THE X-RAY EXAMINATION OF THE HEART.*

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1. Introduction.

The X-ray examination of the heart is one of the most interesting branches of diagnostic radiology but it has been one of the most neglected. In some X-ray departments there are few, if any, patients referred directly for examination of the heart and even when some cardiac abnormality is found, as for instance, during the course of a routine chest examination prior to a barium meal, some such vague report as "the heart appears to be slightly enlarged" is all too common. This is a curious state of affairs for not only is the heart ideally situated for X-ray inspection, being surrounded by translucent lung tissue, but it has been subjected to this method of investigation since the earliest days of radiology. The frontispiece to the first book on radiology, published only a few months after the discovery of X-rays, was a radiograph of the heart which was printed upside down in the first edition, perhaps as an omen of what was to follow (Fig. 1, Plate 1). There are reasons for this neglect; in the first place radiology seldom provides us with a positive diagnosis in cardiac disease comparable with that of renal calculi or even gastric ulcer for example; and in the second place this method of examination has tended to remain in the province of the specialist. The second of these reasons is partly the result of the first, for in general it has only been the cardiologist who has appreciated the valuable information that radiology has to offer in an examination of the heart. Much of the recent advance in this subject has resulted from the work of cardiologists, notably Parkinson and Bedford in this country, who carry out their own fluoroscopic examinations. It often happens that it is only if a patient reaches a cardiologist that any X-ray examination of the heart is carried out, with the result that the general practitioner or general physician fails to obtain information that might have been of great value. In some cases radiologists lack the experience they would gain in this branch of their work if more of these patients were referred to them.

An X-ray examination is our only means of determining the relative sizes of the various chambers of the heart and is the most reliable method available for differentiating between enlargement and displacement. By rotating the patient behind a fluoroscopic screen we may view the heart in relation to neighbouring structures from all angles and note the pulsation of any part. By teleradiography we may obtain permanent accurate records in any position for comparison with other patients or with further views of the same patient at a later date. Modern advances in radiological technique have now made it possible to record the movements of the heart on an X-ray film. This branch of radiology has advanced rapidly from comparative obscurity in the last decade until its true value as an aid in diagnosis and prognosis has become fully recognised.

2. Methods of Examination.

Such methods as kymography, tomography, and cinematography have many useful applications to the study of cardiology but are still in the early stages of development, and are as yet only employed in special centres. Fluoroscopy, orthodiography, and teleradiography are sufficient for all practical purposes and are now almost universally available in this country.

Fluoroscopy. This is by far the most important method of radiological examination of the heart, and is, in fact all that is necessary in the majority of

*Fellowship of Medicine Post-Graduate Lecture delivered at The Royal Cancer Hospital, June 19th 1938.
cases. The patient should be examined erect and rotated from side to side under continuous observation. Care must be taken to note the size and shape of the heart in all positions and the pulsation of each part. The lung fields and the hilar shadows, the costo-phrenic angles, and the movements of the diaphragm are all observed. Added information can sometimes be gained by outlining the esophagus with barium, or artificially increasing the size of the stomach gas bubble.

**Orthodiography.** By this method a permanent record of the cardiac silhouette observed at the fluoroscopic examination is obtained. It has the advantages of simplicity, accuracy in skilled hands, and economy. It has the disadvantages of requiring experience and practice for accurate work, and being difficult in all but the direct anterior position. It is carried out by means of an X-ray tube capable of being moved independently of the fluoroscopic screen. The shutter is closed down until the X-ray beam is limited to a small portion around the central ray, numerous points are then marked off with a grease pencil on the screen as the tube is moved around the cardiac silhouette and the boundaries of the chest wall. When completed these marks are joined and the whole drawing traced off on to transparent paper. By this means distortion is avoided and an accurate representation of the true cardiac outline produced.

**Teleradiography.** Teleradiography is done with the tube at such a distance from the patient (usually 6 feet) that for all practical purposes the rays of the beam are parallel, the resulting picture showing very little distortion. A teleradiograph provides an excellent permanent record in any position, demonstrates clearly the condition of the lung fields, the relationship of neighbouring structures, and eliminates the personal factor so bound up with accurate orthodiography.

3. **The Normal Heart.**

Three standard positions are used for purposes of description, the anterior, the first oblique, and the second oblique. The degree of rotation in the oblique views is taken as being 45°. In actual practice, especially in the second oblique position, a slightly greater degree of rotation than this gives the best view.

