Introduction
The chest x-ray is a valuable tool in the diagnosis of respiratory and cardiac disorders. It also enjoys widespread use in emergency medicine and can detect systemic diseases such as metabolic bone disease and pulmonary metastases. The key to reading a chest film is to take a systematic approach. In this second instalment of the Back to Basics series, a methodical approach to the chest film, as well as some common disorders presenting with lesions identifiable on the chest x-ray, will be discussed.

The reader should note that the aim of this article is neither to present a comprehensive listing of all possible chest radiograph abnormalities nor to discuss the etiologies of these abnormalities. However, a great variety of subtle and obvious abnormalities, which may represent an underlying disease process, are identifiable using a systematic method as described below.

Background Information
X-rays are high-energy photons that penetrate matter to an extent that depends generally on the density of the substance. Gases are least dense. Soft tissues including all solid organs are of intermediate density, while bones and other calcium-containing structures are the most dense. Plain x-ray films are produced by passing x-rays through the body and onto a film. There is an intervening cassette which converts the x-ray energy into light; the light so produced creates an image on the film. Intervening matter attenuates the x-rays to a variable extent, with the result that areas of the film underlying dense structures are exposed to a lesser degree than areas of the film underlying less dense structures. On the developed film, there are four basic densities recognized:

- Gas appears black.
- Fat appears dark grey.
- Water appears light grey.
- Bone appears white.

Hence, an x-ray film really displays a pattern of shadows created by structures in the body lying within the path of the x-rays. Figures 1a and 1b depict normal postero-anterior (PA) and lateral chest x-rays (see below for a discussion of these terms). The borders of a structure will be visualized on an x-ray film only if the radiographic density of the structure is different than that of tissues immediately adjacent to it. Therefore, certain structures are expected to be visible (Figures 1c and 1d contain PA and lateral chest x-rays with the chambers of the heart labelled). For example, the left and right heart borders should be seen on a chest radiograph because the heart, which is water density, is bordered by the lungs, which are gas density. If the heart border is not visible, this suggests that there is a water-density disease process occurring in the lung tissues immediately adjacent to it. On the other hand, if there is an abnormal density overlying the heart border but the heart border can still be seen distinctly through the density, the disease process is not immediately adjacent to the heart itself. This loss of visualization of an expected structure is known as the silhouette sign. It is important for two reasons. First, it implies the presence of a disease process. Second, it can provide three-dimensional information about a two-dimensional image. For example, both the right middle lobe and right lower lobe project to the right of the right heart border. However, the middle lobe actually touches the part of the heart that forms this border, while the lower lobe is situated more posteriorly. Therefore, if one sees an abnormal opacity beside the heart in the right lung base and the heart border is not visible, then the opacity is in the middle lobe. If the heart border is...
still visible, the abnormality is likely in the lower lobe. Figure 2 demonstrates the silhouette sign in a patient with pneumonia and the disappearance of this sign upon successful treatment of the disease.

Postero-anterior (PA) and lateral chest radiographs are the basic standard projections. Other accessory views include an apical lordotic projection, which is useful for small pulmonary lesions in the lung apex that may be obscured by the bony thorax on the PA view. Oblique views are useful for pleural or chest wall lesions. Moreover, the lateral decubitus position (with the patient lying on the affected side and using a horizontal x-ray beam for the PA projection) is a useful technique for detecting small pleural effusions and confirming the gravitational mobility of larger collections.

The following order is suggested in studying chest films. It ensures that no abnormalities will be overlooked. Any order may be used, but one should use the same pattern consistently in order to examine all the structures on every chest film.

**Step 1. Scan the Patient Data and Determine the Film Quality.**

In approaching a chest x-ray, the first piece of information to note is the “L” (left) marker that signifies the patient’s left side to ensure the correct view of the film. The most apparent feature that may suggest a reversed film is the cardiac configuration. An inappropriate cardiac configuration may indicate dex-
trococardiac; however, it is more commonly due to human error. The patient’s name is an obvious detail that should be verified before proceeding with the interpretation of the film. The ethnic background of the patient may be deduced from the name, which may hint at a disease process that is more prevalent within that ethnic group. Other written data that may be useful include patient’s age or date of birth and possibly the hospital ward or department that ordered the film.

