Anaesthesia for patients with mediastinal masses

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Anaesthesia for patients with mediastinal masses may be associated with significant respiratory and cardiovascular complications. In this review, we discuss the anatomical and pathological considerations in these adult and paediatric patients and the three types of intra-thoracic compromise that may be found: compression of the tracheobronchial tree, compression of the pulmonary artery and heart and the superior vena caval syndrome. Patient evaluation by symptom history, computerized tomography and flow-volume loops is emphasized. Preoperative thoracic radiation therapy in severely symptomatic patients is associated with a decrease in postoperative respiratory complications and an improvement in risk. During radiation therapy a small window can be created to spare some tissue for adequate histological diagnosis. Anaesthetic management techniques for these patients are discussed. Life-threatening complications can occur at any point during anaesthesia for patients with mediastinal masses. Anaesthetists should have a high degree of awareness of the underlying anatomy, pathophysiology and anaesthetic alternatives when caring for these patients.

Key words:
AIRWAY: obstruction; ANAESTHESIA: thoracic; COMPLICATIONS: respiratory; HEART: compression; LUNG: pulmonary artery compression; trachea; SYNDROME: superior vena cava

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Patients with mediastinal masses may require anaesthesia for incisional or excisional biopsy, staging laparotomy and a variety of additional procedures during their course of treatment. A large mediastinal tumour, due to its mass effects, may be associated with dramatic cardiopulmonary complications including progressive airway obstruction, loss of lung volume, pulmonary artery or cardiac compression and superior vena caval obstruction.[1] Each of these complications can cause death during anaesthesia if not expertly handled. Providing safe anaesthesia for these patients requires an understanding of the anatomy of the region, the pathophysiology of the lesions and an appreciation of their compressive effects on vital intrathoracic structures.

This review discusses the anatomy of the region, the pathology and the clinical presentations of the mediastinal lesions themselves. The preoperative evaluation and preparation of these patients is discussed, stressing the need for a thorough CT evaluation of the entire thorax. In the discussion on the anaesthetic management, we have stressed that even asymptomatic patients with mediastinal masses have the potential to develop catastrophic airway obstruction.

Anatomy

The mediastinum is that portion of the thorax lying between the right and left pleural sacs. It is bounded anteriorly by the sternum and by the bodies of the thoracic vertebrae posteriorly and extends from the thoracic inlet superiorly to the diaphragm inferiorly. The mediastinum is divided into superior and inferior regions by a plane extending from the sternal angle to the lower border of the fourth thoracic vertebra. The upper region is named the superior mediastinum and the lower region, the inferior mediastinum. The inferior mediastinum is, in turn, divided into the anterior, middle and posterior mediastina by the pericardium. Anatomical structures of major importance to the anaesthetist are found at the junction of the superior, anterior, middle and posterior mediastina. These structures include the superior vena cava, the tracheal bifurcation, the main pulmonary artery, the aortic arch and part of the superior surface of the heart.

