Chapter 3

Postoperative Care and Complications After Thoracic Surgery

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Additional information is available at the end of the chapter

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1. Introduction

Postoperative care of thoracic surgical patients is a very important part of patient recovery and can be very challenging. Pulmonary complications are responsible for significant numbers of deaths and morbidity of patients undergoing thoracotomy. Thoracic surgery impairs postoperative respiratory function resulting in a relatively high risk of developing postoperative pulmonary complications. The incidence (19-59%) is much higher than following upper (16-17%) or lower abdominal surgery (0-5%). The overall incidence of complications following thoracic surgery varies from 15% to 37.5%, primarily due to the type of pulmonary complications studied, the clinical criteria used in the definition and the type of surgery included. The clinical and potential economic impact of these complications is marked, with significantly longer hospital and high Dependency unit stay, frequency of ICU admission and number of deaths.

A centre can achieve excellent results by concentrating on the basics of postoperative care like pulmonary hygiene and physiotherapy, fluid and pain management and management of pleural spaces. Risk factors for complications following thoracic surgery have been identified from numerous clinical studies using a variety of research designs and definitions. The most frequent risk factors include age, preoperative pulmonary function tests, cardiovascular co morbidity, smoking status and chronic obstructive pulmonary disease (COPD). [1]- [4] In the current era there has to be more emphasis on postoperative care due to the complexity of referrals with the thoracic units doing more patients with multiple risk factors for post operative complications. This gets more challenging with cost containment.

High-risk patients can be optimised with preoperative and postoperative cardiopulmonary rehabilitation to reduce their operative risk, frequency of complications and hospital stay and improve postoperative outcomes including postoperative lung function. [5], [6] In addition,

preoperative pulmonary rehabilitation may improve preoperative exercise capacity and so operability. [7], [8] The future development and adoption of innovative strategies is required to reduce the impact of post operative complications in an ageing co morbid population.

In this section will cover the routine care of a postoperative thoracic patient with specific emphasis on prevention and management of common complications.

2. Preoperative optimisation of specific risk factors

The outcome of surgical procedures is not measured only by clinical end points but also shorter stays and lower costs [9]. Patients' discharge is delayed commonly due to inadequate pain relief, infection, arrhythmias, prolonged air leak and debility [9]. Many complications that occur from thoracic operations can be anticipated. An aggressive preoperative work up mitigates morbidity and shortens convalescence.

2.1. Smoking

Preoperative cessation of smoking prevents postoperative complications to a large extent.

Support groups, counselling and nicotine replacement therapy should be used [10]. Historically, 6 weeks of smoking cessation before surgery is recommended to avoid the copious bronchorrhea that accompanies regeneration of the cilia that clear mucus between 2 and 4 weeks after smoking cessation [11].there are few studies which challenge this challenge this notion of timing of smoking cessation. Even 3-5 days of stopping could improve clearance and decrease of secretions. Vaporciyan el al showed that patients who quit smoking 4 weeks or more before surgery had a lower incidence of pulmonary complications than patients who continued to smoke or quit fewer than 4 weeks before pneumonectomy [12]. However, Barrera and co-workers found no difference in the incidence of pulmonary complications between patients who were still smoking at the time of surgery and those who had quit fewer than 2 months before thoracotomy for lung resection [13]. In many centres including ours the recommendation is to stop smoking at any time and provide support services to help out with the same.

2.2. Preoperative education and physiotherapy

Preoperative physiotherapy and education is done in many centres as part of work up for thoracotomy. Physiotherapists and thoracic ward medical and other staff perform a variety of care for patients undergoing surgery both pre and post operatively. All these are done to prevent postoperative complications like atelectasis, pneumonia, effusions and empyema. Various manoeuvres include education, deep breathing and coughing manoeuvres, chest physiotherapy and early mobilization education post sugery [14]. According to few studies this has led to an improvement in the prevention of atelectasis, collapse and consolidation. Many other interventions like incentive spirometry and respiratory muscle strengthening have

been shown to reduce the incidence of these complications. During the work up assessment of the pulmonary functions are done and bronchodilators optimised.

In the education session instructions may be given for deep breathing and splinted coughing exercises, prophylaxis exercises for deep vein thrombosis, and shoulder exercises [15]. There studies which question the benefit of preoperative education and physiotherapy and few studies have shown them to be non-beneficial16 but we continue to follow preoperative education as well as physiotherapy prior to thoracic surgery.

Patients are also investigated for cardiac ailments if there are symptoms, signs or significant cardiac history prior to performing elective thoracic surgery. Investigations may include echocardiography, cardiac viability study or angiogram. Patients who are on antiplatelets should have their medications withheld 7 days prior to surgery is possible. If patients are on warfarin then it is stopped 3 days prior to surgery and are covered with heparin

Patients are given a single dose of antibiotics for elective cases and they are continued for infected cased or restarted postoperatively if needed. If surgical intervention is elective, we advocate a short period of preparation may be beneficial if directed at improving the patient's physical status and specifically at pulmonary preparation, conditioning exercises, and nutrition.

3. Operative factors

3.1. VATS vs. OPEN

Video assisted Thoracoscopic procedures are done with increasing frequency for many indications. The incidence of postoperative complications is 9% after VATS and they include haemorrhage, empyema, air leak, pneumonia and surgical emphysema [17] commonly but most of the complications which happen in thoracotomy could potentially happen with video assisted Thoracoscopic procedures.

