An Atlas of Clinical Echocardiography

Jamie Weir

Ronald Blackwood Pridie

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Jamie Weir MBBS, MRCP(UK), DMRD, FRCR
Consultant Radiologist to the Aberdeen Teaching Hospitals and Honorary Senior Lecturer to the University of Aberdeen

Ronald Blackwood Pridie MRCS, LRCP, DMRD, FRCR, FACC
Consultant Radiologist to Harefield Hospital, Middlesex

in association with
Lesley Ann Grieve DCR
Carole Ann Webb DCR

Superintendent Radiographers at Harefield Hospital

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Preface

The world of echocardiography has seen two fundamental innovations since its conception. The first was the recording of single beam echoes from the diseased mitral valve thirty years ago, and the other was the introduction of cross-sectional imaging fifteen years ago. The aim of this Atlas is to provide a comprehensive pictorial guide to the echocardiographic appearances of cardiac disorders in adults and children. Cardiologists, General Physicians, Radiologists and Imaging Specialists are among a wide spectrum of doctors who need to be able to understand cardiac ultrasound, not only its interpretation but its potential and pitfalls. The marriage of M-mode echocardiography with cross-sectional imaging is described in this Atlas and has proved fundamental in allowing a better understanding of cardiac anatomy and function.

We have deliberately been dogmatic in our approach throughout the text. There are nine chapters in standard divisions and we have placed emphasis on the reproduction of the echocardiogram. The text is designed to underline or explain points of interest and to improve understanding of the image. This will allow the Atlas to be used by those knowing only a little cardiology as well as more specialist readers. The references quoted are not meant to be fully comprehensive but should allow the reader to delve deeper into a particular subject. They provide only the starting point for a literature search.

We are very grateful to the echocardiographic staff of Harefield Hospital for their help throughout the preparation of this work. Our special thanks go to Stephen Neal and Katharine Watts of Pitman Books who put our ideas into print and to Elizabeth Buchan for the typing of the manuscript.