A number of technical factors should be considered before attempting to interpret any chest radiograph, and they include exposure, inspiration, position, and miscellaneous factors. These features constitute the quality of the film, which is a crucial component in chest radiology.

- Exposure. In a correctly exposed film, the degree of penetration should be such that the lower thoracic disc spaces can be clearly seen through the cardiac silhouette. In an underpenetrated film, the intervertebral spaces are not visible through the heart shadow. On the other hand, an overexposed film will be too dark to discern lung vessels.

- Inspiration. Routine chest films are taken while the patient is holding the breath on full inspiration. The dome of the right hemidiaphragm should project over a level between the anterior fifth rib and sixth intercostal space.

- Position. The patient should be positioned such that the coronal plane of the thorax is parallel to the film and at right angles to the X-ray beam. In this position, the spinous processes should project midway between the medial heads of the clavicles. The bony thorax should be the focus when looking for rotation since other midline structures such as the trachea can be shifted in disease. Even slight rotation is undesirable in a chest film because the cardiac and mediastinal shadows will appear distorted.

The lordotic position is employed to look at the apices of the lungs. The patient leans back such that the medial end of the first rib anteriorly projects above the lung apex as opposed to

Figure 2a. PA chest radiograph demonstrating the silhouette sign. In this case, the right heart border is obscured by pneumonia in the right lung. The diseased lung and adjacent heart are of similar density and are therefore indistinct.

Figure 2b. Lateral chest radiograph of the same patient as in Figure 2a.

Figure 2c. PA chest radiograph of the same patient as in Figure 2a after successful treatment of the pneumonia. The right heart border is now distinct.
Step 2. Examine the Chest Wall.
The radiological assessment of the thoracic cage and its associated soft tissues is an integral part of chest radiology. Radiological changes in the chest wall may be due to a pulmonary disease process. However, they may also represent primary lesions of the bones or soft tissues that may be missed if not looked for specifically.

Vertebral column. When viewing both postero-anterior (PA) and lateral films, the vertebral column should be carefully examined. Each vertebra should be inspected in terms of its body, pedicles, spinous and transverse processes, as well as disc spaces. On lateral projections, the vertebral bodies should get progressively blacker from top to bottom. Spinal deformities such as kyphosis, lordosis, and scoliosis may distort the contours of the chest and can be readily recognized on both views. Other radiological changes in the vertebral column include bony erosions and invasions by intrathoracic tumours.

Ribs. The general shape, direction, symmetry, and spacing of the ribs should be noted. The ribs are roughly parallel with the posterior halves horizontal or slightly downward and the anterior ends curving downwards and inwards. Each rib should be examined individually in its entirety. A number of different disease processes may involve the ribs. Congenital abnormalities such as cervical ribs or absent ribs are not uncommon. Diseases of the bone can involve the ribs, including tumours or metastases. Rib fractures due to trauma or stress may also be evident. Rib destruction is a radiological sign of bony involvement by an adjacent intrathoracic lesion, most likely a peripheral lung carcinoma.

Clavicles and proximal humeri. Due to their unique curved shape, the shadows of the two clavicles will appear symmetrical on the radiographs only if there is no rotation of the chest. Irregular erosion can sometimes be seen on the inferior aspect of the medial end of the clavicle. This is a normal anatomical appearance called the rhomboid fossa. Abnormalities of the proximal humerus may also be evident on a chest film.

Skin and subcutaneous tissues. Lesions of the skin and subcutaneous tissues that may be recognized include neurofibromata, warts, and subcutaneous emphysema.

Breasts. The presence or absence of breasts should be noted. The shadows cast by female breasts are variable in size and shape. They may be asymmetrical. Nipples may cast rounded shadows that may mimic a pulmonary nodule. Mastectomy usually produces characteristic radiological changes that are often missed.

Soft tissues. The amount of soft tissue present should be inspected to determine if patient is cachectic. Muscles occasionally cast shadows on PA films and these include the sternomastoid and the pectoralis major. Soft tissue shadows...
known as companion shadows run closely to parts of the bony thorax and are sometimes present as well. In addition, soft tissue masses may also be evident and should be noted.

