Principles of Chest X-ray Diagnosis

George Simon

Fourth edition

PRINCIPLES OF CHEST X-RAY DIAGNOSIS

FOURTH EDITION

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PREFACE TO THE FOURTH EDITION

In this fourth edition some of the original text has been retained, some changes of order have been made and much of the text has been re-written. Either new knowledge has necessitated these changes or there has been a need to present the information more clearly, partly to enable the student to learn more easily and partly to make it easier for the student to understand the x-ray appearances, their possible clinical importance or the pathological states which they might represent.

There are 20 new illustrations of radiographs, 1 tomograph and 2 angiograms.

LONDON, 1977 GEORGE SIMON

ACKNOWLEDGEMENTS

I wish to acknowledge the help and encouragement I have received from all the clinicians whose cases have enabled me to learn something about the causes of the various shadows seen in radiographs.

I am also particularly indebted to the pathologists who have spent much time and trouble on correlating the abnormal shadows seen with the morbid anatomy and the histological features of the lesion; namely to R. J. R. Cureton and W. J. Hanbury for the histology of the various tuberculous lesions and the lung changes associated with bronchial carcinoma; to G. J. Cunningham for tuberculosis and bronchiectasis; and to Lynne M. Reid for bronchiectasis, chronic bronchitis, emphysema, bullae, idiopathic pulmonary fibrosis, unilateral transradiancy, certain basal line shadows, and certain cases of mitral stenosis in which line shadows are seen above the costophrenic recess.

I am indebted to St. Thomas's Hospital for Fig. 8.1, and to the authors and publishers for their permission to use the following illustrations: Figs. 2.44–2.46 from *Clinical Radiology*, **20,** 231 (Simon and colleagues); Fig. 2.11 from *British Journal of Radiology*, **41,** 863 (Simon); Fig. 2.16 from *Surface and Radiological Anatomy* (Hamilton, Hamilton and Simon; Cambridge, Heffer); Figs. 4.12, 4.41, 5.7 and 5.8 from *The Pathology of Emphysema* (Reid; London, Lloyd-Luke); Fig. 5.15 from *Thorax*, **20,** 214 (Waddell, Simon and Reid); Fig. 11.3 from Foster-Carter in *Chest Diseases* (Perry and Holmes Sellors; London, Butterworths).

The old illustrations are from photographs prepared from the original radiographs by D. F. Kemp and A. C. Curd in the photographic department of the Institute of Diseases of the Chest, the Brompton Hospital. The new illustrations are from photographs prepared from the original radiographs by the department of medical illustration, St. Bartholomew's Hospital, the Royal Marsden Hospital and the Institute of Cardiology at the National Heart Hospital.

The bibliography and references given are only a faint indication of my debt to written works. Most of the references are key ones which themselves refer to the work of others on that particular subject.

LONDON, 1977

GEORGE SIMON

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CHAPTER 1

INTRODUCTION AND DEFINITION OF TERMS

INTRODUCTION

THIS BOOK is written for the student radiologist and for the clinician who is particularly concerned with chest diseases, whether he interprets the radiographs himself or has the co-operation of a radiologist.

The material has been arranged under headings descriptive of the x-ray shadows rather than under the clinical disease labels. The author has found this grouping more useful not only in teaching clinical students or radiologists in training but also in the actual day-to-day work. Frequently no firm clinical disease label is available when the first radiographs are inspected, while in many cases the x-ray appearances themselves have led to reconsideration of the initial clinical diagnosis. Nor is the initial clinical diagnosis always relevant to the sphere in which the radiograph may be of use in a particular case. For instance, in mitral stenosis the radiograph is not needed for diagnosis, but is often of help in indicating the haemodynamic effects of the stenosis.

Confronted with an abnormal shadow, the observer's first obligation is to give a factual report on what he sees or thinks he sees in regard to its size, shape, position, and other characteristics, and also its effect on surrounding or nearby normal shadows. A statement of this kind, or an equivalent diagrammatic drawing, is necessary in the patient's interest, since it is a record of what was seen at the time, should the radiographs be mislaid, and an indication of the basis from which diagnostic conclusions were drawn. A certain amount of " observer error " is inevitable at this stage.

