INTRODUCTION

Pleurodesis is the fusion of the visceral and parietal pleura. It usually results from pleural inflammation produced by an injury to the pleura ***(Light et al., 2000).***

Pleurodesis is indicated to prevent recurrence of pleural diseases as pleural effusion and pneumothorax. Pleurodesis following pleural aspiration decreases the chance of pleural effusion recurrence, and has been a widely used long-standing method of controlling recurrent pleural effusions ***(Zaloznik et al., 1983).*** Success of pleurodesis undoubtedly would affect further management plan.

The assessment of the presence of a pleurodesis is difficult. In most clinical articles on pleurodesis for pleural effusion, its presence is assessed by the presence or absence of pleural fluid. However, this assessment only indicates whether fluid has reaccumulated but does not indicate if a pleurodesis has occurred. Neither standard chest radiographs nor CT scans demonstrate whether pleurodesis has occurred.

Ultrasound has received increasing interest from chest physicians in recent years. Modern ultrasound devices are used easily, inexpensive, lightweight and portable ***(Middleton et al., 2004).***

With a sensitivity of 100% and a specificity of 99.7%, sonography is more accurate than conventional radiography in

the detection of pleural effusion because as little as 5 mL of fluid can be visualized ***(Gryminski et al., 1976).***

We hypothesized that the assessment of the pleural gliding sign with ultrasound would be an efficient imaging modality for the evaluation of pleurodesis, and the presence of a pleurodesis would be indicated by the absence of a gliding sign. In an experimental study sliding of the pleura was completely eliminated if the pleurodesis is performed successfully ***(Zhu et al., 2005).*** No data are available, to our knowledge, to confirm these findings in clinical practice.

AIM OF THE WORK

Assess the utility of chest ultrasound in early prediction of the outcome of pleurodesis and identification of changes in pleura and lung that herald success.

Chapter One

INDICATIONS AND OUTCOME OF PLEURODESIS

The term pleurodesis comes from the Greek pleura-desis and consists of the fusion of both pleural sheets (parietal and visceral). Pleurodesis dates back to the beginnings of thoracic surgery ***(Bethune, 1935).***

In order to obtain this objective, different techniques have been employed, such as the instillation of products (chemical or medical pleurodesis) or surgical techniques (mechanical or surgical pleurodesis).

The ideal sclerosing agent should be low-cost, readily available, easy to use, relatively free of side effects, and highly efficient ***(Dikensoy et al., 2005).*** Chemical pleurodesis stands out because it is easy to carry out, has a great variety of sclerosing agents and has been proven effective. Surgical pleurodesis is a mechanical aggression of the parietal pleura to achieve the desired effect.

Before pleurodesis is performed, the lung must be fully inflated and, because this is a palliative procedure, the patient should report symptomatic improvement after pleural fluid drainage ***(Lynch, 1993).***

Clinical indications:

1-Recurrent spontaneous pneumothorax

Emphysematous and bullous disease is one cause of persistent pneumothorax. For pneumothorax without a persistent air leak, conservative medical management such as observation and/or chest tube drainage is considered the standard treatment. However, pneumothorax with persistent air leak may be life-threatening in some patients, requiring more definitive treatment such as surgery to close the air leak or pleurodesis. In past decades, mechanical pleurodesis such as pleural abrasion or blebectomy was used for recurrent pneumothorax.

In cystic fibrosis, lymphangioleiomyomatosis, and thoracic endometriosis, persistent pneumothoraces can occur, but use of pleurodesis in this setting is controversial.

2-Recurrent pleural effusion

Benign pleural effusion

Recurrent accumulation of benign pleural effusions is caused by pleural fluid imbalance due to excessive production of pleural fluid, decreased absorption, or a combination of both. Etiologies include inflammatory conditions, congestive heart failure, hepatic hydrothorax, and prior cardiac surgery. The use of pleurodesis for recurrent benign pleural effusions is controversial, and is only performed in exceptional circumstances ***(Matsubara et al., 2012).***

Malignant pleural effusion

Malignant pleural effusion causes substantial morbidity from dyspnea, cough, and chest pain, which may compromise patient mobility and affect quality of life. Migration of tumor cells to the pleural space results in obstruction of the lymphatic network and blood vessels, leading to pleural effusion. The principal goal in treating malignant pleural effusions is to improve respiratory status. A firstline approach to treating a malignant pleural effusion is systemic treatment including management of heart, kidney or liver failure, and therapy for the underlying malignancy.