**Step 3. Examine the Abdomen.**

In the abdomen, organ masses and great vessels may or may not be visible depending on the presence of fat surrounding them. The amount of abdomen visible on a chest film is variable. The size of the liver and spleen may be assessed in some cases. Other radiological findings that may be observed include distension of the gastro-intestinal tract, free air under the diaphragm possibly indicating visceral rupture, collections of multiple small gas luencies suggestive of an abscess, abnormal calcifications, or surgical clips.

**Step 4. Examine the Diaphragm.**

The diaphragm is a powerful muscle of respiration that consists of a thin muscular sheet. It is attached to the xiphoid, lower six costal cartilages, ribs, and upper lumbar vertebrae. Although the diaphragm functions as a single muscle, it is customary to consider a right and a left leaf. On a PA film, each hemidiaphragm is usually smooth and is horizontal medially with gradual inferior sloping laterally. The point of maximal curvature is normally in the middle third of each hemidiaphragm. Only the upper surface of the diaphragm is visualized on the PA film since the underside of the diaphragm blends into the radiopacity of the upper abdominal viscera. The diaphragm may become visible if there is free air in the peritoneal space separating the diaphragm from other abdominal structures. The point where the diaphragm meets the chest wall laterally on a PA film and posteriorly on a lateral film constitutes a sharp acute angle referred to as the lateral and posterior costophrenic angles, respectively.

The smooth convexity of the diaphragm may appear “bumpy” or “scalloped” in some normal individuals (Figure 4); however, a prominent bulge forming acute angles with the hemidiaphragm usually suggests disease and warrants further investigation. The height of the diaphragm varies considerably with respiration. On full inspiration, the diaphragm is usually seen at the level of the tenth posterior intercostal space or the sixth rib anteriorly. The right hemidiaphragm is normally approximately 2 cm higher than the left hemidiaphragm. Deviation from this position may be due to normal variation but other clues suggestive of pathology should be sought.

Elevation of the diaphragm may be due to a number of conditions including lobar atelectasis, phrenic paralysis, subphrenic infection, and lung diseases associated with volume loss, including pulmonary infarction. Table 1 lists some of the causes of elevation of the diaphragm as seen at radiography and they are divided into bilateral versus unilateral elevation.

**Table 1**

<table>
<thead>
<tr>
<th>Causes of Diaphragmatic Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral Elevation</td>
</tr>
<tr>
<td>Infancy</td>
</tr>
<tr>
<td>Expiration or incomplete inspiration</td>
</tr>
<tr>
<td>Supine radiograph</td>
</tr>
<tr>
<td>Obesity</td>
</tr>
<tr>
<td>Pregnancy</td>
</tr>
<tr>
<td>Ascites</td>
</tr>
<tr>
<td>Large abdominal mass</td>
</tr>
<tr>
<td>Intestinal distension</td>
</tr>
<tr>
<td>Bilateral intrathoracic or subphrenic infection</td>
</tr>
</tbody>
</table>

**Step 5. Examine the Pleura.**

The pleura are thin layers of tissue that envelop each of the pulmonary lobes, forming the fissures where two lobes lie adjacent to one another and line the inner surface of the thoracic cage. Under normal circumstances, aside from the fissures, the pleura is too thin to be seen radiographically; however, it may be visible when it is thickened by disease processes such as inflammation. The pleural space normally contains a small amount of fluid that is not visible radiographically. However, gas and abnormal amounts of fluid in the pleural space can be visualized.

When examining the pleura, the costophrenic angles should be sharp (Figure 5a). Blunting of these angles (Figure 5b) usually indicates pleural effusion or thickening. The entire perimeter of
both lungs should be scrutinized to look for focal or diffuse areas of pleural thickening. Next, the position of the pleural fissures should be determined. The left and right major fissures are usually seen on lateral view only and they run from about T4 in an antero-inferior direction to the junction of the anterior 3/4 and posterior 1/4 of the diaphragm. The right minor fissure is straight or gently curved at about the fifth rib laterally on the PA film and about midsternum on lateral view.

Pneumothorax, defined as gas in the pleural cavity, is commonly spontaneous in etiology and it is usually caused by the rupture of a sub-pleural emphysematous bleb or bulla (Figure 6). Air may also escape into the pleural space from the lung following the rupture of a lung cavity or abscess. Another route of entry of air is from the external environment following an artificial pneumothorax or penetrating wounds. Air may also reach the pleural space via the mediastinum or following the rupture of a subdiaphragmatic abscess. Radiologically, a pneumothorax is manifested as the presence of a thin white line representing the visceral pleura that has separated from the chest wall. This is usually seen in the upper hemithorax on an upright film. The underlying lung relaxes and retracts towards the hilum, leaving a clear radiolucent pleural cavity devoid of lung markings. Furthermore, a large pneumothorax may cause mediastinal shift to the normal side.

