

REVIEW ARTICLE

Computed Tomography of the Chest: Basic Principles

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Abstract

Tomography is a process by which an image layer of the body is produced, while the images of the structures above and below that layer are made invisible by blurring. Computed tomography (CT), the most widely used cross-sectional imaging methods used in medicine, forms cross-sectional images by avoiding super-imposition of structures that occurs in conventional chest imaging, with a >10-fold increase in attenuation sensitivity, within a second without need for breath holding. Like X-ray, an imaging contrast is generated as a consequence of differences in attenuation between the adjacent tissues. The higher the attenuation of the X-ray beam, the brighter the tissue on CT images, and vice versa. The only drawback is the potentially harmful radiation that is measured according to the amount of radiation received by the whole body. Simply, the amount of radiation from a chest CT is equivalent to 400 X-rays. Standard CT usually takes the image of the whole lung and compresses thick slices of about 7-10 mm into images and contrast can be given to highlight structures. High resolution (HRCT) has excellent spatial resolution and very useful for assessing the architecture of the lung. It does not involve IV contrast, acquires thin, non-contiguous slices, at 10-15 mm intervals with thin slices of lung tissues at regular intervals. This reduces the radiation dose by up to 90% compared to standard CT. The axial images are most commonly viewed using lung, mediastinal and bone window. The pulmonary window is specially used for the interpretation of lung parenchyma, airways and interstitial tissues but the mediastinal window is for the interpretation of mediastinal structures. CT interpretation needs a structured and logical approach.

Key words: CT chest, basic principles.

Introduction

Computed tomography (CT) and magnetic resonance imaging (MRI) are the most widely used cross-sectional imaging methods used in medicine. CT was a revolutionary development of the 1970s by Godfrey Hounsfield, an engineer at British EMI Corp. The term *computed tomography* derives from *computed* (with computer), *tomo* (to cut) and *graphy* (pictures). Tomography is a process by which an image layer of the body is produced, while the images of the structures above and below that layer are made invisible by blurring. The conventional chest radiograph superimposes a three-dimensional image onto a two-dimensional surface, so limiting its

clinical usefulness. But CT 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. The whole of the chest can be scanned at a high resolution in a second without need for breath hold. The only drawback is the potentially harmful radiation that the patients receive with each CT examination.¹

The basic principles of CT

CT uses ionizing radiation, or X-rays, coupled with an electronic detector array to record a pattern of densities and create an image of a 'slice' or 'cut' of tissue. The X-ray beam rotates around the object

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within the scanner such that multiple x-ray projections pass through the object and the detector, placed in diametrically opposite side, picks up the image i.e. the beam and detector move in synchrony.

As the X-ray pass through the patient, they are attenuated. The amount of attenuation depends on the type of tissue through which the X-ray beam passes. X-ray imaging contrast is generated as a consequence of differences in attenuation between the adjacent tissues. The higher the attenuation of the X-ray beam, the brighter the tissue on CT images, and the lower the attenuation, the darker the tissue on CT images. Therefore, bone and calcification that significantly attenuate the X-ray beam are white. Fat being rich in carbon, is more transparent than water containing oxygen, which attenuate X-ray to a greater degree. So, fat is blacker than water on CT. Air causes little attenuation of X-rays and is very black.²

Computer 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 lungs and adipose tissue.³

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.

CT and the radiation

X-rays are a form of energy, similar to light and radio waves. X-rays are also called radiation. When radiation pass through the body, dose is measured according to the amount of radiation received by the whole body. The scientific unit of measurement for whole body radiation dose, called effective dose is the millisievert (mSv), a measure of health effect of low levels of ionizing radiation on the human body. We all are exposed to natural sources of radiation all the time. According to recent estimates, the average person in the US receives an effective dose of about 3 mSv per year from natural radiation and cosmic radiation from outer space. These natural “background doses” vary according to where you live. To put it simply, the amount of radiation from one adult chest X-ray (0.01 mSv) is equal to 10 days of natural background radiation.^{1,4}

Standard versus High resolution CT (HRCT)

Standard CT usually compresses thick slices of lungs (7-10mm) into images so no lung tissue is missed and contrast can be given to highlight structures to improve diagnostic accuracy. Major evolutionary leaps are helical, multi detector/ multi slice (MDCT) and dual energy CT. This gives a detailed image of mediastinal vasculature and soft tissue, and chronic pulmonary disease.