In the second stage—that of interpretation—the pitfalls are legion. There is usually an obligation to define the anatomical site or the nature of the underlying pathological process, and finally to correlate any tentative conclusions thus drawn with the clinical picture. This done, the final diagnosis may be at once apparent, or may be arrived at gradually after further clinical and radiological investigations.

The sections in this book take this same course, each type of shadow being in turn described factually and then discussed from the point of view of interpretation and misinterpretation. It is the author's hope that this particular approach to the subject of chest radiology may help the reader to extract the maximum value from what is, after all, an important ancillary aid to diagnosis.

DEFINITION OF TERMS

" Then you should say what you mean," the March Hare went on.
" I do," Alice hastily replied; " at least—at least I mean what I say—that's the same thing, you know."
" Not the same thing a bit ! " said the Hatter.

Lewis Carroll

That the writer of an x-ray report does not always say what he means is often due to confusion over the precise meaning of the terms which he uses. Certain words are expected to convey a quantity of subsidiary ideas, which is not justified, and many words are used to describe x-ray shadows which properly pertain to morbid histology. " There is atelectasis of the left upper lobe " will be frequently found in an x-ray report. Does this mean that there is a shadow giving evidence of lobar shrinkage ? Does it imply only that the lobe is airless with the alveolar walls more or less in apposition, or does it also suggest that the airlessness is due to bronchial occlusion ? Does it exclude or allow for some alveolar exudate or transudate, that is, consolidation, or even dilated mucus-filled bronchi ?

It is not unknown for expressions to be deliberately vague or even misleading. " There is infiltration (or infiltrate—U.S.A.) in the right upper zone ", for example, is a favourite way of shelving the problem

only too prominent in the writer's mind, of whether shadows are tuberculous before there is any clinical proof of this, or whether there is any radiological proof that they are in the lung at all.

There are of course sources of confusion other than verbal ones to account for the high observer-error figures found in so many carefully controlled experiments (Garland, 1950; Newell and his colleagues, 1954). False conclusions are drawn from correct observations. Observers may be asked to determine from an initial radiograph whether there is an abnormal shadow present or not, and may interpret a shadow as a pathological lesion, when in fact it is a normal shadow accentuated by slight rotation of the patient. Or again, observers may be asked to discover from a pair of radiographs taken at an interval of 3 months, whether the patient's condition is better, worse, or unchanged. In the last of the two radiographs, the shadow may be smaller, and may be thus recorded by two observers; but whereas one observer may conclude that this indicates improvement, the other may conclude that it indicates bronchostenosis and atelectasis, and therefore deterioration.

Finally, some errors may occur through failure to notice the shadow at all, because it is indistinct or partly obscured by superimposed normal shadows, because inspection of the radiograph was too hurried, or because the observer's attention was distracted by other shadows or blunted by being focused too long on normal radiographs during a rushed session of work. Errors due to this cause can be greatly reduced if all radiographs are seen by two observers, and less reliance is placed on a single observer and a single anterior-view radiograph to exclude a significant lesion.

Humility is certainly required regarding the supposed accuracy of all observers in detecting and describing common abnormal shadows in radiographs. To deal with only one side of the problem, it would be an advantage if certain words commonly used in x-ray reports could be given a more definite meaning by general agreement. In the meantime, pending this happier state of affairs, a definition of terms is given below for use when reading this book.

Atelectasis

Synonyms—collapse, incomplete expansion

In this book the word will be used only in the sense of absorption atelectasis, meaning that the air is absorbed from the alveoli, which may occur if a bronchus is occluded (Kerley, 1951). It will not be used in relation to passive collapse or relaxation, as under a pneumothorax.

The pathological state of a lobe distal to occlusion of the lobar bronchus is variable. In acute atelectasis, as may occur if a lobar bronchus is blocked by an endotracheal tube during anaesthesia, the lobe shrinks and becomes opaque within seconds, and there may then be just airlessness. In atelectasis lasting more than a few hours there will be additional changes. One is varying degrees of bronchial dilatation beyond the stenosis due to the altered forces acting on the bronchial wall, and the bronchi will soon become full of mucus which may still be secreted, but which cannot escape because of the bronchial occlusion. Also, there will be some intra-alveolar oedema, and perhaps some alveolar wall oedema because of the hypoxia. Finally, in some cases there may be infection and inflammatory exudate. In fact, unless these latter conditions are present, or unless the degree of shrinkage is very great, no shadow will be seen (Dornhorst and Pierce, 1954).

