INTRODUCTION

Video-assisted thoracoscopic surgery (VATS) came into widespread use in the 1990s and early on its development surgeons began to perform lobectomy via VATS incisions. The advantage of VATS over thoracotomy is that major chest wall muscles are not divided and ribs are not spreaded. This leads to reductions in the intensity and duration of post-operative pain and allows patients to return to full activity more quickly ***(Mahtabifard et al., 2007)***.

VATS has multiple indications for diagnosis and treatment of many different thoracic diseases; the commonest are lung wedge resection, pleural and mediastinal biopsy, treatment of cases of pneumothorax, and pleurectomy. Moreover, in recent years a few surgeons have performed routinely major lung anatomic resections by VATS approach, including segmentectomy, lobectomy, and pneumectomy ***(Andrea et al., 2008).***

The VATS procedure differs from medical thoracoscopy in the access to the chest cavity and the ability to perform such surgical interventions as stapler resection, bullectomy, lobectomy, and pneumonectomy. Additionally, unlike medical thoracoscopy, which can be done under local anesthesia in an endoscopy suite, VATS requires an operating room and general anesthesia with double lumen tube intubation. Although medical thoracoscopy is limited in the interventions that can be performed, for many indications medical thoracoscopy is more cost effective than VATS and can be performed in patients that would otherwise be poor candidates for surgical intervention due to underlying comorbidities ***(Tassi and Tschopp, 2010).***

From the standpoint of medical economics, VATS lobectomy is less expensive than lobectomy performed via thoracotomy because hospital length of stay and number of days in the intensive care unit are significantly reduced ***(Casali and Walker, 2009)***.

Postoperative pain is a form of acute and intense pain experienced in the period following surgery, whose adequate control is often problematic.

Constant assessment of pain intensity is recommended for optimal post-operative pain control. This is mostly achieved pharmacologically with monitoring of side effects. Multimodal analgesia is recommended, combining different drug classes, e.g., an opioid (morphine, pethidine, fentanyl, tramadol, codeine) with a non-opioid (NSAID; Cox-2 inhibitor), delivered through various routes, and including neuraxial use of local anesthetics (bupivacaine, ropivacaine) alone or in combination with other drugs, nerve blocks, antihyperalgesics (ketamine, dextromethorphan), and techniques such as patient-controlled analgesia (PCA) and pre-emptive analgesia. An efficient organization of pain services is also recommended ***(Costantini et al., 2011).***

AIM OF THE WORK

This essay is designed to search among available literature and highlight the pathophysiology, presentation of postoperative pain after video assisted thoracoscopic surgeries and recent modalities of management of this type of acute pain.

THORACIC CAGE ANATOMY RELATED TO POSTOPERATIVE PAIN

The neurovascular bundle

A Neurovascular bundle is a term applied to the body nerves, arteries, veins and lymphatics that tend to travel together in the body.

In each intercostal space lie a neurovascular bundle arranged from above downwards, the posterior intercostal vein, the posterior intercostal artery and the intercostal nerve, protected by the costal groove of the upper rib. Posteriorly, this bundle lies between the pleura and the posterior intercostal membrane, but at the angle of the rib it passes between the internal intercostal and the innermost intracostal muscles ***(Ellis and Lawson, 2014).***

