**Radiology for the Non-Radiologist**

**Thoracic CT for the Intensivist**

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**ABSTRACT**

**Objective:** To discuss the recent advances in computed tomography (CT) and to present a simplified approach to CT of the chest to facilitate the understanding and diagnosis of common acute thoracic abnormalities in the critically ill patient.

**Data sources:** Published articles and texts on thoracic disorders and CT diagnosis.

**Summary of review:** In the acutely ill patient with complex pulmonary and cardiac disorders, a thoracic CT can be useful in determining the cardiac, pulmonary, pleural and mediastinal abnormalities present.

With an understanding of the position and appearance of normal intrathoracic structures (and artifacts) acute thoracic disorders can be easily assessed by the non-radiologist, facilitating the correct diagnosis and the appropriate management.

**Conclusions:** Thoracic CT offers the intensive care specialist the option of evaluating the pulmonary system, pleura, mediastinum, heart, pericardium, and aorta where plain radiographs are often inadequate. New mobile CT technology offers CT to patients confined to the intensive care unit due to haemodynamic instability. ([Critical Care and Resuscitation 2001; 3: 250-258](#))

**Key words:** Computed tomography, intrathoracic lesions, acute pulmonary interstitial diseases

Recent advances in computed tomography (CT) have dramatically changed the practice of medicine. With more resources allocated to intensive care units, the utilisation of complex imaging techniques in this area is increasing. New developments in CT have occurred that have facilitated the ability of the clinician to diagnose many disorders, although there are important limitations.

The break through in CT technology occurred with the invention of the slip ring gantry. This enabled the scanner tube to rotate constantly, which, when coordinated with table motion, enabled volumetric data sets to be acquired. This also enabled scans to be rapid and not require separate breath-holds for each image. Today the image can be as fine as 0.5mm with almost instantaneous reconstruction.

The most recent advance in computed tomography is the “sandwiching” of several scanners into a single scanner. This is known as multislice CT. Most of the newest scanners incorporate four slices. This enables large amounts of data acquisition per unit time, thereby increasing scan speed. Speed of data acquisition is of critical importance when patients are unable to suspend respiration (which often occurs in the critically ill patient), or to track the contrast bolus within the arterial phase when CT angiography is performed. The differences in the various scanner types are listed in table 1.

**High resolution thin section CT**

There is a common misconception that “high resolution” equates to better image quality. In CT parlance, high resolution refers to a specific processing algorithm and slice thickness which is commonly applied in chest CT. Slice thickness for high resolution equates to a 1 - 2 mm slice thickness, depending on the scanner make. The critical factor, however, is the way the acquired data is manipulated by the computer. There are several filters and edge enhancements, which can...
modify the image to optimise spatial resolution or contrast resolution.

Table 1. Characteristics of different scanner types

<table>
<thead>
<tr>
<th>Scanner type</th>
<th>Images/tube revolution</th>
<th>Breath holding</th>
<th>Data set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single slice non helical</td>
<td>1</td>
<td>Single breath hold per slice</td>
<td>2 dimensional</td>
</tr>
<tr>
<td>Single slice Helical</td>
<td>1</td>
<td>Single breath hold for multiple slices</td>
<td>2 or 3 dimensional</td>
</tr>
<tr>
<td>Multi-slice helical</td>
<td>up to 16</td>
<td>Single breath hold for multiple slices</td>
<td>2 or 3 dimensional</td>
</tr>
</tbody>
</table>

The classic high-resolution algorithm enhances edges and optimises visualisation of the lung interstitium, thus the use of high resolution CT should probably be limited to evaluation of interstitial lung disease only (e.g. interstitial fibrosis from any cause, interstitial drug reactions, lymphangitis carcinomatosis, bronchiectasis and rare entities such as alveolar proteinosis). The features that distinguish conventional chest CT with high resolution chest CT are listed in table 2.

