

Cardiovascular and Airway Considerations in Mediastinal Mass During Thoracic Surgery

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Abstract

Mediastinal Masses have always posed as a nightmare even for the skilful anaesthesiologists. The compression effects, the proximity to major vascular and airway structures, the complex surgical approaches has altogether made both the diagnostic and therapeutic procedures a high risk event. The scenario is more troublesome if the patient is an infant or child. Here the anaesthesiologists has almost no information regarding 'Position of airway rescue' or 'Position of maximum airway patency' to which he can put the patient in case of any therapeutic misadventure arising out of compressive effect of the mediastinal mass on the airway and/or great vessels once the patient is induced or in the way of being induced for anaesthesia.

Keywords: Anaesthesia; Cardiovascular; Mediastinal mass; Thoracic surgery

Introduction

In 1975 Bitter [1] described a case of respiratory obstruction associated with induction of general anesthesia in a patient with mediastinal Hodgkin's disease. His case report was one of the first described reports which drew the attention of the anaesthesiologists towards the probability of unexpected sudden collapse of the patients with mediastinal mass posted for elective surgery. Later with advancement of imaging studies it was possible to appreciate sudden respiratory and/or cardiovascular compromise in such a patient with a fair accuracy. Modification of anaesthetic technique and introduction of advanced airway management devices improved perioperative outcome of these surgeries to such an extent that currently more complex and less traumatic surgical approaches like VATS are gaining popularity among the thoracic surgeons. These advances have shifted the trends of respiratory complications in these patients towards the early postoperative period rather than intraoperative period [2].

| | | 2010-2011 | 2011-2012 | 2012-2013 |
|--|--------|-----------|-----------|-----------|
| Open surgery/ Diagnostic procedure | Total | 3,453 | 3136 | 2895 |
| | Deaths | 28 | 18 | 25 |
| | % | 0.81 | 0.57 | 0.86 |
| VATS | Total | 218 | 244 | 269 |
| | Deaths | 4 | 2 | 1 |
| | % | 1.83 | 0.82 | 0.37 |

Table 1: Mortality trends in surgery for mediastinal procedure in UK. *Data from Society of Cardiothoracic Surgeons of Great Britain and Ireland (SCTS) (2002–2005). Thoracic surgical register. Available at: www.scts.org. Accessed 12/11/2014.

Anatomy

Anatomy of mediastinum has been described by the classic model and Shields' model. According to classic model [3], the mediastinum is divided into four compartments: superior, anterior, middle, and posterior. The anterior and superior compartments are continuous, so combined to form antero-superior compartment. In 1972 Shields [4] described an alternate model consisting of three-compartment: anterior compartment, middle (or visceral) compartment and a posterior compartment (paraventral sulcus).

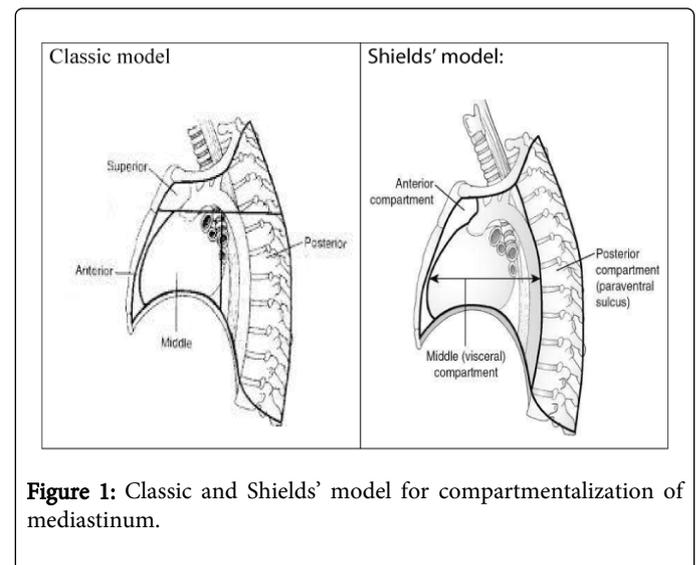


Figure 1: Classic and Shields' model for compartmentalization of mediastinum.