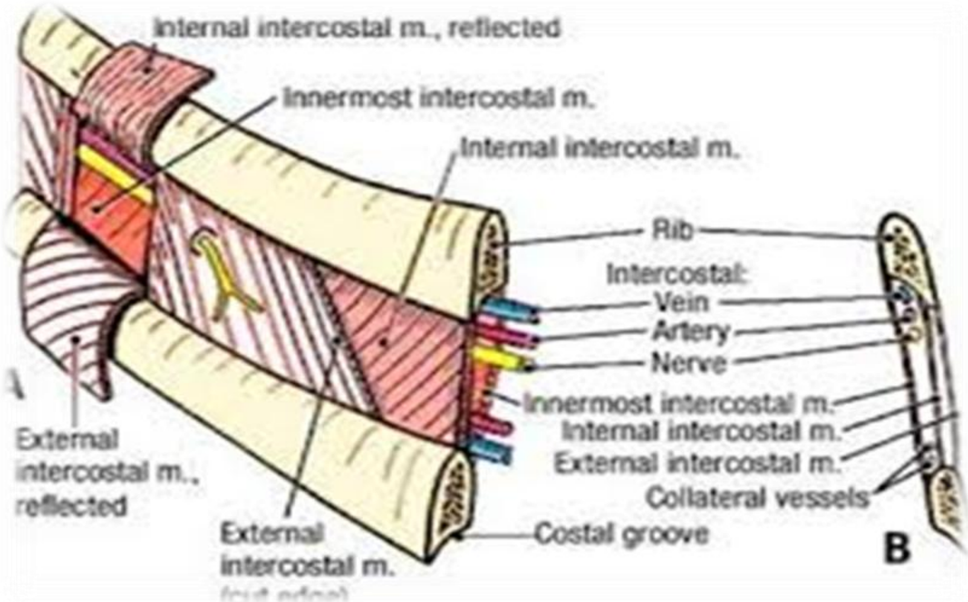

Figure (1): Intercostal neurovascular bundle
(Ellis and Mahadevan, 2011).

Intercostal nerves

The intercostal nerves are the anterior primary rami of T1–11; each lies in the neurovascular bundle. The lower five nerves (T7–11) continue onwards to supply the abdominal wall where others maintain their anatomical position between the 2nd and 3rd layers of muscle of the body wall, i.e. between internal oblique and transversus abdominis ***(Ellis and Lawson, 2014).***

The twelfth (subcostal) thoracic is distributed to the abdominal wall and groin. The intercostal nerves are distributed chiefly to the thoracic pleura and abdominal peritoneum and unlike the anterior roots of the other spinal nerves; each pursues an independent course without plexus formation ***(Boundless 2013).***

The 1st intercostal nerve is atypical; it is the largest of the thoracic rami because of its branch which crosses the neck of the 1st rib to join C8 in the formation of the lowest trunk of the brachial plexus. Its intercostal branch is small and is entirely motor.

Each of the remaining intercostal nerves has the following branches.

1. Collateral, which arises at the angle of the rib and ends either in supplying muscle or as a connecting loop with the main nerve; it is entirely motor.
2. Lateral cutaneous, which arises in the mid-axillary line and gives off an anterior and posterior branch.
3. Anterior cutaneous, which, in each of the upper six intercostal spaces, passes in front of the internal thoracic vessels, then surfaces to supply the overlying skin. The lower five nerves pierce rectus abdominis to supply the anterior abdominal wall ***(Ellis and Lawson, 2014).***

Unlike the nerves from the autonomic nervous system that innervate the visceral pleura of the thoracic cavity, the intercostal nerves arise from the somatic nervous system. This enables them to control the contraction of muscles, as well as provide specific sensory information regarding the skin and parietal pleura. This explains why damage to the internal wall of the thoracic cavity can be felt as a sharp pain localized in the injured region while damage to the visceral pleura is experienced as an un-localized ache ***(Boundless, 2013).***

Paravertebral space

The thoracic paravertebral space (TPVS) is a wedge shaped potential space that lies on either side of the vertebral column. The boundaries of the space are posteriorly the superior costotransverse ligament; anterolaterally the parietal pleura and medially the vertebral body, the intervertebral disc and the intervertebral foramen ***(Bondàr et al., 2010; Ellis and Lawson, 2014).***

