Introduction

Pneumonia continuous to be a major cause of morbidity and mortality in adults, accounting for approximately 55,000 deaths, 1.2 million hospitalizations, and 1.7 million emergency departments annually ***(Kochanek et al., 2016).***

Pneumothorax is defined as the presence of air within the pleural space and is a common problem in the Intensive Care Units. Pneumothoraces can occur spontaneously, as a result of trauma, or from iatrogenic causes such as central venous catheter insertion, mechanical ventilation, thoracocentesis, and lung biopsy ***(Strange et al., 1999).***

The prevalence of pneumothorax in mechanically ventilated patients is high ranging from 4% to 15% and it is considered as one of the most serious complications of positive pressure ventilation. Traumatic pneumothorax is also commonly seen in the ICU. It is the second most common sign of chest trauma following rib fracture, and its incidence is up to 50% of patients with chest trauma ***(Wilson et al., 2009).***

The diagnosis of pneumonia is based on clinical features plus radiologic findings consistent with pulmonary infection. Traditionally, chest x-ray (CXR) has been the primary radiographic test used to evaluate for community acquired pneumonia (CAP) ***(Mandell et al., 2007).***

However, the use of chest computed tomography (CT) to evaluate patients with acute respiratory symptoms has markedly increased during the past two decades as clinical practice has evolved to more commonly assess for non-infectious conditions, such as pulmonary embolism and aortic dissection, and to more thoroughly image the lungs for signs of pneumonia ***(Kocher et al., 2011).***

CT is more sensitive than CXR for identifying radiologic signs of pneumonia, resulting in some patients having pneumonia visualized on CT but not on concurrent CXR (CT only pneumonia) ***(Syrjala et al., 1998).***

The clinical significance of radiologic signs of pneumonia visualized only on CT is largely unknown, creating uncertainty about whether these patients should be managed according to the same principles as those with pneumonia identified on CXR, or whether CT-only pneumonia is a distinct, less severe disease ***(Waterer, 2015).***

Chest radiographs have traditionally been the first test ordered to both make and rule out the diagnosis of pneumothorax in the setting of trauma or after invasive procedures. In the critically ill, the supine or semi-recumbent anterior-posterior film is frequently obtained making the reliability of chest radiographs to be limited ***(Ball et al., 2005).***

If there is doubt regarding the findings on a chest radiograph and the patient is stable, it is advised to conduct further imaging with ultrasonography (US) or chest computed tomography (CT) scan ***(Mowery et al., 2011).***

Thoracic CT scan is considered the gold standard test for both diagnosing and determining the size of pneumothorax. However, it is expensive and cannot be performed on a routine basis. In addition, the transportation of critically ill patients and exposure to radiation carries a measurable risk ***(Kelly et al., 2006).***

Aim of the Work

To compare the chest CT scan and chest x-ray for early detection of pulmonary complications for adults hospitalized in intensive care unit.

Chapter I: Thoracic Computed Tomography

The conventional chest radiograph superimposes a three-dimensional image onto a two-dimensional surface, so limiting its clinical usefulness. Since its introduction in 1971, X-ray computed tomography (CT) has rapidly evolved into an essential diagnostic imaging tool that forms a cross-sectional image, avoiding the super-imposition of structures that occurs in conventional chest imaging, with a >10-fold increase in attenuation sensitivity. Although CT imaging is reported by radiologists, it is important for both anaesthetists and intensivists to be able to interpret the scans, as reporting facilities may not be immediately available. Furthermore, the radiologist may not fully report all facets of a detailed scan and further information may be acquired by a physician with the ability to interpret CT scans. This is the first in a series of two articles written for anaesthetists and intensivists covering both thoracic anatomy and pathology as it relates to CT ***(Whiting et al., 2015).***

A- The basic principles of CT:

A CT scanner makes many measurements, from different rotational angles, of X-ray attenuation (*weakening in force or intensity*) through the cross-sectional plane of the thorax. It then uses these data to reconstruct a digital representation of the cross-section with each pixel of the image representing a measurement of the mean attenuation through the thickness of the predetermined segment. This measurement quantifies the fraction of radiation removed in passing through a given amount of material of a certain thickness. This is expressed in Hounsfield Units (HU), with water measuring zero on this scale. Examples of those materials that attenuate more than water, thus have a positive HU, are muscle, liver, and bone. Those that attenuate less, having a negative HU, are lung and adipose tissue ***(Henwood, 2008).***