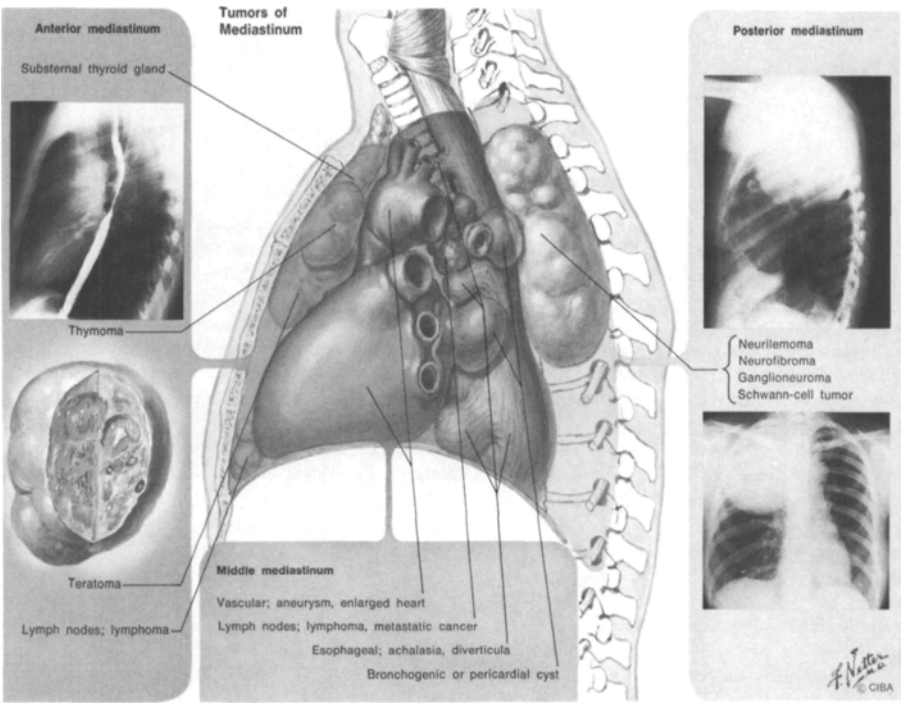

FIGURE 1 Tumours of the mediastinum. Reproduced, with permission, from the Ciba collection of medical illustrations by Frank G. Netter MD.

Pathology

Although specific tumours have a predilection for particular regions of the mediastinum, many kinds of tumours have been reported in the various mediastinal regions (Figure 1). In adults, thymomas account for a large proportion of anterior mediastinal tumours, with a 50 per cent malignancy rate and a 50 per cent association with a myasthenia gravis symptomatology. Thyroid tumours may extend below the sternum and present as anterior mediastinal masses, as may teratomas in their benign as well as malignant forms. Lymphoid tumours usually occur in the anterior or middle mediastinum. Ninety per cent of lymph node masses in the middle mediastinum are malignant as a result of metastatic spread. Other masses in the middle mediastinum include those of vascular origin (aneurysms), oesophagus (achalasia, diverticula) or cysts (bronchogenic, pericardial). Masses of the posterior mediastinum are usually of neurogenic origin (neurofibromas, Schwannomas and benign ganglioneuromas arising from the sympathetic chain).

In children, tumours of the mediastinum are most often bronchial cysts, teratomas, or lymphomas. In a series of 188 children, the majority of malignant tumours were Hodgkin's and non-Hodgkin's lymphomas of the anterior and middle mediastinum.[2] Patients with Hodgkin's or non-Hodgkin's lymphomas commonly have intrathoracic involvement. Indeed, despite the fact that Hodgkin's lymphoma accounts for little more than four per cent of paediatric malignant mediastinal lesions, almost half of children and young adults with Hodgkin's lymphoma have a mediastinal mass at the time of their initial examination.[3-5] Tumours of neurogenic origin are again most commonly found in the posterior mediastinum in children (Table I). Mediastinal masses of young childhood (less than two to four years of age) tend to be benign, while those occurring in older children (principally lymphomas) tend to be malignant.

Signs, symptoms and pathophysiology

Patients with mediastinal masses can present with the signs or symptoms listed in Table II. These signs and

TABLE I Mediastinal mass location

Superior	*Anterior*	*Middle*	*Posterior*
Children			
Lymphoma	Lymphoma	Lymphoma	Neurogenic tumours
Thymoma	Teratoma	Tuberculous nodes	Oesophageal duplication cysts
Retrosternal thyroid	Cystic hygroma		Diaphragmatic hernia (Bochdalek)
Parathyroid tumours	Thymoma		
	Pericardial cysts		
	Diaphragmatic hernia (Morgagni)		
Adults			
Lymphoma	Lymphoma	Lymphoma	Neurogenic tumours
Thymoma	Metastatic carcinoma	Metastatic carcinoma	Lymphoma
Retrosternal thyroid	Teratoma	Teratoma	Hernia (Bochdalek)
Metastatic carcinoma	Bronchogenic cyst	Bronchogenic cyst	Aortic aneurysm
Parathyroid tumours	Aortic aneurysm	Aortic aneurysm	
Zencker's diverticulum	Pericardial cyst	Pericardial cyst	
Aortic aneurysm			

symptoms can be referable to the respiratory and/or cardiovascular systems, depending on the location of the mass. The incidence of these complications is related to the size of the mediastinal mass and to the extent of disease within the thoracic cavity.[6]

Compression of the tracheobronchial tree

Although preoperative assessment of the patient's airway at the bedside is essential, the severity of a patient's preoperative respiratory symptoms may bear no relationship to the degree of respiratory compromise encountered during anaesthesia. A number of asymptomatic patients have developed severe airway obstruction during anaesthesia.[1,7,8] Respiratory distress has occurred during induction of anaesthesia and intubation and also during emergence after extubation.[2] For this reason, preoperative radiation should be considered for each patient whose mediastinal tumour is radiation-sensitive.[5] Hodgkin's lymphomas, for example, are very sensitive to radiation and/or steriod therapy with dramatic reductions in tumour size occurring within 24–48 hours. If the anaesthesia/surgery/oncology team decides upon preoperative radiation of the mediastinal tumour, efforts should be made to exclude some tissue from the radiation field so that an accurate histological diagnosis can be made.

