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CLINICAL CARDIAC RADIOLOGY

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Introduction

This book is about the chest x-ray in heart disease. It is intended to be a practical book for radiologists and for physicians and surgeons who use the chest x-ray as part of their clinical examination of the patient. X-ray examination of the heart is not new, but until recently the true significance of many of the appearances could be verified only by the occasional autopsy. Cardiac catheterization, angiocardiography and open heart surgery have changed this. The book is based on a study of films in over 1,500 patients in whom the anatomy of the heart and the physiology of the circulation were known. The significance of the numerous radiological signs has been evaluated and, in many cases, re-evaluated in relation to anatomy and physiology. Computer techniques have been employed when appropriate. Standard postero-anterior, penetrated postero-anterior and lateral views only have been used. There is very little reference to oblique views, as the authors feel that no more useful information is obtained provided a penetrated frontal view is available: also, technically satisfactory oblique films can often be obtained only after screening, which as a routine involves an unacceptably high radiation dose. Fluoroscopy of the heart, however, may be clinically indicated and the findings are described. Barium swallow is also not used as a routine, but only when additional information might be obtained. Angiocardiographic appearances are described and related to plain film findings.

The first half deals with changes in the size, shape and position of the heart, its chambers and the great arteries and veins, followed by the appearances of the lungs resulting from alterations in pressure and flow. There is also a section on skeletal and other extracardiac changes in heart disease, much of the material being based on the St. Cyres lecture for 1971 delivered by one of us (K.J.). In the second half, lesions are considered individually in clinical groups, stressing where the chest x-ray is of help in differential diagnosis and in deciding the severity or relative importance of a lesion.

The approach throughout is a clinical one, because the authors feel that the x-ray should be interpreted in the light of the clinical findings and form an integral part of the clinical examination of the patient.

How to Use the Book

PART ONE

Part One of this book is devoted to the general radiology of the heart, the lungs and the other systems in heart disease.

The radiology of the heart (Section I, Chapters 1–6) provides information more about anatomy than about physiology. The two most important exercises are to determine whether the heart is enlarged and which chamber is enlarged. Large right and left ventricles have characteristic shapes, but they are often misleading, particularly in biventricular enlargement in rheumatic heart disease. Right atrial size is difficult to assess unless the chamber is obviously dilated. The left atrium can be quite accurately assessed on the penetrated anterior and lateral views. This is of much importance in left-sided lesions; when the left atrium is normal, lesions affecting the left ventricle are suggested, but if it is more than slightly enlarged, mitral valve disease of some variety is likely. Other features one should particularly look for are the size and position of the pulmonary trunk and aorta, and the presence of cardiac calcification.

The lungs in heart disease (Section II, Chapters 7–12) provide much information about haemodynamics and often show on which side of the heart the lesion lies; the Table below relates lung changes to haemodynamics and outlines their basic anatomical significance.

Lungs	*Haemodynamic significance*	*Anatomical significance*
Normal (Chapter 7)	Normal pulmonary flow and pressures	Lesion in either side of the heart not affecting haemodynamics
Plethora (Chapter 8)	Left-to-right shunt	Chamber enlargement depends on site of shunt
Oligaemia (Chapter 8)	Reduced pulmonary flow	Lesion in right heart
Proximal vessel dilatation (Chapter 9)	Pulmonary arterial hypertension	Right heart affected by pulmonary vascular disease from many causes
Proximal vessel dilatation and plethora (Chapters 8 and 9)	Pulmonary arterial hypertension with left-to-right shunt	Chamber enlargement depends on site of shunt and degree of pulmonary hypertension
Upper zone vessel dilatation; oedema (Chapter 10)	Pulmonary venous hypertension	Lesion in left heart or pulmonary veins
Upper zone vessel dilatation: lower lobe vessel narrowing (Chapter 10)	Pulmonary venous and arterial hypertension: elevated pulmonary vascular resistance	Lesion in left heart or pulmonary veins
Upper zone vessel dilatation and plethora (Chapters 8 and 10)	Left-to-right shunt and pulmonary venous hypertension	Chamber enlargement depends on site of shunt and left heart lesion

The thoracic cage and general disease associated with the heart are discussed in Section III, Chapters 13, 14 and 15. This section is set out in some detail particularly for clinicians who may not be familiar with extracardiac radiology.