Atelectasis is, broadly speaking, airlessness with shrinkage. In either case there may or may not be main or lobar bronchial occlusion, and the most that the radiologist can do when confronted with such a shadow is to see whether there is an associated shadow which might indicate the possibility of bronchial occlusion, or to try to demonstrate or exclude this by tomography or bronchography, unless it is about to be, or already has been, demonstrated by bronchoscopy.

Lobar shrinkage without occlusion of the lobar bronchus is illustrated in Fig. 3.55, and bronchial occlusion with little lobar shrinkage in Fig. 3.65.

If bronchial obstruction has already been demonstrated, the term " obstructive atelectasis " may be used in reference to the radiographic appearance of a homogeneous shadow with evidence of lung shrinkage.

Prefixes to the word " atelectasis " which will not *be used in this book*

The following prefixes are often attached to the word " atelectasis " in x-ray reports, but are considered an unsatisfactory way of describing an x-ray shadow because the underlying pathology is variable and cannot be deduced with any certainty from the radiograph. They will not be used in this book.

Compression atelectasis.—Synonyms—passive collapse, collapse—used in relation to the state of the lung under a pneumothorax. The increase in external pressure is only relative and, since there is still a negative intrapleural pressure, the word " compression " is really unsuitable. The condition will be referred to as " relaxation of the lung ". The term could be used in a tension pneumothorax.

Mantle atelectasis.—Zones of airless alveoli, some with evidence of lung shrinkage, and some with oedema and consolidation without shrinkage, are seen by the morbid histologist round nearly every lesion, be it a pneumonic focus, a cavity (" mantle atelectasis ") or a neoplasm. These airless zones are often microscopic in size, and too small to be demonstrable in a radiograph. Whenever a shadow is described in this book, only the main pathology will be indicated, and very small airless areas will be ignored.

Focal atelectasis.—Small areas of airless lung are found histologically in chronic bronchitis, emphysema, some pneumoconioses, and many other conditions. They may be small areas of absorption atelectasis, or of relaxed lung compressed by surrounding bullae or areas of consolidation. They are usually either invisible in the radiograph or are masked by the more spectacular surrounding lesions, so that there would be no occasion to use the expression to describe multiple small shadows in an x-ray report. Nor is it possible from the radiograph, when numerous small ill-defined shadows are seen, to decide whether these represent small areas of consolidation or areas of focal atelectasis.

Plate or linear atelectasis.—This description has been given to a long linear or band-like shadow which is often seen running horizontally in a lower zone (Fleischner, 1941). The pathology of these lesions, however, is mixed and the range of change is evenly balanced between airlessness, alveolar exudates with or without lung shrinkage, a thrombosed vessel, fibrotic organization and indrawn or thickened pleura. No useful purpose is served by labelling the shadow after one set of changes rather than another. In fact, the majority of these puzzling long line shadows are due to a local vascular occlusion of an artery by an embolus or to thrombosis in a vein either intrinsic or secondary to an arterial embolus. Associated with the vascular occlusion or with a scar from a healed infarct there may be some indrawing of the pleura towards the lesion which may be responsible for a part of the line shadow (*see* p. 122).

Congenital atelectasis.—This condition differs from " absorption atelectasis " in that there never has been air in the affected alveoli. The area of opacity is caused by the failure of a lobe or the whole of one lung to aerate and expand when breathing was first initiated. The term " failure to aerate " is more descriptive in such a case.

Bronchial occlusion

Synonym—complete obstruction of the bronchus

This may be the result of an intraluminal foreign body; or of an organic disease of the bronchial wall, particularly tuberculous endobronchitis and neoplasm; or of extrinsic pressure, most often from an enlarged or healing hilar lymph gland. The result of the occlusion of a main, lobar or sometimes segmental bronchus is airlessness with atelectasis (collapse) of the lung distal to it. The occlusion may be permanent or temporary; should it be relieved the lung will recover, unless there is irreversible damage from infection.