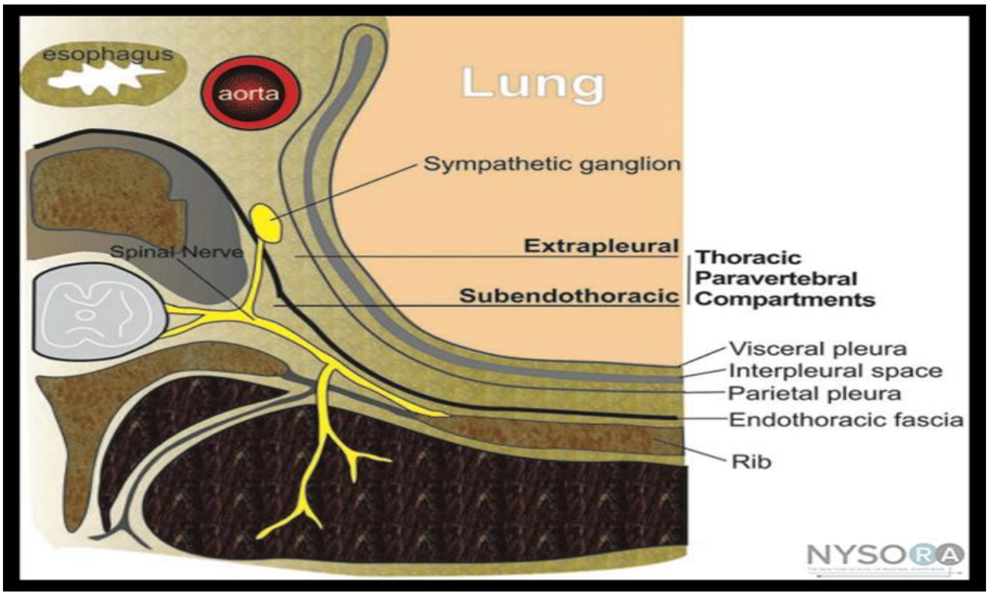

Figure (2): A schematic representation of the thoracic paravertebral space and its structures of relevance to paravertebral block ***(Bouzinac et al., 2010).***

It communicates medially with the epidural space and laterally with the intercostal space. The inferior limit of this space occurs at the origin of the psoas major muscle and the superior limit extends into the cervical region.

The thoracic paravertebral space TPVS contains fatty tissue in which lies the intercostal (spinal) nerve, the dorsal ramus, the intercostal vessels, the rami communicantes and the sympathetic chain ***(Bondàr et al., 2010).***

Interposed between the parietal pleura and the superior costotransverse ligament is the endothoracic fascia, which is the deep fascia of thorax. This fascia divides the space into two compartments anterior "extrapleural paravertebral compartment" and the posterior "subendothoracic paravertebral compartment". The nerves are located behind this fascia ***(Batra et al., 2011).***

It allows access for blocking the nerve roots without invading the epidural or subarachnoid space ***(Ellis and Lawson, 2014).***

The pleura

The lungs are enveloped in a twin walled serous sac – two layers of the pleura – that meet at the hilum to form the pulmonary ligament. A potential space exists between the two pleural layers (visceral and parietal), which contains a thin film of serous fluid ***(Erdmann, 2001).***

Pleural nerve supply

The vessels and nerves of the parietal pleura are derived from somatic sources. The arterial supply is from the intercostal, internal thoracic and musculophrenic arteries. The venous drainage is to the azygos system of veins. The lymphatics pass to the intercostal, parasternal, diaphragmatic and posterior mediastinal nodes. Intercostal nerves supply the costovertebral pleura. The diaphragmatic pleura is supplied by the phrenic nerve over the domes, and by intercostal nerves near its periphery. The mediastinal pleura is supplied by the phrenic nerve. The visceral pleura has an autonomic nerve supply and is insensitive to sensory ordinary stimuli ***(Sinnatamby, 2011).***

Phrenic nerve

Arising principally from C4 in the neck, the nerve passes down over the anterior scalene muscle across the dome of the pleura behind the subclavian vein. It runs through the mediastinum in front of the lung root. Each nerve lies in the thorax as far lateral as possible, being in contact laterally with the mediastinal pleura throughout the whole of its course. Under the surface of the diaphragm each phrenic nerve splits into three main branches: anterior, lateral and posterior, which radiate from the point of entry, giving off branches as they go. Each nerve is the sole motor supply to its own half of the diaphragm. About two-thirds of the phrenic nerve fibers are motor; the rest are sensory to the diaphragm (except for the most peripheral parts which receive intercostal afferent fibers), and to the mediastinal pleura, the fibrous pericardium, the parietal layer of serous pericardium, and the central parts of the diaphragmatic pleura and peritoneum ***(Keith et al., 2010).***