HRCT scanning has excellent spatial resolution and very useful for assessing the architecture of the lung. It does not involve IV contrast. It acquires thin, non-contiguous slices, between 1 and 1.5 mm in thickness and sampling the parenchyma at 10-15 mm intervals that is thin slices of lungs scanned at regular intervals, so there is every chance to miss lung lesions in between the thin slices. This reduces the radiation dose by up to 90% compared to a whole-volume helical CT scan. For this reason, it has advantage in the younger, and those required more frequent scanning. It is predominantly used to assess the lung parenchyma for conditions such as interstitial lung disease and bronchiectasis.^{1,4}

Table I
Radiation doses of CXR, CT head & CT chest

Procedure	Approximate effective radiation dose (millisievert)	Number of CXR	Comparable to natural background radiation for
CXR	0.01	1	10 days
CT head	2-3	100	8-12 months
CT chest	4-8	400	16-36 months
Annual Background exposure	2-3	100	

Interpretation of CT chest

To interpret CT scans of the chest, it is important to follow a structured, logical approach. The axial images are most commonly viewed using lung, mediastinal, and bone window that can be readily selected from the PACS toolbar. Horizontal slices of the patient are shown as if you are looking towards the patients head from the foot end of the bed while they are lying supine, i.e., their left is on your right and vice versa.⁵ It is important to note that free air will rise (appear anteriorly) and free fluid will descend (appear posteriorly) due to the effect of gravity on the supine patient. Coronal and sagittal sections are viewed as like as chest X-rays. In the mediastinal window the lungs are overexposed and simply appear black.⁶ The pulmonary or lung window is specially to interpret lung parenchyma, airways and interstitial tissues but the mediastinal or soft tissue window is for the interpretation of mediastinal structures like great vessels, heart, thyroid, thymus, muscles and lymph nodes.⁷

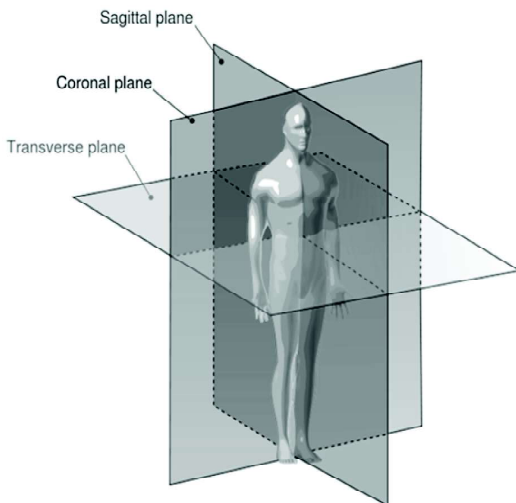


Fig 1 Planes of imaging

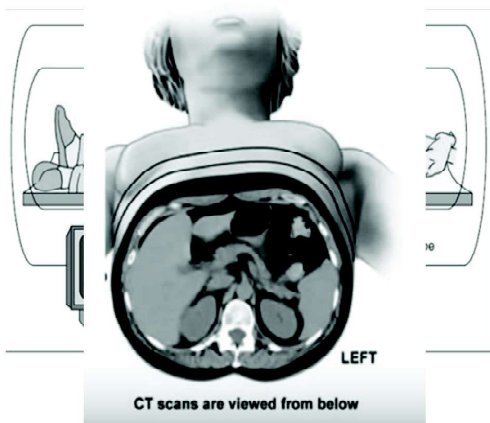
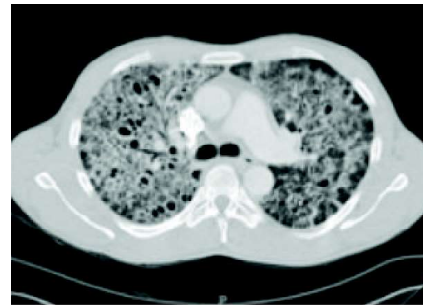