Bronchiectasis

The term " bronchiectasis " originally referred to bronchial dilatation only, but is now used to include the many associated pathological changes seen either in the plain radiographs, such as the opacities of a thickened bronchial wall which may actually have a narrowed lumen, or in the bronchograms, such as the narrowing and occlusion of the smaller bronchi as well as the dilatation of the more proximal bronchi. Since occlusion is commonly present both of the side branches and the end of a dilated bronchus (Fig. 11.5), the term " bronchitis obliterans " can be used synonymously with bronchiectasis, and describes better the functional consequences of the lesion.

Bronchostenosis

Synonym—partial obstruction of the bronchus

This condition may have the same causes as bronchial occlusion. It may be present without any distal lung changes, or it may be associated with a variety of changes in the radiograph, such as evidence of lobar shrinkage without an opacity, hypertransradiancy due to a check-valve over-inflation, or

evidence of distal inflammation or bronchiectasis. It also often causes airlessness, the x-ray picture being then the same as that beyond a total occlusion. Since it is not often possible to distinguish between partial or complete obstruction of the bronchus from the radiographs, and since a bronchus may be intermittently occluded, the term " bronchostenosis " is used to cover all degrees of obstruction unless complete bronchial occlusion is known to exist.

Bulla

The term bulla is derived from the Latin meaning a blister (or the amulet worn around the neck by Roman girls).

Pathologically it refers to a local elevation of the pleura above the general contour of the lung (best seen when the lung is removed from the body) and filled with air. This subpleural collection of air may have replaced destroyed alveoli or may contain distended but architecturally intact alveoli, but in either case its wall consists of pleura and to a varying degree connective tissue septa and compressed lung.

Radiologically a bulla appears as a relatively transradiant zone with either narrow, too few, or no vessels within it and which is partly demarcated by a fine hair-line shadow representing its wall.

Bullous area

A bullous area describes an x-ray appearance in which a transradiant and avascular area is seen but there is no hair-line shadow representing its wall. The wall may in fact be present but not shown in the particular projection used, or it may be too thin to be shown, or it may consist of candy floss lung which is invisible.

A similar x-ray appearance may be seen, and the same term used, if the transradiant zone is the result of an emphysematous area of lung. In this case some of the larger vessel shadows may be seen running across the transradiant zone, but the loss of smaller vessel shadows will still be apparent.

Circular or oval shadows

These are purely descriptive terms and will cover all shadows of this shape whether the pathological lesion is believed to be an infiltration, an infiltrate, an exudate, a nodule, and so forth. If the shadow is visible in two planes, it may be styled a "spherical shadow".

Very small circular shadows.—Shadow 1·5 mm or less. Synonyms—if multiple: fine mottling, pin-point or micro-nodular shadows.

Small circular shadow.—Shadow up to 2 cm. Synonyms—if multiple and individual shadows 1·5–3 mm: mottling, nodular shadows; if 3–8 mm: coarse mottling, coarse nodular shadows.

Large circular shadow.—A shadow measuring 2 cm or more in diameter.

Consolidation

This is a pathological term indicating the state of the lung where the alveolar air has been replaced by fluid, cells or a cellular exudate, and there is airlessness without shrinkage as in all types of pneumonia. It includes replacement of the air by a transudate as in pulmonary oedema and by blood whether due to trauma, inhalation, or infarction. It also includes replacement of the alveolar air by neoplastic cells, the alveoli remaining intact, a condition which occurs in some kinds of carcinoma.

Difficulties arise in the use of the term because the x-ray appearances are the same whatever the cause and often whatever the stage of consolidation. In the earliest stages the radiograph may show patchy clouding, but the shadow soon becomes homogeneous with little or no lobar shrinkage. If lobar shrinkage occurs at a later date, the appearances will be those of atelectasis or collapse, and can be so designated.

When a homogeneous shadow is seen with only slight or moderate lung shrinkage, the compromise term " collapse-consolidation " or " consolidation-collapse " can be used, though it is scarcely worth while since it does not indicate the most important feature, namely whether bronchial occlusion is present or not.

Density

Unless it is qualified as " number per unit area " the word " density " will refer to the radio-opacity of the lesion. Judged from the radiograph this radio-opacity will be relative. The shadow of the heart

may be as white as that of calcified pericardium in a lightly exposed film, but in a film taken with more exposure, the heart will be grey, and the denser more radio-opaque calcified pericardium will remain white. A shadow will therefore be considered dense if it remains more or less white on the radiograph, while a nearby shadow of somewhat similar or larger size is grey.