JW

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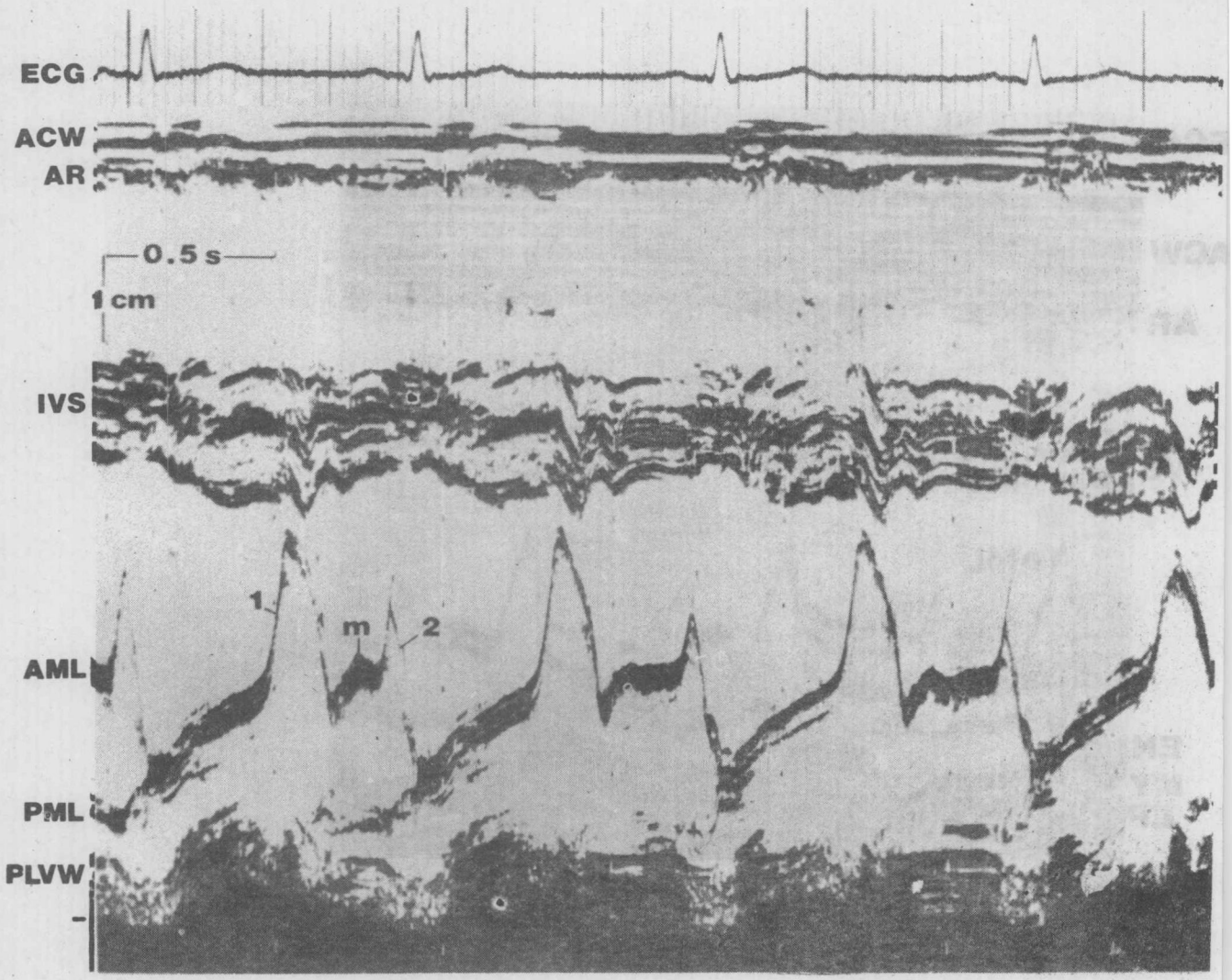
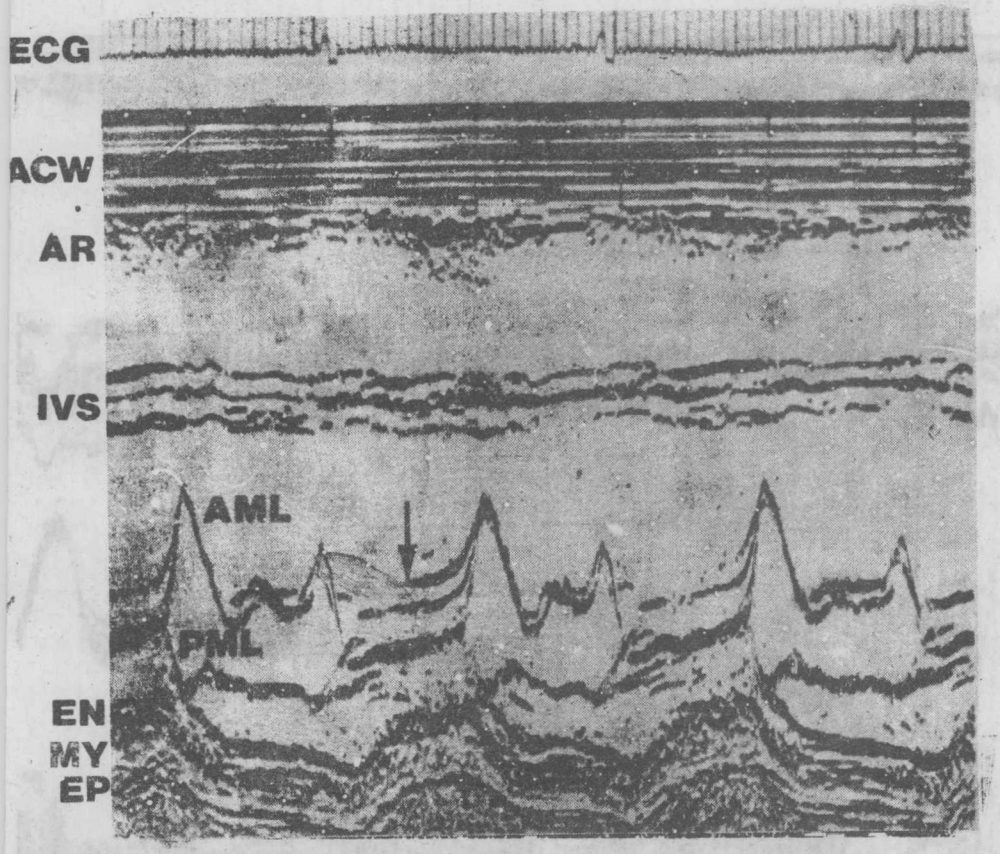


1.01 Normal Anterior Mitral Valve Leaflet

ECG	Electrocardiogram
ACW	Anterior chest wall
AR	Anterior wall of right ventricle
IVS	Interventricular septum
AML	Anterior mitral leaflet
PML	Posterior mitral leaflet
PLVW	Posterior left ventricular wall