All three compartments are bounded inferiorly by the diaphragm, laterally by the pleural space, and superiorly by the thoracic inlet. The anterior compartment is bounded anteriorly by the sternum and posteriorly by the great vessels and pericardium.

Classification of Anterior Mediastinal Mass

Lymphoma most common in pediatric age group.

Thymoma most common in adults (Table 3).

| Anterior | Visceral (middle) | Paravertebral (posterior) |
|-------------------------------|--|--|
| Thymus | Pericardium/heart | Sympathetic chain |
| Internal thoracic vessels | Great vessels | Proximal intercostal nerve, artery, and vein |
| Internal thoracic lymph nodes | Trachea | Posterior paraesophageal lymph nodes |
| Fat and connective tissue | Proximal right and left mainstem bronchi | Intercostal lymph nodes |
| | Esophagus | |
| | Phrenic nerve | |
| | Thoracic duct | |
| | Proximal azygos vein | |
| | lymph nodes | |
| | Fat and connective tissue | |

Table 2: Components of mediastinal compartments as proposed by Shields [4,5].

Clinical presentation

Patient may be asymptomatic initially. Chest pain and fullness is a common presenting symptom. Lymphomas may present with history of fevers, chills, night sweats and weight loss. Myasthenia may present with muscle weakness, ptosis, diplopia. Palpitation, sweating, tachycardia and thyrotoxic symptoms may be present in retrosternal goitre. Symptoms may appear due to compressive effect or malignant involvement of nearby structures. Severity of symptoms depends on: size, site, consistency, nature, compressed structures etc. [6]. Tracheal compression may manifest as cough, stridor, dyspnoea, orthopnoea, postural dyspnoea, cyanosis, hoarseness or recurrent respiratory tract infections. Compression of heart may result in dysrhythmia, cyanosis or syncope [6,7]. Venous return may be compromised by compression or generalised increased intra-thoracic pressure by a large mass. In some cases patient may present with SVC obstruction, characterised by engorgement of the veins of the neck, right upper arm, chest wall and oedema of neck, head and upper arm [8,9]. These cases may be associated with malignancy [7,8], considered as high risk case [10,11-14] and proper work-up is necessary before surgery. Kurata [15] described a case of superior and inferior vena cava syndrome due to intracaval and intracardiac extension of invasive thymoma. Compression or malignant involvement of sympathetic chain may manifest as Horner’s syndrome (ptosis, miosis, anhidrosis, apparent enophthalmos, absence of pupillary dilatation on shading the eye and abolition of ciliospinal reflex) [7]. Gradation of symptoms to mild, moderate or severe depends on patients’ tolerance to supine position [16]. Patients with severe symptoms will not voluntarily lie supine even for a short duration [7,17].

Anesthetic management problems

Although the mediastinum has been described to be divided into different compartments, the demarcation between the compartments are arbitrary and a space occupying lesion from one compartment may easily compress the structures of other compartments [16-18].