PART TWO

Whereas Part One is a general narrative description of cardiac radiology, Part Two is designed to help the radiologist or clinician make a diagnosis as precisely as possible from the chest x-ray. Lesions with common clinical and radiological features are grouped into sections. Sections IV and V deal with defects of cardiac septation in which there are shunts with or without cyanosis. Section V forms a classification of lesions causing central cyanosis in congenital heart disease. Section VI is concerned with lesions primarily involving endocardial structures, producing obstruction or regurgitation. Section VII deals with diseases primarily involving the myocardium or pericardium. The Table below is a précis of Part Two, and is a simplified guide showing the salient clinical and radiological features common to each section.

Section IV—Shunts Without Cyanosis

	Lungs	*Heart*	*Clinical features*
Atrial shunts (Chapter 16)	Plethora Anomalous veins	Right ventricle + Heart displaced to left Pulmonary trunk + Aorta small	Right ventricle + Fixed split of second sound Ejection systolic murmur
Ventricular shunts (Chapter 17)	Plethora	Pulmonary trunk normal or slightly + Aorta normal Left atrium +	Left ventricle + Right ventricle + Pan-systolic murmur
Aorto-pulmonary shunts (Chapter 18)	Plethora	Left ventricle + Left atrium + Pulmonary trunk variable Aortic knuckle + in ductus	Left ventricle + Continuous murmur

Section V—Shunts With Cyanosis

Right-to-left shunts due to obstruction in right heart

	Lungs	*Heart*	*Clinical features*
Fallot's tetralogy (Chapter 19) and its differential diagnosis (Chapter 20)	Oligaemia	Right ventricle + Bay in left border (rarely post-stenotic dilatation of pulmonary trunk) Aorta +	Right ventricle + Single second sound

Right-to-left shunts due to obstruction in the lungs

	Lungs	*Heart*	*Clinical features*
Eisenmenger syndrome (Chapter 21)	Proximal vessel dilatation	Heart normal or slightly + Right ventricle + Pulmonary trunk +	Right ventricle + Pulmonary second sound + Ejection sound

Right-to-left shunts without obstruction in right heart

	Lungs	*Heart*	*Clinical features*
Veno-arterial mixing lesions (Chapter 22)			
(*a*) *Proximal to lungs*			
Complete transposition Total anomalous pulmonary venous drainage Single atrium Single ventricle Double outflow right ventricle Truncus arteriosus	Proximal vessel dilatation Plethora	Variable chamber enlargement	Pulmonary arterial hypertension Other features variable

(*b*) *In lungs*

	Lungs	*Heart*	*Clinical features*
Arteriovenous fistula	Solid opacity with large vessels	Normal	Silent or continuous murmurs

(*c*) *Distal to lungs*

Superior or inferior vena cava draining to left atrium	Normal if isolated lesion	Normal if isolated lesion	No murmurs unless associated with other lesions

Section VI—Obstruction and Regurgitation

	Lungs	*Heart*	*Clinical features*
Diseases of tricuspid valve and right atrium (Chapter 23)	Normal or oligaemia	Right heart + Left ventricle and left atrium + in tricuspid atresia	Right ventricle + Left ventricle + in tricuspid atresia Inspiratory murmurs left sternal edge
Diseases of pulmonary valve and right ventricular outflow (Chapter 24)	Normal or oligaemia	Normal heart size Pulmonary trunk +	Right ventricle + Pulmonary second sound late and diminished Inspiratory murmurs in pulmonary area
Diseases of mitral valve, left atrium and pulmonary veins (Chapter 25)	Upper zone vessel dilatation Lower zone vessel narrowing Oedema	Left atrium + Calcification mitral valve	Mitral murmurs Expiratory apical murmurs
Diseases of aortic valve, left ventricular outflow and aorta (Chapter 26)	Normal or upper zone vessel dilatation	Left ventricle + Ascending aorta + Calcification aortic valve	Left ventricle + Expiratory basal murmurs

