

Computed tomography of the chest: I. Basic principles

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Key points

- Computed tomography (CT) scans can detect pathology that may be missed on a conventional chest radiograph.
- Clinicians need to be aware of the potentially harmful radiation that patients are exposed to, with each individual CT scan that is performed.
- The benefits and risks of i.v. contrast should be discussed with the radiologist before the scan. **Not all i.v. access is suitable for administration of contrast media.**
- Other imaging modalities such as MRI and ultrasound can confer specific advantages to diagnosis in certain conditions.
- A detailed knowledge of the anatomy of the thorax is required to fully interpret a CT scan of the chest.

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.

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**.¹

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.²

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 mSv³** (Table 1).

Indications for CT chest

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

Table 1 Adult effective doses for various CT procedures.⁴ *Based on ICRP 103's approximation of 5.5% per Sv. ICRP (2007) Report 103:2007 Recommendations. International Commission for Radiological Protection. †Based on NRPB 'Living with Radiation' 1998. 7.5 h flight each way, 0.005 mSv h⁻¹ at 10 km above sea level

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

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

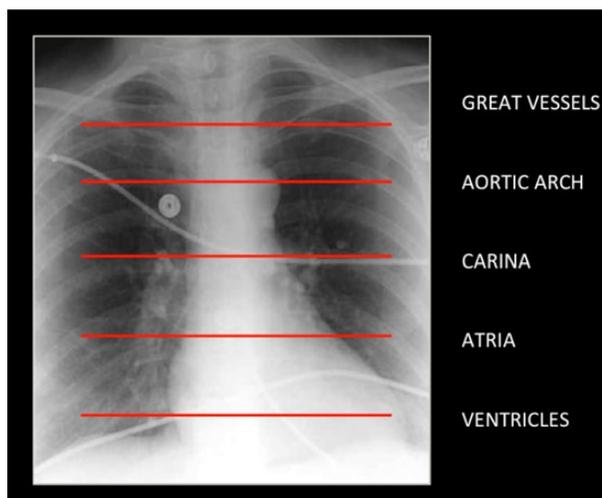


Fig 1 The important structures of the thoracic cavity can be identified at certain key points within the chest as identified on the chest radiograph.

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. Positron emission tomography (PET), or PET CT confers advantages for diagnosis of malignant tumours or metastatic disease. Ultrasound (US) scan use is increasing on 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.

Role of contrast CT chest imaging

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.

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.

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:

- **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.

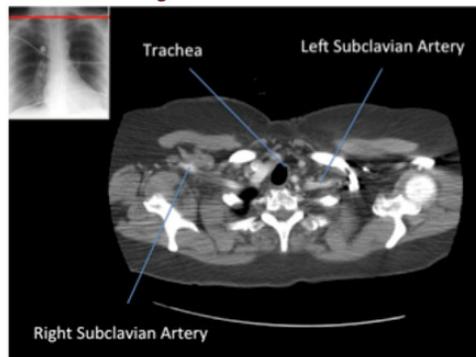
Anatomy of the thorax

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).

Interpretation of CT chest

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.

Great Vessels Region



Located within this region are the:

- trachea
- oesophagus
- subclavian vessels
- carotid vessels
- lung apices
- Boney structures