![FIG. 2.—Normal heart. Anterior view.](image1)

![FIG. 3.—Normal heart. First or right anterior oblique view.](image2)
Anterior View. (Fig. 2). The left border of the heart shadow is formed from above downwards first by the last part of the aortic arch (the aortic knob) forming a short prominent curve, then by the pulmonary artery and conus arteriosus of the right ventricle forming a longer and less prominent curve, and lastly the main curve formed by the left ventricle. The right border from above downwards is formed by the superior vena cava and the right auricle. The right cardio-phrenic angle is frequently filled in by a small triangular shadow thrown by the inferior vena cava. The left cardio-phrenic angle may be filled in by a rather less dense shadow due to the presence of fat on the anterior surface of a fold from the pericardium to the mediastinal and diaphragmatic pleurae. The right ventricle lies in front and the left auricle behind in this view.

The First or Right Anterior Oblique View. (Fig. 3.) The patient is rotated from the anterior position to his left so that he has his right shoulder towards the screen, this brings the left auricle from behind so that it can be seen on the border of the heart adjacent to the spine. This border is separated from the spine by a clear space known as the retro-cardiac or Holtzknecht's space. The esophagus runs down through this space and when outlined with barium shows four impressions (Fig. 4). These are formed from above downwards by the aortic arch, the left bronchus, the left auricle and lastly just above the diaphragm the descending aorta. The left bronchus impression is deepened by enlargement of the pulmonary artery. The left auricle impression is normally very slight, may be absent and tends to disappear in full inspiration. In this position the left auricle occupies the middle third of the right border of the heart, the right ventricle forms the greater part of the left border, the right auricle lies in front and the left ventricle behind.

The Second or Left Anterior Oblique View. (Fig. 5.) The patient is rotated to his right so that his left shoulder is towards the screen. This brings the

![Fig. 4](image-url)  FIG. 4.—Normal heart. Right anterior oblique view with barium filled esophagus showing four normal impressions due to the aortic arch, the left bronchus, the left auricle and the descending aorta.

![Fig. 5](image-url)  FIG. 5.—Normal heart. Left anterior oblique view.
right ventricle to the right border of the heart, and the left auricle and left ventricle to the left border. The arch of the aorta can be seen in this view passing from right to left and the trachea is visible descending vertically behind the aortic arch and dividing into the two main bronchi just below it. Below the aortic arch is a clear space crossed by the left pulmonary artery which is known as the infra-aortic clear space or the aortic window. Above the aortic arch is a triangular clear space bounded by the aorta below, the spine to the left, and the left subclavian artery to the right. This supra-aortic clear space was described by Parkinson and Bedford who called it the aortic triangle. The diameter of the aorta may be measured between these supra- and infra-aortic clear spaces. This second oblique view is also valuable in demonstrating the relative sizes of the two ventricles.

![Diagram of heart chambers and lung structures](image_url)

**FIG. 6.—Projections from a transverse section through the chest to show the relations of the various chambers of the heart in the three standard positions.**

The relations of the various chambers of the heart in the three standard positions may perhaps be more easily understood by studying projections from a transverse section through the chest (Fig. 6).

**Variations in the Normal.** Several methods of calculating heart size from a series of measurements taken in one plane have been published but hearts vary considerably in the measurements made in a single plane, and these may be misleading as a guide to heart size. The most useful tables are those predicting the transverse diameter from the patient's weight and height. There is no direct method of measuring the heart volume, the indirect volumetric reconstruction method devised by Palmieri is too complicated and lengthy for practical purposes. Deductions from heart measurements are difficult and of doubtful value in ordinary practice, whereas direct fluoroscopic examination alone
gives the experienced observer a very clear idea of the heart size and the relative sizes of its individual chambers. The measurements most commonly quoted are the transverse diameters of the heart and chest, the ratio of which is known as the cardiothoracic ratio and is normally 1:2 but may vary from 1:4—1:1.9 (Fig. 7).

Measurement of the diameter of the aorta is a more simple matter as measurement in one plane is all that is required. This measurement may be made in the second or left anterior oblique position, between the aortic triangle and the aortic window, or in the anterior position between the maximum point of convexity of the aortic knob and the maximum point of concavity of the aortic impression on the barium filled esophagus (Fig. 7). This last is known as Kreuzfuch’s measurement and should not exceed 3.2 cms.