Most importantly the incidence of postoperative pain is much less in VATS than open procedures and they have shorter hospital stay. The proponents of VATS have published many series about the feasibility, lesser complication rate, reduced pain, early mobility and discharge [18], [19]. There are groups who did not find any statistical benefit in performing VATS and have quoted a higher bleeding and intraoperative complication rate [20]. In our unit we perform VATS for all kinds of thoracic procedures if patients are suitable for it. VATS lobectomy is a safe procedure, which reduces peri operative pain and improves postoperative physical status. The results obtained with early stage lung cancer are excellent and may reflect inherent oncologic advantageous consequent upon reduced operative trauma. Detection of early stage lung cancer is potentially rewarding and will become a practical imperative if survival results are to be improved. Thus the scope for VATS resection may increase significantly. In our view VATS lobectomy is the procedure of choice for early stage lung cancer and multicentre prospective randomised trials comparing this therapy against conventional open resection are overdue.

3.2. Use of staplers and glues to reduce and seal air leaks

Various procedures like wedge resections, lobectomies, excision of bullae may cause prolonged air leaks especially if patients have COAD. Traditionally diathermy dissection and ligation was used and later staplers were used for parenchymal resections. Although certain studies pointed towards improved results with regards to air leaks using staplers [21] and reported that surgical morbidity due to air leaks decreased with this technique other studies have not shown any particular reduction in duration of air leaks using staplers alone. [22]

The air leaks caused by the holes of the suture needles are of the same magnitude as that caused by the surface tension between the parallel staple lines when the lung inflates. Nevertheless staplers are quicker to use and they have a big role in minimally invasive Thoracoscopic procedures

Polyglycolic acid fabric, polydioxan ribbon, bovine pericardial strips, bovine collagen, and recently, expanded polytetrafluoroethylene have been employed in an attempt to reinforce the staple lines, especially for resections performed in emphysematous lungs [23]- [27]. Other techniques like the electrothermal bipolar sealing have shown good results in lung parenchymal surgery.

Air leaks are common after pulmonary resections. They can be inspiratory, expiratory, continuous and forced expiratory. Most of the leaks are expiratory or forced expiratory. Inspiratory leaks happen on positive pressure ventilation. If there is no pleural space then they are managed by underwater seal. If there is a space negative suctions is applied to the underwater seal. If the leak persists beyond a particular time frame then TALC or reopening should be considered.

4. Post operative care

4.1. Pain management

Pain management is of paramount importance post operatively as it is essential for patients to comply for chest physiotherapy and ambulation and they will be unable to do so if they have severe pain. There are various ways by which pain is managed. They include epidural catheters preoperatively, paravertebral methods pre or intraoperatively or intravenous patient controlled analgesia. On withdrawing these agents patients will need oral analgesics for duration of time till they are pain free. These include paracetamol, NSAID and narcotic agents.

4.1.1. Epidural analgesia

The catheter is placed approximately with the midpoint of the dermatomal distribution of the skin incision. Epidural local anaesthetics increase segmental bioavailability of opioids in the cerebrospinal fluid and increase the binding of opioids to m receptors and the blocking of the release of substance P in the substantia gelatinosa of the dorsal horn of the spinal cord [28]. The thoracic segmental effects of local anaesthetic and opioid combinations is the only way to

minimize motor and sympathetic blockade maintain conscious level and cough reflex and reliably produce increased analgesia with movement and increased respiratory function after thoracotomy [29]. Generally the most popular regimens are fentanyl or diamorphine combined with levobupivacaine [29]. The regimens can be administered as an infusion, patient controlled analgesia or both.

Potential issues include failure, technical difficulty and hypotension. It can also reduce the effectiveness of coughing, especially in patients who already have a low FEV1. It is not offered when there is local or systemic sepsis.

Paravertebral block is an effective modality to provide pain relief. It can be done by the anaesthesiologist before the start of surgery or by the surgeon before closure. It offers several technical and clinical advantages and is indicated for anaesthesia and analgesia when the afferent pain input is predominantly unilateral from the chest and/or abdomen. We prefer placing the catheter under direct vision during thoracic surgery and give pain relief as a continuous infusion. The chest drain loss of local anaesthetic is four times lower than that of interapleural block [30].

4.1.2 Systemic analgesics

Opioids remain the mainstay of postoperative analgesia and have demonstrated their efficacy in the management of severe pain. The side effects include nausea, vomiting, ileus, biliary spasms and respiratory depression, Opioids can be administered IM, subcutaneously, or IV.

A very efficient method of delivery of opioids is via PCA (Patient Controlled Analgesia) devices. Numerous studies have demonstrated the safety and opioid-sparing effect of PCA. After thoracic surgery PCA is often combined with other modalities to offer adequate pain relief.

4.1.3. Intrapleural

Intrapleural local anaesthetics produce a multi-level intercostal block. However, the analgesia is extremely dependent on patient position, infusion volume, and the type of surgery. With the drains insitu most of the anaesthetic is drained out and hence the efficacy of the procedure is less. In spite of occasional successes most clinicians have not found the reliability of intrapleural techniques adequate to justify their use on a routine basis. [31]

4.1.4. Other techniques

Cryoanalgesia is the application of a -600ºC probe to the exposed intercostal nerves intra-operatively produces an intercostal block that can persist for up to six months. This can be moderately efficient to decrease post-operative pain, but is associated with an incidence of chronic neuralgia that has lead many centres to abandon the technique [32]. Transcutaneous electrical nerve stimulation (TENS) may be useful in mild to moderate pain but is ineffective when pain is severe. [33]