Low density.—Small shadows caused by cells or body fluids.

Fairly high density.—Larger shadows—particularly those due to fluids.

Dense or very high density.—Shadows produced by lesions containing a lot of relatively radio-opaque atoms, such as iron, or calcium derived from the body fluids, or atoms of high atomic weight introduced from without, such as iron, calcium, barium, tin or iodine.

Disseminated or diffused circular shadows

Shadows which are widely disseminated more or less uniformly over a considerable area, or throughout both lung fields.

Effusion

This usually refers to a pleural effusion, whether serous, purulent, haemorrhagic, fibrinous or transudate and includes semi-solid states of any of these. In the case of a pleural effusion, especially if encysted, the x-ray appearances may be the same whether the exudate is still fluid or whether it has in the course of time been invaded by fibroblasts and thus converted into a solid mass of fibrous tissue. The actual pleural cells rarely proliferate and the term " pleural thickening " usually refers to the shadow caused by an organizing exudate. Fluid in other sites will be denoted with a prefix, for example, mediastinal, extrapleural, pericardial.

Honeycomb shadow, or small ring shadows

Synonym—cystic lung

These are fine white ring shadows enclosing a transradiant zone, and measuring up to, say, 5 mm in diameter. If the ring shadows are larger, the condition is described as " coarse honeycomb shadow " (Figs. 1.1 and 4.47).

Ill-defined opacity

Synonym—area of patchy clouding

This is a poorly demarcated or diffuse shadow, often amorphous, but may be roughly circular or oval. If multiple, they can be described as blotchy shadows.

Linear or band-like shadow (includes tooth paste and gloved-finger shadow)

This is a descriptive term. Linear shadows vary from " hair-line " to 2 mm in thickness; there are also band-like shadows varying from 2 mm to 2 cm in thickness. Relatively wide band-like shadows, some 5–8 mm in width, are described as " tooth paste " shadows being in appearance like a column of tooth paste after extrusion on a flat surface (Figs, 1.1 and 4.24).

A band-like shadow with an expanded and rounded end as in Figs. 1.1 and 4.25 is described as a " gloved-finger " shadow.

Patchy clouding

Amorphous shadows, 1–2 cm in size, so not oval or circular in shape, and with poorly defined margins.

Potter–Bucky diaphragm

Synonyms—Potter–Bucky, Bucky, moving grid

These two names have come into common use to describe a piece of apparatus, the essential component of which is a grid interposed between the patient and the film with the object of absorbing some of the unwelcome scatter radiation. (It is said that Bucky invented the grid, and Potter made it move.) It will be used as a generic term to cover any type of such grid, whether moving or stationary, and whatever mechanism is used for moving it during the exposure.

Reticulation

This term is used to describe a fine linear shadowing with an interlacing pattern, usually spaced 5–8 mm apart, although a coarser pattern is possible. No pathological basis directly corresponds with this network, which is the result of more or less linear shadows, circular shadows, and small ring shadows being superimposed on each other. In the author's experience such a pattern is very rare and often the shadow thus described is not truly reticular but on close inspection is seen to be due to a mixture of nodular, linear and small ring (honeycomb) shadows; and when this is so the term reticular is probably best avoided.

Ring shadow

Synonym—cavity

A transradiant space surrounded by a zone of opacity representing its wall. Ring shadows can be classified by the diameter of the ring and by the thickness of the shadow representing the wall around the air space. The ring shadow or wall may enclose nothing but a relatively transradiant air space or there may be a shadow of some contents additional to the transradiant zone.

Septal lines

Synonym—Kerley " B " lines

Septal lines are used to suggest the cause of several horizontal line shadows usually about 1–3 mm wide and 1 cm apart in the region just above a costophrenic recess (Figs. 1.1 and 4.17). The line may be 1·5–2 cm long, or may continue medially as a vessel (vein) shadow.