Anaesthesia in the supine patient leads to a decrease in the dimensions of the rib cage, a cephalad displacement of the dome of the diaphragm and a reduction in thoracic volume.[9] The fact that patients may be asymptomatic while awake and yet exhibit significant obstruction during anaesthesia can be explained, in part, by the reduction that occurs in the dimensions of the chest wall, limiting the available space for the trachea relative to the tumour. The decrease in tracheal distending pressure that is caused by the action of inhalation agents on chest wall muscle tone promotes tracheal collapse. This is especially true in the presence of tracheomalacia caused by tumour erosion. The supine position also causes an increase in central blood volume, which can further increase tumour blood volume and size. Oedema, bleeding and haematoma formation in the tumour as a result of surgical biopsy can also further contribute to airway compromise.

Most patients who have severe respiratory symptoms have significant decreases in tracheal cross-sectional area.[15] Infants and small children may exhibit obstructive airway symptomatology earlier than adults simply because of geometry and physics. Small decreases in airway diameter produce relatively larger decreases in tracheal luminal area as well as greater increases in airway resistance.

TABLE II Clinical findings in patients with mediastinal masses

History	*Physical examination*	*Laboratory*
Airway		
Cough	Decreased breath sounds	Chest *x*-ray (PA and lateral to look for tracheal deviation or compression)
Cyanosis	Wheezing	
Dyspnoea	Stridor	
Orthopnoea	Cyanosis	
		Flow-Volume loops supine and sitting
Cardiovascular		
Fatigue	Neck or facial oedema	
Faintness	Jugular distension	Chest *x*-ray changes in cardiac silhouette
Headache	Papilloedema	Echocardiogram done supine and sitting
SOB and orthopnoea	BP changes or changes in pallor with postural changes	
Cough	Pulsus paradoxus	

Compression of the pulmonary artery and heart

Although compression of the main pulmonary artery is relatively rare, due in part to the protective effect of the aorta, a higher pressure vessel, compression of either the pulmonary trunk or one of the main pulmonary arteries can result in sudden hypoxaemia, hypotension or cardiac arrest.[10]

An important symptom to be wary of is syncope during a forced Valsalva manoevre such as occurs with a bowel movement.[9] This manoevre may critically diminish venous return and suggests significant cardiac or pulmonary artery encroachment. Keon reported a case involving a nine-year-old boy with an anterior mediastinal mass in whom hypotension and bradycardia progressing to cardiac arrest developed during anaesthetic induction. Left thoracentesis, performed to relieve a suspected tension pneumothorax, was not helpful. The patient died in the operating room and autopsy showed lymphomatous involvement of the pericardium and pulmonary artery.[11] He recommended that in any patient with evidence of cardiac impairment, diagnostic procedures such as cervical node biopsies be performed under local anaesthesia with the patient in the sitting position. He ascribed the assumption of the supine position with further gravitational effects of the tumour upon the heart and pulmonary artery as an important factor contributing to the arrest. Halpern *et al.* presented an eight-year-old child with a similar history preoperatively who died upon anaesthetic induction in the supine position and who subsequently was found at post mortem to have tumour encroachment of the pericardium, outer myocardium and pulmonary arteries by a diffuse non-Hodgkin's lymphoma.[12] This unfortunate outcome might have been avoided by the use of the chemo- or radiotherapy to shrink the tumour before general anaesthesia.

Patients with masses compressing the pulmonary artery may be relatively asymptomatic while awake yet may develop severe life-threatening hypoxaemia, during anaesthetic induction or under mild sedation, that requires emergency extracorporeal bypass.[13] The assumption of the supine position, the change in chest wall muscle tone under general anaesthesia and the institution of positive pressure ventilation all can combine to diminish pulmonary blood flow critically. As of this writing, there are no determinates of which patients will be intolerant of anaesthesia or sedation and hence require extracorporeal bypass. If the decision is made that bypass should be immediately available, the pump team should be in the OR, the pump should be primed and ready to run, the patient's groins should be prepped and draped and the cannulation lines should be in the sterile field. In this way, should a disaster occur, minimal time will be wasted putting the patient on bypass.