4.2. Management of fluid electrolytes

Patients are managed generally in a high dependency unit post surgery or the wards if it is a dedicated thoracic unit. Post thoracic surgery especially in resections intravenous fluids are given in reduced amounts to prevent pulmonary insufficiency. Care is taken not to overhydrate the patient and oral feeding in encouraged as soon as possible. Intravenous fluids should be used judiciously and a conservative strategy of administration of maintenance fluids is recommended at 1–2 ml/kg/h in the intra- and post-operative periods and that a positive fluid balance of 1.5 l should not be exceeded, to mitigate the risk of multifactorial post operative acute lung injury/ARDS. Caution should be exercised with regard to silent hypovolaemia, impaired oxygen delivery and acute kidney injury. A high index of suspicion for pulmonary insufficiency should be adopted if there is volume overload. If a patient develops signs of hypo perfusion after these thresholds are exceeded, inotropic/vasopressor support should be considered. [34]

4.3. Intercostal catheter

Intercostal catheter is watched for drainage and air leak. If the postoperative chest X-ray shows expanded lung fields the no suction is applied even if there is bubbling. If there is airspace the suction is applied. It is preferable to use a balanced drainage system in all patients. In pneumonectomy patients no suction is applied after surgery and the balanced drainage system is filled with 1cm of liquid unlike routine thoracic cases where it is filled with 2 cm of fluid. In pneumonectomy patients the drains are removed the next day and in lobectomy patients as soon as possible. Suction is also applied in cases of pleurodesis with talc so that the visceral and parietal pleurae are approximated. If the drains have to stay due to persistent minimal bubbling and if the parenchyma is expanded without any suction a Heimlich valve container is attached for earlier complete ambulation or discharge.

4.4. Physiotherapy and early mobilisation.

Postoperative insufficiency occurs because of infection, inability to clear secretions or oedema around day 2 or 3, to prevent these from happening attention should be given to physiotherapy, bronchodilators, restriction of intravenous fluids and tracheal toilet. Chest physiotherapy includes deep breathing and coughing exercises and incentive spirometry. Pulmonary insufficiency is more common in patients have low FEV1. If there is inability to do so then endotracheal suctioning or mini tracheostomy should be used for clearing secretions. Diuretics are used if necessary and antibiotics are started if clinically indicated without waiting for radiological deterioration.

Early postoperative ambulation and physiotherapy reduces complications like atelectasis, pneumonia, empyema and DVT.

Aspiration should be prevented postoperatively as it can result in multiorgan dysfunction and sepsis. Patients should be allowed to eat only when they are fully alert and sitting up. If there is a tendency to aspirate patients are kept nil by mouth and nasogastric feeding initiated as required. If there is damage to the vocal cords then a speech pathology is sought for and

patients are initially kept on nasogastric feeds and based on recovery are put on graded diet beginning from thickened fluids.

4.5. Deep Venous thrombosis prophylaxis

The prophylaxis should start when the patients are admitted in the hospital. Everyone should be given a prophylactic dose of heparin subcutaneously if not contraindicated at a dose 5000 IU twice daily and this is continued in the postoperative period till discharge. All patients should have stockings and the high-risk patients should be on compression stockings. If there are signs of DVT then a Doppler in arranged and patients put in treatment dose of heparin infusion and an IVC filter put in if necessary.

5. Complications

5.1. Postoperative haemorrhage

Immediate postoperative bleeding can be caused due to surgical bleeding or coagulopathy, surgical bleeding being more common. A set of standard coagulation tests are performed and coagulopathy is corrected accordingly. Depending on the coagulation profile factors like FFP, Platelets, cryoprecipitate or factor 7 is given if the patient is bleeding due to profound coagulopathy.The threshold for taking back a patient for re-exploration should be low, as a surgical cause of bleeding should be ruled out. Bleeding after thoracic surgery is rare. It occurs in less than 2% of video assisted Thoracoscopic procedures (VATS) and around 01% to 3% of open procedures. [35]- [38] Generally postoperative bleeding results from technical complications, but certain co morbidities may predispose a patient to bleeding. A chest tube output of 1000 ml in 1 hour necessitates an immediate return to the operating room with concurrent correction of coagulopathy. Serial drainage exceeding 200 ml per hour for 2 to 4 hours after correction of a coagulopathy also indicates surgical bleeding and dictates re-exploration. If the patient is hemodynamic ally stable but the chest output is high, checking the haematocrit on the chest tube drainage can be helpful in distinguishing active bleeding from a lymphatic leak. If a patient in the immediate postoperative period is hemodynamically unstable but the chest tube output does not suggest active haemorrhage, a chest radiograph may show radiopacity of the operative side with thrombosed chest tubes. [40]

Medications like aspirin, other antiplatelet agents' warfarin could cause increased bleeding tendencies. Several herbs like garlic, ginseng etc. effect a prolonged bleeding time, which can result in peri operative haemorrhage. [39] The effect of herbal medications in thoracic surgery specifically is lacking, but discontinuing herbs 2 weeks before a lung resection is recommended. [40]

Recommendation for perioperative antiplatelet the current recommendations aim at providing the best option for patients. There are issues regarding continuing or discontinuing these medications. These recommendations are mainly form observational data. [41], [42], [43]

In the current era Aspirin is a lifelong therapy and it is not necessary to stop it for surgery when there are specific indications like prevention after stroke, acute coronary syndrome, MI, or coronary revascularization, regardless of the time since the event that led to the recommendation of aspirin. [44]

Dual antiplatelet therapy is recommended during the two weeks after simple dilatation, six weeks after bare-metal stents, and at least 12 months after drug-eluting stents. [41], [42], [43] Elective operations should be postponed beyond these delays but most of the thoracic procedures have to be done as soon as possible as a bulk of cases are due to malignancy hence unless the hemorrhagic risk is excessive, dual antiplatelet therapy should not be interrupted before surgery.