The other important factor is that the separation of slices is usually 1 mm at 10 mm intervals. This means that 90% of the lung is not imaged and a 5 mm nodule could easily be missed. For this reason, evaluation for masses, nodules and nodes should be undertaken with conventional chest CT.

The term “thin section CT” is generically applied to any scan where the slice thickness is < 3 mm. This may be used in areas requiring small detail (e.g. in the petrous temporal bones). It does not imply a specific processing algorithm.

Three dimensional imaging

Advances in computing power in the last few years has also enabled vast amounts of data to be processed to provide 3-dimensional (3-D) rendered images in almost real time. The use of 3-D imaging is helpful in assessing structures that are in the same plane as the scan. These include discoid atelectasis in the lungs, folds of bowel and vessels. The 3-D images are also often helpful in surgical procedures allowing the surgeon to plan the extent and limits of the operation. Coronal maximum intensity projection reconstructions (MIP) also allow cross sectional imaging in any plane to aid surgical planning (Figure 1).

Figure 1. Coronal maximum intensity projection reconstructions of the chest. In this case the tumour in the right hilum and its metastases are clearly visible in relation to the superior vena cava.

Table 2. Comparison of conventional chest CT with high resolution chest CT

<table>
<thead>
<tr>
<th></th>
<th>Conventional chest CT</th>
<th>High resolution chest CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slice thickness</td>
<td>5 - 10 mm</td>
<td>0.5 - 2 mm</td>
</tr>
<tr>
<td>Slice space</td>
<td>Contiguous</td>
<td>every 10 mm</td>
</tr>
<tr>
<td>% of lung imaged</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>Processing algorithm</td>
<td>Moderate edge enhancement</td>
<td>High edge enhancement</td>
</tr>
<tr>
<td>Indications</td>
<td>General, tumour assessment</td>
<td>Interstitial lung assessment</td>
</tr>
</tbody>
</table>

Other CT technology

Mobile CT

The recent introduction of the Philips Tomoscan M scanner into Australia heralded a new era in the practice of CT in the intensive care unit. This is a “CT scanner on wheels” which enables CTs to be performed at the bedside in the intensive care unit. The main limitation to such a device has been financial due to staffing requirements. It is cumbersome to operate and requires...
at least two operators to manage (Figure 2). However, in a high volume department with sufficient staffing resources it should prove to be an important tool for the intensive care specialist and may also be useful in the operating theatre for surgical guidance.

NORMAL THORACIC ANATOMY

Pulmonary anatomy

Fissures and lobes

The recognition of fissures on the CT scan is relatively easy. Fissures are pleural planes that overlie the distal-most air spaces. Thus fissures, if scanned in perpendicular planes, will have the appearance of a thin line surrounded by areas of relative paucity of vessels or airways (Figure 3). However, the pleura is often not thickened and the thin line is not seen. In these cases the location of the fissures are implied by the plane of “avascular” lung that is observed. The horizontal fissure, in particular, usually manifests only as an avascular slice on CT, due to the horizontal scan plane. Localising the fissures facilitates localisation of lesions into the upper, lower or middle lobes.

Bronchi and pulmonary vessels

The bronchi and pulmonary arteries are branched like a tree with a dichotomous branching. Bronchi are air filled and thus black on CT. Pulmonary arteries have a density of soft tissues when seen on plain chest CT, and have a density of diluted contrast when contrast is administered. They are usually traceable to the main pulmonary arteries on sequential scans. Pulmonary veins, on the other hand, have fern like or fishbone branching, and can be traced to the left atrium, thus differentiating them from arteries.

The aorta and other major intrathoracic arteries and veins are shown in figures 4 and 5.

