal tube), especially under anaesthesia (see below). Anaesthetic risk is increased in patients with a narrowing of the trachea or bronchi on computerised tomography (CT) scan to < 50% of predicted cross-sectional area.[12] Symptoms like dyspnoea are good predictors of the degree of obstruction, with a good correlation between severity of symptoms and cross-sectional area of the airways.[13]

The compression effects of mediastinal tumours place these patients at severe risk of decompensation under anaesthesia.[1] During general anaesthesia, especially with the use of muscle relaxants and positive pressure ventilation, lung volume is reduced due to a loss of inspiratory muscle tone and the loss of the tethering effect of the expanded lung on the airway, which is normally present during spontaneous ventilation. There is a reduction in the normal transpleural pressure gradient which distends the airway during spontaneous inspiration, leading to further reduction in airway caliber. Whereas the diaphragm moves in a caudad direction during spontaneous inspiration, pulling the airways open, it moves cephalic at end-expiration during positive pressure ventilation, resulting in further airway compromise. Gravity pulls the tumour onto the great vessels and tracheobronchial tree. These effects are exaggerated in small children due to the increased cartilages component of their ribs which results in an increased compliance of the chest wall and an inability of the chest wall to support the tumour which then compresses major structures in the mediastinal cavity. The small child already has small diameter airways with high airway resistance. Poiseuille[14] teaches that during laminar flow in a tube, resistance is inversely proportional to the radius to the power of four. During positive pressure ventilation, laminar flow is disrupted and during subsequent turbulent flow, the pressure gradient that drives gas flow is proportional to the density of the gas. Heliox, a mixture of oxygen and helium (helium has a lower density than air) has been used successfully in a child with a mediastinal mass during anaesthesia with a laryngeal mask and spontaneous breathing.[15] Due to the above pathophysiological reasons, spontaneous ventilation is preferred in patients with mediastinal masses. The oxygen demand in children is higher than in adults and the functional residual capacity (FRC) of the child is reduced, predisposing to faster desaturation. The addition of CPAP during spontaneous ventilation could maintain the FRC.[16]

Two possible disadvantages to spontaneous breathing during superior mediastinoscopy are firstly the possibility that the child might move in the absence of a muscle relaxant, with subsequent injury to any of the vital structures adjacent to the scope and secondly the possibility of air embolism, as this procedure is done in the head-up position to reduce engorgement of blood vessels and the operative site is therefore above the heart. The tip of the mediastinoscope is located intrathoracically and therefore directly exposed to pleural pressure, making the possibility of venous air embolism likely when venous bleeding occurs. Spontaneous breathing will enhance this risk due to the generation of negative intrathoracic pressure during inspiration.[9]

Perioperative management of patients for mediastinoscopy

The preoperative preparation of the child should aim at optimising respiratory and cardiovascular function.[1] In patients with mediastinal masses, the nocturnal sleeping position of the child (likely position to cause least compression of major structures) should be determined. A thorough history and clinical examination[1] aim to detect SVC syndrome, tracheobronchial compression, compression of the heart or great vessels, involvement of the myocardium, cardiac tamponade and other complications of mediastinal masses as well as complications generally associated with malignancies or chronic disease. It should be remembered that wheezing is often the only sign of tracheobronchial compression in small children.[17] A peripheral lymph node should always be sought. This could be used for biopsy under local anaesthesia with sedation and will spare the patient a general anaesthetic with the associated risks. The child should also be assessed for contraindications for the procedure.[9] Special investigations[1] include a full blood count with platelet count, renal function and electrolytes. Blood gas analysis should be done per indication. Imaging should include

a chest X-ray and a contrast-enhanced CT scan to determine the size of the mass or lymph node involvement. Magnetic resonance imaging (MRI) scans may be better able to determine nerve plexus and blood vessel involvement and are especially indicated in patients with iodine allergy or in thyroid tumours. Transthoracic echocardiography can assess the involvement of cardiac structures and supply dynamic information about ventricle compression, SVC compression and compromise of the pulmonary outflow tract.[16,18] Some authors advocate the usefulness of lung function tests in the supine and sitting positions in older children,[1] which may reveal distortion of the expiratory flow rate in intrathoracic obstruction, distortion of inspiratory flow rate in extrathoracic obstruction and equal reduction in inspiratory and expiratory flow rates in fixed lesions. Others argue against the usefulness of lung function tests in the work-up of patients with mediastinal masses due to their poor correlation with the degree of obstruction.[16]

The need for biopsies are often urgent, as some common Hodgkin lymphomas display a doubling time of 12 hours.[16] If the tumour is large with significant cardio-respiratory compromise, steroids and/or irradiation are suggested in order to shrink the tumour and reduce its compression effects. Although this might compromise the integrity of the tissue and reduce the likelihood of a proper tissue diagnosis,[16] studies have shown that adequate tissue diagnosis is possible, especially if a section of the tumour is shielded from radiation.[19]

Standard nil per os guidelines are adhered to, prophylactic antibiotics prescribed or administered in theatre and blood products ordered on standby. Sedative premedication is probably best avoided in patients with cardiovascular or respiratory compromise.