Fluid that accumulates with the pleural space may be a clear transudate, a sero fibrinous or purulent exudate, a hemorrhagic effusion, or a chylous exudate. Radiologically, they cannot be differentiated. Pleural fluid occupies the pleural cavity at the expense of the underlying lung tissues but will also displace the chest wall outward and the diaphragm inferiorly. Pleural fluid first collects under the lung as subpulmonic effusion and it is often seen on the PA film as a shift of the most convex part of the hemidiaphragm from the middle third to the junction of the middle and lateral thirds. As the amount of fluid increases, blunting of the posterior costophrenic angles can be detected followed by the lateral costophrenic angles. Subsequently, increasing fluid density is seen moving up the thorax, obscuring the diaphragm, with the height of the fluid being greatest at the periphery.

Calcification of the pleura can be seen following empyema, hemothorax, or asbestos exposure. Radiologically, irregular sheets of pleural calcification composed of amorphous plaques are observed. The pleural calcification following empyema and hemothorax is usually unilateral and there may be other signs suggestive of the cause, including pulmonary scarring and calcification (i.e., TB) or healed rib fractures. Other signs commonly associated with extensively calcified pleura include pleural thickening, marked tenting of the diaphragm, or filling of the costophrenic angles. In asbestosis, the pleural calcification is usually bilateral and consists of shallow plaques on the diaphragmatic or lower costal pleura.

**Step 6. Examine the Heart.**
The major presentations of cardiac disease on the chest film are chamber enlargement and abnormal pulmonary vasculature.
Accordingly, when examining the silhouette of the heart, the first step is usually to determine if any enlargement is present. On the PA film, the cardiothoracic ratio provides a quantitative estimate of suspected cardiac enlargement. The cardiac diameter is determined by measuring the distance from the rightmost edge of the heart to the midline, and adding that to the distance from the midline to the leftmost edge of the heart; these two line segments are usually not on the same plane. The thoracic diameter is the largest transverse diameter between the inner margins of the ribs. The cardiothoracic ratio equals the cardiac diameter divided by the thoracic diameter. A cardiothoracic ratio greater than 0.5 is a rough determinant of cardiac abnormality in adults, although it can reach 0.6 in children and in elderly patients.

Note that a widened cardiac silhouette cannot be equated with cardiomegaly. The cardiac silhouette can be widened by pericardial disease, or rarely by mediastinal disease, in addition to cardiomegaly. As well, true cardiomegaly can be present with a normal cardiothoracic ratio; for example, if the patient has emphysema and an abnormally large thoracic diameter, then the heart may be enlarged but not to a degree to reach a ratio of 50%.

Different chambers of the heart contribute to different portions of the cardiac silhouette, and consequently enlargement or dilatation of individual cardiac chambers produces characteristic changes on the PA and/or lateral chest films. Figure 7 illustrates generalized cardiomegaly with no specific chamber enlargement, and also reveals enlarged pulmonary arteries. Figures 7b through 7f demonstrate specific chamber enlargement. In general, simple chamber hypertrophy without dilatation can be difficult to detect on plain chest radiographs, since the cardiac silhouette may be of normal size.

Another point worth noting is that many common cardiac diseases do not produce visible changes on plain chest films. Examples include acute myocardial infarction, mild or early valvular disease, as well as restrictive and hypertrophic cardiomyopathy.

Left ventricular dilatation may be due to long-standing systemic hypertension with heart failure, aortic valvular disease, or dilated cardiomyopathy, three of the commonest causes of cardiac enlargement on the chest x-ray. The most striking feature is leftward expansion of the cardiac silhouette with a prominent cardiac apex. On the lateral film, the cardiac silhouette projects posteriorly more than 1.7 cm behind the inferior vena cava, 2 cm above the point of intersection of the latter with the diaphragm. This is known as the Hoffman-Riggler sign, and is very specific to left ventricular enlargement. However, it is often difficult to locate the point of intersection of the inferior vena cava with the diaphragm and it is important that the patient is not rotated. As well, if there is enlargement of the right ventricle then it can push the LV posteriorly, so before using this sign, check that the RV is not radiographically enlarged.