Current multiple row detector helical CT scanners can scan more efficiently than ever before. The patient moves into a continuously rotating scanner within the gantry while a vast number of images per second are acquired in a spiral or helical profile. The large number of overlapping images improves spatial resolution in both the cross-sectional image and three-dimensional reconstructions ***(Mahesh, 2002).***

With the increasing utilization of CT, clinicians need to be aware of the potentially harmful radiation they are prescribing their patients to receive with each CT examination. These doses can be compared with the average annual effective dose from background radiation of about 3 mSv ***(Mettler et al., 2008)*** (**Table 1**).

Table (1): Adult effective doses for various CT procedures ***(International Commission on Radiological Protection, 2007).***

Examination	Average effective dose (mSv)	Number of years of natural background radiation (2.2 mSv)	Lifetime additional risk of cancer* (~in...)	Number of flights from London to New York (return)†
Neck	3	1.4	6100	40
Head	2	0.9	9100	27
Abdomen	8	3.6	2300	107
Pelvis	6	2.7	3000	80
Chest	7	3.2	2600	93
Chest for pulmonary embolism	15	6.8	1200	200
Spine	6	2.7	3000	80
Coronary angiography	16	7.3	1100	213

B- Indication for Chest CT:

There are many indications for a CT chest (**Table 2**). CT is the gold standard investigation for diagnosis of pulmonary embolus and after major trauma, CT of the head, neck, and body is now mandatory. In thoracic anaesthesia, preoperative CT scans of the chest are invaluable for planning the insertion of a double-lumen tube. On the intensive care unit (ICU), they are not just used to diagnose conditions such as interstitial lung disease, atypical infection, and acute respiratory distress syndrome (ARDS) but can help detect small or anterior pneumothoraces and evaluate loculated pleural effusions that can aid interventional strategies. Other imaging modalities should always be considered as they may confer certain advantages. Magnetic resonance imaging (MRI) is increasingly used for evaluation of structural and functional cardiac pathology ***(Raju et al., 2017).***

Positron emission tomography (PET), or PET CT confers advantages for diagnosis of malignant tumours or metastatic disease. Ultrasound (US) scan use is increasing in the ICU for echocardiography, lung ultrasound, and before percutaneous tracheostomy insertion. US has the major advantage of being deliverable at the point of care and is relatively safe with an absence of radiation exposure ***(Kumar, 2015; Tomography, 2002).***

Table (2): Indications for CT chest

Indication	Examples of identified pathologies
Primary lung cancer/staging of metastatic disease	
Evaluation of a solitary pulmonary nodule on CXR	
Mediastinal pathology	Lymphoma, Tumour, Great vessel disease, Thoracic aortic aneurysm, Aortic dissection, Pneumomediastinum, Thyroid enlargement
Cardiac	Tumour—myxoma, Pulmonary hypertension, Congenital heart disease, Coronary artery occlusion
Pericardial disease	Pneumo/haemopericardium, Pericardial effusion, Inflammation
Parenchymal disease	Consolidation (Pneumonia), Interstitial pulmonary fibrosis, Chronic obstructive pulmonary disease, ARDS, Bronchiectasis, Oedema, Atypical infection (PCP, fungal)
Trauma	Rib fractures and flail segments, Pulmonary contusion, Disruption to the thoracic aorta, Pneumohaemothorax, Diaphragmatic rupture
Pulmonary embolism	Acute—right ventricular (RV) strain, Chronic—RV hypertrophy
Pleural abnormalities	Empyema or loculated effusions, Small pneumothoraces, Haemothorax

C- Role of Contrast CT:

I.V. contrast media enables the confident identification of vascular anatomy, aids delineation of adjacent non-vascular structures, and improves both the detection and characterization of pathological lesions. It is used to aid assessment of mediastinal structures, vascular structures, chronic pleural disease, lung masses, and differentiation of parenchyma from the pleura or pleural collections. Contrast may also be administered orally for assessment of the oesophagus ***(Bae, 2010).***