Theatre preparation includes a variety of reinforced (armoured) endotracheal tubes of different sizes, micro-laryngeal tubes (MLT; Covidien Inc) which are paediatric size tubes but of adult length, different sizes rigid bronchoscopes, and a competent surgeon able to use the scopes. These airway devices can be used to bypass an obstruction in the tracheobronchial tree. The presence of perfusion technologists and a cardiopulmonary bypass (CPB) pump are regarded essential by some, while others feel that CPB should be instituted electively if the risk of complete cardiovascular or tracheobronchial compression exists, as CPB cannot be successfully instituted in time in the event of sudden collapse.[1]

Patients with mediastinal masses are positioned in the semi-sitting position[1] as the supine position often exacerbates symptoms. Patients for superior mediastinoscopy are positioned head-up (30 °)[20] to reduce vascular engorgement,[9] thereby reducing the risk of vascular injury during surgery. This has the added benefit of displacing the diaphragm in a more caudad direction during positive pressure ventilation,[16] but increases the risk of venous air embolism[9] (see above). To enable access to the operative site, the trunk of the patient is often elevated and the neck extended, especially for superior mediastinoscopy. When anaesthetising patients with mediastinal masses, theatre personnel should be prepared to change the position of the patient at any stage in case of cardiovascular collapse or tracheobronchial obstruction. The preferred position then is the one determined preoperatively as the patient's preferred nocturnal sleeping position, failing which, the lateral decubitus positions (especially the left lateral decubitus)[21] or prone position should be trialed.

Standard American Society of Anesthesiologists (ASA) monitoring is applied. Capnography allows early detection of airway compression or cardiovascular collapse and temperature monitoring is mandatory, especially in small children. Depth of anaesthesia monitoring permits an adequate anaesthetic plane during maintenance with intravenous agents or in compromised patients where excessive inhalational agent concentration might further suppress cardiovascular function. Neuromuscular transmission monitoring might prevent postoperative residual muscle relaxant effects, but is probably more important in adult patients with myasthenic effects of mediastinal malignancies. Urinary catheterisation is usually not indicated due to the short nature of the procedure.

In patients with mediastinal masses, intravenous access should be obtained while the patient is awake if at all possible, to allow for intravenous administration of emergency drugs if cardiovascular or respiratory collapse ensue. Two large-bore lines should be inserted in preparation of possible massive bleeding. In the presence of SVC syndrome, these should be inserted in the lower limbs due to the slow circulation of blood in the SVC distribution and the possibility of further engorgement with fluid administration. Central venous cannulas are not routinely inserted, but should it be warranted in a patient with SVC syndrome, the preferred site is the femoral vein. In other instances, the central venous catheter is placed on the side most likely to develop a pneumothorax caused by the surgical procedure. If placed in the right radial artery during superior mediastinoscopy, the arterial line tracing may disappear or display false low readings, when the innominate artery is occluded. Although this is a way of monitoring the patency of the innominate artery (to prevent cerebrovascular damage), it is preferable to insert the arterial line on the left (in order not to lose the trace) and to place a second saturation probe (apart from the one used to monitor saturation which should be on the left) on the right hand for monitoring the innominate artery.

Local anaesthesia is not indicated in the majority of paediatric patients. Older children or moribund younger patients could be considered for local anaesthesia with sedation. In comparison with general anaesthesia, this has the beneficial effects of being safer in terms of cardiovascular and respiratory function, often reduces theatre times and enables early detection of pneumothorax and recurrent laryngeal nerve injury.[22] In adults and much older children, awake fibre optic intubation with spontaneous ventilation could be attempted.[18]