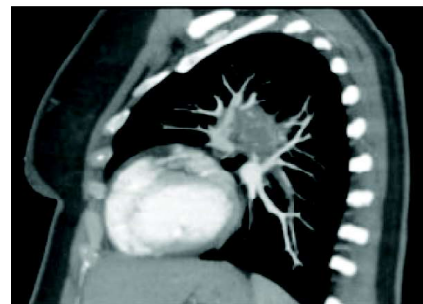
Fig 2 Axial view



a. Axial view (Top to bottom)



b. Coronal view (Front to back)



c. Sagittal view (Side to side)

Fig 3 The possible anatomical orientation of the image 'slices'²

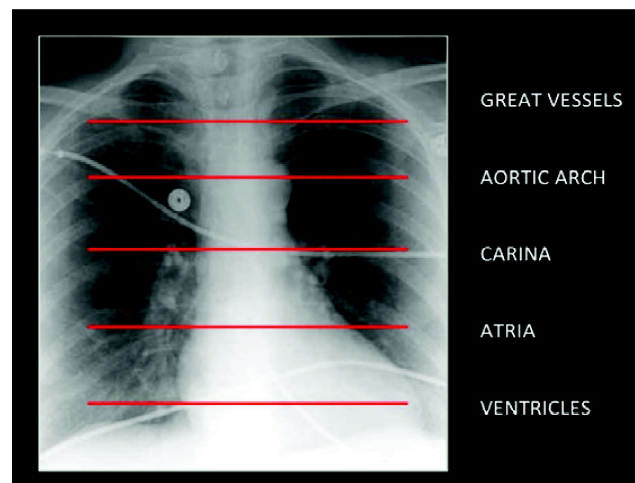


Fig 4 The important structures of the thoracic cavity can be identified at certain anatomical key points within the chest as identified on the chest radiograph¹