Section VII—Myocardial and Pericardial Disease

	Lungs	*Heart*	*Clinical features*
Ischaemic heart disease (Chapter 27)	Normal or upper zone vessel dilatation	Normal or left ventricle + Left ventricular aneurysm Calcification in coronary arteries or aneurysm	Ischaemic pain ECG changes
Cardiomyopathy (Chapter 28)	Normal or upper zone vessel dilatation	Left ventricle + Right ventricle + less often	Left ventricle + Right ventricle + Dysrhythmia Failure
Cardiac aneurysm, tumour and cyst (Chapter 29)	Normal or upper zone vessel dilatation	Localized bulge Bizarre shape Calcification	Mimics valve disease Failure Dysrhythmia
Pericardial effusion (Chapter 30)	Normal Upper zone vessel dilatation only with large heart	Enlarged heart difficult to tell from chamber dilatation	Chest pain Pericardial rub ECG changes
Constrictive pericarditis (Chapter 30)	Normal or upper zone vessel dilatation	Heart usually enlarged but may be normal Pericardial calcification	High venous pressure Small pulse Pulsus paradoxus Quiet heart Diastolic sound

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Contents

SECTION VI: Obstruction and Regurgitation

SECTION VII: Myocardial and Pericardial Disease

Appendices

PART ONE
General Radiology

SECTION I
The Heart

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General Radiology

SECTION I
The Heart

CHAPTER I

Radiological Anatomy and Assessment of Heart Size

RADIOLOGICAL ANATOMY

As changes in heart size and shape are so often accompanied by important alterations in the arteries and veins of the mediastinum, all cardiovascular structures within the mediastinum are considered together and regarded as forming the cardiovascular shadow on the anterior and lateral views of the chest. They can be identified on plain radiography if they are bordered by radiolucent lung or if, by enlargement or acquisition of calcium, they produce a shadow of greater radio-density than the surrounding structures.

On the anterior view the normal border-forming cardiovascular structures are as follows (*Figure 1*).

Right upper border
Innominate vein and superior vena cava or innominate artery and ascending aorta.

Right lower border
Right atrial appendix and right atrium.
Inferior vena cava.

Left upper border
Left subclavian artery.
Aortic arch (aortic knuckle).

Left middle border
Pulmonary trunk (main pulmonary artery).
Left atrial appendix.

Left lower border
Left ventricle.

In children under the age of two years the thymus often obscures the upper cardiovascular borders. Thymic enlargement may occasionally persist in normal children until the age of about six years and is occasionally unilateral (*Figure 2*).

On the lateral view of the chest, the following are the normal border-forming cardiovascular structures (*Figure 3*).

Anterior upper border
Superior vena cava.
Ascending aorta.
Pulmonary trunk.

Anterior lower border
Right ventricle.

Posterior upper border
Left atrium and pulmonary veins.

Posterior lower border
Left ventricle (sometimes right atrium).
Inferior vena cava.