I.V. contrast is administered via a high-pressure syringe pump at between 3 and 6 ml s^{-1}. Vascular access must be of an adequate gauge to allow flow at these rates while being robust enough to cope with the pressure injection (most institutions favour an 18 G cannula placed correctly in the ante cubital fossa). Administration via central access risks catheter rupture and great vessel perforation. Certain central venous catheters are re-inforced and safe to administer contrast through, but local policy and manufacturer's guidance should always be followed ***(Bae, 2010).***

There are certain situations where it is important to scan in the absence of contrast and for this reason, it is essential that the radiologist is given a full history and is aware of the issues that are to be addressed. Examples of such situations are ***(Payor et al., 2015):***

- Acute aortic dissection: intramural haematoma, an early sign, may be obscured by the dense aortic contrast.

- Small oesophageal leaks: leaked oral contrast may be difficult to detect if I.V. contrast has been administered, as it can be obscured by adjacent vessel enhancement.

High-resolution CT thorax

High-resolution CT scanning is very useful for assessing the architecture of the lung and does not involve I.V. contrast. It acquires thin, non-contiguous slices, between 1 and 1.5 mm in thickness, sampling the parenchyma at 10–15 mm intervals. This reduces the radiation dose by up to 90% compared with a whole-volume helical CT scan. For this reason, it has an advantage in the younger, and more frequently scanned, cooperative patient. It is predominantly used to assess the lung parenchyma for conditions such as bronchiectasis, interstitial lung disease, emphysema, sarcoidosis, and atypical infections, for example, fungal or pulmonary tuberculosis ***(Sluimer et al., 2003; Spillane et al., 1993).***

D- Anatomy of The Thorax:

To allow for a better understanding of the structures visualized within the thorax on CT, we can orientate ourselves using the familiar posterior–anterior chest radiograph (**Figs 1–4**).

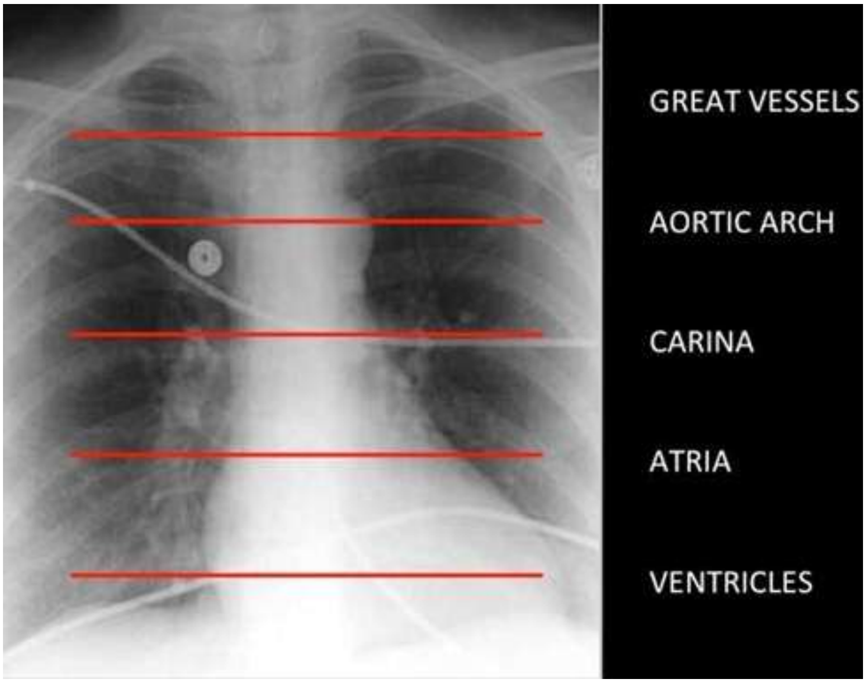

Figure (1): The important structures of the thoracic cavity can be identified at certain key points within the chest as identified on the chest radiograph ***(Whiting et al., 2015).***