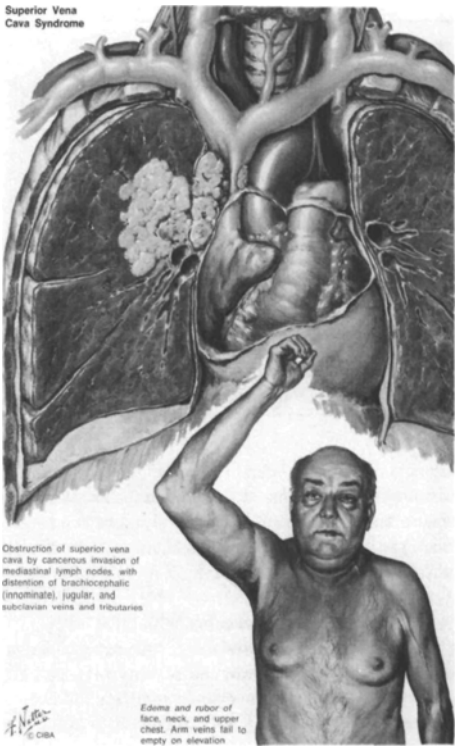

FIGURE 2 Superior Vena Cava Syndrome. Reproduced, with permission, from the Ciba collection of medical illustrations by Frank G. Netter MD.

The superior vena cava syndrome

Superior vena caval syndrome (SVCS) caused by a mediastinal tumour has been reported with some frequency. First described by Hunter in 1757, SVCS usually progresses insidiously into a pathognomonic constellation of signs and symptoms related to obstruction of venous drainage in the upper thorax. Increased venous pressure leads to: (1) dilatation of collateral veins of the upper part of the thorax and neck, (2) oedema and plethora of the face, neck and upper torso, (3) suffusion and oedema of the conjunctiva with or without proptosis, and (4) CNS symptoms like headache, visual distortion or altered mentation. Venous distention is most prominent in the recumbent position but in most instances the veins do not collapse in the normal manner when the patient assumes the upright position (Figure 2). The most common symptom is shortness of breath with one of the earliest signs

being facial/periorbital oedema. Central nervous system changes are characteristic of more rapidly progressive disease.

Cancer accounts for 97 per cent of all cases of SVCS while benign causes account for only three per cent.[14] These include intrathoracic thyroid goitre, catheter-induced SVC thrombosis, pericardial constriction, idiopathic sclerosing mediastinitis and infectious causes like tuberculosis.

Acute worsening of SVCS symptomatology has been reported to occur as a result of generous fluid administration. Some authors recommend diuresis in patients with SVC tumours causing obstructive symptoms, assuming that diuresis will also decrease tumour volume. One should bear in mind, however, that a diuresis may cause a decrease in preload leading to hypotension, worsening a situation already complicated by compromised venous return.

Evaluation/preparation of the patient

Both symptomatic and asymptomatic patients with mediastinal masses are encountered in clinical practice. Azizkhan reviewed 50 consecutive children with mediastinal masses. Thirty presented with respiratory symptoms, nine of whom were described as having "severe life-threatening respiratory compromise with dyspnoea, orthopnoea, and stridor." Thirteen of these 30 children had marked tracheal or mainstem compression (35–93 per cent of age-adjusted normal) by CT evaluation. Orthopnoea has been reported in seven cases characterized by airway collapse with anaesthetic induction.[11,12,15]

In addition to a thorough history and physical examination, postero-anterior and lateral chest radiographs done within a week of surgery should be available. Smergel reviewed the utility of the plain chest film and recommended fluoroscopy and barium swallow to evaluate the middle mediastinum (especially to differentiate normal thymus from abnormal anterior mediastinal masses). He suggested that this may obviate the need for further radiological studies.[16] However, these radiological techniques afford only a two-dimensional view of the tracheobronchial tree and significant compression can occasionally be missed.[15] In general, the size of a mediastinal mass and the degree of tracheal compression compared with age-adjusted normals can accurately be established by CT scan.[15,17–21] It is claimed that magnetic resonance imaging has a better ability to differentiate between the masses and cardiovascular structures and gives improved evaluation of posterior mediastinal masses with intraspinal extension, while CT scanning, particularly in children, appears to be superior in the evaluation of intrathoracic calcification and bronchial abnormalities.[22] Subclinical