However, if the pleural effusion fails to respond, a more targeted approach such as thoracentesis, pleural drainage, pleuroperitoneal shunt, pleurectomy and pleurodesis is often necessary. The British Thoracic Society has published guidelines for management of malignant pleural effusion ***(Roberts et al., 2010).*** They recommend observation if the patient is asymptomatic. Pleural effusions treated by aspiration alone are associated with a high rate of recurrence of effusion at 1 month, so this treatment is not recommended if life expectancy is more than a month. With very short life expectancy, therapy with an intercostal indwelling smallbore chest tube followed by pleurodesis is recommended for recurrent aspiration unless significant lung trapping is present. Talc is the most effective sclerosant available for pleurodesis.

Table (1): Characteristics of chemical pleurodesis agents ***(Ferrer et al., 2001).***

Agents	Advantages	Disadvantages
Talc	Cheap, easily available, highest efficacy	Reports of ARDS, renal failure
Bleomycin	Efficacy similar to talc	Very costly, chest pain, fever nausea
Povidone iodine	Cheap, easily available	Anaphylaxis, randomized study required involving larger number of patients
Tetracycline/ doxycycline	Easily available	Very painful, ARF

Main reason for failure of pleurodesis:

A trapped lung resulting from inability to expand because of an obstructing endobronchial lesion, adhesion, or a complicated pleural process is the main reason for failure of pleurodesis ***(Hartman et al., 1993).***

Contraindications of pleurodesis:

Patients whose disease appears to be terminal, those with severe comorbid disease, those with a very low pleural fluid pH, those with lung entrapment, and those with mainstem bronchial occlusion with tumor should not be treated with chemical pleurodesis ***(Heffner et al., 2000).***

Chapter Two

IMAGING OF OUTCOME OF PLEURODESIS

Chest radiography is often non-specific and can show pleural thickening, nodularity, and sometimes pleural effusions that may mimic malignancy. The mediastinum may shift to the side of treatment due to constriction of the underlying lung ***(McLoud et al., 1980).*** (Fig. 1a).

If a history of pleurodesis is lacking, the tendency of high-attenuation material to be distributed in the posterior costophrenic angles or apical regions may be a clue to the diagnosis. Although findings of pleurodesis are not rare on CT and can be quite characteristic, there are few reports of the CT appearances after pleurodesis ***(Ahmadzadehfar et al., 2007).***

Pleurodesis-related lesions tend to be distributed in the posterior costophrenic angles or apical regions on CT ***(Kwek et al., 2004)*** (Figs. 1, 2, 3, 4). The appearance is that of diffuse pleural thickening or one or more focal plaque-like or nodular pleural lesions. In addition, localized high-attenuation areas due to the high intrinsic attenuation of talc are typical for talc pleurodesis ***(Ahmadzadehfar et al., 2007)*** (Figs. 1b, 2b). The distribution and appearance of the lesions helps to distinguish post-pleurodesis changes from patients with other high attenuation lesions such as asbestos-related pleural plaques or calcification from prior empyema or hemothorax. Pleural plaques tend to be bilateral and located anteriorlaterally and posteromedially.

Pleural effusions in addition to thickening are more likely to be associated with pleurodesis than prior empyema or hemothorax, although the appearances may overlap.