Heart

The anatomy of the major intrathoracic vessels are shown in figures 6 and 7. The normal anatomy of the heart is outlined in figure 8. Note the ventricular septum, left ventricular thickness, pulmonary artery size and pericardial thickness.
Atelectasis and consolidations are probably the commonest manifestations of lung pathology in the intensive care unit. Their appearance on CT are nonspecific (Figures 9, 10 and 11). Similar to plain chest radiography, atelectasis results in volume loss and shift of structures; consolidation, on the other hand, does not result in volume loss. In reality, however both disorders often coexist. Both result in increased density of lung parenchyma, and both can produce air bronchograms, though this is commoner in consolidation. The role of CT is primarily to detect lesions undetectable on chest X-ray (e.g. anterior pneumothoraces, loculated pleural effusions, malpositioned appliances and incidental lesions).
Pulmonary embolism

Spiral CT pulmonary angiography (CTPA) is rapidly gaining acceptance as a valid test for detecting pulmonary emboli (Figures 12 and 13). In most series, the sensitivity and specificities are comparable or better than VQ scanning. The other advantage of computed tomography is its ability to detect other unsuspected pathology. Some authors even advocate replacing the VQ scan with spiral CTPA, in the diagnosis of pulmonary embolism.

There are few firm answers, but most authors will agree that CTPA is nearly 100% specific and sensitive for pulmonary emboli in the main pulmonary arteries and close to 90% for pulmonary emboli in the segmental pulmonary arteries. Furthermore, the sensitivities of CTPA for subsegmental and smaller pulmonary arteries are at least as good as VQ scans.

For patients with severe renal impairment or contrast allergy, VQ scanning is clearly the test of choice. The utility of CTPA specifically in the intensive care unit patient however remains to be tested.

Pulmonary hypertension

Acute elevation of pulmonary arterial pressure results in acute engorgement of the pulmonary artery. Thus, in cases of acute pulmonary embolus, dilatation of the pulmonary trunk (which is normally of similar calibre to the aorta) suggests a haemodynamically significant embolus.

In chronic pulmonary hypertension, prominent
central pulmonary vessels are present but there is early “pruning” of the pulmonary artery branches, resulting in paucity of lung markings peripherally. The lung parenchyma should also be assessed to determine if there are changes of chronic obstructive pulmonary disease, fibrosis or emphysema which may point to a diagnosis of cor pulmonale (Figures 14 and 15).

**Figure 14.** A chest CT of a patient with idiopathic pulmonary hypertension. Note right atrial and right ventricular dilatation and prominent central pulmonary vessels.

**Figure 15.** A chest CT from the patient in figure 14, with dilatation of central pulmonary arteries. Note that the pulmonary trunk (PA) is larger than the ascending aorta (A).

**Mediastinal adenopathy or masses**

Adenopathy in the intensive care unit patient presents a diagnostic dilemma as to whether the nodes are reactive (i.e. to inflammation) or due to primary pathology (e.g. lymphoma). In most cases, the clinical history, comparison images or concurrent chest CT findings will contribute to making the correct diagnosis (e.g. presence of axillary adenopathy, ipsilateral lung infiltrates, etc).

**Acute respiratory distress syndrome**

ARDS is a clinical diagnosis. The CT findings of ARDS are extensive ground glass opacity and consolidation, which may be symmetric or asymmetric, in addition to the manifestations of the cause of ARDS for example due to pneumococcal pneumonia. There is much variability in the prevalence of pleural effusions, air bronchograms, pneumatoceles and Kerley B lines. There is some interest in the use of CT in predicting the prognosis of ARDS, although the value of this is unproven. However, chest CT is quite non-specific in diagnosis of the causes of ARDS in most cases.

**Figure 16.** A chest CT of a patient with ARDS. Note the extensive areas of consolidation which are predominantly found in the posterior portions of both lungs.

**Empyema, loculated effusions and pneumothoraces**

The diagnosis and characterisation of pleural effusion or pneumothorax can be difficult in the intensive care unit patient who, a) cannot be positioned for satisfactory lateral chest X-ray or lateral decubitus films or, b) has markedly distorted normal anatomy due either to surgery of congenital deformity (e.g. scoliosis see Figure 17). The diagnosis of loculated collections may have a major impact on the management of these patients as multiple chest drains or video assisted thoracoscopy may be required (Figure 18). In the intensive care unit setting, the diagnosis of empyema with ultrasound has been advocated.