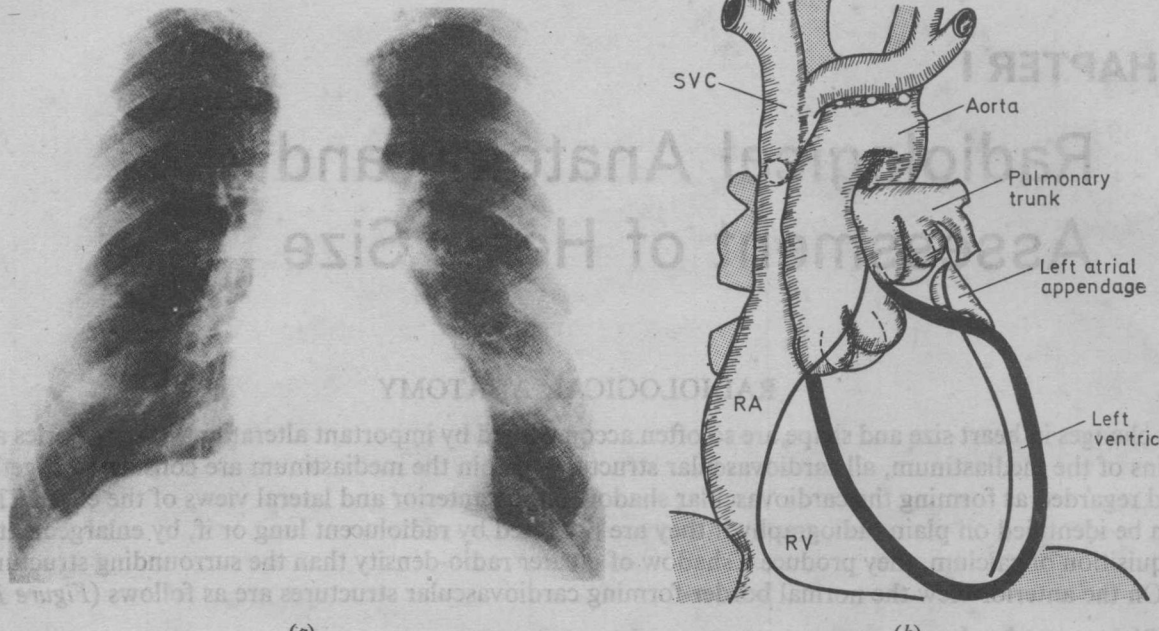


Figure 1 (above). (a) Normal chest radiograph—anterior view. (b) Diagram of border-forming structures—anterior view. SVC=superior vena cava; RA=right atrium; RV=right ventricle

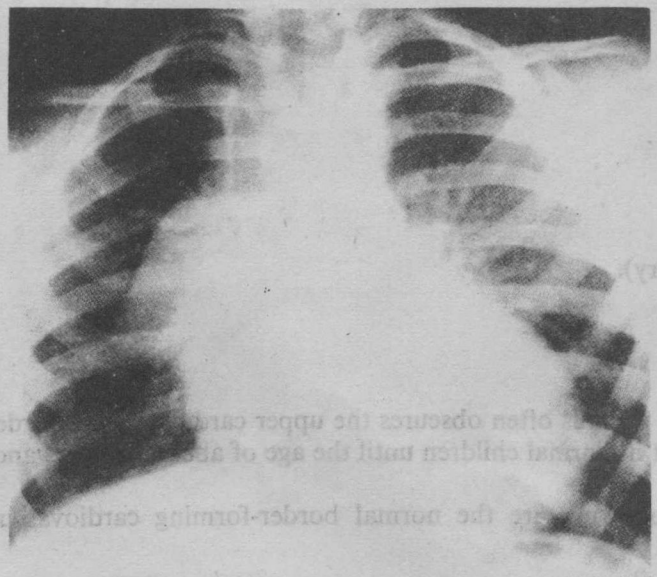


Figure 2 (left). Enlarged thymus in child

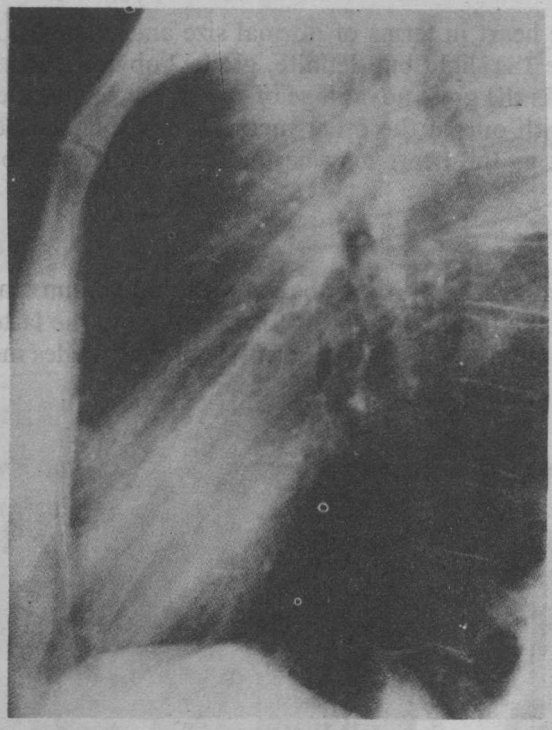
Superiorly the anterior border-forming structures limit the posterior extent of the retrosternal air space, and inferiorly a variable amount of right ventricle is in contact with the posterior surface of the sternum. The pulmonary veins prevent a clear-cut view of the posterior contour of the left atrium, but the posterior borders of the left ventricle and inferior vena cava are well seen.