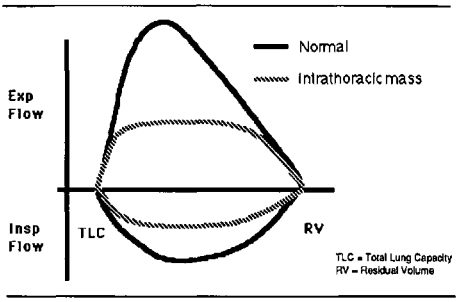

FIGURE 3 Flow-Volume Loop for a Patient with a Normal Airway and a Patient with an Intrathoracic Mass.

airway compression can be found on CT scan in 50 per cent of children with mediastinal masses.[23]

The degree of tracheal compression found on CT scan is a general predictor of whether anaesthetic difficulty with the airway may be expected. In Azizkhan's series, of the five patients who developed total or near total airway obstruction during induction or emergence from anaesthesia, all had greater than a 50 per cent decrease in tracheal cross-sectional area as measured by CT scan.[15] Prognostically, the size of a mediastinal mass has been shown to be significant with regard to the length of the disease-free interval, but is not a predictor of overall survival.[24]

In addition to anatomical/radiographical studies of the chest, dynamic studies of the airway may be carried out in cooperative patients. Flow-volume loops have been recommended to demonstrate the changes in flow rates at different lung volumes.[15,25,26] Maximal inspiratory and expiratory flow-volume curves obtained with the patient in the upright and supine positions enable the functional degree of impairment to be quantitated and help to distinguish fixed from variable major intrathoracic airway lesions.[27] A disproportionate reduction in maximal expiratory flows should also alert the physician to the presence of tracheomalacia and its inherent risk of precipitating dynamic airway collapse after tracheal extubation. Figure 3 illustrates the flow-volume loop typical of an advanced mediastinal mass causing intrathoracic tracheal compression.

Flexible fibreoptic bronchoscopy under topical anaesthesia is another method of evaluating dynamic airway obstruction.[28–30] It allows assessment of the functional anatomy of the entire airway and the response of the airway to variations in intrathoracic pressure, particularly with changes from the supine to sitting and semi-prone positions.[27] Ultrasonography and echocardiography have been useful in assessing myocardial contractility and the degree of tumour encasement of the heart and great vessels.[31,32]

Piro in 1976 recommended emergency pre-biopsy radiation therapy based on five of 74 patients with unirradiated mediastinal masses developing life-threatening complications following tracheal intubation.[33] In a subsequent series from the same institution, a tissue diagnosis could not be obtained in eight of 19 patients,[34] but the lack of histological confirmation did not change the treatment course; seven patients received empirical therapy based on their presumed diagnosis resulting in lack of relapse in four. Following treatment, the presumed diagnosis was actually confirmed in the others. In Azizkhan's series, five of the 13 symptomatic patients were judged extremely high risk and node or needle biopsy was performed with subsequent radiation and chemotherapy followed by a general anaesthetic. Five patients of eight were not treated with radiation prior to their general anaesthetic and subsequently developed total airway obstruction that resolved with positional change, passing the tracheal tube distal to the obstructing lesion or the reinstitution of mask ventilation with PEEP.

Pathological diagnosis is interfered with when patients are pretreated with high-dose steroids if lymphoma is suspected. At The Children's Hospital, this treatment approach is avoided in the pre-biopsy period in favour of radiation. The surgeons in our institution would prefer that radiation to the thorax be used with sparing of some tumour tissue for biopsy rather than using steroids which cause rapid lympholysis in a nonspecific manner. Preoperative radiation therapy due to severe clinical or radiological findings has been associated with a decrease in postoperative respiratory complications and an improvement in risk category.[35]

Other tissue diagnostic strategies which have been employed successfully while avoiding the administration of a general anaesthetic have been percutaneous needle aspiration of the hilum and mediastinum[36,37] and thoracoscopy[38,39] for children as well as adults.

Anaesthetic management

Management starts with securing intravenous access. If there is concurrent SVCS, a lower limb vessel is preferred. Intravenous injections in the upper extremities are less desirable because of a slowing of drug distribution. With low flow rates, local irritation with thrombosis or thrombophlebitis may also result and serious efforts should be made to secure vascular access in the lower extremities only.

Careful assessment of the airway preoperatively is important in all patients with a diagnosis of a mediastinal mass, particularly in those with the SVCS. The same degree of oedema that is present externally in the face and neck may be encountered in the mouth, oropharynx, and hypopharynx.