Left atrial enlargement may result from mitral valvular disease or ventricular septal defects. Left atrial enlargement can create what appears to be a double right heart border on the PA film, although this may rarely be seen in normal individuals. However, if the distance from the midpoint of the double density to the midpoint of the left main bronchus is greater than 7 cm, left atrial enlargement is likely. Another sign is widening of the angle of the carina, although this sign is also non-specific and is a late finding. Enlargement of the left atrial appendage straightens the left heart border and may even cause a bulge, and must not be confused with enlargement of the pulmonary outflow tract, which is immediately superior to it.

On the PA film, the appearance of right ventricular enlargement may be similar to that of left ventricular enlargement in that both cause enlargement of the cardiothoracic ratio. A distinguishing feature, however, is elevation of the cardiac apex above the left hemidiaphragm, although this is not a common finding in adults. Because early changes of right heart enlargement are difficult to detect on the PA film, the lateral film is especially important. With few exceptions, the mediastinum immediately behind the sternum is normally clear and has the density of air-filled lung. With right heart enlargement, the anterior border of the cardiac silhouette is in contact with the sternum for more than one-third of its height.

Right atrial enlargement is difficult to determine on the chest radiograph until it is very large. When evident, it appears as visibility of the right heart border over a length of at least half that of the mediastinum.

Pericardial diseases can also enlarge the cardiac silhouette. Pericardial effusions can be confused with cardiomegaly because they have a similar density to the heart on the plain film. Hence, the history and other investigations are important. The most likely indication of a pericardial effusion is rapid enlargement or a rapid decrease in the size of the cardiac silhouette. As well, the cardiac contour takes on a globular shape. Other imaging methods such as echocardiography, CT, or MRI are indicated when pericardial disease is suspected.

Direct visualization of the cardiac valves is not possible on plain chest films. However, when mechanical prosthetic valves are present, they are readily demonstrated and serve as useful landmarks. Aortic valvular calcification, which may be present in aortic stenosis, can be seen most readily on the lateral film as a radiodense halo within the cardiac silhouette. Mitral calcification, which may be present with mitral stenosis, may be visible near the left cardiac border. These calcifications must not be confused with the much more common calcification of the mitral and aortic annuli.
Figure 7a. PA chest radiograph showing cardiomegaly and enlarged pulmonary arteries. Note that the entire heart is enlarged, with no specific chamber involvement. Compare hilar vascular enlargement with hilar enlargement due to lymphadenopathy (Figure 9).

Figure 7b. PA and lateral chest radiographs illustrating right ventricular enlargement.

Figure 7c. Lateral chest radiograph showing left atrial enlargement. Note the line indicating expansion of the heart border a considerable distance posteriorly.

Figure 7d. PA chest radiograph showing left atrial enlargement. Note the distorted position of the airway as indicated by the lines.

Figure 7e. PA chest radiograph demonstrating left ventricular enlargement.

Figure 7f. Lateral chest radiograph demonstrating left ventricular enlargement.
Step 7. Examine the Mediastinum.

The mediastinum is the portion of the thoracic cavity between the lungs. Anatomically, it contains the heart; for the purposes of studying the chest x-ray, however, the heart is considered separately.

Radiologically, it is helpful to divide the mediastinum into the anterior mediastinum (heart and structures anterior to the trachea), posterior mediastinum (spine and paravertebral structures), and middle mediastinum (containing all other mediastinal structures, including the tracheobronchial tree, esophagus, and some pulmonary vessels). This classification is useful because it can be used to narrow the differential diagnosis of a mediastinal mass. Remember that it is difficult to determine which mediastinal compartment contains a lesion without examining both the PA and lateral films, but the silhouette sign can be helpful. Figures 8a (PA film) and 8b (lateral film) reveal an anterior mediastinal mass.

Mediastinal diseases result in changes in the shape and size of the mediastinum focally or as a whole. In particular, mediastinal widening on the PA film is generally indicative of a disease process in the mediastinum. However, a pulmonary mass in contact with the mediastinum can occasionally be difficult to distinguish from a true mediastinal mass. There are many causes of mediastinal masses and as mentioned above, these are best considered in terms of the compartment in which they are present. A list of the more common causes is presented in Table 2.