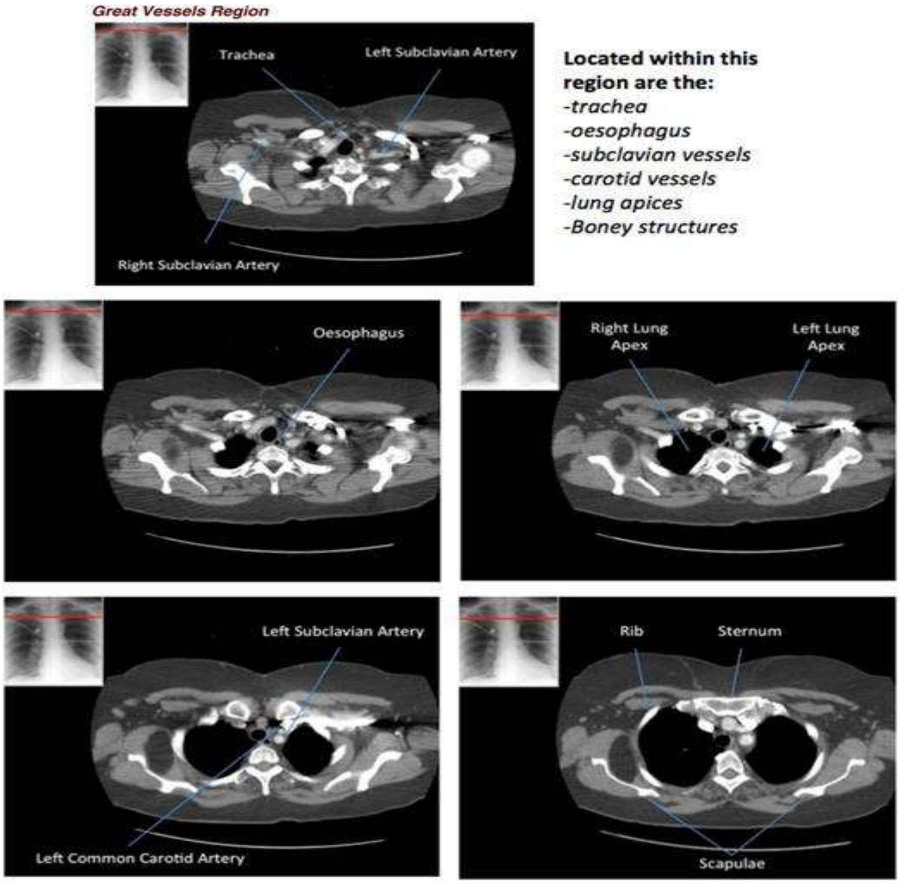

Figure (2): CT scans depicting anatomy at the level of the great vessels ***(Whiting et al., 2015).***