In very young children the heart is rather large in relation to the chest but by puberty it is usually long, narrow, and centrally placed. From puberty to adult life the heart assumes one of the three normal adult types according to the general bodily development. There is the big fisted, thick-set, “stocky” type of individual with a transverse type of heart and a high diaphragm, the thin “lanky” type of individual with the vertical type of heart and low diaphragm (Fig. 8), and the more usual type somewhere between these two extremes.

The Normal Pulsation of the Heart. Diagnostic radiology, as Sir Walter Langdon-Brown so neatly described it, is “the pursuit of shadows” and in observing cardiac pulsation it must be remembered that we only see the shadow in one plane of a composite movement. By pulling the screen away from the patient the distortion is increased so that the pulsation is magnified. In the anterior view the left border will be seen to give a slow outward movement during
diastole and a quick inward movement during systole. The aortic knob moves sharply upwards and outwards during systole. The upper part of the right border of the heart may show aortic pulsation but no pulsation may be visible if the aorta is medial to it. The lower part of the right border shows a rather variable pulsation depending on the degree of rotation of the heart.

Displacement of the Normal Heart. Displacements due to changes in the lungs or pleura such as fibroid phthisis, pleural effusion, pneumothorax, etc., are usually easily diagnosed by radiographs if not obvious clinically. The same applies to displacements due to changes in position of the diaphragm, such as occur in pregnancy, phrenic paralysis or diaphragmatic hernia. Displacement due to scoliosis is important owing to the fact that it is much more likely to be overlooked. A slight convexity to the right is the common form of dorsal scoliosis. As this displaces the heart to the left an erroneous impression of enlargement may be produced unless this is corrected by rotating the patient slightly to his right to bring the heart into its true relation with the chest (Fig. 9). This has been a common source of error particularly in children.

The effect of inspiration and expiration on the size and shape of the cardiac silhouette is considerable (Fig. 10) and some disagreement as to the best phase of respiration in which to take teleradiographs has resulted. As long as the extremes are avoided and a standard technique rigidly adhered to, the exact phase would not appear to matter very much. A position of gentle inspiration is probably best on the grounds that the patient keeps still more easily, better definition is obtained, particularly in the oblique views and the silhouette appears rather smaller than in expiration so that any distortion due to respiration will tend to be on the side of normality. Shadows overlying the heart may sometimes give rise to difficulty but these may usually be separated from the heart shadow by turning the patient into oblique or lateral positions.
4. Acquired Cardiac Abnormalities.

Mitral Stenosis. This is the most common valvular lesion and gives one of the most characteristic X-ray pictures. Enlargement occurs behind the obstructed valve in the left auricle, pulmonary artery, and right ventricle. The left auricle enlarges backwards and to the right so that in the anterior view it appears as an extra shadow on the right border superimposed on the shadow of the right auricle (Fig. 11). In the first oblique view the backward enlargement of the left auricle is seen encroaching on the clear retro-cardiac space. A barium swallow demonstrates the backward displacement of the oesophagus due to this enlargement, a long and deep left auricular impression being present (Fig. 12, Plate I). The right ventricle enlarges upwards and to the left and in the anterior view fills in the concavity on the left border of the heart below the aortic knob, so that the cardiac silhouette shows practically a straight line from the aortic knob to the apex of the left ventricle. The branches of the pulmonary artery may be dilated, there may be congestion of the lung fields and occasionally a hydrothorax. The aorta tends to be small particularly if the lesion was acquired at an early age.

An X-ray report on a typical case of this kind might read "There is moderate enlargement of the pulmonary artery and conus arteriosus of the right ventricle, and some enlargement on the right border of the heart. In the first oblique view the retro-cardiac space was obscured and the oesophagus displaced backwards by enlargement of the left auricle. The aorta was small, there were no signs of pulmonary congestion. The appearances are those seen characteristically in mitral stenosis." These changes are very marked in advanced cases and aneurysmal dilatation of the left auricle may occur, its shadow filling the greater part of the right chest in the anterior view (Fig. 13).