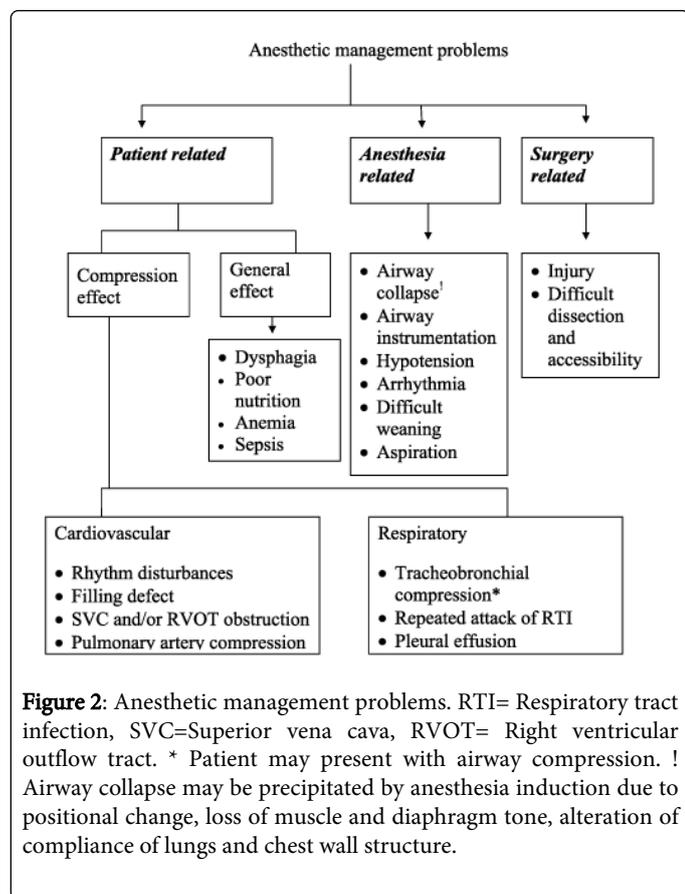
| Neoplastic | Infectious | Vascular |
|---|--|---|
| 1. Thyroid Substernal goitre Ectopic thyroid tissue | Acute descending necrotizing mediastinitis-Bacterial | Aneurysm of the aortic arch with projection in the anterior mediastinum |
| 2. Thymus Thymic hyperplasia Thymoma Thymic carcinoma Thymic carcinoid Thymic cyst Thymolipoma | Subacute Fungal Mycobacterial Histoplasma Actinomycosis | Innominate vein aneurysm |
| 3. Teratoma Mature Immature With malignant component | | Superior vena cava aneurysm |
| 4. Germ cell tumors Seminoma Yolk sac tumours Embryonal Carcinoma Choriocarcinoma | | Dilation of the superior vena cava (with anomalous pulmonary venous return) |
| 5. Lymphoma Hodgkin’s Non-hodgkin’s | | Persistent left superior vena cava |
| 6. Ectopic parathyroid with adenoma | | |
| 7. Lipoma/Liposarcfoma | | |
| 8. Fibroma/Fibrosarcoma | | |

Table 3: Classification of Anterior Mediastinal mass [5].

This effect is more seen in children because of more incidence of neurogenic tumour [17,19], small thoracic cavity size, more compressible cartilaginous structure of the airway, reduced cardiopulmonary reserve or difficulty in obtaining a history of positional symptoms in children [16]. Some study found higher mortality in children [20,21], whereas according to some there is no significant difference in mortality in different age group [22]. Another definite problem in pediatric age group is institution of femoro-femoral bypass under local anesthesia. Authors suggest judicious use of ketamine or sevoflurane to assist the procedure.

Patients may be asymptomatic at presentation. But during induction or even with mild preoperative sedation, there may be reduction of muscle tone and/or protective reflexes which may culminate in tracheobronchial compression and precipitation of severe

hypoxia. Severe respiratory complications during anesthesia induction in a patient with mediastinal mass may be attributed to several factors. Firstly, reduction of lung volume with commencement of general anaesthesia cause decrease in tracheobronchial diameter [16]. Secondly, larger airways become more compressible due to reduction of smooth muscle tone [16]. Thirdly, with diaphragmatic paralysis or paresis there is elimination of normal transpleural pressure gradient which acts to maintain airway patency during inspiration [18]. Fourthly, loss of tone of the chest muscles lead to loss of structural support to the airway [16]. LMA insertions and all other modalities practised in standard difficult airway algorithm may be of no value because airway obstruction occurs distally [20,23]. Prolonged compression of trachea may result in tracheomalacia [7], which may interfere with weaning from ventilator.



Cardiac problems may arise from compression over the heart, compression of pulmonary artery, pericardial effusion or direct myocardial involvement from mediastinal masses. Diastolic filling may be compromised due to mass effect or pericardial effusion. Cardiac compressions may result in rhythm disturbances and syncopal attack [7]. Presence of pericardial effusion has been proved to be definitely associated with adverse outcome in intraoperative period [2]. Compression of pulmonary artery (PA) may obstruct right ventricular outflow, reduce pulmonary blood flow and severely diminish venous return to left atrium [9]. These patients may present with a flow murmur and outcome may be fatal [13,24]. Dysrhythmia may occur due to pericardial or myocardial involvement or secondary to respiratory or hemodynamic problems [13]. Large lymphomas may exert a tamponade like effect on the heart. Anesthetics may reduce cardiac contractility and severely diminish cardiac output. Keon [25]

reported a patient with mediastinal mass and symptoms mimicking pericardial tamponade or constrictive pericarditis suffered from sudden severe cardiovascular collapse and death when halothane induction compromised myocardial contractility. Pulmonary edema may occur due to various causes during perioperative period and complicate the situation. Eicher et al. [26] have described two cases of pulmonary edema due to obstruction of pulmonary venous flow.

