A method for reading plain chest X-rays

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Dr teWaterNaude is a Public Health Medicine specialist, and has for the past 12 years been involved in reading standard plain frontal chest radiographs (chest X-rays or CXRs), primarily for compensation purposes. He is a member of The South African Society of Occupational Medicine (SASOM).

INTRODUCTION

Chest X-rays (CXRs) are an important investigation in lung disease. Many occupational lung diseases can be diagnosed by chest radiography which is routinely used in occupational medical surveillance and screening. We are often faced with the task of reading a CXR that may be normal, has a plethora of abnormalities, or an abnormality which is easy to spot but we then forget to read the rest of the image. It helps to have a systematic approach such as the one presented here, which allows a comprehensive reading of the subject's image. The putative advantage of the method presented here is that the areas read are both alphabetical and contiguous. There are many similar systems[1] and radiologists suggest that we find a system that works for us, and use it consistently.[2]

The CXR compliments the medical examination; it is not a substitute. It is important to keep in mind that it is a two dimensional snapshot of the chest, where the multiple structures visualised are flattened into a single representation. More information is gained by requesting a lateral view, or requesting a computed tomography (CT) scan of the chest, which is a three dimensional view. Although this involves higher costs and radiation, CT scans can be invaluable in providing more definitive information as to the nature of an abnormality found on a CXR. The value of comparing the current CXR with previous films cannot be over-emphasised.

A FEW INITIAL CONCEPTS

Positioning

In a postero-anterior (PA) CXR, the X-rays penetrate from the back of the patient to the image capture plate in the front. PA CXRs facilitate moving the scapulae off the lung fields, and the heart is captured close to the actual size as the heart is an anterior structure.

Radiographic densities

Five radiographic densities are described in Table 1, in descending order of density.

STANDARDS OF QUALITY

Chest radiographs are acquired according to international standards.[3] For occupational medicine purposes, the reading guidelines set by bodies such as the International Labour Organization (ILO) and the National Institute for Occupational Safety and Health (NIOSH), are excellent benchmarks. They have both published standards for the reading of CXRs.[4,5]

One first reads for quality and then reads the image itself. Prior to this, however, one needs to ensure that the reading environment is suitable. The reading room should be evenly lit with low ambient light, no direct sunlight, no glare, with clean viewing surfaces, and be clean, quiet and free from distractions.[4] One should be able to appreciate subtle density differences on the images one is viewing. Digital images need to be viewed on a medical grade monitor, where the pixel pitch (the dark space between individual pixels) is less than 0.2 mm. As to the eye-to-image distance, for analogue one can read as close as 25 cm from the lightbox, but 40-60 cm is favoured by many. With digital images, similar guidelines apply, except that the image should be at least two thirds the full size, whether it is viewed on the screen or as a printed copy.

ASSESSING IMAGE QUALITY

The image must be clearly labelled with the subject's name, the date that the image was acquired, and a marker for left or right. An adequate inspiration allows one to count six or seven anterior ribs and/or nine to ten posterior ribs above the diaphragm. It is easier to count on the right side.

To assess positioning, check whether the thoracic spinous processes (Vs) are centrally aligned and are equidistant from the medial ends of the clavicles. The spinous processes are posterior, the medial ends of the clavicles are anterior, and this makes it easy to see if there is rotation or poor positioning. If there is significant rotation, the lung densities may appear dissimilar and the cardiac silhouette abnormal. The scapulae should be entirely excluded from the thoracic cage which should also not be cut off at the top (apices), the bottom (costophrenic angles), or on either side.

On a well-exposed image, detailed pulmonary vessels and spine are seen behind the heart, with the intervertebral discs just visible. If the image is under-penetrated one will not be able to see the thoracic vertebrae.

The most common quality errors to look for are over- or under-exposure,

Table 1. Radiographic densities

	Density	Comments
5	Metal	Usually absorbs all X-rays and appears the densest, e.g. barium, foreign bodies
4	Calcium	The naturally most dense occurring material, e.g. bones with calcium and phosphate (absorbs most X-rays)
3	Liquid/tissue	Both fluid (e.g. blood) and soft tissue (e.g. muscle) have same densities on plain radiographs e.g. muscles. Heart muscle and blood in the heart are indistinguishable as they have the same density
2	Fat	Grey, somewhat more lucent than soft tissue
1	Gas	Absorbs the least radiation and appears the least dense, e.g. trachea, lungs, and the stomach or intestine, where these contain air

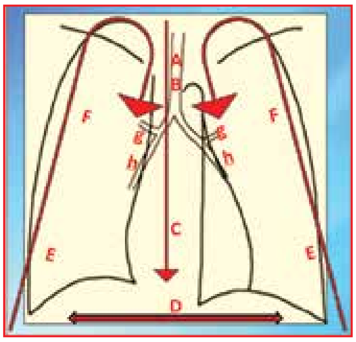
under-inspiration, rotation in any axis, cut-off areas such as the apices and costophrenic angles, scapulae overlying the lungs, slightly unfocused images (possibly due to movement), and artefacts (opacities that are not part of the intended image). The advent of digital chest imaging has reduced, but not eliminated, such quality errors.