Even if clopidogrel treatment must be interrupted in high-risk surgical situations, aspirin must be continued without interruption.41,42,43 Heparin has no antiplatelet activity and therefore is not an adequate substitution for aspirin or clopidogrel treatment because stent thrombosis is a platelet-mediated phenomenon. [42] Although not proven by any randomised controlled trials bridging therapy with a short-acting platelet glycoprotein IIb/IIIa inhibitor like tirofiban is a possible substitution for clopidogrel while aspirin is being maintained. [46] After the operation, antiplatelet therapy is resumed within the first 12 to 24 hours; clopidogrel therapy is reinitiated with a 300-mg loading dose, which reduces the time to achieve maximal platelet inhibition to four to six hours and decreases the risk of hyporesponsiveness from competition of other drugs with hepatic cytochromes.

Ticagrelor is used more often these days and should be stopped 36 to 48 hours prior to a planned procedure. It is reversible $P2Y_{12}$ adenosine disphosphate receptor binder with shorter duration of action unlike clopidogrel which is irreversibly binds to it. The perioperative management for it is similar to the clopidogrel.

Warfarin should be discontinued 3 days preoperatively, the INR checked. It should be substituted with heparin and APTT checked.

Conversion to an open thoracotomy for control of bleeding is done in case of bleeding due to VATS. Intraoperative bleeding can be massive from injury to the pulmonary artery or vein. Proximal control of the pulmonary artery before dissection of its branches is a safe preventive measure in open lobectomies. Rarely vascular stapler on a pulmonary vessel can cause bleeding and so can its used in the parenchyma. Suturing of the lung is done to control bleeding. Bleeding can also happen from peribronchial tissue, parenchyma, adhesions, intercostal vessels, and muscles.

In some patients, postoperative bleeding develops that is not hemodynamically significant enough to indicate re-exploration but results in a residual clotted hemothorax. As is true for a posttraumatic clotted hemothorax, treatment options include VATS or open exploration and evacuation of the hematoma to prevent development of a trapped lung, respiratory compromise, and empyema.

5.2. Cardiac complications

Arrhythmia, more particularly atrial fibrillation (AF), is by far the most common cardiac complication after thoracic surgery, with an incidence ranging from 10% to 20% after lobectomy and as much as 40% after pneumonectomy [46]- [47]

Risk factors for tachyarrhythmias include [48], patient related (pre-existing cardiovascular disease, postural change, limited pulmonary reserve), surgery related (extensive procedure, intrapericardial pneumonectomy, extra pleural pneumonectomy, anaesthetic agents, major bleeding), treatment related (previous thoracic irradiation) or older age [47], [49]. The most common arrhythmia encountered is supraventricular tachycardia.

If patients have atrial fibrillation with haemodynamic compromise then electrical cardioversion should be carries out immediately. If patients have sympromatic AF chemical cardioversion should be attempted first followed by electrical cardioversion if necessary. New-onset postoperative AF is often transient and self-limiting and it is generally accepted that rate comtrolling agents be given first. Rate control resolves AF in most cases in thoracic surgery. AF generally resolves within 1 day of hospital discharge with rate control alone. [50]

A selective Beta 1-blocking agent is recommended as the initial drug for rate control in the absence of moderate-severe chronic obstructive pulmonary disease or active bronchospasms and Diltiazem should be the first agent used in the presence of moderate-severe chronic obstructive pulmonary disease or active bronchospasm. [51]

Digoxin as a single agent should not be used for rate control, although it may be effective in combination with a beta1-blocker or diltiazem. Beta blockers are considered better than calcium channel blockers and digoxin for treating AF in thoracic surgery. The only concern is COPD where it may cause bronchospasms specific beta 1 blockers such as metoprolol are considered safer in this regard. [52]

When chemical cardioversion is employed in the setting of continuous or recurrent paroxysmal postoperative AF, the most reasonable initial drugs are intravenous followed by oral amiodarone or oral flecainide. [51]

Amiodarone is not given if the patient has severe lung disease or if the patient as undergone pneumonectomy The incidence of ARDS was 11% in the patients treated with amiodarone and 1.8% in the nonamiodarone group [53]. Flecainide is not given if there is organic cardiac disease. Other drugs include disopyramide, ibutilide, procainamide, propafenone, quinidine, and sotalol. Patients who received flecainide had an approximately doubled rate of mortality or cardiac arrest, likely due to a proarrhythmic effect on the ventricle possibly due to structural heart disease. Side effect of amiodarone relevant to thoracic surgery is its pulmonary toxicity [51].

Both amiodarone and flecainide are highly effective and relatively safe drugs, but the specific contraindications to their use must be kept in mind antiarrhythmic therapy is given usually from 1 to 6 weeks. The only study that has evaluated optimal length of therapy with antiarrhythmic drugs, once initiated, for postoperative AF (after coronary artery bypass graft

surgery) found that there was no difference in the rate of recurrent AF whether the treatment was continued for 1, 3, or 6 weeks after discharge. [54]

Anticoagulation Therapy For patients with two or more risk factors for stroke (age >75 years, hypertension, impaired left ventricular function, prior stroke or transient ischemic attack) who have postoperative AF that recurs or persists for more than 48 hours, anticoagulation therapy is reasonable if not otherwise contraindicated. [51]

For patients with fewer than two risk factors for stroke and patients considered not suitable for warfarin who have postoperative AF that recurs or persists for more than 48 hours, aspirin, 325 mg daily is recommended. [51]

Oral metoprolol initiated preoperatively and continued postoperatively decreased the incidence of atrial fibrillation from 40% to 6.7% ($p < 0.05$). [55] In another trial, administration of magnesium sulphate starting the day of operative resection also resulted in a decrease in the incidence of atrial fibrillation from 26.7% to 10.7. [56]

5.3. Ischemia

In a large series the incidence of ischemic electrocardiographic changes was 3.8% and myocardial infarction in 1.2%. According to this study hypotension and abnormal exercise testing were the strongest predictors for ischemic events. [57]

Patients are monitored invasively, base line medication was continued, and peri operative fluid administration was minimalized. We recommend continuous monitoring for at least 2 days in high-risk patient.