Aortic Incompetence. The aortic knob is prominent, the pulmonary artery and conus arteriosus are small and the left ventricle is enlarged so that the left border of the heart presents the opposite to the straight line or convexity of mitral
stenosis, being markedly concave (Fig. 14). The pulsations along this border are forcible, the left ventricular movement being followed by forcible aortic pulsation in a "see-saw" manner. In the left, or second oblique view, the enlarged left ventricle may be seen projecting over the vertebral shadow and the aorta can be well visualised pulsating forcibly. Calcification in the aortic valves should be looked for. Combined mitral and aortic disease is quite common and presents features of both conditions according to the relative severity of each. The enlargement of the pulmonary artery and left auricle is combined with a prominent pulsating aorta and enlargement of the left ventricle.

**Pericardial Effusion.** It is estimated that there must be about 250 c.c. of fluid in the pericardial sac of an adult before recognition of a pericardial effusion is possible radiologically. The normal cardiac contours are obliterated, the silhouette is large and globular, and the vascular pedicle is shortened (Fig. 15). If the stomach gas bubble is artificially increased in size it may be seen to be deformed and displaced, at the same time absence of pulsation on the heart border in this region is noted. Pulsations at the base of the heart are usually of the nature of diffuse to and fro movements but with big effusions no pulsations may be visible at all. The heart shadow is not visible within the shadow cast by the effusion.

**Chronic Constrictive Pericarditis. Pick's Disease.** In this disease the pericardial layers, visceral and parietal, become bound together by adhesions, thickened, and sometimes calcified (Fig. 16, Plate II). When serious symptoms result they are due to interference with the return flow of venous blood to the heart, a condition known as inflow stasis. The heart is either normal in size or abnormally small, pulsation is diminished and calcification of the pericardium may be seen.

**Hypertension.** This may cause general enlargement of the heart but the left ventricle is chiefly affected and this may be shown in the anterior and second oblique views (Fig. 17). The aortic knob may be high and prominent but this may occur in atheroma or merely with old age. Congestive failure is nearly always associated with a general enlargement of the heart which is, however, of

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**Fig. 14.** Aortic incompetence.

**Fig. 15.** Pericardial effusion.
slow development. One of the clinical conceptions that radiology has disproved is the occurrence of rapid dilatation of the heart with the onset of congestive cardiac failure.

**Cardiac Aneurysm.** A cardiac aneurysm may result from a coronary thrombosis; it usually occurs in the left ventricle and may develop in a few weeks. It presents as a progressive bulging or sharp angulation of the wall, and abnormal pulsations such as systolic distension in the region of the left ventricle may be observed (Fig. 18). Some cardiac aneurysms are not demonstrable by radiographic methods.

**Atheroma.** Advanced changes may be present with normal X-ray appearances but localized or fairly general calcification of the aorta can often be demonstrated. Slight dilatation of the lumen of the aorta may occur with advancing years but elongation without any dilatation is the more common picture.
PLATE I.
Dr. D. Waldron Smithers - - - The X-Ray Examination of the Heart

PRACTICAL
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A Hand-Book of the Applications of the X Rays.

By H. Snowden Ward,
Editor of The Photogram,

With Chapters by E. A. Robins and A. E. Livermore.

With many illustrations.

Published for The Photogram, Ltd.,
DAWBARN & WARD, LTD., 6, FARRINGDON AVENUE, LONDON, E.C
1896

FIG. 1.—The frontispiece of the first book on radiology in any language.
Radiograph of the heart taken by Dr. McIntyre in Glasgow in 1896.

FIG. 12.—Mitral stenosis first oblique view barium filled œsophagus displaced by enlarged left auricle.
FIG. 16.—Pick's disease. Chronic constrictive pericarditis showing calcification of the pericardium. Left lateral view.

FIG. 24.—Patent ductus arteriosus.
The aorta, being fixed at the heart and at the diaphragm, is forced to widen its arch as it elongates and this is known as unfolding of the aorta (Fig. 19). In the anterior view it gives rise to a broad vascular pedicle and in the oblique views shows a wide span to the arch of the aorta and a forward swing of the middle part of the descending portion. This forward swing makes an impression on the oesophagus and has been mistaken for an aneurysm of the descending aorta. With the patient's head thrown back so as to stretch the oesophagus, it is often possible to see the rigid aorta at the level of the aortic arch displaced by the act of swallowing. The heart itself is normal in size unless there are changes present due to associated conditions.