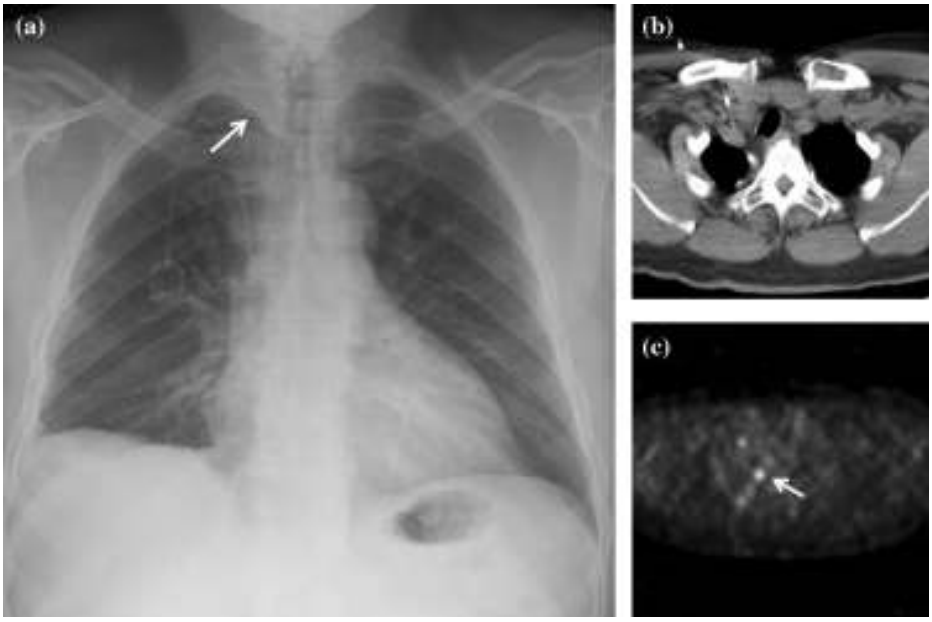

Fig. (1): A 64-year-old man with MALT lymphoma. The patient underwent talc pleurodesis for a right-sided pleural effusion. **A** Chest radiography shows pleural thickening and linear high attenuation in the right apex after the procedure (arrow). **B** CT shows a high attenuation nodule in the right apical pleura. **c** FDG-PET shows a hot spot (arrow) corresponding to the high attenuation focus on CT.

Pleurodesis-related lesions may remain unchanged over several years, a key distinguishing feature from active malignant disease. Loculated effusions are a typical finding after talc infusion (Fig. 3b) but can be seen after sclerotherapy with any agent. If surgical resection has been performed, staples and/or scar can be seen in the lung parenchyma (Fig. 4). In patients receiving autologous blood pleurodesis, pleural

thickening or calcification may be mild or not identifiable (Fig. 3). The appearances after OK-432 pleurodesis are non-specific but pleural effusions or thickening are often present (Fig. 5). Over the past two decades, positron emission tomography (PET) with F-18 fluorodeoxyglucose (FDG) has been an effective method to diagnose, stage and assess treatment response in malignancy ***(Ahmadzadehfar et al., 2007).***

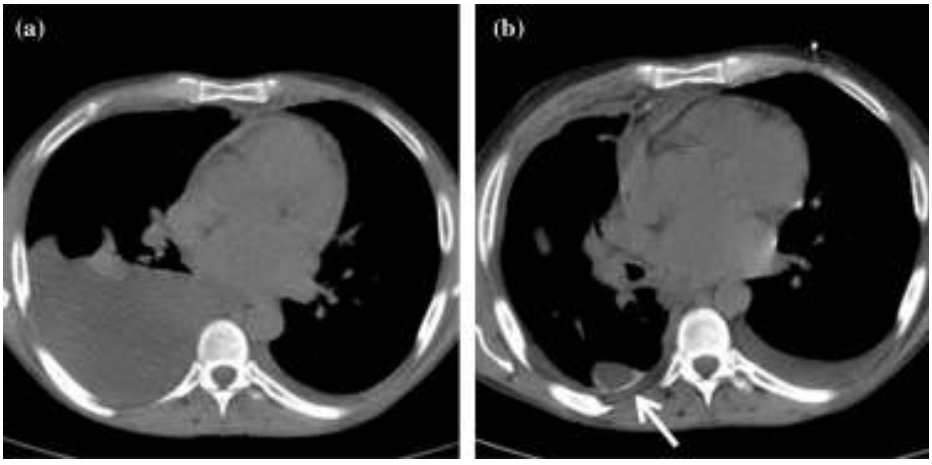

Fig. (2): A 45-year-old man with persistent benign pleural effusions from chronic renal failure and alcoholic cirrhosis which were uncontrolled medically. **A** Axial CT images demonstrate right pleural effusion and passive atelectasis. No pleural nodules or evidence of malignant disease is identified. **b** One month after talc pleurodesis, the right pleural effusion has substantially decreased. A curvilinear high attenuation area can now be seen in the posterior pleura.