**CARDIAC PATHOLOGY**

Patients with severe cardiac dysfunction are often admitted to the intensive care unit. The rapid CT scanners currently available are increasingly used to demonstrate cardiac pathology. The hallmarks of cardiac failure seen on CT are the same as those seen with chest
X-ray (e.g. cardiac chamber dilatation, pulmonary vascular engorgement, pleural effusion and interstitial pulmonary oedema).

Figure 17. A scout image from a chest CT scan showing complex appearance on frontal x-rays.

Figure 18. An axial CT scan shows satisfactory position of chest drain in the large left pneumothorax, with left lung collapse with mediastinal shift to the left and areas of saccular bronchiectasis bilaterally.

Cardiomyopathy

A chest CT can demonstrate the presence of enlarged cardiac chambers and dilated vessels (Figures 19 and 20). Thinning of the cardiac wall and ventricular aneurysms can also be detected. The CT diagnosis of cardiac pathology can be made using the same principles utilised for evaluating plain chest X-rays.

Cardiac masses

Primary cardiac neoplasms are rare and difficult to diagnose, but can often be characterised by their echocardiographic, CT and MRI characteristics.11,12 Atrial myxomas are the commonest primary cardiac neoplasm accounting for over 50% of cardiac neoplasms.13 They have a predilection for the left atrial septum, specifically from the fossa ovalis.

Pericardial effusion

The normal pericardium on CT imaging is of “pencil line” thickness. A pericardial effusion is easily recognised from a chest CT (Figures 21 and 22). A large
effusion may cause pericardial tamponade. Late stages of tamponade can result in equalisation of the heart chamber sizes (i.e. the ventricles and atria become similar in size). A large effusion may also lead to compressive cardiac effects.\textsuperscript{14} Although azygos vein reflux has been reported as a useful sign of pericardial tamponade,\textsuperscript{15} azygos vein reflux and reflux of contrast into the hepatic veins can occur in any disorder associated with an elevated right heart pressure. Nevertheless, chest CT may be the initial diagnostic modality demonstrating tamponade in cases of chest trauma.\textsuperscript{16}

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{figure21.png}
\caption{A chest CT demonstrating a small pericardial effusion (arrowheads).}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{figure22.png}
\caption{A chest CT demonstrating a massive pericardial effusion (P) due to lymphoma.}
\end{figure}

\textbf{Pericardial masses}

Pericardial masses and metastases are rare, usually arising from direct invasion by lung cancer, lymphoma or metastasis, especially from melanoma.\textsuperscript{17}

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{figure23.png}
\caption{A chest CT demonstrating an aortic dissection (Stanford type A) involving the aortic arch (arrowheads).}
\end{figure}

\textbf{Aortic dissection}

Chest CT or MRI are the tests of choice for excluding an aortic dissection in the hypertensive patient who has tearing chest pain and in the absence of ECG abnormality.\textsuperscript{18} In Australia, due to the poor access to MRI, chest CT is the usual modality of choice (Figures 23 and 24). The main role of imaging is to exclude dissection and, if diagnosed, to determine if the dissection involves the aortic arch (which determines if the patient is to be managed surgically or not). On chest CT the intimal flap manifests as a thin membrane of tissue separating the true from the false lumen. The false or true lumen may be thrombosed and thus reliance on the presence of contrast on either side of the membrane may yield false negative results.\textsuperscript{19} Aortic rupture will be discussed in the later article on abdominal CT.

CT is an invaluable tool in diagnosis of unsuspected pathology in the intensive care unit patient. In addition to assessment of pulmonary pathology, thoracic CT offers evaluation of the heart, pericardium, pleura mediastinum and chest wall. The advent of mobile CT has the potential to result in a dramatic change in the daily management of critically ill patients.