Problems may be aggravated or new complications may arise with change of posture, airway manipulation, even institution of CPB. Cantor and Fitzsimons [27] have described a 40 year old patient presented with anterior mediastinal mass compressing the RVOT and SVC. There was no preoperative symptom of compression. But with initiation of cardiopulmonary bypass and reduced venous return through systemic veins, compression on the major vascular structures aggravated and cerebral oxygen saturation dropped. They managed the situation with neck flexion and relieving the obstruction on SVC. Central venous access may be difficult due to compression of SVC [9]. Factors statistically significant associated with mortality during hospitalizations were sepsis, superior vena cava syndrome, and massive pleural effusion [28]. Although the anesthetic management problems may be categorized as patient related, anesthesia related or surgery related, the problems are interrelated and combined factors play role during occurrence of complications.

Evaluation of patient at risk

Patients with mediastinal mass may be posted for possible diagnostic or therapeutic surgical procedures. Patient should be thoroughly evaluated prior to surgery both clinically and by radiological studies.

1. From symptoms and sign [16]:

- A. Asymptomatic
- B. Mild: Can lie supine with some cough/pressure sensation
- C. Moderate: Can lie supine for short periods but not indefinitely
- D. Severe: Cannot tolerate supine position.

2. Imaging studies:

A. Chest X-ray: Postero-anterior and lateral views are obtained. Location of the mass, dimension of the mass, tracheobronchial compression, nature of the mass (cystic, solid or calcified) to be examined [7,29].

B. CT scan: Currently considered as most appropriate [21] and first choice [29] modality to delineate the anatomy of the mediastinal mass. On CT scanning, the size of tumour, contour, perimeter of capsule, septum, haemorrhage, necrotic or cystic component, and calcification, homogeneity within tumour, and presence of mediastinal lymphadenopathy, pleural effusion and great vessel invasion are assessed [29]. It also serves to assessment of airway compression by variety of indexes.

1. Tracheal diameter: Tracheal compression or obstruction is measured by dividing the smallest antero-posterior diameter by that of the thoracic inlet [30]. A 35% decrease in the diameter of tracheobronchial lumen is associated with respiratory symptoms, while a greater than 50% decrease may be associated with complete airway obstruction during induction or emergence from GA [7,31].

2. Tracheal cross section area: King et al. [32] described a simple method. The widest (d1) and narrowest (d2) diameters were measured at two points: the largest appearing area, usually found at the thoracic inlet with lung apices appearing in the picture, was chosen as the patient's 'normal' trachea and used as its control [33]. Narrowest point diameter was determined from the CT scan sections above the carina. Cross sectional area is calculated using the formula $CSA = \pi (d1/2 * d2/2)$. A value of control CSA (CSAc) and narrowest point CSA (CSAn) is obtained. Compression is calculated by, $\%CSA = CSAn/CSAc * 100$. Reduction of cross sectional area more than 50% of predicted is associated with significant respiratory complications [34], even if the patient is asymptomatic [30].

3. Mediastinal Thoracic Ratio (MTR) and Mediastinal Mass Ratio (MMR): $MMR = \text{maximum width of the mediastinal mass} / \text{maximum thoracic width}$ [33]. King et al. [32] subdivided MMR into three groups: MMR less than or equal to 0.30, between 0.31-0.43 and greater than or equal to 0.44. Higher the MMR, higher the risk of compression.

MTR is calculated by comparing the size of the mediastinal mass with the thoracic diameter. A patient with a MTR of more than 50% has higher risk of perioperative respiratory complications [7].

MRI scan: Ideal [35] imaging modality to delineate soft tissue relation of mediastinum. Chemical-shift MRI has been shown to be useful in distinguishing normal thymus and thymic hyperplasia from thymic neoplasm and lymphoma [36].

