

INTRODUCTION

It is a well-known fact that many patients experience moderate to severe pain after surgery due to inadequate pain treatment (*Bloch et al., 2002*).

Every effort should be made to overcome this phenomenon. One of the most severe types of postoperative pain has been reported after thoracic surgery. Some patients develop chronic postthoracotomy pain that may last for months or years. In addition, severe postoperative pain contributes to postoperative pulmonary dysfunction. It may cause pulmonary atelectasis leading to ventilation/perfusion abnormalities and hypoxemia, as well as infection. The proper choice of perioperative analgesic technique plays an important role in controlling pain after thoracotomy with minimal incidence of adverse effects. Postthoracotomy pain may be difficult to be controlled with a single modality. A variety of agents can be used including systemic opioids, non steroidal anti inflammatory drugs, ketamine, and regional analgesia such as epidural, intrathecal, paravertebral, intercostal and intrapleural analgesia (*Lehmann, 2003*).

AIM OF THE WORK

The aim of the study is to discuss the anatomical and physiological basis of post thoracotomy pain, pulmonary function tests and the different techniques available to control postthoractomy pain.

CHAPTER 1

ANATOMY AND NERVE SUPPLY OF THE THORAX

The Thoracic Wall:

It's mainly composed of bones and muscles. The volume of the thoracic cavity can be varied during respiration. In infants, it's thin due to their underdeveloped muscles and their soft thoracic cages. The skin of the thoracic wall consists of a superficial layer (the epidermis) and a deep connective tissue layer (the dermis). The fasciae are deep to the skin. The superficial fascia is composed of loose connective tissue. The deep fascia is thin. It covers the muscles and is attached to the periosteum of bones. It also presents a barrier to infection. The thoracic cage is formed by (12 thoracic vertebrae and inter-vertebral discs, 12 pair of ribs and costal cartilages, and the sternum) (*Keith L. Moore, 1999*).

Surface anatomy of the thoracic vertebrae:

The spinous processes of all thoracic vertebrae are usually palpable in the posterior median line. When the neck and the trunk are flexed, the first visible spinous process is C₇ (the vertebra prominens). The spinous process of T₁ may be also prominent. Other spinous processes are just palpable but not prominent on flexing the neck and the trunk. The limited

movement between the thoracic vertebrae protects the heart and the lungs (*Hall, 1995*).

Surface anatomy of the anterior thoracic wall:

The clavicle lies subcutaneously at the junction of the thorax and the neck. It can be easily palpated. The sternum also lies subcutaneously in the middle part of the thorax and is palpable throughout its length. The sternal angle is located at the junction of the manubrium and the body of the sternum, 5cm inferior to the jugular notch. It directs the palpating finger to the second costal cartilage, the starting point from which the ribs are counted. The xiphoid process is the small inferior part of the sternum. It projects over the left lobe the liver into the epigastric region of the abdomen (*Healey and Hodge, 1990*).

On each side of the sternum, the ribs can be palpated but the first rib is difficult to feel because it lies deep to the clavicle and is covered by muscles. The costal margins are palpable, extending inferolaterally from the xiphisternal joint. The superior part of the costal margin is formed by the 7th costal cartilage and the inferior part is formed by the 8th to 10th costal cartilages. The infrasternal angle varies in size from person to person and increases during inspiration. It's used in cardiopulmonary resuscitation (CPR) locating the proper hand position on the body of the sternum (*Ellis and Feldman, 2003*).

The Breasts:

The breasts are the most prominent superficial structures of the anterior thoracic wall specially in women. They overlie the pectoral muscles. They are usually rudimentary throughout life in men. The mammary glands are accessory organs of the female reproductive system. They are important for lactation. The mammary gland is a modified sweat gland. During puberty, the female breasts grow and the areolae enlarge. The areolae contain numerous sebaceous glands. During the first pregnancy, the areolae change permanently to brown.

The nipples are conical prominences located in the center of the areolae. The tip of the nipples is fissured containing the openings of the lactiferous ducts (*Richard et al., 2004*).