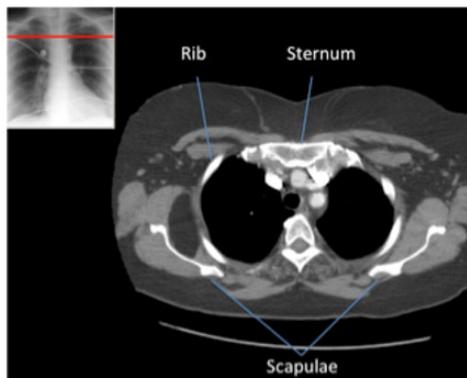
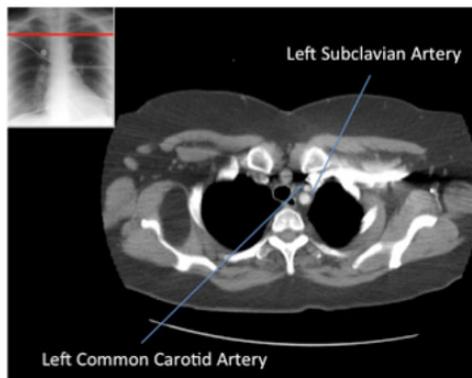
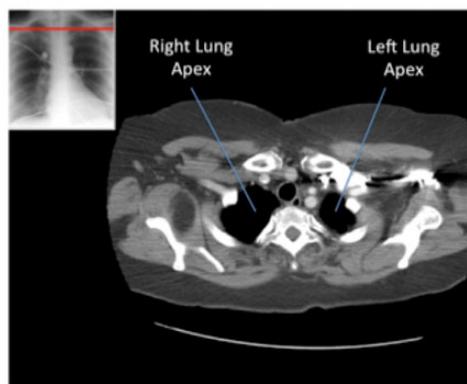
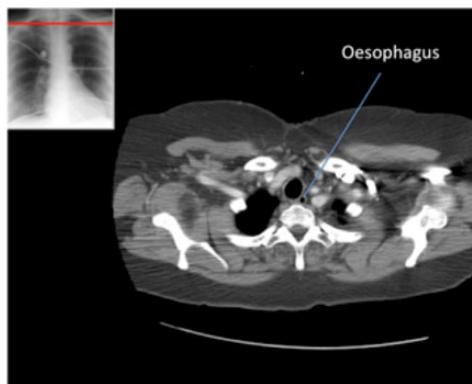
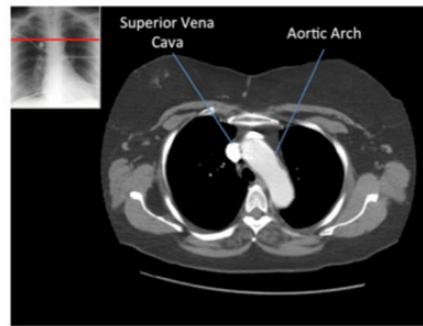


Fig 2 CT scans depicting anatomy at the level of the great vessels.

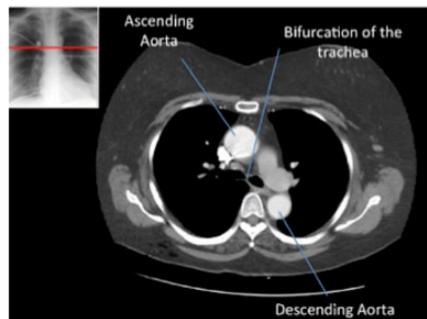
Aortic Arch Region



Located within this region are:

- Superior Vena Cava
- Aortic Arch

Carina and Pulmonary Vessel Region



Located within this region are the:

- Ascending and Descending Aorta
- Bifurcation of the trachea
- Aortic Arch
- Pulmonary Arteries
- Pulmonary Trunk

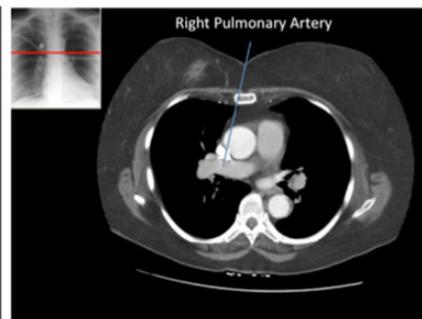
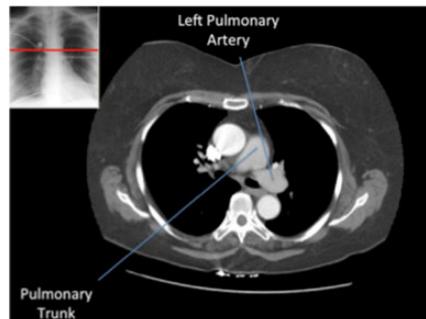


Fig 3 CT scans depicting anatomy at the levels of the aortic arch and carina.