Great Vessels Region

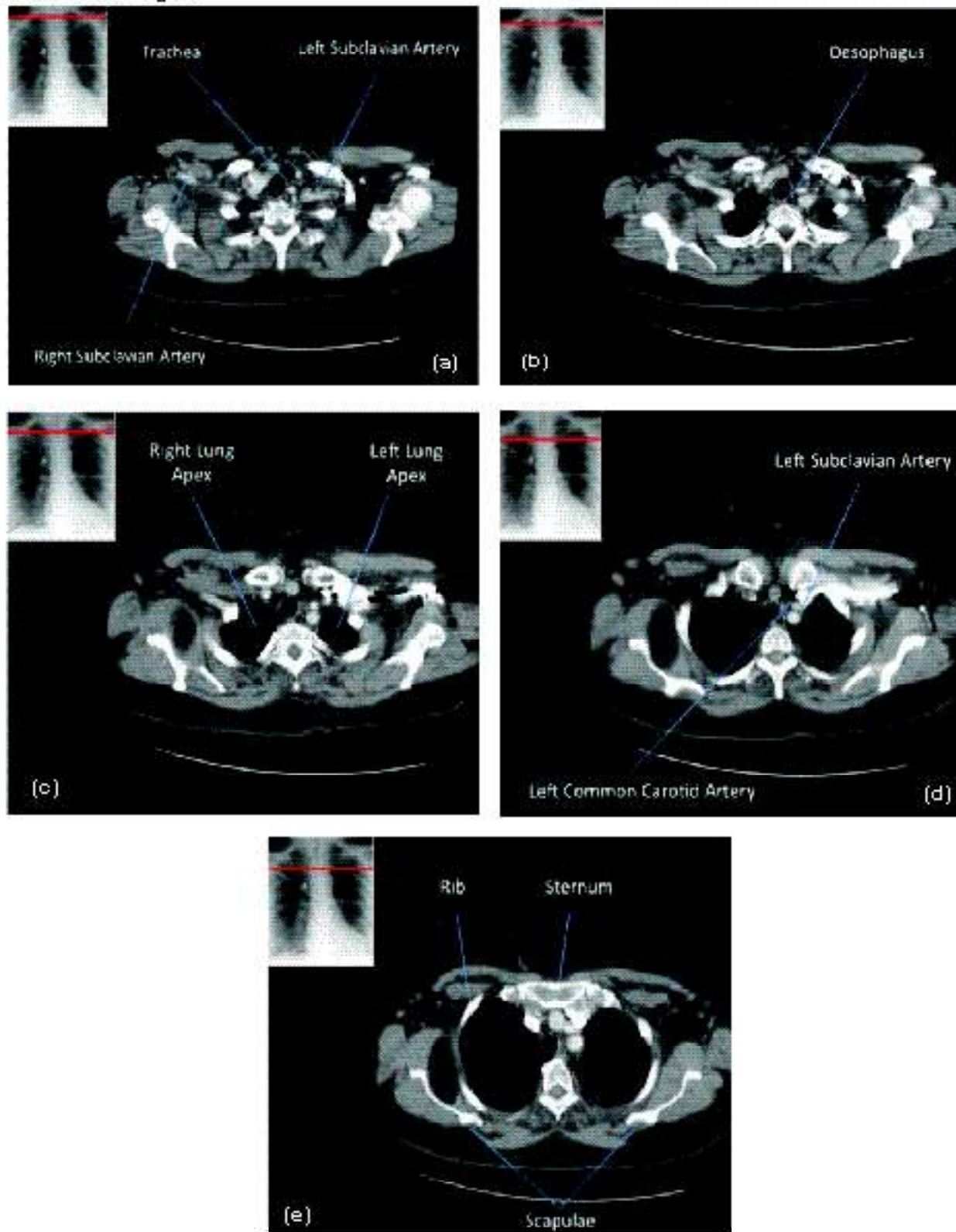
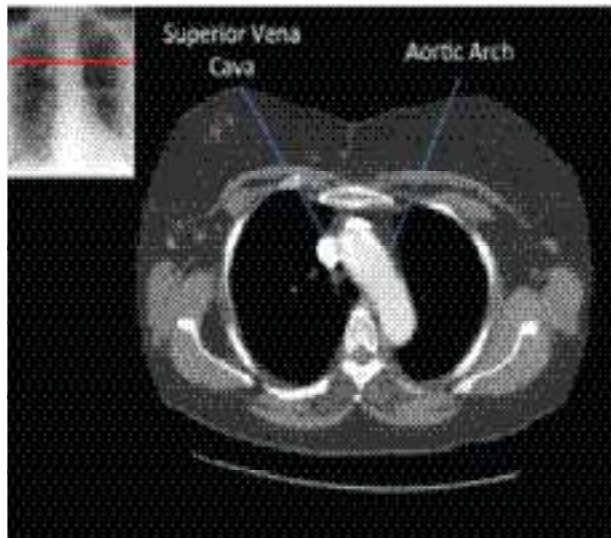
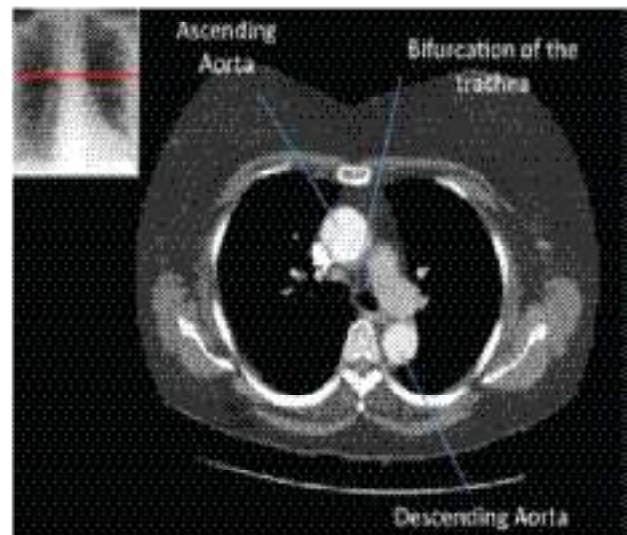