Vascular structures are also present in the mediastinum and may be sites of disease. A key landmark on the PA film is the aortic knob (or aortic knuckle), which appears as a small bulge on the left side of the mediastinum. The aortic knob is the arch of the aorta, and may be seen to contain a ring-shaped density in older individuals, representing calcification. The aorticopulmonary window is the portion of the mediastinum that lies between the aortic knob and the left pulmonary artery. Masses in this area are abnormal and usually represent masses in the mediastinum, most frequently lymphadenopathy.

Pneumomediastinum is a condition in which air is trapped in the mediastinum. This gas produces linear, radiolucent streaks within the otherwise radiodense mediastinum. Pneumomediastinum has many causes, including alveolar rupture and dissection of gas along bronchovascular bundles into the mediastinum. It usually occurs during mechanical ventilation, but may also occur in other instances of increased intrathoracic pressure such as coughing, sneezing, and Valsalva manoeuvres. Pneumomediastinum is usually benign and may be associated with pneumopericardium, pneumothorax, and subcutaneous emphysema.
Hilar lymphadenopathy (Figure 9) has a number of infectious, inflammatory, and neoplastic causes (see Table 3). The appearance of the nodes may give additional clues to the diagnosis. For example, dense calcification suggests a granulomatous process, while eggshell calcification, in which the nodes appear to have only a thin attenuated rim of calcium, is found in only a few diseases, such as silicosis, sarcoidosis, and histoplasmosis.

The hilar regions of each lung can be difficult to assess and therefore must be carefully examined so that lesions are not missed. There are some constant features of the hila that can be used as a framework within which lesions can be identified:

- Typically, the left hilum is 1-2 cm higher than the right; deviation usually suggests lobar collapse or lobectomy.
- The mainstem bronchi are often visible in the superior and medial portions of the hila as tubular structures of lower density than the surrounding hilar tissue.
- The superior portion of the right hilum is formed by a branch of the right superior pulmonary vein and the inferior portion is formed by the right interlobar artery, a branch of the right pulmonary artery.
- The left pulmonary artery arches over the left mainstem bronchus before bifurcating.
- Each hilum looks like a flattened V, with the apex pointing medially and located at or lateral to the cardiac silhouette. This structure is called the hilar angle. Changes in the contours of the hilar angle are suggestive of disease.

The hilum contains vascular structures, lymph nodes, and branches of the airway. The usual causes of hilar abnormalities are pulmonary vascular disease, hilar lymphadenopathy, and focal masses.

In evaluating the hila, consider the density, size, and contours of each. Marked hilar asymmetry or unilateral abnormalities usually indicate the presence of lymphadenopathy or a mass. Bilateral hilar enlargement may be due to bilateral lymphadenopathy or vascular enlargement. When lobulated, this enlargement is likely due to lymphadenopathy while it is likely to be a vascular enlargement when it is smooth.

**Table 2**

<table>
<thead>
<tr>
<th>Anterior Mediastinum</th>
<th>Middle Mediastinum</th>
<th>Posterior Mediastinum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyroid goitre/carcinoma</td>
<td>Lymphoma</td>
<td>Neural tumours</td>
</tr>
<tr>
<td>Lymphoma</td>
<td>Tuberculosis, histoplasmosis</td>
<td>Metastatic lymphadenopathy</td>
</tr>
<tr>
<td>Germ cell tumours</td>
<td>Sarcomatosis</td>
<td>Lymphoma</td>
</tr>
<tr>
<td>Thymoma</td>
<td>Hiatal hernia</td>
<td>Aortic aneurysm</td>
</tr>
<tr>
<td>Pericardial fat</td>
<td>Esophageal diseases</td>
<td></td>
</tr>
<tr>
<td>Aortic aneurysm</td>
<td>Metastatic lymphadenopathy</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9. PA chest radiograph showing bilateral hilar lymphadenopathy. Compare this radiograph with Figure 7a (bilateral hilar enlargement due to enlarged pulmonary arteries).
Step 9. Examine the Lungs.
The lungs appear dark on the chest film because most of the volume of the inflated lung is gas. The darkness of the lung fields is interrupted by the shadows of the ribs and pulmonary vasculature. The latter appear to branch repeatedly and progressively taper as they course peripherally from the hila. Since the airways are also air-filled, they do not cast shadows on the chest film except for some of the larger ones when seen end-on, in which case their walls attenuate the X-ray beams sufficiently. This is most likely to occur near the hilum.