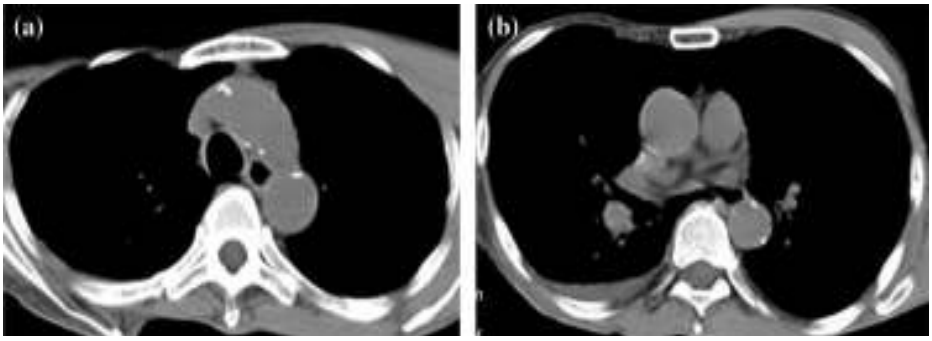

Fig. (3): A 57-year-old man with bullae of the lung after treatment with autologous blood pleurodesis for pneumothorax. His right-sided musculature is atrophied due to a prior stroke. **a**, **b** There is no pleural thickening or area of high attenuation, with only a small pleural effusion remaining.

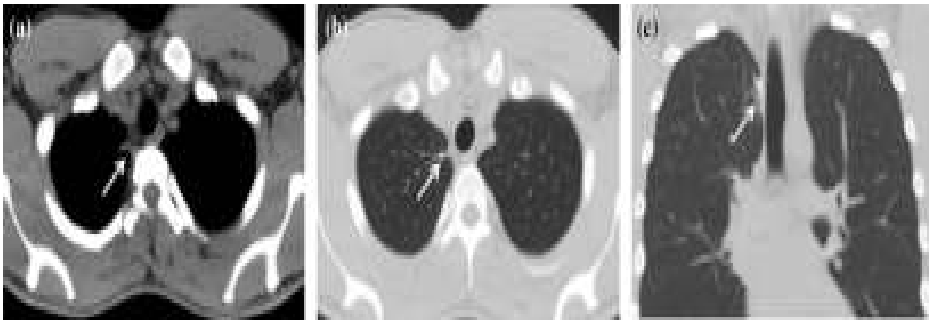

Fig. (4): A 23-year-old man with bullae causing recurrent pneumothorax. Resection of bullae and radiofrequency pleural ablation was performed. **a**, **b** After VATS, CT shows a high-attenuation area in the right apex corresponding to staple material and focal plaque-like pleural thickening (arrow). Scarring is also present in the lung parenchyma. **c** On coronal imaging, the staple-related high attenuation is shown to abut the plaque-like pleural thickening (arrow). There is no pleural hyperattenuation such as would be seen with talc pleurodesis.

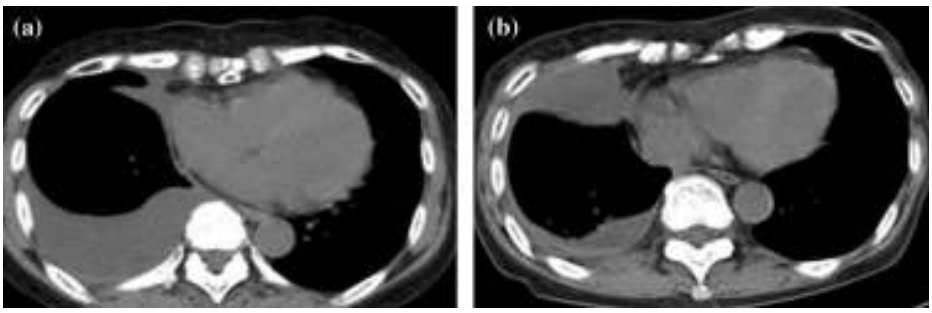

Fig. (5): A 61-year-old man with history of OK-432 pleurodesis after partial resection for lung cancer with malignant pleural effusion. **a** On the pre-pleurodesis CT, a right pleural effusion is shown. **b** After OK-432 pleurodesis, the pleural effusion has decreased and is more loculated. The pleura is also thickening.