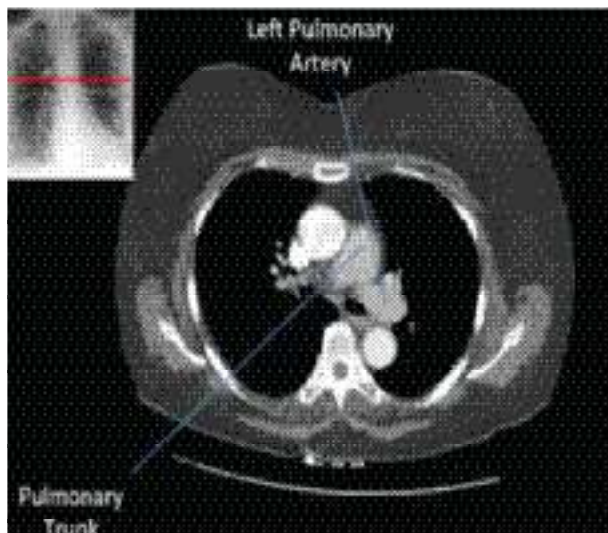
Fig 5 CT scans depicting anatomy at the level of the great vessels¹ (a,b,c,d,e)
Located within this region are the: trachea, oesophagus, subclavian vessels, carotid vessels, lung apices, bony structures

Aortic Arch Region

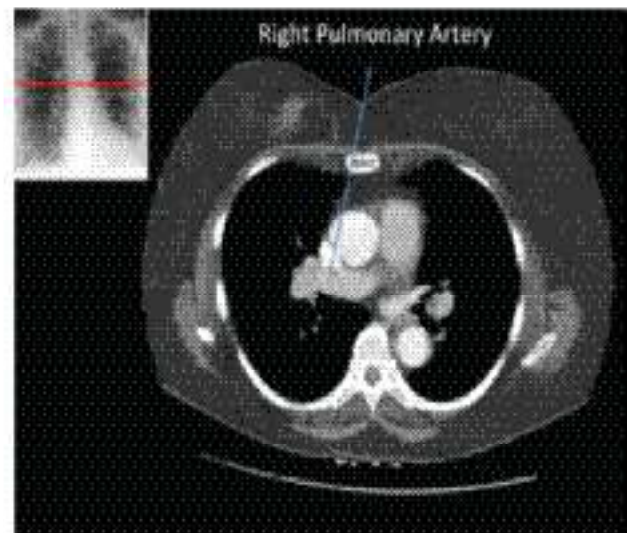
(a)

Carina and Pulmonary Vessel Region

(b)



(c)

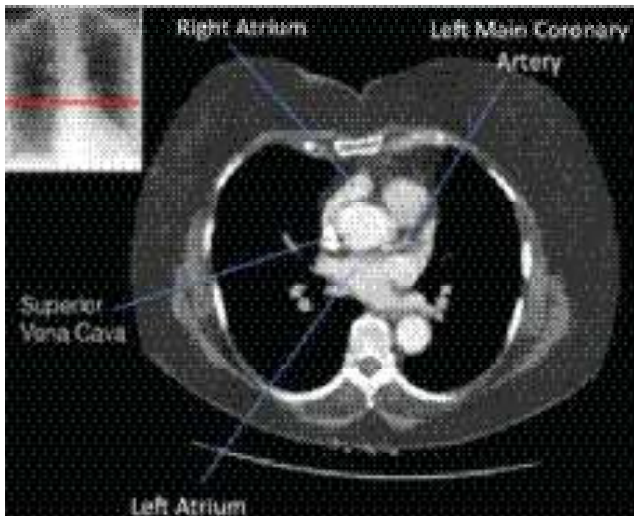


(d)