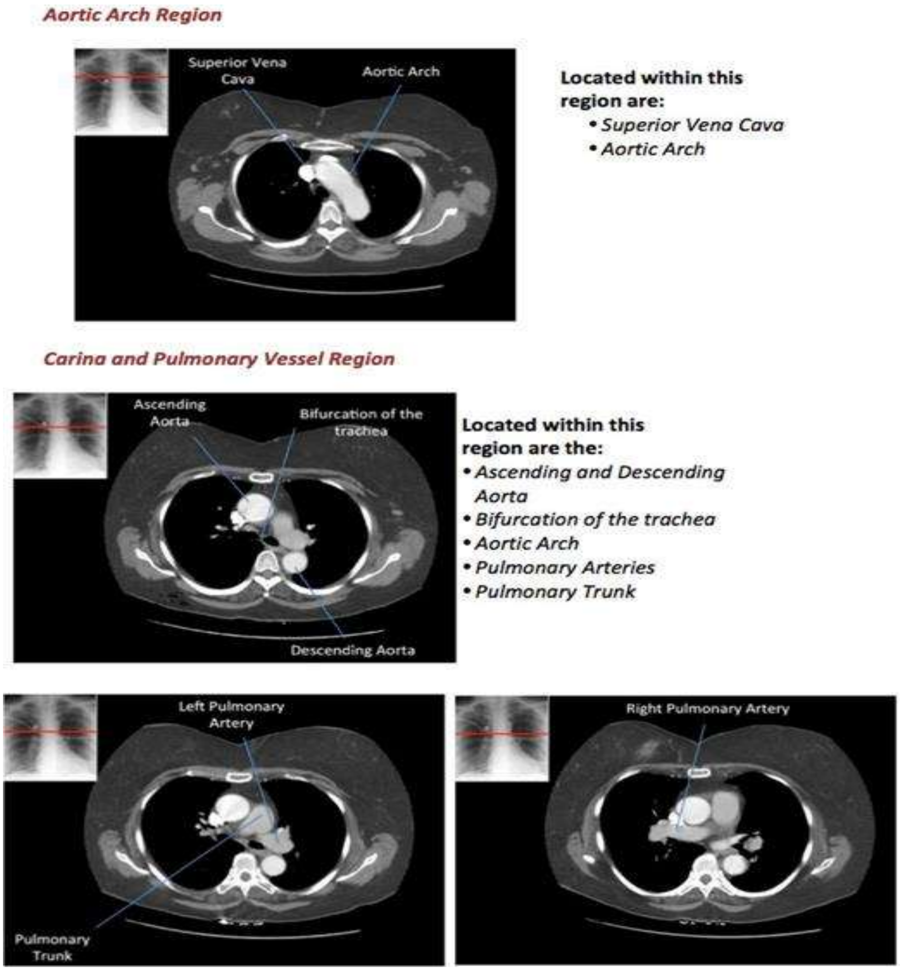

Figure (3): CT scans depicting anatomy at the levels of the aortic arch and carina ***(Whiting et al., 2015).***