Important cardiovascular structures which may be rendered visible because of their increased density are as follows.

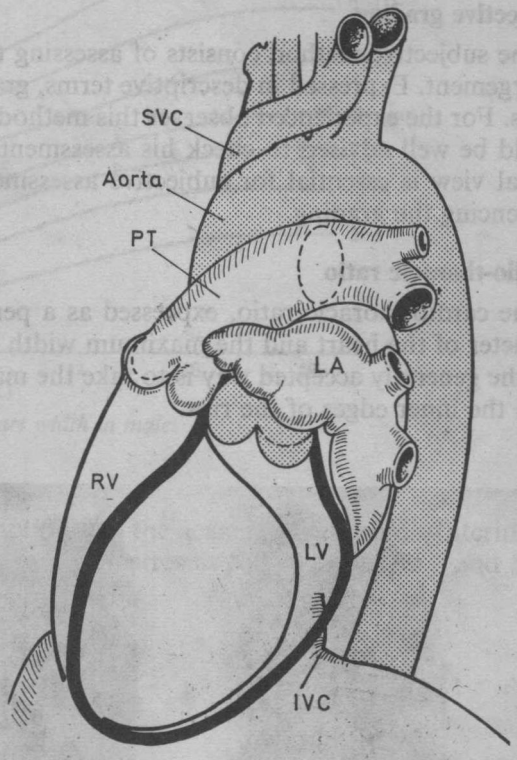
(1) The left atrium (*Figure 4*), the proximal ascending aorta, the descending aorta and the azygos vein (*see Figure 14*) on the anterior view.

(2) The aortic arch and descending aorta on the lateral view.

(3) Any calcified structures, particularly the aortic and mitral valves, the pericardium, the coronary arteries and the left atrium (*see page* 52).



(*a*)



(*b*)

Figure 3 (*above*). (*a*) *Normal chest radiograph—lateral view.* (b) *Diagram of border-forming structures—lateral view. SVC=superior vena cava; PT=pulmonary trunk; LA=left atrium; RV=right ventricle; LV=left ventricle; IVC=inferior vena cava*

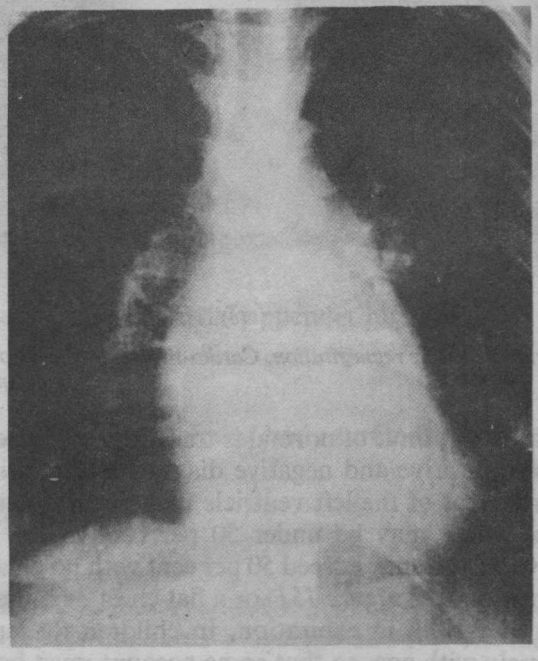


Figure 4 (*right*). *Penetrated anterior view. Enlarged left atrium showing increased density*