Innervation of the breast:

The breast is supplied by lateral and anterior cutaneous branches of the 2nd to 6th intercostal nerves including sensory and sympathetic fibers which supply the skin, smooth muscle of the areolae and nipples, blood vessels and mammary glands (*Keith L. Moore, 1999*).

The Intercostal Nerves:

There are 12 pairs of thoracic nerves. By passing through the intervertebral foramina, the nerves divide into ventral and dorsal primary rami. The ventral ramus of T₁₂ is not in an intercostal space and is called the sub-costal nerve. The dorsal

rami pass posteriorly to supply the muscles, bones, joints and skin of the back (*Richard et al., 2004*).

Typical Intercostal Nerves:

A typical intercostal nerve (third to sixth) enters the intercostal space posteriorly between the parietal pleura and the internal intercostal membrane. At first, it runs near the middle of the intercostal space. Near the angle of the rib, it passes between the internal intercostal and the innermost intercostal muscles. Here, the intercostal nerve enters and is sheltered by the costal groove where it lies just inferior to the intercostal artery (*Keith L. Moore, 1999*).

Branches of a Typical Intercostal Nerve:

- 1- Communicating branches connect each intercostal nerve to a sympathetic trunk.
- 2- Collateral branches supply the intercostal muscles.
- 3- Lateral cutaneous branches divide into anterior and posterior branches supplying the skin on the lateral aspect of the thoracic and abdominal walls.
- 4- Anterior cutaneous branches supply the skin on the anterior aspect of the thorax and abdomen.
- 5- Muscular branches supply the subcostal, transversus thoracic, levatores costarum and serratus posterior muscles (*Hall, 1995*).

- **The thoracoabdominal nerves** (inferior five intercostal nerves T₇ to T₁₁) supply the thoracic and abdominal walls. As soon as they enter the superficial fascia, they are known as (the anterior cutaneous nerves of the thorax and abdomen) (*Richard et al., 2004*).
- **The subcostal nerve** follows the inferior border of the 12th rib and passes into the abdominal wall. It supplies the quadratus lumborum muscle, the 4 muscles of the anterior abdominal wall and the pyramidalis muscle (*Hall, 1995*).

Atypical Intercostal Nerves:

The first and second intercostal nerves pass on the internal surfaces of the first and second ribs. The 1st intercostal nerve has no anterior cutaneous branch. It divides into a superior part joining the brachial plexus and an inferior part becoming the 1st intercostal nerve. The 2nd intercostal nerve may give a branch to the brachial plexus. The lateral cutaneous branch of the 2nd intercostal nerve is called the intercostobrachial nerve supplying the floor of the axilla (*Keith L. Moore, 1999*).

The dermatomes:

The intercostal nerves supply successive segments of the thoracoabdominal wall. The band of skin supplied by each pair of the intercostal nerves is known as a dermatome (*Hall, 1995*).

The Thoracic Cavity:

The thoracic cavity is divided into 3 divisions: 2 pleural cavities and the mediastinum. The pleural cavities are completely separate from each other. Each lung is surrounded by a pleural sac having a parietal layer (external wall) and visceral layer (investing the lung). The space between the lungs and pleurae is called the mediastinum. The mediastinum contains all the structures in the thorax (such as the heart) except the lungs and the pleurae. It extends from the thoracic inlet superiorly to the diaphragm inferiorly and from the sternum and costal cartilages anteriorly to the bodies of the thoracic vertebrae posteriorly (*Tobias et al., 1988*)

The Lungs:

The main function of the lungs is to oxygenate the mixed venous blood (*Lippincott, 1996*).