The American College of Cardiology and the American Heart Association guidelines [58] for peri operative cardiovascular evaluation for no cardiac surgery remain the best available method for risk assessment in noncardiac thoracic surgery. Thoracic surgery is categorized as a high-risk surgical procedure in this matter. Coronary angiography is advocated in case of major clinical predictors such as unstable angina, decompensated heart failure, significant arrhythmias, or severe valvular disease. In cases of intermediate or minor clinical predictors the decision whether to perform an angiography is based on non-invasive testing [59].

As adenosine and dipyridamole should be avoided in patients with clinical bronchospasms, dobutamine stress echocardiography is the evaluation of choice for patients with cardiac ischemia referred for thoracic surgery [60]. In general the indications for coronary angiography are similar to those in the nonoperative setting. No prospective randomized data exists on the role of prophylactic coronary bypass surgery. Whether percutaneous coronary intervention is superior to bypass surgery is uncertain, but in cases of angioplasty with stenting it is probably safer to postpone surgery for 2 to 4 weeks. In conclusion, the preoperative cardiac assessment of thoracic surgery patients is of great importance, although prospectively controlled data for this type of surgery are lacking. [59]

5.4. Right-to-left shunt

It is estimated that 20% of the general population may have a persistently patent foramen ovale (PFO). With the increased right-sided pressures associated with pulmonary resection, these patients can develop a right-to-left shunt with refractory hypoxia in the postoperative period. This shunting increases most dramatically after a right pneumonectomy. In some patients, symptoms may not present until after 1 to 5 months, particularly after a right pneumonectomy. [61] Patients often present with dyspnoea (platypnea) and hypoxia (orthodexia) in the upright position, which resolves upon recumbence. This is because of nediastinal shift, which modifies the relationship between the right and left atrium and distorts the foramen ovale. Cardiac rotation and compression of the right atrium by pleural fluid causes preferential flow of the inferior caval vein into the left atrium. Hemodynamic factors may also have a role, such as reversal of the interatrial pressure gradient. A decrease in right ventricular compliance and the hydrostatic pressures in the left lateral decubitus or orthostatic positions increase the shunt. Lastly, factors such as pulmonary emboli, right ventricular infarction, increased intrathoracic pressure, chronic obstructive pulmonary disease, and positive pressure ventilation may drive shunt physiology. [62] The aetiology of this complication is unclear.

The diagnosis is made with arterial blood gas analysis, nuclear lung perfusion scanning, echocardiography, MRI, and cardiac catheterization or a combination thereof. Standard treatment is surgical repair, although several cases of successful intravascular occlusion of the septal defect have been performed.

Other causes of dyspnoea must be evaluated, including but not limited to pulmonary embolism, airway narrowing, and post resection pulmonary oedema.

5.5. Cardiac herniation

Cardiac herniation is a rare complication and happens in the early postoperative period. Cardiovascular collapse is the presenting feature Jugular pulse is elevated and there can be cyanosis in the drainage area of superior venacava. Ventricular fibrillation may occur [63]. Treatment is emergency thoracotomy with reposition of the herniated heart into the pericardial sac and repairing the defect of the pericardium [64]. Most documented cases of cardiac herniation have occurred through surgically created defects as a result of intrapericardial pneumonectomy or lobectomy with partial pericardectomy [65]. Combination of a sudden superior vena cava syndrome and heart sounds in the right side of the chest should alert the physician to the possibility of cardiac herniation. Surgical defects of the pericardium as a result of right intrapericardial pneumonectomy should be closed. This can be accomplished either by suturing the cut edges of the pericardium to the epicardium or by patching the defect with bovine pericardial patch, PTFE patch or parietal pleura. In cases of left pneumonectomy, it may be sufficient to enlarge the pericardial defect in order to prevent strangulation, should herniation occur [66].

5.6. Heart failure

Few studies have addressed the problem of postoperative right ventricular dysfunction, which is because of changes in right ventricular afterload and contractility [67]- [71]. Although right ventricular end-diastolic volume remains stable in the early postoperative hours, significant increases may be observed on the first and second postoperative days. Although many authors [69]- [71] claim that afterload alteration is the major determinant of RV dysfunction. Pulmonary artery pressure and pulmonary vascular resistance only rose modestly in a study [66], suggesting that the rise in afterload is not the only causing factor. Another argument favouring afterload augmentation as the cause of RV dysfunction is the fact that postoperative pulmonary artery pressure, pulmonary vascular resistance, and central venous pressure only change significantly during exercise [70]. Changes in RV function are able to compensate for the increased RV end-diastolic volume at rest, but not during exercise, with a resultant increase in pulmonary artery pressure and pulmonary vascular resistance. [59] One study used serially performed transthoracic echocardiography to assess the effects of pulmonary resection [71]. Only pneumonectomy patients had mild postoperative pulmonary hypertension without significant RV systolic dysfunction. Pulmonary embolism and cardiac herniation are rare mechanisms that may cause RV dysfunction.

Left heart failure is generally a consequence of impaired right heart function, either by decreasing left ventricular preload or by shifting the intraventricular septum resulting in a decreased left ventricular volume. Other causes of left ventricular dysfunction are acute myocardial infarction, pre-existing valvular disorders or cardiac herniation. [59]

5.7. Pulmonary oedema

Respiratory complications occur in 5-14% of patients [72]- [74]. The risk factors include age of the patient, extent of resection, preoperative lung function and other co morbidities.