Suggested approach for CT chest interpretation:

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

Summary

This article is an introduction to some of the thoracic anatomy that can be reliably identified with modern multi-detector spiral CT scanners. Familiarity with normal anatomy and an

understanding of the clinical setting allow the attending clinician to begin to interpret these images with the guidance and support from an experienced thoracic radiologist. The **second article** in this series will examine pathology that may be identified in the anatomic locations reviewed in a systematic examination.

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Declaration of interest

None declared.

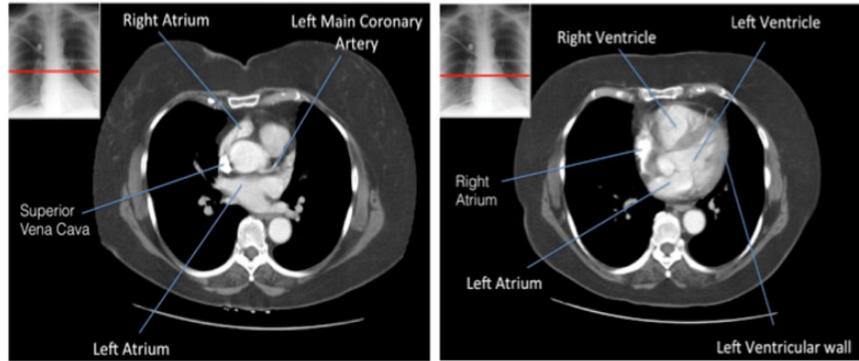
MCQs

The associated MCQs (to support CME/CPD activity) can be accessed at www.access.oxfordjournals.org by subscribers to BJA Education.

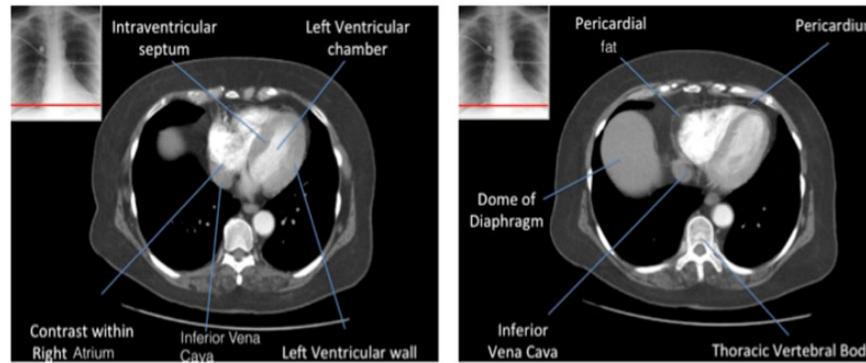
Atria Region

Located within this region are the

- Atria
- Coronary Arteries
- The superficial aspects of the Ventricles



Ventricular Region



Located within this region are the

- Ventricles
- Interventricular Septum
- Pericardium
- Pericardial Sac
- Dome of Diaphragm

Fig 4 CT scans depicting the anatomy at the level of the atria and ventricles.

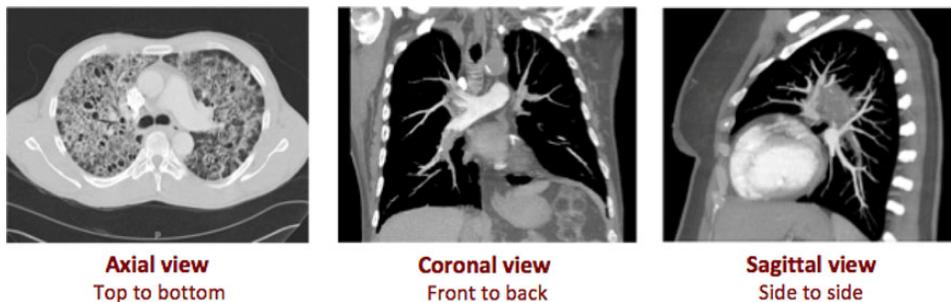


Fig 5 The possible anatomical orientation of the image 'slices'.

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