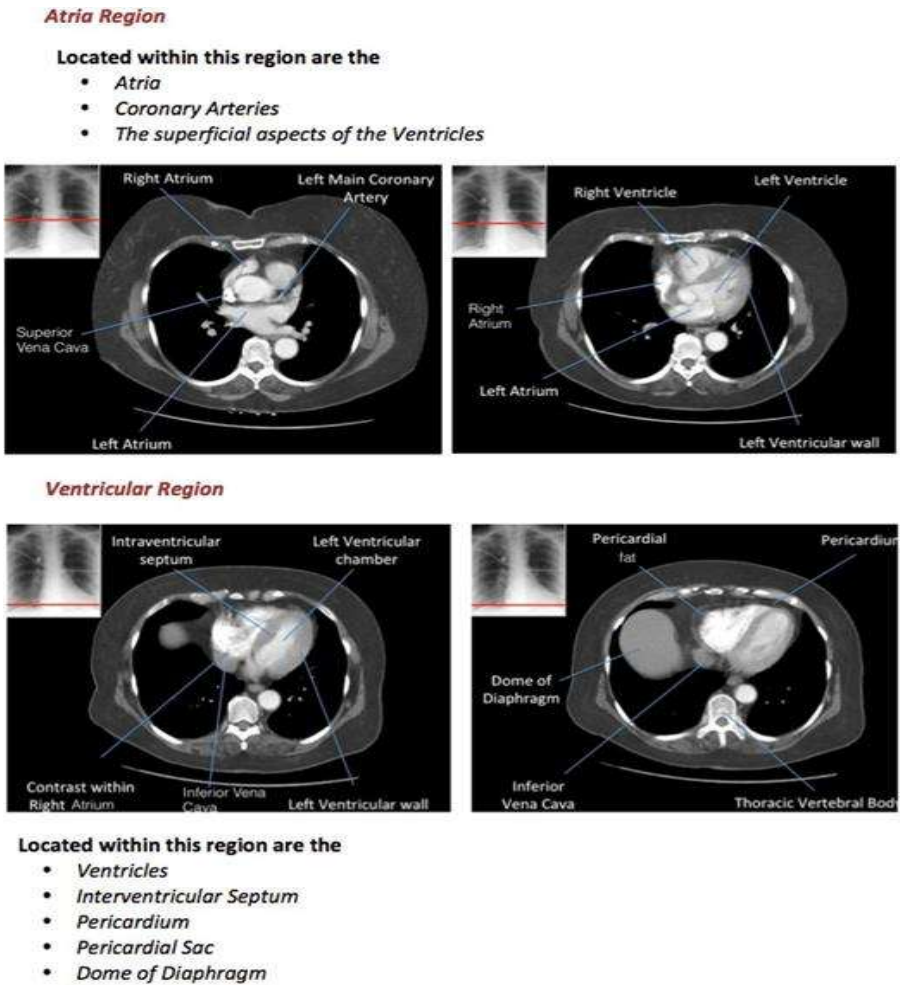

Figure (4): CT scans depicting the anatomy at the level of the atria and ventricles ***(Whiting et al., 2015).***

E- Interpretation of Chest CT:

When interpreting CT scans of the chest, it is important to follow a structured, logical approach. The images are most commonly viewed using lung, mediastinal, and bone windows that can be readily selected from the PACS toolbar ***(Little, 2015; Peldschus et al., 2005).***

Suggested approach for CT chest interpretation:

i. A full review of the patient's history and examination.

ii. Check the patient characteristics match those of the patient to be reviewed. Previous imaging may be compared with the most recent scan to aid diagnosis.

iii. Identify the orientation of the lung images on the film. The axial image is displayed as if you are looking at the patient from the feet end of the bed. Coronal and sagittal views can be reconstructed as long as the original slices are thin and contiguous (**Fig. 5**).

iv. A systematic approach ensures that abnormalities are identified. Easily identifiable anatomical structures will allow the clinician to gain orientation. The ability to scroll through the imaging helps with dynamic assessment and anatomical differentiation.

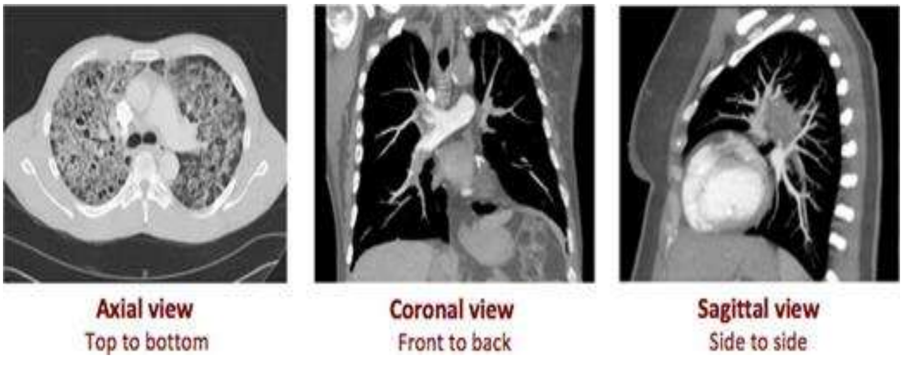

Figure (5): The possible anatomical orientation of the image 'slices' ***(Whiting et al., 2015)***

F- Advantages of Chest CT over Chest X-ray

Chest CT plays a crucial role in the care of the critically ill patient. A study performed by **Müller and colleagues** concluded that the most common indications for requesting a CT scan were sepsis of unknown origin, evaluation of pleural effusion, evaluation of patient with malignancy, and assessment of complications of thoracic surgery ***(Müller, 1993).***

It is not uncommon for the clinicians to request a CT in the patient who is acutely decompensating to try to elucidate possible causes, such as pulmonary embolism, source of bleeding in a postoperative patient, empyema, aortic dissection, or aortic intramural hematoma, especially as the portable CXR may be limited, nonspecific, or noncontributory. Pleural effusions can be difficult to detect on a portable CXR, and their appearance also can mimic airspace consolidation. Thus, chest CT in many instances may be the only way to accurately assess for both the presence and size of a pleural effusion. Although pleural fluid can be detected readily at CT, CT is of limited value in differentiating transudates from exudates. CT, however, does have the advantage over ultrasound when it comes to diagnosing empyema (and differentiating it from lung abscess) and in the characterization of malignant effusions ***(Ayres and Gleeson, 2010).***

Features on CT that favor empyema over lung abscess include: presence of sharp margin, thin wall, lenticular shape, the split-pleura sign (which will be discussed later in