MAKING SPECIFIC FINDINGS

One has to examine each area. One does not merely see the important findings without looking specifically at that area.

An obvious abnormality on CXR carries a caveat – do not give in to 'search satisfaction'. This is because an obvious abnormality may not be the most important. Note it and continue with a systematic check of the rest of the image.

The method for reading progresses alphabetically and traces contiguous areas, as indicated Figure 1.



A = Airways
B = Bone
C = Cardiac
D = Diaphragms
E = Effusions and edges
F = Fields and forget-me-nots
g = Great vessels
h = Hila

Figure 1. A diagrammatical representation of the order of reading, following the alphabet and contiguous areas
(Source: Jim teWaterNaude)

One is looking for the usual patterns when one examines each area, for structures or areas that are different from what one would expect, or four Bs: bigger, bolder, budged (displaced), or bilaterally dissimilar.

Airway

Check that the trachea is in the midline, and that the inside walls are parallel all the way down to the carina where the bifurcation angle averages 70-80 degrees, but has a wide range, with >90 degrees deserving attention. Note that, as the trachea is followed downwards, it might slope slightly towards the right. (Outside of the emergency setting, two of the more common causes of tracheal displacement are an enlarged thyroid and unfolding of the aortic arch, which may occur in the elderly or in hypertension.)

Bones

Check the bones for broad symmetry and abnormalities, checking the clavicles, the ribs and spine first, followed by the scapulae and shoulder area. Look for fractures, osteoporosis, missing ribs, densities and lucencies.

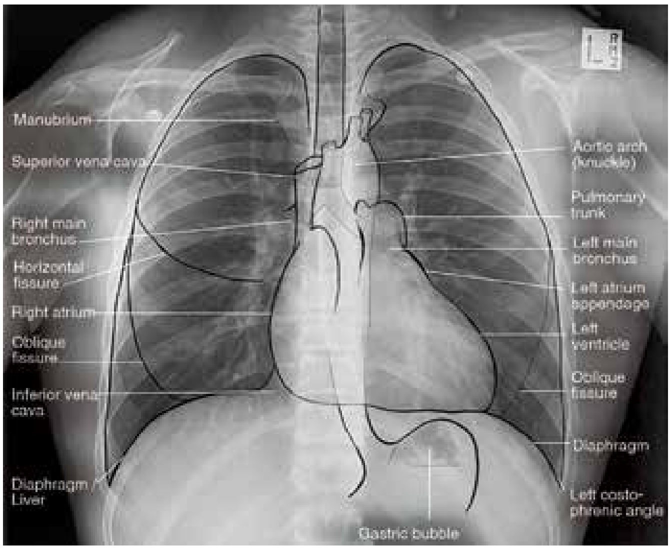


Figure 2. A normal frontal chest radiograph, with the main structures sketched and annotated. Note that, of the fissures, only the horizontal fissure and the lower end of the oblique fissure on the right might be seen on a normal CXR
(Source: http://www.ivline.org/2012/06/quick-guide-to-chest-X-rays.html)

Cardiac

The heart has a teardrop-like shape with one-third on the right, and two-thirds to the left, of the midline. The transverse diameter of the heart (the distance between vertical lines abutting the outermost margins of the right and left borders) should be less than half the transverse diameter of the chest, being the widest horizontal line between the inside edges of the rib margins. The left and right borders are uninterrupted.

The right heart border is formed by the right atrium, and the left border by the left atrial appendage and the left ventricle. Cardiac margins are sharp because there is a contrast between the fluid-density of the heart and the contiguous air-density of the lung. One cannot visualise the partition of the ventricles because there is no contrast between them, both being of fluid-density. If the adjacent lung is devoid of air, the clarity of the silhouette will be lost. This silhouette sign is extremely useful in localising lung lesions, as indicated in Table 2.

Having searched vertically and centrally, the next steps are to trace the structures laterally.

Diaphragm

Each hemidiaphragm is dome shaped, with the right being slightly higher by 1.5-3 cm (in approximately 5% of people, the left hemidiaphragm may be slightly higher than the right, as a normal variant). The outlines of each are smooth, with the highest part being in the middle of the lung field, sloping down laterally to the costophrenic angles which should be sharp and bilaterally similar.