However, a number of case studies have described what appears to be a specific syndrome of post pulmonary resection lung injury, which has been called post-pneumonectomy pulmonary edema (PPO). [75], [76], [77] The syndrome consisted of the onset of severe respiratory failure, within 48 h of operation, associated with diffuse radiographic changes on plain chest films consistent with pulmonary oedema. However, central pressure measurements showed no evidence of left ventricular failure or cardiogenic pulmonary oedema. Its incidence is approximately 2.5% to 4% [78]- [83].

The mechanisms of injury are that ischaemia–reperfusion injury and [84] reactive oxygen species. [85] Pulmonary capillary stress failure occurs when the pulmonary microvascular bed is subjected to increased pressure and could produce capillary injury. [86]

Following are the recommendations and statements concerning fluid administration: (1) there is no "third space" in the thorax, (2) total positive fluid balance in the first 24 hours should not exceed 20 mL/kg, (3) a urinary output greater than 0.5 mL/kg/h is unnecessary, (4) the use of invasive monitoring techniques is advisable if increased tissue perfusion is necessary postoperatively, (5) factors that contribute to increased pulmonary venous pressures should be minimized postoperatively, (6) hyperinflation of the residual lung should be avoided, (7)

regular chest roentgenograms should be obtained postoperatively, (8) prolonged periods with the residual lung in the dependent position should be avoided, and (9) prophylactic digitalization has not been shown to reduce the incidence of post resection supraventricular arrhythmias or of postpneumonectomy pulmonary edema. [59]

Therapy [59] consists of administration of diuretics, restriction of fluid, nutritional support, and maintenance of adequate oxygenation, even with mechanical ventilation if necessary. Despite aggressive treatment, the clinical outcome is poor with mortality exceeding 50%. Nitric oxide ventilation and extracorporeal membrane oxygenation were tried as possible therapies. In particular the use of inhaled nitric oxide, in doses of 10 to 20 ppm, was able to lower mortality rates to 30% in a small series of patients. In the same report early intubation (at first signs of ARDS), aspiration, bronchoscopy, and postural changes are also advocated.

Pulmonary hypertension is a major concern for patients undergoing general thoracic surgery and often contraindicates pulmonary resection. Multiple aetiologies exist, such as cardiomyopathy or intrinsic cardiac valvular disease, as well as destructive pulmonary parenchymal processes resulting in cor pulmonale. The presence of pulmonary hypertension puts patients at increased risk for anaesthesia and surgical morbidity.

5.8. Postpneumonectomy syndrome

Postpneumonectomy syndrome refers to bronchial compression occurring as a result of massive mediastinal shift following pneumonectomy [87]- [89]. Incidence is approximately one in 640 cases [90]. This syndrome is much more common after right pneumonectomy: the mediastinum undergoes counterclockwise rotation as it shifts toward the pneumonectomy space [87], [88], [90], [91], [92]. This results in stretching, distortion, and compression of the left main bronchus between the pulmonary artery anteriorly and the aorta and vertebral column posteriorly. The syndrome has also been described after left pneumonectomy, both in patients with and without an aberrant right aortic arch [92], [94], [95], [96], [99]

Risk factors include young age and female sex [88], [97], [98]. These patients have more elastic mediastinal tissues (thus prone to shifting) and a softer, more compliant airway (thus subject to compression). [77] Patients typically present with exertional dyspnoea, stridor, and recurrent pulmonary infection] within one year of pneumonectomy. The onset is usually gradual, but acute obstruction may ensue in children. [99]

Airway stenting has been used in the treatment of inoperable patients and as a bridge to surgery in cases of acute obstruction [95], [98]. Definitive treatment involves surgical repositioning of the mediastinum in the midline. The mediastinum is then maintained in position by a saline-filled silicone prosthesis which is inserted into the pneumonectomy space. [99]

5.9. Lobar torsion and gangrene

Lobar torsion represents a rotation of the bronchovascular pedicle with resultant airway obstruction and vascular compromise. This disorder has been described in 3 different circumstances: as a complication of thoracic surgery, after blunt trauma, and spontaneously [100]

The overall incidence of lung torsion has been reported as 0.089%–0.2%, and is equally rare after thoracic surgery. [100], [101]. The pathophysiological mechanisms of torsion development were previously postulated as an airless lobe, incision of the inferior pulmonary ligament, pleural effusion, a long slim lobar pedicle, and lack of pleural adhesions. [100]

Patient's condition manifests as high fever, severe chest pain, massive haemoptysis, bronchorrhea, and sepsis, seen radiographically as abrupt consolidation and abnormal location of the collapsed lung. Only meticulous observations of both clinical and radiological manifestations, although uncharacteristic, can provide an indication of torsion development. [102]. Thereafter, bronchoscopy, contrast chest computed tomography, or angiography can be diagnostic in finding the distorted or occluded bronchi or tapered pulmonary artery. [100], [102]. Subsequent manoeuvres, such as contrast computed tomography, would have been diagnostic and prompted reoperation. Intrathoracic bleeding was suspected considering the history of extensive mediastinal adhesions, voluminous drainage, and blood loss. The distinguishing features were: the chest opacity appeared hypertensive, and the resultant huge tension markedly shifted the mediastinum; the serous fluid drainage, albeit a large amount, was inconsistent with the severity of the anaemia; and radiographically, there was a convex pulmonary margin around the chest tube. Wagner and Nesbitt stated that lobar torsion after right upper lobe resections accounted for 70% of the cases in the literature, whereas 15% followed resection of the left upper lobe. Torsion could happen in any lobe [103]

Options for surgical intervention include simple detorsion or resection of the involved pulmonary segments. Detorsion alone is advocated only in patients who undergo re-intervention within a few hours of the primary procedure; while in the majority of patients, pulmonary resection is mandatory due to pulmonary gangrene. Embolisms to other vital organs are the main complications after surgery, which should therefore be carefully monitored. [102]

It seems reasonable to staple or suture the middle lobe to the lower lobe after a right upper lobectomy if the oblique fissure is complete to prevent middle lobe torsion. Postoperatively, the possibility of a lobar torsion after lobectomy should be considered when an infiltrate or complete atelectasis persists or worsens; bronchoscopic intervention should be performed promptly.