In healthy people who live in a clean environment, the lungs are light pink, but in city dwellers they are often dark because of the inhaled dust particles trapped by pulmonary phagocytes. The lungs are attached to the heart and the trachea by (the pulmonary arteries, the pulmonary veins and the main bronchi) and to the pericardium by the pulmonary ligaments. Each lung has an apex, base, root and hilum (*Tobias et al., 1988*)

The Apex of the Lung:

The rounded apex of the lung extends through the superior thoracic inlet into the root of the neck. Here, it lies in close contact with the dome formed by cervical pleura. Owing to the obliquity of the thoracic inlet, the apex of the lung extends up to 3 cm superior to the anterior end of the first rib and its costal cartilage and the medial end of the clavicle. These bony structures afford some protection to the apex, but its most superior part is protected only by soft tissues. The apex of the lung is crossed by the subclavian artery, which produces a groove in the mediastinal surface of the lung.

The Base of the lung:

This is the concave diaphragmatic surface of the lung which is related to the dome of the diaphragm. The base of the right lung is deeper because the right dome of the diaphragm rises to a more superior level.

The Root of the lung:

It is the highway for transmission of the structures entering and leaving the lung at the hilum. It connects the medial surface of the heart and the trachea and is surrounded by the reflection of parietal to visceral pleura.

The Hilum of the lung:

This is where the root is attached to the lung. It contains the main bronchus pulmonary vessels (one artery and two veins), bronchial vessels, lymph vessels, and nerves entering and leaving the lung (*Lippincott, 1996*).

The main differences between the right and left lungs:

The right lung has three lobes while the left lung has two. The right lung is larger and heavier than the left lung, but it is shorter and wider because the right dome of the diaphragm is higher and the heart and pericardium bulge more to the left. The anterior margin of the right lung is straight, whereas this margin of the left lung has a deep cardiac notch (*Healey and Hodge, 1990*).

The Bronchopulmonary segments:

The segments of a lung supplied by segmental bronchi are called bronchopulmonary segments. Within each segment there is further branching of the bronchi. Each segment is pyramidal in shape with its apex facing the root of the lung and its base on the pleural surface. Each segment is named according to the segment bronchus that supplies it. The left superior lobe has a lingular bronchopulmonary segment. Each bronchopulmonary segment has its own segmental bronchus artery and vein (*Richard et al., 2004*).

Innervation of the lungs & pleura:

The lungs and visceral pleura are innervated by the anterior and posterior pulmonary plexuses which are mixed plexuses, containing vagal and sympathetic fibers. The efferent fibers of the vagus nerve are broncho constrictor to the smooth muscles of the bronchial tree, vasodilator to the pulmonary vessels and secretomotor to the glands of the bronchial tree. The afferent fibers are sensory to the respiratory epithelium. The efferent sympathetic fibers are branchodilator, vasoconstrictor to the pulmonary vessels and inhibitors to the glands of the bronchial tree. The function of the afferent sympathetic fibers is unknown. The costal pleura and the peripheral parts of the diaphragmatic pleura are supplied by the intercostal nerves while the central part of the diaphragmatic pleura and the mediastinal pleura are supplied by the phrenic nerves (*Healey and Hodge, 1990*).

The Pericardium:

The pericardium is a double- walled fibroserous sac that encloses the heart and roots of its great vessels. This conical pericardial sac is located in the middle mediastinum, posterior to the body of the sternum and the second to sixth costal cartilages and anterior to T5 to T8 vertebrae. The pericardium or pericardial sac, containing the heart and pericardial cavity, consists of two parts: 1) A strong external layer composed of tough fibrous tissue, called the fibrous pericardium, and 2) An internal double- layered sac composed of a transparent

membrane called the serous pericardium. The nerves of the pericardium are derived from the vagus, phrenic nerves and the sympathetic trunks (*Hall, 1995*).

The Heart:

The heart propels the blood through the blood vessels to various parts of the body. The right side of the heart receives deoxygenated blood from the body and pumps it into the lungs whereas the left side receives oxygenated blood from the lungs and pumps it into the aorta for distribution to the body.

The heart and the roots of the great vessels occupy the pericardium in the middle mediastinum. These structures are related anteriorly to the sternum, the costal cartilages, and the medial ends of the third to fifth ribs on the left side. The heart has a base, apex, three surfaces (sternocostal, diaphragmatic and pulmonary) and four borders (right, inferior, left, and superior) (*Paul Laizzo, 2005*).