Premedication is light or deleted because of concerns about the potential for airway obstruction. A drying agent is helpful if a difficult intubation is anticipated. The patient is transported to the operating room in the head-up position to minimize airway oedema. When practical and as indicated by the severity of symptoms and preoperative evaluation, an intra-arterial catheter should be inserted; a central venous or pulmonary artery catheter may be inserted via femoral vein in cases of SVCS.

The method chosen for induction of anaesthesia and tracheal intubation depends upon the preoperative evaluation. If it is necessary for the patient to maintain the sitting position in order to achieve adequate ventilation the anaesthetic induction should also proceed in this position. Fibreoptic bronchoscopy to secure the airway should be seriously considered in these patients. Older children will tolerate awake fibreoptic bronchoscopy with midazolam/fentanyl sedation and airway topicalization with lidocaine fairly well but, in younger children, this approach is impractical. In these younger patients, an inhalation induction with spontaneous respiration prior to the actual fibreoptic bronchoscopy is preferable. To minimize hypotension due to venous pooling, the legs of these patients should be wrapped with Tensor® bandages prior to or during the actual start of the inhalational induction. Ventilatory obstruction has been relieved by lateral or prone positioning of the patient and in one case by performing a direct laryngoscopy with the endotracheal tube *in situ*.[8,15]

Spontaneous ventilation, avoiding the use of muscle relaxants, is the ideal. Positive pressure ventilation may critically reduce already narrowed airways and cause anaesthetic gases flowing through narrowed airways to turbulate and impair gas exchange significantly.[40]

In most patients with symptoms of respiratory obstruction, peripheral tissue for biopsy is usually available and a local anaesthetic technique with or without sedation should be employed. A recent report has also emphasized the importance of obtaining diagnostic tissue via mediastinoscopy in order to begin treatment while avoiding the risks of thoracotomy.[41]

After securing the airway, the next most important intraoperative problem encountered is bleeding in association with the SVCS. Substantial venous blood loss results from the abnormally high central venous pressure. Unexpected arterial bleeding may also occur because of the distorted anatomy and difficulty in dissection. In these circumstances, cross-matched blood should be immediately available in the operating room at the time of sternotomy.

Perioperative course

After diagnostic procedures such as mediastinoscopy. bronchoscopy and thoracoscopy, severe respiratory failure requiring reintubation and ventilation may occur when the SVC obstruction has not been relieved. This may be due to impaired respiratory muscle function, abnormal response to muscle relaxants in patients with malignancy or increased airway obstruction due to tumour swelling as a result of partial resection or biopsy. Post-obstructive pulmonary oedema has also been reported in a patient following biopsy of an anterior mediastinal mass through a neck approach.[42] All of these patients must be closely monitored in the first few postoperative hours.

Conclusions

Mediastinal tumours most commonly compress and obstruct the tracheobronchial tree but compression of the main pulmonary artery, atria and the superior vena cava can occur as well. Compression of any of the above structures can cause life-threatening complications at any time during anaesthesia. Anaesthetists should have a high degree of awareness of these complications and be adept at dealing with them should they arise.

Intubation of these patients either with sedation or during a judicious inhalational induction of anaesthesia is encouraged and paralysis with positive pressure ventilation should be avoided. Should severe airway obstruction occur, putting the patient into the lateral or prone position may be lifesaving. In symptomatic patients requiring a diagnostic tissue biopsy, a local anaesthetic technique should be employed.

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Résumé

Les enfants et les adultes qui ont une masse médiastinale sont à risque de complications respiratoires ou cardio-vasculaires lors de l'anesthésie. Nous en décrivons l'anatomo-pathologie et les trois types de problèmes intrathoraciques associés: compression trachéo-bronchique, compression du coeur et de l'artère pulmonaire et enfin, syndrome de la veine cave supérieure. Nous insistons sur l'évaluation par l'histoire, la tomodensitométrie et la courbe débit-volume. On peut diminuer le risque de complications respiratoires par une radiothérapie pré-opératoire chez les patients très symptomatiques tout en épargnant une fenêtre qui servira au diagnostic histologique. Nous décrivons aussi les techniques anesthésiques appropriées. Des complications graves peuvent survenir à n'importe quel moment de l'anesthésie chez ces patients. Dans ces cas là, l'anesthésiste doit être bien au fait de l'anatomie et de la pathophysiologie de la lésion et des alternatives qui s'offrent à lui.