Flexible bronchoscopy might precede mediastinoscopy and anaesthesia should be planned accordingly. Induction of anaesthesia[23] should be done in a semi-fowler or sitting position in the presence of symptomatic mediastinal masses and should aim at maintaining spontaneous respiration and cardiovascular function. The use of inhalational agents or ketamine have been described.[24] It must be kept in mind that ketamine stimulates the formation of secretions[25] which might further increase airway

resistance in small or obstructed airways and necessitates the co-administration of an anticholinergic agent. Ketamine may also cause cardiovascular collapse in chronically ill patients with depleted catecholamine stores.[26] Where muscle relaxants will be omitted, spraying of the vocal cords with lignocaine might aid the blunting of the intubation response and might reduce intraoperative coughing,[9] but might result in postoperative aspiration due to inhibition of sensory innervation of the supraglottic airway.[27] Intravenous induction is permitted in children with intravascular access in the absence of mediastinal masses. Intubation should be done with care in patients with head and neck engorgement to avoid airway bleeding. A reinforced (armoured) tube should be used in patients with mediastinal masses in order to prevent the mass from occluding the airway and for superior mediastinoscopy to prevent the surgeon from occluding the tube while working in close proximity with the patient's head. Endotracheal tubes should be carefully secured to prevent dislodgement by the surgeon, especially during superior mediastinoscopy.[18]

Maintenance of anaesthesia[23] should aim at spontaneous respiration in patients with mediastinal masses and could again be accomplished with inhalational agents or ketamine. Inhalational or intravenous techniques are used in patients where positive pressure ventilation is permitted. Nitrous oxide (N_2O) is best avoided due to the possible risk of procedure-related pneumothorax which will expand in the presence of N_2O. The use of muscle relaxants is optional but advisable during mediastinoscopy in the absence of compressing lesions, in order to afford the surgeon optimal operating conditions and to prevent sudden patient movement with injury to vital structures, especially during superior mediastinoscopy. The focus of intraoperative care should be on the early identification and management of complications[11] caused by the surgical technique (especially during superior mediastinoscopy) or the disease process (especially during anterior mediastinoscopy).

During anterior mediastinotomy the visibility is better with less likelihood of injury to anatomical structures, but patients often present with complications of mediastinal masses. During superior mediastinoscopy, the scope is placed adjacent to a number of vital structures and massive bleeding from any of the major vessels (innominate artery, innominate vein azygos vein, aorta, bronchial artery, pulmonary artery etc) is possible. Massive bleeding requires emergency sternotomy or thoracotomy. In the instance of SVC injury, additional intravenous access should be obtained in the lower limbs.[18] Other possible intraoperative complications include pneumothorax, innominate artery compression, oesophageal injury, tumour seeding, chilothorax or air embolism. Intraoperative dysrhythmias are possible due to pressure on the heart or great vessels, pulling on mediastinal structures, pericardial or pleural effusion, or myocardial involvement of the malignancy. Negative pressure pulmonary oedema may follow deep inspiratory efforts against obstructed airways which generate large negative pressures (mainly seen in adults).

Due to the minimally invasive nature of mediastinoscopy, intra- and postoperative analgesic requirements are limited to balanced pharmacological analgesic regimens in conjunction with local infiltration of wound sites.

Following both superior mediastinoscopy and anterior mediastinotomy, patients are mostly extubated in theatre. Patients with mediastinal masses should be nursed in the head-up position in the postoperative period in order to reduce venous engorgement, and monitored closely for complications.[11,17] They may experience worsening of obstruction caused by swelling or increase in turbulent air flow due to pain, coughing, tachypnoea or anxiety.[18] The incidence of postoperative respiratory complications is proportional to the size of the tumour. Following superior mediastinoscopy, bleeding caused by blood vessel injury might manifest in the postoperative period. Postoperative hemiparesis may follow intraoperative carotid artery compression, while recurrent laryngeal nerve injury may cause vocal cord paralysis with stridor or airway compromise and phrenic nerve injury may result in respiratory compromise. Any of the two mediastinoscopy sites might be complicated by infection.

In summary, the anaesthetic plan for both superior and anterior mediastinoscopy is determined by the underlying pathology and the selected route of surgical access. Vigilance and adaptability are crucial as clinical conditions can change rapidly. Good planning and sound knowledge of the pathology and surgical techniques are therefore paramount.

Interests: No interests are declared.

Acknowledgements:

The author would like to acknowledge the contribution of Dr JM Dippenaar for proofreading and valuable suggestions.