Caution in interpreting PET/CT findings should be exercised after talc pleurodesis because case reports indicate that the appearance may mimic a malignant pleural effusion. Post-pleurodesis plaque-like nodularity may show increased pleural FDG uptake with the maximum standardized uptake value (SUVmax) ranging from 2.0 to 16.3 ***(Kwek et al., 2004)*** (Fig. 1c). The FDG uptake can persist for months or years after pleurodesis. It is important to be aware of this possibility to avoid misinterpreting uptake as recurrent disease.

Chapter Three

ULTRASOUND OF THE THORAX

History of Ultrasound

The use of ultrasound in medicine began during and shortly after the 2nd World War in various centers around the world. The work of Dr. Karl Theodore Dussik in Austria in 1942 on transmission ultrasound investigation of the brain was the first published work on medical ultrasonics. From the mid-1960s onwards, the advent of commercially available systems allowed the wider dissemination of the art. Rapid technological advances in electronics and piezoelectric materials provided further improvements from bistable to greyscale images and from still images to real-time moving images. The technical advances at this time led to a rapid growth in the applications to which ultrasound could be put. The development of doppler ultrasound had been progressing alongside the imaging technology but the fusing of the two technologies in duplex scanning and the subsequent development of colour doppler imaging provided even more scope for investigating the circulation and blood supply to organs, tumours, etc. The advent of the microchip in the 1970s and subsequent exponential increases in processing power have allowed faster and more powerful systems incorporating digital beam forming, more enhancements of the signal and new ways of interpreting and displaying data, such as power Doppler and 3-dimensional imaging ***(Bolliger et al., 2009).***

Chest Ultrasonography Overview

Physics of ultrasonography:-

Diagnostic ultrasonography is the only clinical imaging technology currently in use that does not depend on electromagnetic radiation. This modality is based on the properties of sound waves, and hence the mechanical and acoustic properties of tissues. Diagnostic ultrasound is mechanical energy that causes alternating compression and rarefaction of the conducting medium, traveling in the body as a wave usually at frequencies of 2–10MHz. In general it is assumed that the speed of sound in tissue is constant at 1,540 m/s ***(Middleton et al., 2004).***

When a pulse of ultrasound energy is incident upon the body, it interacts with the tissue in a variety of ways. Some of the incident energy is directed back towards the source and is detected. The time delay between the energy going into the body and returning to the ultrasound probe determines the depth from which the signal arises, with longer times corresponding to greater depths. This information is used in the creation of an image. Other factors that make the tissues distinguishable on a screen are their slightly different acoustical properties; one is known as the acoustic impedance ***(Hedrick et al., 2004).***

At the boundary between two different tissue types the sound waves can be:- **(a) Reflected**, like light off a mirror, this

being the primary interaction of interest for diagnostic ultrasound, as it allows the major organ outlines to be seen; the diaphragm and pericardium are specular reflectors; **(b) Refracted**, like light rays passing through a lens and hence having their directions altered; **(c) Scattered**, like sunlight in the sky, sending sound waves off in different directions; this occurs when the ultrasound wave encounters a surface that is 'rough' and **(d) Attenuated or absorbed**, as they lose energy, which is converted to heat in the tissue ***(McDicken, 1991)***.

Acoustic Shadowing and Artifacts:-

In biologic tissues the speed of the sound is lowest in gas, faster in fluid, and fastest in bone, where the molecules are more closely packed. The sound pulses transmitted into the body can be reflected, scattered, refracted or absorbed. Absorption or attenuation is the loss of acoustic energy by conversion to heat energy, more prevalent in bone than soft tissue, and more prevalent in soft tissue than in fluid. It is a key cause of acoustic shadowing. Where there is a distinct loss of the echoes behind an imaged structure. Acoustic shadowing is so common in ultrasound images that it is sometimes called an artifact. It is the result of the energy (of transmitted sound) that is being decreased by reflection and/or absorption. The shadowing behind gas is due to strong reflections at gas/tissue interfaces. The reflected pulse interacts with interfaces in front of the gas causing secondary reflections, which leads to low level echoes, causing 'dirty' images. However, the shadowing that occurs