5.10. Cardiac tamponade

Pericardial tamponade, though rare after open lobectomy, should be considered along with other complications when a patient repeatedly develops hypotension with therapies that causes venodilation. A rising CVP and its equalization with pulmonary artery diastolic pressure indicate cardiac tamponade. Symptoms include those related to cardiac tamponade: low cardiac output and Beck's triad (hypotension, muffled heart sounds, and increased central venous pressure). Diagnosis of this complication again requires a high index of suspicion. Echocardiography is the diagnostic study of choice to visualize impaired filling of the right ventricle because of increased pericardial pressure from the pericardial effusion.

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Treatment include an urgent pericardiocentesis as a temporizing measure followed by reopening of the thoracotomy or a formal median sternotomy, which allows full inspection of the interior of the pericardium and provides adequate access for definite management of the cause. Minor injuries during retraction and dissection can produce life-threatening conditions like pericardial tamponade. Episodes of unexplained hypotension suggest a cardiac aetiology; a high index of suspicion and urgent surgical intervention can prevent adverse outcome.

5.11. Chylothorax

The thoracic duct can be injured during any thoracic procedure. Pleuro-pulmonary procedures, esophageal resection, intrapericardial and mediastinal procedures, and even less invasive procedures like subclavian puncture may lead to thoracic duct injury and subsequent chylothorax [104]- [108]. The incidence of chylothorax after pulmonary resection is between 0.7% and 2%. [109]- [110] This complication typically occurs at the time of resection. Aetiologies in thoracic surgery include aggressive mediastinal lymph node dissection with incomplete ligation of lymphatic channels or direct injury to the thoracic duct either during extra pleural pneumonectomy or division of the pulmonary ligament. There will be loss of calories, fluids, and proteins cause nutritional deficiency, dehydration, and immunologic dysfunction and if not drained can cause respiratory compromise.

Chylothorax can compress the lung resulting in shortness of breath and respiratory distress. Empyema is a rare complication due to the bacteriostatic nature of lecithin and fatty acids. Sterile chyle does not cause pleuritic pain or a fibrotic inflammatory reaction. Loss of proteins and vitamins, more than fat, leads to metabolic and nutritional defects, immunodeficiency, coagulopathy, malnutrition and death. A prompt diagnosis and an accurate early treatment are therefore essential. Analysis of the effusion demonstrates a triglyceride level >110 mg/dL and a lymphocyte count >90%, gram, Sudan 3 stain, chylomicrins on electrophoresis. The total protein concentration in the effusion is near or equal to the plasma protein concentration.

Leads to cardiopulmonary abnormalities and metabolic and immunologic

Mostly, it occurs from 2 days to 4 weeks postoperatively and varies from slight to severe forms determined by the volume and rate of chyle loss. Conservative treatment initially involves replacing the nutrients lost in the chyle and draining large chylothoraces using chest drain insertion if necessary, to ensure complete lung expansion, nil by mouth or the administration of low fat medium chain triglycerides by mouth. Medium chain triglycerides are directly absorbed in to the portal system, bypassing the intestinal lymph system. This reduces the flow of chyle in the thoracic duct allowing it the opportunity to heal. [111] If the chyle leak does not stop following the use of medium chain triglycerides, then total parenteral feeding to reduce the chyle flow even further should be considered. [111]- [112] Somatostatin and octreotide have proved to be useful in the conservative treatment of chylothorax. These agents reduce intestinal chyle production, thereby reducing the volume flowing through the injured thoracic duct. [113]- [115]

Chemical pleurodesis with TALC is an alternative option in the majority of patients that are too unwell for surgical closure of the chyle leak. A cannulation and embolisation technique

prospectively to treat chylothorax was curative in patients' with demonstratable duct leakage [115] however reproducibility and success have varied in different centres. Surgical therapy [115] is recommended in cases where despite conservative management the patient drains more than 1.5 l/day in an adult or >100 ml/kg body weight per day in a child, leaks chyle at a rate of >1 l/day for5 days or has persistent chyle flow for more than 2 weeks. Surgery is also recommended if there has been a rapid decline in nutritional status despite conservative management. Thoracic duct ligation can be performed during thoracotomy or by thoracoscopic intervention. [116], [117] The main problem is identifying the chyle leak. Ligation of the thoracic duct is successful in 90% of patients when performed just above the right hemidiaphragm. [118] Ligating here, also has the advantage of halting flow from any unidentified accessory ducts. Collateral circulation redirects the chyle around the ligation point ensuring that the chyle still completes its journey to the circulation. In cases of loculated or complicated chylothorax pleural decortication with pleurodesis may be performed. [115]

5.12. Prolonged air leak

One of the common problems after thoracic surgery is prolonged postoperative air leak. Not all patients have an air leak after pulmonary resection. However, many patients having a lobectomy, segmentectomy, or a complicated wedge resection will leave the operating room with a leak

The vast majority of postoperative air leaks, however, are alveolar air leaks, and therefore initial management should be aimed at treating this entity. The management of bronchopleural fistulas is substantially different than that of alveolar air leaks, often requiring early surgical intervention. [119]