Transthoracic echocardiography: Delineates cardiac involvement by the mass and indicated in all patients as asymptomatic patients may also harbour significant compression of major vascular structure [27]. It aids additional information regarding pulmonary and systemic vascular compression. Neoplastic involvement of heart or pericardium may pose additional threat to the anaesthesiologists by precipitating sudden severe hemodynamic catastrophe [25,37]. Presence of pericardial effusion is a strong predictor of intraoperative cardiovascular catastrophe [2].

Flow volume loops: Typical finding is an increased mid-expiratory plateau when changing from the upright to the supine [18]. Compression to be considered severe if PEF is less than 50% of the predicted and supine flow volume loop study shows severe expiratory plateau [7]. Not a reliable diagnostic study [7,18].

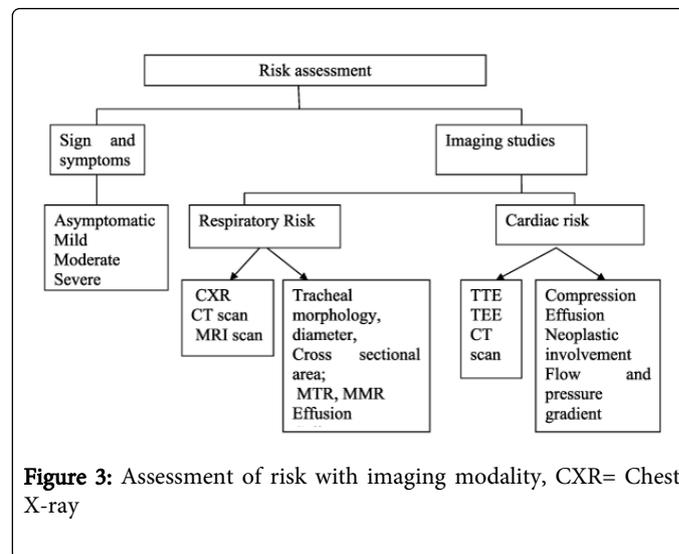
3. Identification of children at risk [16,38]

- A. Airway narrowing/displacement on imaging
- B. Anterior location of tumor
- C. Histological diagnosis of lymphoma
- D. Symptoms/signs of superior vena cava obstruction
- E. Radiologic evidence of vessel compression
- F. Pericardial effusion
- G. Pleural effusion

Anesthesia Management Protocol

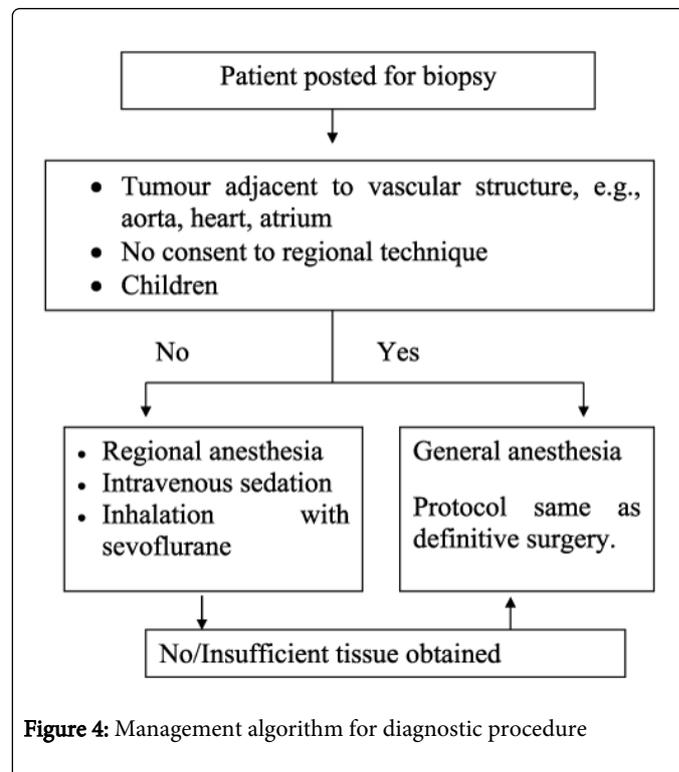
Patients with mediastinal mass may be posted for diagnostic biopsy procedures or therapeutic surgical removal. Management protocol differs in both the cases. Preoperative chemotherapy and/or radiotherapy should be advised to appropriate patients [6,7,13,18].