The diaphragm

The diaphragm is the main muscle of ventilation, and, during nonstrenuous breathing, it does the vast majority of the work. A mobile central tendon that originates from the vertebral bodies, lower ribs, and sternum anchors it. As the diaphragm contracts, negative pressure is generated in the intrapleural space, causing inflow of air into the lungs. As the diaphragm relaxes, the volume within the thoracic cavity decreases and air moves out. During nonstrenuous breathing, exhalation is mainly passive. Approximately 50% of the diaphragm's musculature is composed of fatigue-resistant, slow twitch muscle fibers ***(Tamul et al., 2013).***

Role of phrenic nerve in referred pain to the shoulder

Pain referred from thoracic surfaces of diaghragm (C4) is classically felt in the shoulder tip as (pleura, pericardium) supplied by the phrenic nerve which is usually located there ***(Scawn et al., 2001; Sinnatamby 2011).***

VIDEO-ASSISTED THORACOSCOPIC SURGERIES (VATS) (SURGICAL THORACOSCOPY)

VATS is a type of thoracic surgery performed using a small video camera that is introduced into the patient's chest via a scope. The surgeon is able to view the instruments that are being used along with the anatomy on which the surgeon is operating. The camera and instruments are inserted through separate holes in the chest wall also known as "ports". These small ports are advantageous because the chance for infection and wound dehiscence are drastically reduced. This allows for a faster recovery by the patient and a greater chance for the wound to heal ***(Muhammad, 2011).***

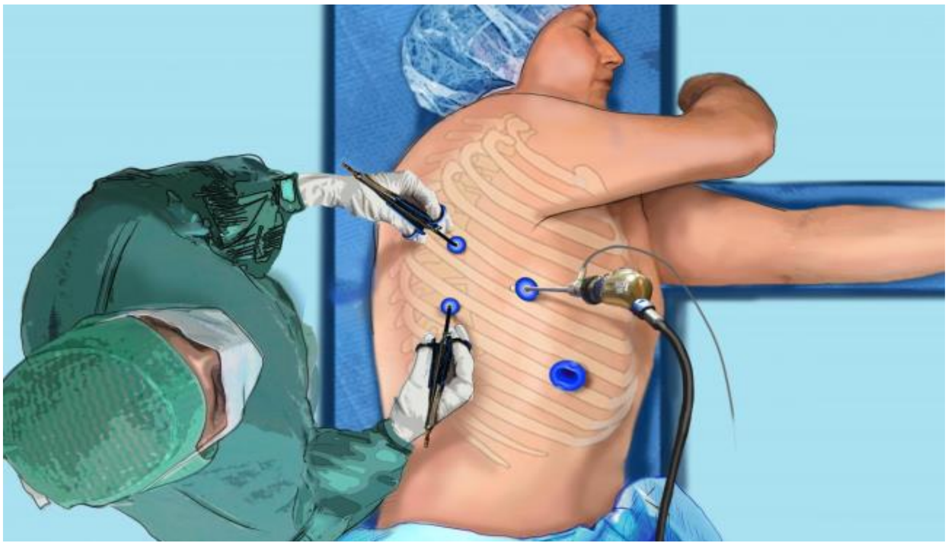

Figure (3): Video-assisted thoracic surgery ***(Fournel et al., 2014).***

During thoracoscopic surgery, one to four small (approximately 1-inch) incisions are used, as compared with one long 6- to 8-inch chest incision that is used during traditional open thoracic surgery. Surgical instruments and the thoracoscope are inserted through these small incisions. For a VATS lobectomy, 4 incisions are usually used. The largest incision is about 4 cm long. Incisions are made in a triangulated fashion, with the incisions at least 5 cm apart so that the instruments do not cross. This so-called baseball diamond approach aligns the camera and instruments to manipulate the lung and perform a resection. For single incision cases, curved instruments are helpful ***(Marhold et al., 2008).***

Indication for VATS

VATS is used in both diagnostic and therapeutic pleural, lung, and mediastinal surgery. Specific indications include the following:

Some Common Indications for Diagnostic and theraputic VATS

VATS has enjoyed widespread use for technically straightforward operations such as pulmonary decortication, pleurodesis, and lung or pleural biopsies, while more technically demanding operations such as esophageal operations, mediastinal mass resections, or pulmonary lobectomy for early stage lung cancer, have been slower to catch on and have tended to remain confined to selected centers. It is expected that advanced VATS techniques will continue to grow in numbers spurred by patient demand and greater surgeon comfort with the techniques ***(Rocco et al., 2010).***

At the beginning of last century, VATS began to be applied also for resection of lesions occurring less commonly within the mediastinum, such as pleuropericardial cysts, lipomas, teratomas or fibrous tumors of the mediastinum. It was introduced to the thoracic field and applied for the removal of posterior mediastinal lesions. However, the removal of dumbbell-type lesions may be considered challenging and, in this sense, a combined neurosurgical and thoracoscopic approach would be an excellent strategy ***(Melfi et al., 2016).***

VATS has been used extensively in spinal deformities such as scoliosis with results comparable to open procedures, but there has been limited use of VATS for decompression in active tuberculosis of dorsal spine ***(Singh et al., 2014).***

The most frequent indications for thymectomy are myasthenia gravis. The debate between trans-cervical and trans-sternal thymectomy continued until a less invasive approach video-thoracoscopic surgery was developed in thoracic surgery. A large amount of data has been published regarding minimally invasive thymectomy for myasthenia gravis, reporting interesting results. Both unilateral and bilateral VATS techniques have been applied for thymectomy, and have been demonstrated to result in less operative trauma, lower morbidity and shorter hospital stays when compared to the trans-sternal approach ***(Ng et al., 2010).***

Table (1): Some Common Indications for Diagnostic VATS

Some Common Indications for Diagnostic VATS

- Pleural disease
  - Indeterminate pleural effusions
  - Pleural mass lesions
  - Identification of source of hemothorax or chylothorax
  - Localization of pleuro-peritoneal fistula
  - Pleural space infections and empyema thoracis (identification of causative microbes such as tuberculosis)
- Pulmonary disease
  - Diffuse interstitial disease/ pulmonary infiltrates
  - Solitary pulmonary nodules
  - Lung cancer: staging & assessment of operability
- Mediastinal disease
  - Mediastinal cystic & solid mass lesions
  - Mediastinal lymphadenopathy (especially if lymph nodes not accessible by mediastinoscopy or if previous mediastinoscopy performed)
  - Assessment of response to chemo-/ radiotherapy (mediastinal tumors or nodal metastases)
- Complications of chest trauma
- Congenital & acquired diaphragmatic defects
- Spinal disease
- Esophageal disease

(Shields et al., 2009)

In the past, most patients necessitating operative intervention secondary to chest trauma would be subjected to an open thoracotomy incision, which has been labeled as the most morbid of surgical incisions further compounding the physiologic stress response to the injury itself. This provided the impetus for a less invasive method to diagnose and treat thoracic injuries paving the way for thoracoscopy ***(Manlulu et al., 2004).***

Advantage of VATS over thoracotomy

Sternotomy and thoracotomy have been proven over decades to provide highly effective means of access to thoracic structures. However, both incisions have the potential for causing significant pain that may last for extended periods and both result in bone fractures that require a minimum of six weeks to heal during which time patients must refrain from heavy lifting or strenuous activity ***(Shields et al., 2009).***

The instrumentation for VATS includes the use of a camera-linked 5 mm or 10 mm fiber-optic scope, with or without a 30-degree angle of visualization, and either conventional thoracic instruments or laparoscopic instruments which is less traumatic compared to Sternotomy which requires the use of a sternal saw to divide the sternum and requires spreading of the divided portions of the sternum with a sternal retractor to allow for visualization of the thoracic structures, the passage of instruments into the chest, and removal of specimens. Thoracotomy, as most commonly performed, requires the division of one or more major muscles of the chest wall including the latissimus dorsi, pectoralis or serratus muscles, along with spreading of the ribs with a rib spreader ***(Tamura et al., 2013).***