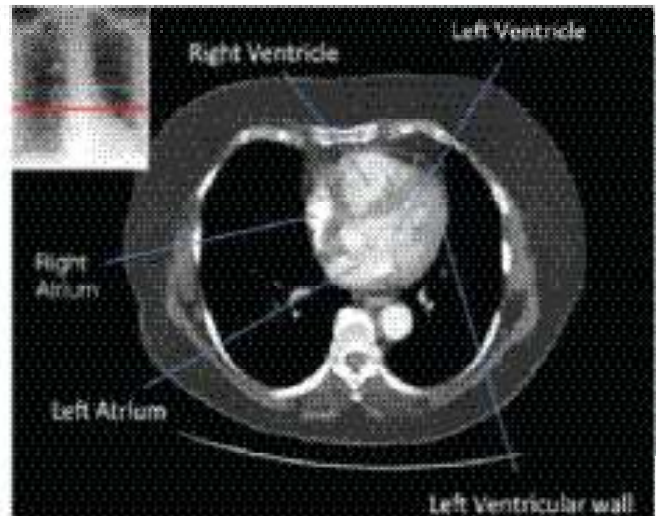
Fig 6 CT scans depicting anatomy at the levels of the aortic arch (a) and carina¹ (b,c,d)

Located within aortic arch region are: Superior Vena Cava, Aortic Arch. Located within carina and pulmonary vessel region are the: Ascending and Descending, Aorta, Bifurcation of the trachea, Aortic Arch, Pulmonary Artries, Pulmonary Trunk

Atria Region

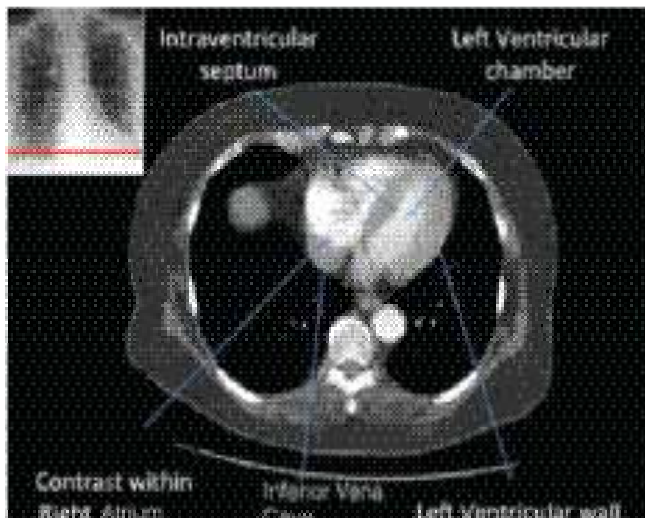


(a)

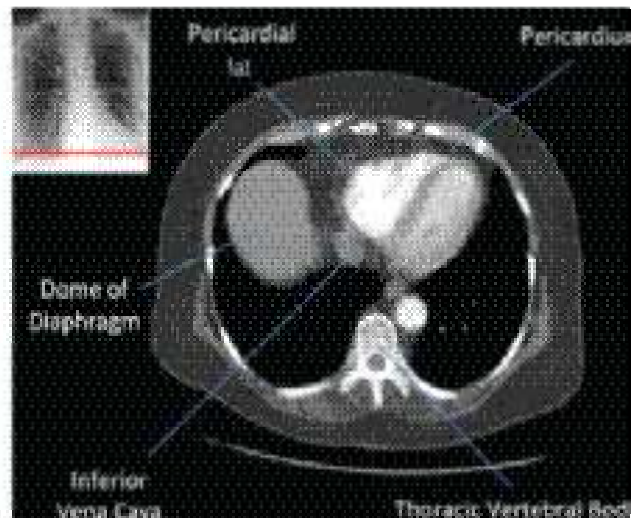


(b)

Ventricular Region



(c)



(d)

Fig 7 CT scans depicting anatomy at the level of the atria and ventricles¹ (a,b,c,d)

Located within atria region are: Atria, coronary arteries, the superficial aspects of the ventricles

Located within ventricular region are the: Ventricles, interventricular septum, pericardium, pericardial sac, dome of diaphragm

Conclusion

Computed tomography, a revolutionary development of the 1970s has established itself as a robust modality in medical science. It has the capacity to rapid acquisition of images in few seconds, have

impressive spatial resolution and ability to discriminate between structures and detecting abnormality on the basis of density and contrast enhancement against only the issue of radiation exposure.

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