HEART SIZE

Heart size may be recorded by:

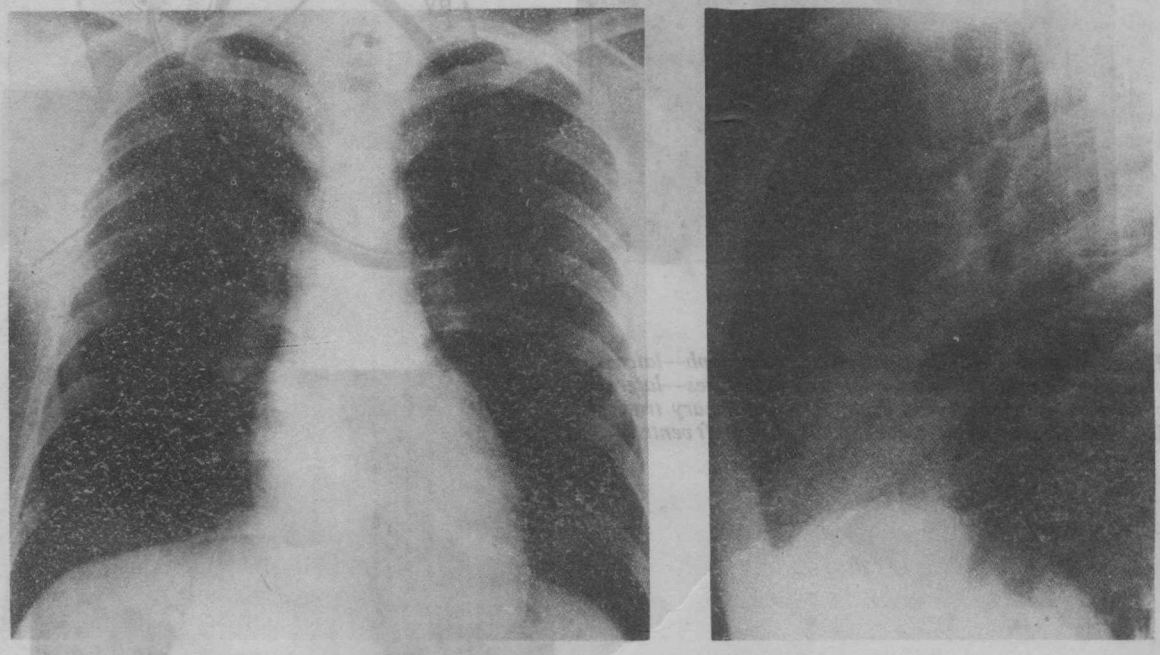
(1) Grading it subjectively.
(2) Measuring the cardio-thoracic ratio.
(3) Calculating the heart volume.

Subjective grading

The subjective method consists of assessing the heart in terms of normal size and grades 1, 2 and 3 enlargement. Expressed in descriptive terms, grade 1 is slight but definite, grade 2 obvious, and grade 3 gross. For the experienced observer this method has the great advantage of speed, but the inexperienced would be well advised to check his assessment with one of the other methods as explained below. A lateral view is essential for subjective assessment as the heart may be unduly deep or shallow, thus influencing the grading.

Cardio-thoracic ratio

The cardio-thoracic ratio, expressed as a percentage, is the ratio between the maximum transverse diameter of the heart and the maximum width of the thorax. Methods for determining the latter vary, but the generally accepted way is to take the maximum width above the costo-phrenic angles measured from the inner edges of the ribs.