References

1. Soliman D, Cladis F, Davis PJ. The pediatric patient. In: Fleisher LA, editor. Anesthesia and uncommon diseases. 6th ed. Philadelphia, PA: Elsevier. 2012.
2. Harken DE, Black H, Clauss R, Farrand RE. A simple cervicomediastinal exploration for tissue diagnosis of intrathoracic disease. N Engl J Med. 1954;251(26):1041-1044.
3. Carlens E. A method for inspection and tissue biopsy in the superior mediastinum. Dis Chest. 1959;36:343-352.
4. Mc Neill TM, Chamberlain JM. Diagnostic anterior mediastinotomy. Ann Thorac Surg. 1966;2(4):532-539.
5. Saund MS, Chang MY, Mentzer SJ. Cervical mediastinoscopy and anterior mediastinotomy. In: Sugarbaker DJ, Bueno R, Krasna MJ, Mentzer S, Zellos L, editors. Adult chest surgery. 2nd ed. New York: McGraw-Hill; 2009. p. 1101-1107.
6. Glick RD. Mediastinal masses. In: Mattei P, editor. New York: Springer; 2011. p. 323-332.
7. Gun F, Toker A, Kaya S, et al. Cervical mediastinoscopy for paratracheal masses in pediatric patients. Pediatr Hematol and Oncol. 2008;25;393-397.
8. Glick RD, Pearse IA, Trippett T, et al. Diagnosis of mediastinal masses in pediatric patients using mediastinoscopy and Chamberlain procedure. J Pediatr Surg. 1999;34(4):559-564.
9. Benumof JL. Anesthesia for special elective diagnostic procedures. In: Anesthesia for thoracic surgery. Philadelphia: WB Saunder. 1995;491-512.
10. Donnelly RJ, Laquaglia MP, Fabri B, et al. Cervical Thymectomy in the treatment of myasthenia gravis. Ann R Coll Surg Engl. 1984;66:305-308.
11. Ehrenwerth J, Brull SJ. Anesthesia for thoracic diagnostic procedures. In: Kaplan JA, Slinger PD, editors. Thoracic anesthesia. 3rd ed. Philadelphia, PA: Churchill Livingstone;2003. p. 174-195.
12. Shamberger RC, Holzman RS, Griscom NT, et al. CT quantitation of tracheal cross-sectional area as a guide to the surgical and anesthetic management of children with anterior mediastinal masses. J Pediatr Surg. 1991;26(2):138-142.

13. Shamberger RC, Holzman RS, Griscom NT, et al. Prospective evaluation by CT and pulmonary function tests of children with mediastinal masses. Surgery. 1995;118(3):468-471.
14. Sutera SP, Skalak R. The history of Poiseuille's law. Annu Rev Fluid Mech. 1993; 25:1-19.
15. Polaner DM. The use of heliox and the laryngeal mask airway in a child with an anterior mediastinal mass. Anesth Analg. 1996;82:208-210.
16. Hammer GB. Anesthesia for Thoracic Surgery. In: Cote C, Lerman J, Anderson BJ. A Practice of Anesthesia for Infants and Children. 5th Edition. Elsevier Saunders: Philadelphia, PA. 2013:277-290.
17. Ferrari LR. Supraclavicular node biopsy and mediastinal masses. In: Stehling L, editor. Common problems in pediatric anesthesia. 2nd ed. St Louis, MO: Mosby; 1992. p. 457-464.
18. Bussières JS, Rousseau A. Anaesthesia for thoracic surgery. In: Alston RP, Myles PS, Ranucci M, editors. Oxford textbook of cardiothoracic anaesthesia. Oxford: Oxford University Press; 2015. p. 365-387.
19. Foley RW, Rodriguez MI. Preoperative irradiation of selected mediastinal masses. J Cardiovac Surg (Torino). 2001;42:695-697.
20. Anesthesia for thoracic surgery. In: Morgan GE, Mikhail MS, Murray MJ, editors. Clinical anaesthesiology. 4th ed. New York: McGraw-Hill; 2006. p. 585-613.
21. Lerman J. Anterior mediastinal masses in children. Sem Anesth, Periop Med Pain. 2007;26:133-140.
22. Ward PH. Stephenson SE. Exploration of the mediastinum under local anesthesia. Ann Otol Rhinol Laryngol. 1966;75:368.
23. Ahmed-Nusrath A, Swanevelder J. Anaesthesia for mediastinoscopy. Continuing Education in Anaesthesia, Critical Care and Pain. 2007;7(1):6-9.
24. Datt V, Tempe DK. Airway management in patients with mediastinal masses. Indian J Anaesth. 2005;49(4):344-352.
25. Heinz P, Geelhoed GC, Wee C, Pascoe EM. Is atropine needed with ketamine sedatin? A prospective, randomized, double blind study. Emerg Med J. 2006;23(3):206-209.
26. Scherer D, Leder M, Tobias JD. Pro-Con Debate: Etomidate or Ketamine for Rapid Sequence Intubation in Pediatric Patients. Pediatr Pharmacol Ther. 2012;17(2):142-149.
27. Raphael JH, Stanley GD, Langton JA. Effects of topical benzocaine and lignocaine on upper airway reflex sensitivity. Anesthesia. 1996;51:114-118.