Air leaks that persist beyond a certain point may prolong the hospital length of stay. The Society of Thoracic Surgeons database mentions air leaks are those which are typically present when the patient could otherwise be discharged were it not for a continued air leak. The STS Thoracic Surgery Database defined prolonged air leak as lasting >5 days. Prolonged air leak may be associated with an increased complication rate and certainly may increase length of stay. Okereke et al. [120] found complications in up to 30% for patients with any air leak but only 18% in patients without, but this may have been a marker of extent of surgery or disease. Varela and colleagues [121] found that air leak lasting at least 5 days was associated with greater pulmonary morbidity, such as atelectasis, pneumonia, and empyema. They also found that the length of stay was extended by 6 days. Most leaks will stop within 2 to 3 weeks

By far the most common treatment of airleaks is watchful waiting with continuous drainage through a tube thoracostomy. More than 90% of air leaks seemed to stop within several weeks after operation with this form of management alone, with only rare development of an empyema. [119]A valved, outpatient system, such as a Heimlich, can only be considered in patients who have no more than a small, stable, asymptomatic pneumothorax on water seal. [119]

Blood patch or chemical pleurodesis may be considered as the next step. Experience with these techniques is variable. The instillation of sclerosing materials into the pleural space through

the thoracostomy tube promotes symphysis of visceral and parietal pleura and may produce leak closure. Given the low rate of infection reported in published series, it remains unclear whether antibiotics should routinely be used. [119]

Autologous blood patch is another nonsurgical option to treat PAL after the operation or spontaneous pneumothorax [122]- [127]. To summarize, blood-patch pleurodesis involves the instillation of autologous blood into the pleural space through a chest catheter. It is simple, relatively painless, and often effective, but some information suggests that blood-patch pleurodesis may also carry an increased risk of intrathoracic infection. Although there are six articles on this subject, it is difficult to draw definitive conclusions due to the variable study sizes (from 2 patients to 32 patients), quantity of blood injected (50 to 150 mL), and endpoint definitions.

Pneumoperitoneum instilled through a transabdominal catheter has been reported to be effective in some cases [128], [129]. Surgical options to accomplish pleural symphysis or control the source of an alveolar air leak, or both, include video-assisted thoracic surgery (VATS) with parenchymal stapling, VATS with chemical pleurodesis, VATS with pleural abrasion [130], [131], VATS with application of topical sealants [132], [133], and the less well-supported use of VATS with laser sealing of the site of leak [134]. Omental or muscle flaps placed at re-thoracotomy can also be used successfully to obliterate the pleural space in patients with incomplete lung expansion and residual air leaks [135].

6. Injuries to surrounding structures

Injuries can happen to the oesophagus, phrenic nerve, recurrent laryngeal nerve, dural lacerations and spinal cord injury and peripheral embolisation of tumour.

6.1. Injury to the phrenic nerve

Thoracic surgical procedures can produce phrenic nerve injury. It happens when there are adhesions or in redo surgeries. Surgeries like anterior mediastinal tumor excision, resection of superior sulcus tumours, repair of thoracic outlet syndrome, or right-sided mediastinal lymph node dissection could all cause phrenic nerve injury. Such injuries may be temporary or permanent. Presenting features are shortness of breath on exertion and impaired exercise tolerance [136]. If patients are on a ventilator then there may be difficulty in weaning of ventilator. X-ray shows elevation of the affected hemi diaphragm. This is confirmed by ultrasound or fluoroscopy, which is the diagnostic study of choice in evaluation of these injuries. The best method of management of unilateral palsy is diaphragmatic plication [136].

6.2. Injury to the recurrent laryngeal nerve

Injury to the recurrent laryngeal nerve generally present in the postoperative phase with a weak hoarse and whispery voice. They nay describe a voice, which gets weaker as the

day progresses, which may cause aspiration or impaired physiotherapy due to inability to cough effectively. A laryngoscopy is done to confirm the diagnosis and adduction of the affected vocal cord or sluggish motion will be absent. Treatment depends on whether the injury is temporary or permanent. A fibre optic evaluation is necessary to test swallowing and sensation. To assist with pulmonary physiotherapy and decrease the risk of aspiration, medialization laryngoplasty may be suggested [136]. This can be done as an office procedure with the aid of autologous fat, Gel foam, collagen, or polytetrafluoroethylene. [136]

7. Infections

Infectious complications after pulmonary surgery include operative wound infection, empyema, and nosocomial pneumonia. Antibiotic prophylaxis should therefore be guided against these three entities. The incidence varies from 5% to 24.4%. They are responsible for increased hospital mortality to up to 19% as well as increased costs and length of hospital stay. In one study 53.6% of the germs identified were gram-negative bacteria, 39.3% gram-positive bacteria, and 7.1% were fungi [137]. These infections should be aggressively treated with appropriate antibiotics after culture. Chest physiotherapy, pain control, bronchodilators, and early ambulation should be done for all patients but regardless of these pneumonia develops. Postoperative atelectasis after pulmonary surgery should be aggressively managed before it deteriorates into pneumonia. Our policy is to give Ticarcillin Sodium and Potassium Clavulanate 3.1 g four times a day in divided doses till a positive culture is obtained.

The incidence of empyema is dropping but could happen if there is prolonged air leak. Generally they are managed with antibiotics but may necessitate thoracotomy and wash out.

Other complications include pulmonary embolism, deep venous thrombosis, renal failure, strokes, major gastrointestinal bleed and late empyema. These complications should be recognised very early and aggressive management should be instituted if they are to be tackled successfully.

Thus postoperative care and management of postoperative complications is a team approach and good preoperative and intraoperative measures minimize the incidence of postoperative complications and early recognition and treatment is essential for successful outcomes.

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