(*a*) (*b*)

Figure 5. Aortic regurgitation. Cardio-thoracic ratio 44 per cent. Heart volume 650 ml/m² body surface area (upper limit of normal 550 ml/m²)

The upper limit of normal is traditionally 50 per cent, but rigid acceptance of such a figure may result in false positive and negative diagnoses of cardiac enlargement. For example, in aortic regurgitation, enlargement of the left ventricle may occur downwards more than laterally, thus hardly increasing the ratio, which may be under 50 per cent in the presence of obvious cardiac enlargement (*Figure 5*). Conversely, it may exceed 50 per cent with no enlargement if the heart is compressed as a result of sternal depression (*see Figure 151*) or a flat chest or if the diaphragm is high because of obesity or exposure of the radiograph in expiration. In children the upper limit of normal is above 50 per cent and varies inversely with age, so that some account must be taken of this when interpreting serial readings during

growth. Measurement of the transverse cardiac diameter rather than the ratio may be of some help (*Figure 6*).

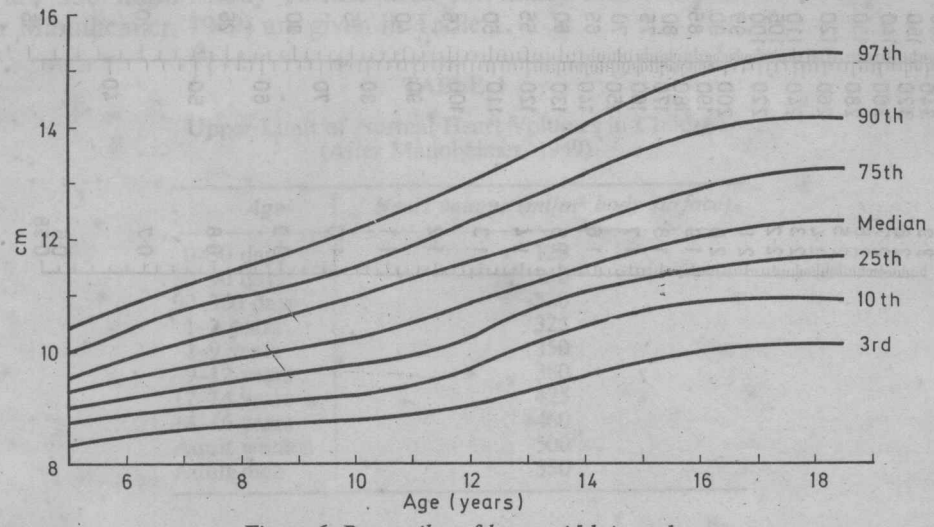


Figure 6. Percentiles of heart width in males

Heart volume

The calculation of heart volume is based on the assumption that the heart is an ellipsoid. Anterior and lateral views are required, and measurements are taken in centimetres as follows (*Figures 7* and *8*).

Figure 7. See text for explanation. RA–SVC = right atrium–superior vena cava junction; PT–LAA = pulmonary trunk–left atrial appendix junction; RCPA = right cardiophrenic angle

Figure 8. See text for explanation

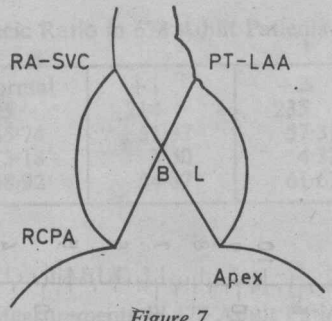


Figure 7

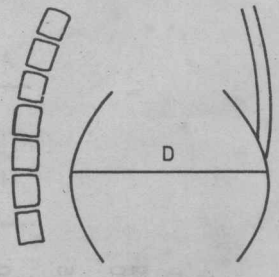


Figure 8

Long diameter (*L*)
From the superior vena caval/right atrial junction to the cardiac apex.

Broad diameter (*B*)
From diaphragm/right atrial junction to pulmonary trunk/left atrial appendix junction.

Depth diameter (*D*)
The greatest horizontal depth of the heart.

The volume of the heart (*V*), expressed in millilitres per square metre of body surface area, is calculated by the formula

$$V = \frac{L \times B \times D \times K \times M}{A}$$

where *K* is the ellipsoid constant (0·63), *M* is the magnification factor, and *A* is the body surface area in square metres derived from height and weight tables (Du Bois standards—*Figures 9* and *10*). The magnification factor (*M*) depends on the radiographic technique used. At the National Heart Hospital, the