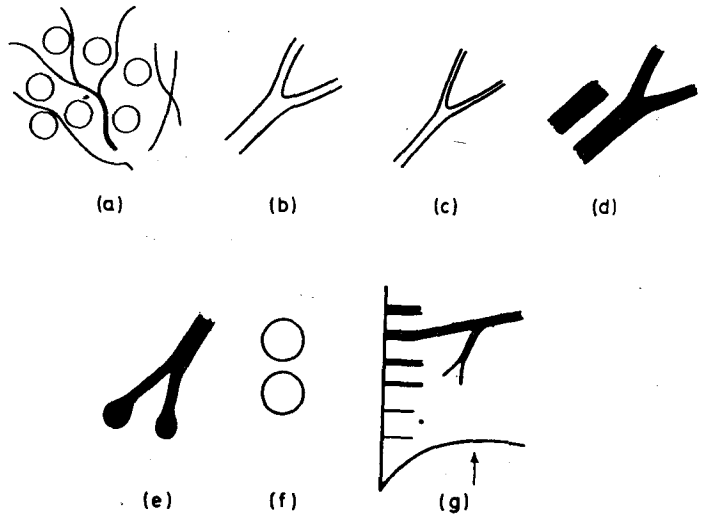

Fig. 1.1.—Diagrammatic illustration of some of the terms used. (*a*) Honeycomb shadows (*see* Fig. 4.47). (*b*) Tubular shadow; parallel line shadow (*see* Fig. 4.31). (*c*) Tram line shadow (*see* Fig. 4.30). (*d*) Tooth paste shadow (*see* Fig. 4.24). (*e*) Gloved-finger shadow (*see* Fig. 4.25). (*f*) Ring shadow (*see* Fig. 14.5). (*g*) Septal line shadow (arrow points to diaphragm) (*see* Fig. 4.17).

Thickened pleura

The term is used to denote a widening of a normal pleural hair-line shadow such as the horizontal fissure or, in a lateral view, the main fissure, or in either view the visibility of a part of the pleura not ordinarily seen such as that over an apex or just above the costophrenic recess in the lower axillary region. Histological examination may show an exudate between the layers of the pleura, which may be fluid, semi-fluid or even solid and cellular in the course of time, without any increase in the width of the layer of pleural cells over it. Therefore there may be no actual pleural cell thickening corresponding to this x-ray description.

Tubular shadow

A shadow with two fine white linear walls which are more or less parallel and which enclose a central transradiancy about 3–8 mm wide (Figs. 1.1 and 4.31). If the parallel line shadow is in the position of a bronchus and the transradiant zone between the lines is of the appropriate diameter for a bronchus at that level, the term " tram line " shadow may be used (Figs. 1.1 and 4.30).

CHAPTER 2

ANATOMICAL LANDMARKS AND VARIATIONS

THE BASIC ANATOMICAL LANDMARKS OR THE BASIC ANALYSIS

When inspecting a chest radiograph it is very useful to identify some basic anatomical landmarks and record the findings systematically. A suggested routine is as follows:

(1) Read the request form to note the name, age and sex of the patient, and then inspect the radiograph for consistency with this data.

(2) Inspect the diaphragm for rib levels and relative levels of the two domes, their shape and clarity of outline (*see* below).

(3) Check the orientation of patient (*see* pp. 10–12).

(4) Inspect the heart shadow for size, shape and position (*see* pp. 12–15).

(5) Inspect the tracheal transradiancy for position and width of lumen (*see* p. 16).

(6) Inspect the hilar shadows for size, shape and position (*see* pp. 16–19).

(7) Scan the lung vessels, and thus note any small shadow that is not a vessel. Check the distribution and size of the lung vessels in the upper and lower half of each lung, and at comparable levels in the right and left lung (*see* pp. 19–21).

(8) Check that the transradiancy of the two sides is the same.

(9) Identify, if visible, the horizontal fissure and check position.

These basic observations can be done in less than a minute and may be invaluable in coming to any conclusions. If the basic anatomical features appear normal and no additional shadows are seen, this constitutes the normal chest. If some variation is seen in the basic anatomy, then pause to consider whether it represents a normal variation (*see* below), or is an indication of some pathological lesion.

Even when gross abnormal shadowing is seen, the basic anatomy may assist in coming to the final conclusions. For example, a much raised dome towards a shadow will suggest an infarct rather than a bacterial pneumonia, or if the trachea is displaced towards an area of homogeneous opacity, it will indicate a reduction in lung volume, perhaps from collapse.