**Syphilitic Aortitis.** Marked elongation is not found as the result of syphilis, which, unlike atheroma, frequently produces dilatation of the lumen. This may take the form of diffuse widening of the entire aortic shadow, irregular fusiform widening, or a local aneurysmal dilatation. Irregularity of the aortic wall with loss of parallelism is a common finding (Fig. 20). In the left oblique view a marked prominence of the ascending aorta with increased pulsations limited to this region are said to be characteristic findings in early syphilitic aortitis but the diagnosis of this condition in its early stages is clinical rather than radiological. There is no enlargement of the heart unless there is some associated aortic incompetence, hypertension or coronary artery stenosis.

**Thyrotoxicosis.** Radiology has two important applications to the study of thyrotoxicosis. One is in diagnosis, for X-ray findings may sometimes be the first to suggest thyrotoxicosis as the cause of cardiac symptoms, the other is in prognosis, for the degree of enlargement and pulsation is very useful in assessing the severity of the myocardial damage. There is some general enlargement of the cardiac silhouette (Fig. 21) both ventricles showing moderate enlargement. There is no marked enlargement of the left auricle or conus arteriosus as in mitral stenosis, but some enlargement and marked pulsation of the pulmonary artery are usually visible especially in the right oblique view. The pulsation generally is increased but is most marked in the pulmonary artery, aortic arch, and superior vena cava. An X-ray examination may also help by revealing the presence of
a retro-sternal thyroid, which may be seen in the anterior view or forming the right border of the supra-aortic clear space or aortic triangle in the left oblique position.

Mycœdema. Only small slow pulsations are present in a heart that is generally enlarged. There is quite frequently an associated pericardial effusion.

5. Congenital Cardiac Abnormalities.

Some congenital cardiac defects give no abnormal X-ray findings and some, such as coarctation of the aorta, may give a characteristic picture. Between these two groups may be found changes that though not characteristic, may be of considerable aid in the diagnosis. Only a few conditions with fairly characteristic X-ray findings will be mentioned here.

Dextrocardia. This may be present with complete transposition of the viscera, when the stomach gas bubble will be seen on the right side or may be present as a single transposition when other congenital malformations of the heart are frequently associated with it.

Coarctation of the Aorta. The aorta is sharply constricted in the region of the ductus arteriosus and a collateral circulation is established which causes dilatation and elongation of the intercostal arteries; these are thrown into folds which press on and erode the inferior borders of the ribs (Roesler's sign) (Fig. 22). The aortic knob is absent or small and the ascending aorta dilated and prominent in most cases. There is compensatory enlargement of the left ventricle as it is forced to work against an abnormal resistance.

Patent Inter-auricular Septum. This may produce a very large cardiac silhouette due to gross enlargement of the right side and of the pulmonary artery (Fig. 23). The right ventricle enlarging as it does upwards and to the left, causes the heart shadow to enlarge chiefly on the left side. The gross enlargement and pulsation of the two main branches of the pulmonary artery with general cardiac enlargement are the outstanding features.

Patent Ductus Arteriosus. The heart is slightly or moderately enlarged and the blood passing from the aorta to the pulmonary artery causes dilatation of the main pulmonary vessels (Fig. 24, Plate II). Both ventricles may be slightly enlarged.
Fallot’s Tetralogy. This common congenital lesion consists of pulmonary stenosis, patent intra-ventricular septum, dextro-aorta and right ventricular hypertrophy. There is a depression in the region of the pulmonary artery and conus arteriosus due to the small pulmonary artery, and an enlargement of the left border of the heart below this due to the large right ventricle pushing over to the left side; the dextro-aorta may be seen projecting on the right side (Fig. 25). The right ventricular enlargement to the left raises the apex and produces a boot-shaped appearance known as the "cœur en sabot." In the left oblique view the right ventricle and not the left is shown to be mainly responsible for the enlargement.

This lecture was based on an article published in the St. Thomas's Hospital Gazette in conjunction with Dr. Evan Jones to whom I am very grateful for much assistance as well as for permission to reproduce Figs. 16 and 24. I am also indebted to Professor J. M. Woodburn Morison for permission to reproduce Fig. 12 and to photograph the frontispiece of a book in his possession which is reproduced as Fig. 1.
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Postgrad Med J 1938 14: 312-323
doi: 10.1136/pgmj.14.156.312

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