Air Space Disease

Air space disease refers to any pathological process that results in the replacement of air in the distal air spaces (alveolar sacs and alveoli) with a water density material. These disease processes produce small (5-10 mm), fluffy, and ill-defined nodular opacities called acinar shadows. Multiple acinar shadows tend to coalesce, forming larger radiopaque regions.

Another key radiological sign of air space disease is the presence of air bronchograms, which occur when alveoli filled with a water-density substance outline air-filled bronchi. Note that air bronchograms may be absent if the disease process has involved the bronchi as well (i.e., mucus, tumour occlusion, etc.). In addition, when some of the alveoli are not involved by the disease process, air alveolograms may be seen, and appear as tiny radiolucencies amongst opacified lung tissue. Figure 10 illustrates air space disease.

A variety of substances may fill the alveoli and create air bronchograms and air alveolograms. The determination of the nature of this substance will depend on other radiographic features including location, extent, rapidity of onset and progression, and presence of other abnormalities such as cavitations, as well as the clinical history, physical examination, and further investigations. The most common causes of air space disease are presented in Table 4.

It is also useful to note whether the involvement of air spaces is focal or diffuse. Focal air space disease is commonly due to infection (pneumonia) or neoplastic diseases, while diffuse air space disease is more likely to represent congestive heart failure or adult respiratory distress syndrome. Another clue in the diagnosis of pneumonia is that the spread of the disease is confined by the lung fissures, which may be highlighted as sharp interfaces between radiolucent and radiopaque lung tissue.
Interstitial Disease

**Interstitial lung disease** is any pathologic process involving the alveolar walls rather than the alveolar air spaces. That is, the alveoli are not filled by the disease process or only minimally affected compared to the interstitium. Except in very severe cases, air bronchograms and air alveolograms are not found. Figure 11a demonstrates an interstitial disease process.

![Figure 11a](image)

**Figure 11a.** Close-up view of a PA chest radiograph demonstrating interstitial disease. Note the reticular or appearance of the lung. This patient had idiopathic pulmonary fibrosis.

Some lung diseases have both an intra-alveolar component and an interstitial component. In these instances, air bronchograms and acinar shadows are present in addition to interstitial patterns. Examples of these diseases include pulmonary edema, bronchioloalveolar carcinoma, sarcoidosis, lymphoma, and bronchiolitis obliterans with organizing pneumonia.

Atelectasis

Atelectasis is the collapse, in whole or in part, of a lung. It is
similar to air space disease in the sense that both processes produce airless alveoli. The difference between the two is that in atelectasis, the air is lost (expelled or absorbed) and not replaced by another substance. This results in a loss of lung volume.

The direct radiologic sign of atelectasis of a lobe is the displacement of lung fissures bordering that lobe (Figures 12a and 12b). When fissural displacement is not obvious, additional signs of atelectasis may be helpful but are not necessarily diagnostic. These indirect signs include:

- Increased radiopacity in the atelectatic lung tissue;
- Hilar displacement (normally the left hilum is 1-2 cm higher than the right);
- Mediastinal shift (usually the trachea with upper lobe collapse and the heart with lower lobe collapse);
- Compensatory hyperinflation (other parts of the lungs expand to take the place of the collapsed lobe, especially the lung closest to it; this is manifested as increased radiolucency and is most evident in the adjacent lobe(s) compared to the contralateral lung);
- Elevation of the ipsilateral hemidiaphragm.

The causes of atelectasis are described as obstructive, adhesive, cicatrizing, and passive. These are summarized in Table 6.