THE DIAPHRAGM

Inspection of the diaphragm shadow in a radiograph should never be hurried or neglected, since it quite often gives valuable clues to the presence of a lesion.

Four features should be noted: (1) the level of the right dome in the mid-lung field; (2) the difference in level between the right and left domes; (3) the curvature of each dome; and (4) the clarity of outline of each dome.

The Level of the Right Dome in Full Inspiration

The level of the right dome should be taken in relation to the anterior inferior angle of the nearest rib shadow in the mid-lung field (Fig. 2.1). In most normal adults radiographed standing up and in full suspended inspiration this point of the diaphragm will lie between rib 5–6½. In a few normal persons it may be as high as rib 4½, especially if the individual is of a short stocky build, while in some long thin persons of the asthenic type it may be as low as rib 7.

In about 15 per cent of normal children it is at rib 7, even when the lung length is not great, owing to the bony parts of the ribs being relatively shorter and tending to lie more horizontally than in many adults.

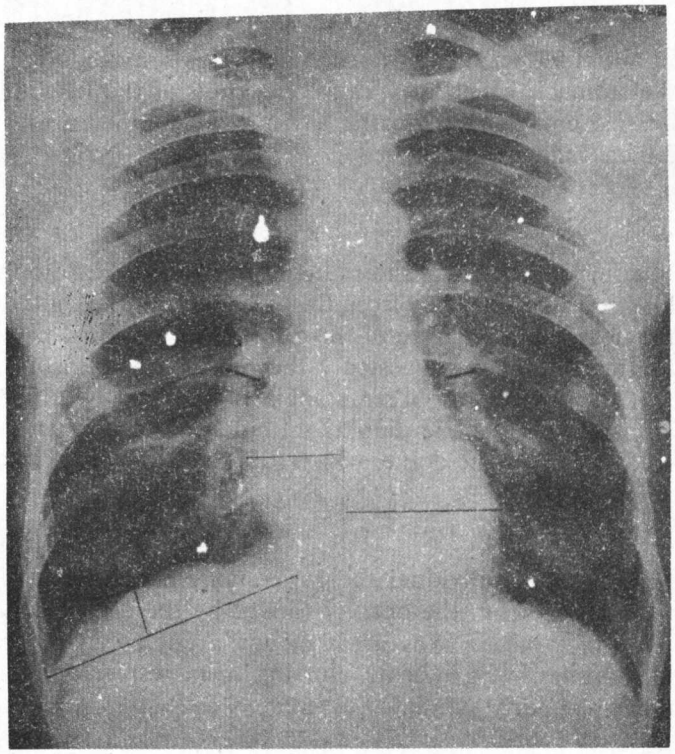

Fig. 2.1.—Lines marked on radiograph to show a method of measuring the transverse diameter of the heart and the basal arteries. Method of assessing diaphragm curve also shown. Dots to right and left hilum points.

Fig. 2.2.—Method of assessing curve of the right dome when cardiophrenic recess invisible if obscured by a fat pad or mediastinal pleural shadow.

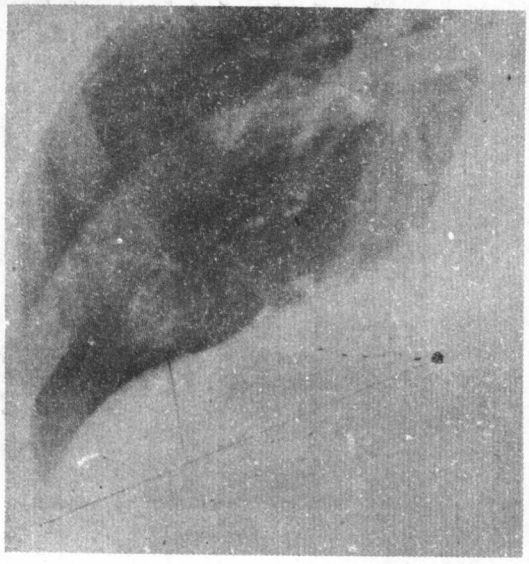

Fig. 2.3.—Elevation of left dome by large quantity of swallowed air in the fundus end of the stomach.