Table 2. Lesion location using the silhouette sign

Structure obscured on the right	Structure obscured on the left
	Aortic knuckle – left upper lobe
Ascending aorta – right upper lobe	Descending aorta – left upper or lower lobe
Right heart border – right middle lobe	Left heart border – lingula segment
Right hemidiaphragm – right lower lobe	Left hemidiaphragm – left lower lobe

Check for bolder densities or lucencies along the outlines, flattening of the domes, blunting of the angles, and loss of clarity of the outlines.

The search then continues upwards along the inner margin of the lateral edge of the ribs.

Edges and effusions

Effusions fill up the costophrenic angles if there is about 300 ml of free fluid in the pleural space. They are visible in the posterior costophrenic sulcus on a lateral chest radiograph, with as little as 75 ml fluid. Effusions may be small and subtle, where they are recognised by blunting, by displacement (budging) of the highest part of the apparent hemidiaphragm laterally, and by bilateral dissimilarities. Larger and more obvious effusions have concave medial margins.

The inner lateral edges of the ribcage are examined in turn, tracing each side up to the apex and midline, looking at the overlapping ribs and the most peripheral 2 cm inside the ribs. The pleurae are not normally visible. One is looking for plaque-like pleural densities, normal fat lines running parallel and inside the rib margins, lucencies as in pneumothoraces, short thin lines abutting and perpendicular to the pleural surface, and any unusual peripheral opacities.

Fields and forget-me-nots

Each lung field is examined in turn. Normal broncho-vascular markings should taper from each hilum and be almost invisible at the lung periphery. The areas to examine systematically are the apices, behind the clavicles, below the clavicles, and the bottom half of each visible lung. One looks for asymmetry, infiltrates (interstitial or alveolar), masses, nodules, homogenous or non-homogenous areas of opacification, air bronchograms, and bronchial cuffing. The minor and major fissures may be visible in the presence of pleural thickening or fluid. There may also be diffuse patterns in the lung field, essentially dots, lines or nets, and these should be described.

The forget-me-nots, or so-called review areas, are the apices, behind the clavicles, behind the heart, and below the diaphragms. In the ABC system, this is where one can describe foreign bodies which can be outside the body, e.g. buttons, hair and jewellery, or inside, e.g. clips, drains, ECG leads, lines, pacemakers, tubes and valves.

Having done a full circuit of the radiograph, one returns to the top and examines two more areas.

Great vessels and environs

The great vessels are contained in the area below the thoracic inlet and above the ventricles. They are the ascending aorta, the aortic arch (the three major branches that arise from the arch are not normally visible), the descending aorta, and the superior vena cava. The brachiocephalic veins are not normally visible. The azygos vein may be seen as an ovoid density, adjacent to the concavity formed by the upper margin of the right main bronchus at the tracheal bifurcation. With hypertension, the aortic knuckle may become prominent and extend more than 4.5 cm laterally of the left tracheal border. Widening of the upper mediastinum (wider than the vertebrae) and changes to the right paratracheal stripe (loss of continuity, increase in thickness, or distortion) are almost always signs of abnormal pathology. Normally, the right paratracheal stripe extends from the clavicle to the right tracheobronchial angle and is 2-3 mm wide. Below the aortic arch and above the pulmonary artery on the left, is the aorto-pulmonary window which is usually concave. If it is not concave, consider a possible pathology, especially involving lymph nodes.

Hila

The hilum is the portal of entry and exit to the lung and includes bronchi, pulmonary arteries, pulmonary veins and lymph nodes. On the frontal view, most of the hilar shadows represent the left and right pulmonary arteries. The right hilum is lower than the left in contrast to the normal right hemidiaphragm being higher than the left.

Reminder: the hila can be bigger, budged (displaced) up or down, bolder or bilaterally dissimilar.

Increases in size may be caused by masses, lymphadenopathy, or pulmonary hypertension. The last may cause enlarged pulmonary trunks (more than 16 mm in diameter) with quick tapering of the vessels and their virtual invisibility in the outer third of the lung fields, commonly referred to as peripheral pruning.

If the hila are higher or lower than usual, there is probably loss of volume from lobar scarring, lobectomy, atelectasis or collapse.

Calcified lymph nodes may be seen as a dense focal area, and are often caused by prior tuberculosis infections. In silicosis or sarcoidosis, one looks for eggshell calcification of the nodes.

Impression

Concluding, one summarises the findings, and then gives the entire CXR another short examination to gain a second impression. A way to do this is to de-focus, sit back and relook.

ACKNOWLEDGEMENT

Professor Hillel Goodman has unselfishly taught this non-radiologist how to read chest radiographs over the past decade, and helped in conceptualising and proofreading this article.

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