### Table 6
**Types and Causes of Atelectasis**

<table>
<thead>
<tr>
<th>Type</th>
<th>Mechanism</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstructive</td>
<td>Lesion blocks air flow to a small lung region, a lobe, or an entire lung</td>
<td>Asthmatic mucous plugs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Foreign bodies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Endobronchial tumours</td>
</tr>
<tr>
<td>Adhesive</td>
<td>Lack of resistance to collapsing forces in alveolar walls causes alveolar closure</td>
<td>Radiation pneumonitis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surfactant deficiency</td>
</tr>
<tr>
<td>Cicatrizing</td>
<td>Scarring following an inflammatory process causes contraction of lung tissue</td>
<td>Tuberculosis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pneumoconioses</td>
</tr>
<tr>
<td>Passive</td>
<td>An intrathoracic space occupying lesion causes a local reduction in negative intrathoracic pressure allowing lung elastic fibres to shorten thereby reducing the size of air spaces</td>
<td>Emphysematous bullae</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pneumothorax</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hydrothorax</td>
</tr>
</tbody>
</table>

Pulmonary Nodules or Masses
When confronted with a solitary pulmonary nodule, the main consideration is whether the lesion is benign (as in Figure 13a) or malignant (as in Figure 13b). The radiological signs of malignant and benign nodules are summarized in Table 7. A nodule is generally considered benign if it exhibits a benign calcific pattern or it exhibits no growth over a 2-year period.
Pulmonary versus Extrapulmonary Disease
Pulmonary disease refers to diseases of the lung parenchyma and airways, whereas extrapulmonary disease (for this discussion) involves structures outside the lung that cause mass effects on it. The distinction between extrapulmonary and pulmonary diseases becomes difficult in the case of a peripheral lesion. Some useful signs in determining if a peripheral lesion is inside the lung (pulmonary) or outside but bulging into the lung (extrapulmonary) are presented in Table 8. Figure 14 is an example of an extrapulmonary lesion that might initially be confused with pulmonary disease.

Table 7

<table>
<thead>
<tr>
<th>Physical Characteristics</th>
<th>Malignant</th>
<th>Benign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Margins</td>
<td>Not well-defined, spiculated (“corona radiata”)</td>
<td>Usually well-defined (but so are metastases)</td>
</tr>
<tr>
<td>Contour</td>
<td>Lobulated</td>
<td>Spherical (but so are metastases)</td>
</tr>
<tr>
<td>Calcium</td>
<td>None</td>
<td>Central nidus, lamellated, “popcorn”, diffuse</td>
</tr>
<tr>
<td>Growth Rate</td>
<td>Doubling time of 10 – 465 days</td>
<td>Doubling time &lt; 10 or &gt; 465 days</td>
</tr>
<tr>
<td>Associated Signs</td>
<td>Lymphadenopathy, bone destruction, pleural effusion</td>
<td></td>
</tr>
</tbody>
</table>

The three most important causes of a solitary pulmonary nodule are granulomas, malignant tumours, and hamartomas, in order of frequency. Lesions also included in the differential diagnosis of solitary pulmonary nodule are metastatic tumours, carcinoid and other neuroendocrine tumours, arteriovenous malformations, round atelectasis and other miscellaneous lesions.

Figure 13a. Close-up view of a chest radiograph showing a small, well-circumscribed pulmonary nodule. This mass was benign.

Figure 13b. Close-up view of a chest radiograph showing an ill-defined pulmonary nodule. This nodule was later determined to be malignant.

Figure 14. Close-up view of a PA chest radiograph showing an extrapulmonary mass impinging on the lung. The patient had an intercostal lipoma.
Conclusion
The chest x-ray is an invaluable source of information and an indispensable diagnostic tool in medicine. The careful examination of the chest radiograph constitutes an essential component in the management of a number of different diseases. In order not to miss important yet subtle findings, a consistent and organized method should be followed at every encounter. The systematic approach to the chest film presented here can serve as a guide for the novice reader to further develop and adopt his or her own style.

Acknowledgement
The authors would like to thank Drs. Naem Merchant and Leon Zelovitsky for reviewing the cardiac section of this manuscript.

References

<table>
<thead>
<tr>
<th>Table 8</th>
<th>Pulmonary versus Extrapulmonary Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signs</td>
<td>Pulmonary</td>
</tr>
<tr>
<td>Angle between lesion and chest wall</td>
<td>Acute</td>
</tr>
<tr>
<td>Homogeneity of density</td>
<td>May have air bronchograms</td>
</tr>
<tr>
<td>Border with air-containing lung</td>
<td>Well or ill-defined</td>
</tr>
</tbody>
</table>

volume 77, number 2, March 2000 153