Tissue biopsy should be obtained within 72 hours of initiation of treatment otherwise it may cause tumour lysis and interfere with accuracy of tissue diagnosis [39].



Management protocol for diagnostic procedures

There are four approaches for tissue assessment of mediastinal tumors: percutaneous needle aspiration, mediastinoscopy, anterior mediastinotomy (Chamberlain's procedure), and video-assisted thoracoscopic biopsy.



If a patient with mediastinal mass is posted for a diagnostic biopsy, the authors insist on regional anesthesia technique. However, it may be assisted by cautious use of sedation, either with inhalation

anesthetics (preferably sevoflurane [40]) or intravenous short acting agents (such as Dexmedetomidine infusion or titrated dose of propofol-ketamine). The rationality behind this technique is biopsy comes with all the deleterious effects of anesthesia on the airways and great vessels (compressive effects); and add to the trouble the mediastinal mass remains *in situ* after the biopsy procedure is over making the postoperative period stormy and risk prone [41]. Whatever, anesthetist should be prepared for emergency airway management and patient should be aroused with earliest evidence of airway compromise. Safe surgical approaches include: awake CT-guided or ultrasound guided needle biopsy for children [42] and awake anterior mediastinoscopy with local anesthesia in adults [18]. The authors also insist for consideration of prebiopsy steroid in the high-risk child without extrathoracic lymphadenopathy or a pleural effusion [16,43] to reduce postoperative edema related compression and narrowing of the airway [17].

Management protocol for definitive surgery

In preoperative clinic,

1. Categorization of patients according to symptoms
2. Identification of patients at risk
3. Preoperative chemotherapy and/or radiotherapy for neoplastic masses
4. Needle aspiration of cystic nonvascular lesions
5. Determination of patient position in which airway and cardiovascular compression is minimal.

Goals of anesthetic management:

1. Avoid compressive effects at any cost.
2. Flexibility in patient positioning. Supine position is not mandatory [16].
3. Avoidance of preoperative sedatives [7].
4. Mandatory preoperative establishment of femorofemoral bypass in selective cases [7,16,18,44].
5. Spontaneous ventilation as far as practicable. (noli pontes ignii consumere) [16].
6. Secure airway beyond stenosis when patient is awake, if feasible [16].
7. Availability of rigid bronchoscope throughout the procedure [7].
8. Short acting muscle relaxant after airway is secured and/or femorofemoral bypass is established [7].

9. Strict intraoperative and postoperative monitoring and adequate analgesia.

10. Postoperative mechanical ventilation when indicated.

Some modifications should be applied especially if the mass is compressing SVC:

1. Wide bore venous access in lower extremity.
2. SVC cannulation should not be attempted for the risk of haemorrhage, embolisation, erroneous pressure reading and unpredictable drug effect [13].
3. Central venous access via femoral route.

4. Transtracheal injection of local anesthetic is discouraged to avoid cough induced haemorrhage.

5. The anaesthesiologist should be familiar to the exact position of the mass and surrounding anatomy. This may help to change the patient position to relieve the obstruction.