The Base of the Heart:

The base is located posteriorly and is formed mainly by the left atrium. It lies opposite T5 to T8 (supine position) and T6 to T9 vertebrae (erect position) and faces superiorly, posteriorly and toward the right shoulder. The base is separated from the diaphragmatic surface of the heart by the posterior part of the coronary groove.

The Apex of the Heart:

The blunt apex is formed by the left ventricle, which points inferolaterally. The apex is located posterior to the left fifth intercostal space in adults, 7 to 9 cm from the median plane and just medial to the left midclavicular line.

The sternocostal (Anterior) Surface of the Heart:

This surface of the heart is mainly formed by the right ventricle.

The Diaphragmatic (Interior) Surface of the Heart:

This surface of the heart is usually horizontal. It is formed by both ventricles, mainly the left one. This surface is related to the central tendon of the diaphragm. The posterior interventricular groove divides this surface into a right one-third and a left two-thirds (*Paul Laizzo, 2005*).

The Borders of the Heart:

The right border is formed by the right atrium. The inferior border is formed mainly by the right ventricle and only slightly by the left ventricle. The left border is formed mainly by the left ventricle and only slightly by the left auricle. The superior border is where the great vessels enter and leave the heart. It is formed by the right and left auricles with the superior conical portion of the right ventricle (the infundibulum)

between them. The pulmonary trunk arises from the infundibulum (*Paul Laizzo, 2005*).

Innervation of the Heart:

The heart is supplied by autonomic nerve fibers from the vagus nerves and the sympathetic trunks. Branches of both vagus nerves and both sympathetic trunks form the cardiac plexus. The cardiac plexus lies anterior to the bifurcation of the trachea, posterior to the arch of the aorta and superior to the bifurcation of the pulmonary trunk. Stimulation of the sympathetic nerves increases the heart rate and the force of the heart beat with coronary vasodilatation while stimulation of the vagi slows the heart rate, reduces the force of the heart beat with coronary vasoconstriction (*Richard et al., 2004*).

The Vagus Nerves:

The vagus nerves (Xth cranial nerves) arise from the medulla of the brain. The thoracic parts of these nerves descend from the neck, posterolateral to the common carotid arteries. Each nerve enters the superior mediastinum posterior to the appropriate sternoclavicular joint and brachiocephalic vein (*Keith L. Moore, 1999*).

The Right Vagus:

This nerve enters the thorax anterior to the right subclavian artery and runs posteroinferiorly through the superior mediastinum on the right side of the trachea. It then

passes posterior to the right brachiocephalic vein and the superior vena cava where it breaks up into a number of branches that contribute to the right pulmonary plexus, located posterior to the root of the right lung. This plexus supplies the bronchi and lungs. The vagus nerve leaves this plexus as a single nerve and passes to the esophagus, where it again breaks up and contributes fibers to the esophageal plexus. This plexus supplies the esophagus, pericardium, and pleura. The right vagus nerve also gives rise to cardiac nerves, which contribute to the cardiac plexus supplying the heart. This plexus is located between the arch of the aorta and the bifurcation of the trachea. After passing anterior to the subclavian artery, the right vagus nerve gives rise to the right recurrent laryngeal nerve, which hooks around the right subclavian artery and ascends in the neck between the trachea and esophagus to supply the larynx (*Keith L. Moore, 1999*).

The Left Vagus Nerve:

This nerve descends in the neck posterior to the left common carotid artery between it and the left subclavian artery. When it reaches the left side of the arch of the aorta, it diverges posteriorly from the left phrenic nerve. It is separated laterally from the phrenic nerve by the left superior intercostal vein. The left vagus nerve passes posterior to the root of the left lung, where it breaks up into a number of branches that contribute to the left pulmonary plexus. The left vagus nerve leaves this plexus as a single trunk and passes to the esophagus, where it joins fibers from the right vagus in the esophageal plexus.