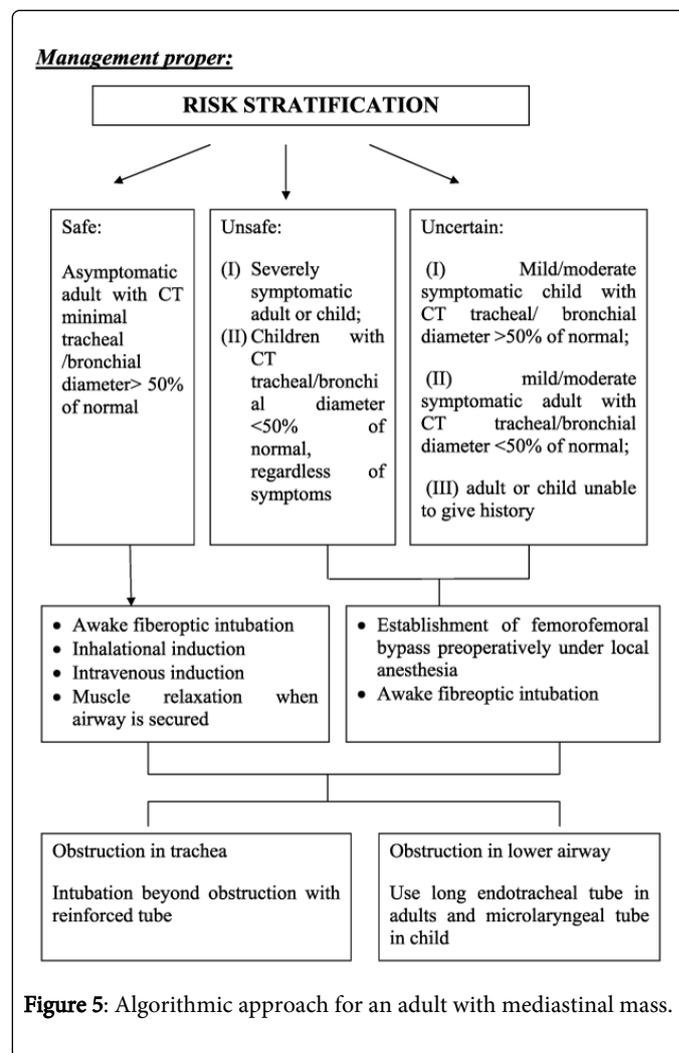


Figure 5: Algorithmic approach for an adult with mediastinal mass.

The postoperative care is very important in this group of patients. Airway emergencies are more fatal in postoperative period [2]. Airway edema [45] may occur and may necessitate smaller size of endotracheal tube. In diagnostic cases obstruction may occur secondary to enlargement of the mass by edema or haemorrhage [46] or surgical manipulation [13] or if the SVC obstruction not fully relieved [41]. Pulmonary edema may occur following surgery and both cardiogenic and non-cardiogenic causes may be responsible. Negative pressure or re-expansion pulmonary edema is also fairly common [47-49].

Role of cardiopulmonary bypass

There has been a long controversy regarding the role of cardiopulmonary bypass in management of mediastinal mass. Recent studies have clearly indicated that 'standby' cardiopulmonary bypass is not a good option for these cases [7,16,18,44,50-52].

Bautista et al. [51] described a case of a 35 years old male patient posted for tracheobronchial stenting who within seconds of change in posture, developed significant arterial desaturation of oxygen and bradycardia, requiring the interruption of the procedure and severe catastrophic consequences thereafter. The patient was resuscitated but significant neurological sequel developed thereafter and the patient died after twelve days. In case of emergency even in presence of a primed bypass circuit, experienced technician and staffs, it will require at least 5-10 minutes before adequate oxygenation can be ensured within which irreversible neurological damage may ensue [17]. For this reason, the authors strongly recommend against the use of 'standby' cardiopulmonary bypass and advocate the use of an alternate mode of oxygenation from the beginning of anesthesia in 'unsafe' and 'uncertain' group of patients (see algorithm). This recommendation strongly corroborates with the views of Slinger and Karsli [18] who opined, "Patients with severe positional symptoms due to airway or cardiovascular compression cannot be safely given induction of general anesthesia, even with maintenance of spontaneous ventilation, unless an alternative technique to maintain oxygenation or circulation (extracorporeal membrane oxygenation or cardiopulmonary bypass) has been established." Alternate mode of oxygenation usually provided by a femorofemoral bypass instituted under local anesthesia [13,16,18,44]. Cases using venoarterial extracorporeal membrane oxygenation have also been described in literature [50,51]. Recently in 2014, Said SM and others [52] emphasized on awake cardiopulmonary bypass to prevent hemodynamic collapse and loss of airway in a severely symptomatic patient with a mediastinal mass. They described a case report of a 37-year-old woman posted for resection of a large anterior mediastinal mass through sternotomy. Cardiopulmonary bypass was instituted using the right femoral vessels under local analgesia to allow safe anesthetic induction.

Management of airway and cardiovascular emergency

Life threatening airway obstruction or cardiovascular collapse may be precipitated even during providing anesthesia to the 'safe' group of patients. The authors strongly recommend use of short acting anesthetics, inhalational anesthesia (preferably sevoflurane), avoidance of muscle relaxants and maintenance of spontaneous ventilation until the airway is secured. Awake fibreoptic intubation forms the cornerstone of airway management in this group of patients to prevent airway related emergency. Intubation and ventilation with 100% O₂ is of little value unless obstruction is relieved, but should be attempted until other means are available. Immediate repositioning of the patient to maximum airway patency, awakening the patient and if necessary emergency thoracotomy or median sternotomy should be performed to relieve the obstruction.

Tracheobronchial splinting, Helium-oxygen mixture, standby cardiopulmonary bypass have all been described in literature as management modalities in this scenario [7] but practical applicability may be questionable for all setups.

Cardiovascular emergency may arise from multiple factors. Sudden cardiac arrest due to any reasons should be managed by ACLS protocol. Patients unresponsive to therapy may benefit from immediate surgical intervention to remove the compression. Compression to pulmonary artery (PA) may result in diminished venous return to left side of heart and a drop in cardiac output. Inadequate diastolic filling may result from pericardial effusion, compression of the heart by the mass or compression of PA. Adequate preload should be maintained. Dysrhythmias should be managed by

maintaining plane of anesthesia, correction of electrolyte and acid base abnormality if any, maintaining optimum preload and afterload, and if necessary by drugs like lidocaine or epicardial pacing.

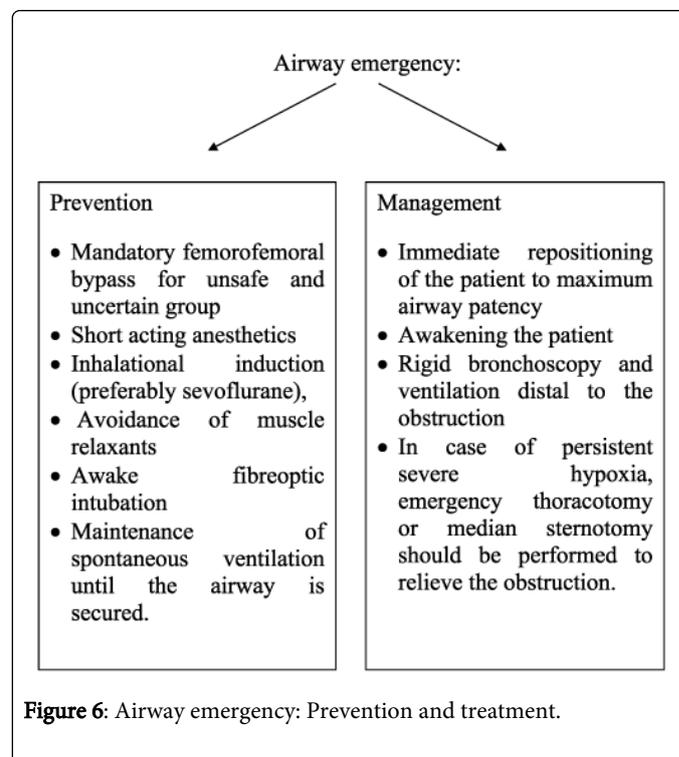


Figure 6: Airway emergency: Prevention and treatment.

Conclusion

The authors hereby strongly reinforce the use of preoperative chemotherapy or radiotherapy as applicable in case of mediastinal masses of neoplastic origin or aspiration if cystic in nature before induction in the preoperative clinic so as to minimize the compressive effect of the mass.

Secondly, the authors emphasize that cardiopulmonary bypass should be instituted in an elective manner in selective cases and not as a rescue option.

Thirdly, ACLS protocol for cardiac arrest. But not difficult airway algorithm for airway management. LMA insertion during airway emergency may be of no value as obstruction occurs distally

Fourthly, categorization of patients into different risk groups is essential and both the clinical and radiological criteria must be observed in order to arrive at a management approach.

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