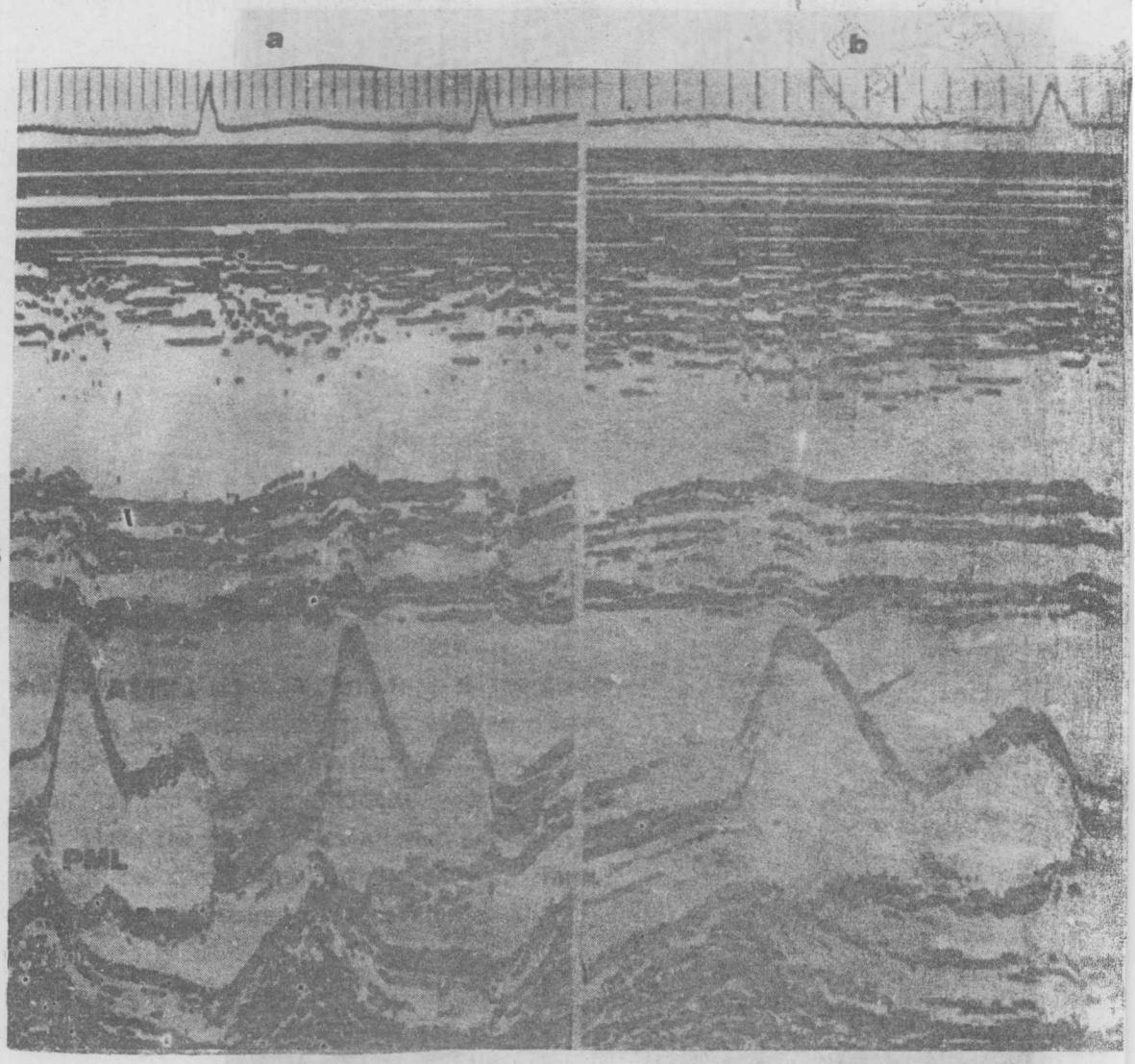
The anterior mitral leaflet moves towards the interventricular septum at the beginning of diastole, after the T wave of the electrocardiogram. This movement is rapid and is part of the mitral valve opening. As soon as the valve is fully open its starts to move posteriorly. A second anterior movement of the anterior mitral cusp occurs after the P wave of the electrocardiogram and is associated with left atrial systole. Following this, there is closure of the valve at the onset of ventricular systole. Frequently an additional small anterior movement of the mitral valve is seen in mid diastole (M). This mid diastolic movement is inconstant and appears most frequently when the heart rate is slow. To achieve maximal amplitude of movement and to measure the diastolic closure rate (DCR), the anterior mitral cusp should be recorded with the transducer in a position on the praecordium directly over its free margin. When the transducer position and angulation is optimal the rate of opening (1) and closing (2) at the beginning and end of diastole will be at least 300 mm/sec. The diastolic closure rate of the mitral valve is probably best measured as the maximum rate of closure (*see* 1.05 and 9.03). The amplitude of movement of the anterior cusp is at least 2 cm in normal subjects [1, 2, 3].



1.02 Normal Anterior and Posterior Mitral Valve Leaflets

The anterior and posterior cusps move in opposite directions in diastole. The amplitude of anterior mitral cusp movement is normally at least 2 cm and is greater than the posterior cusp movement. The maximum movement range of the anterior cusp is frequently not recorded when both anterior and posterior cusps are seen on the same echo. Mitral valve opening follows the isovolumic relaxation phase at the onset of the early rapid filling phase in the normal subject. The anterior and posterior cusps remain in apposition throughout systole. Additional echoes are frequently seen anterior to the closed cusps in systole (*arrow*) arising from the chordae tendinae and are the result of beam spread.

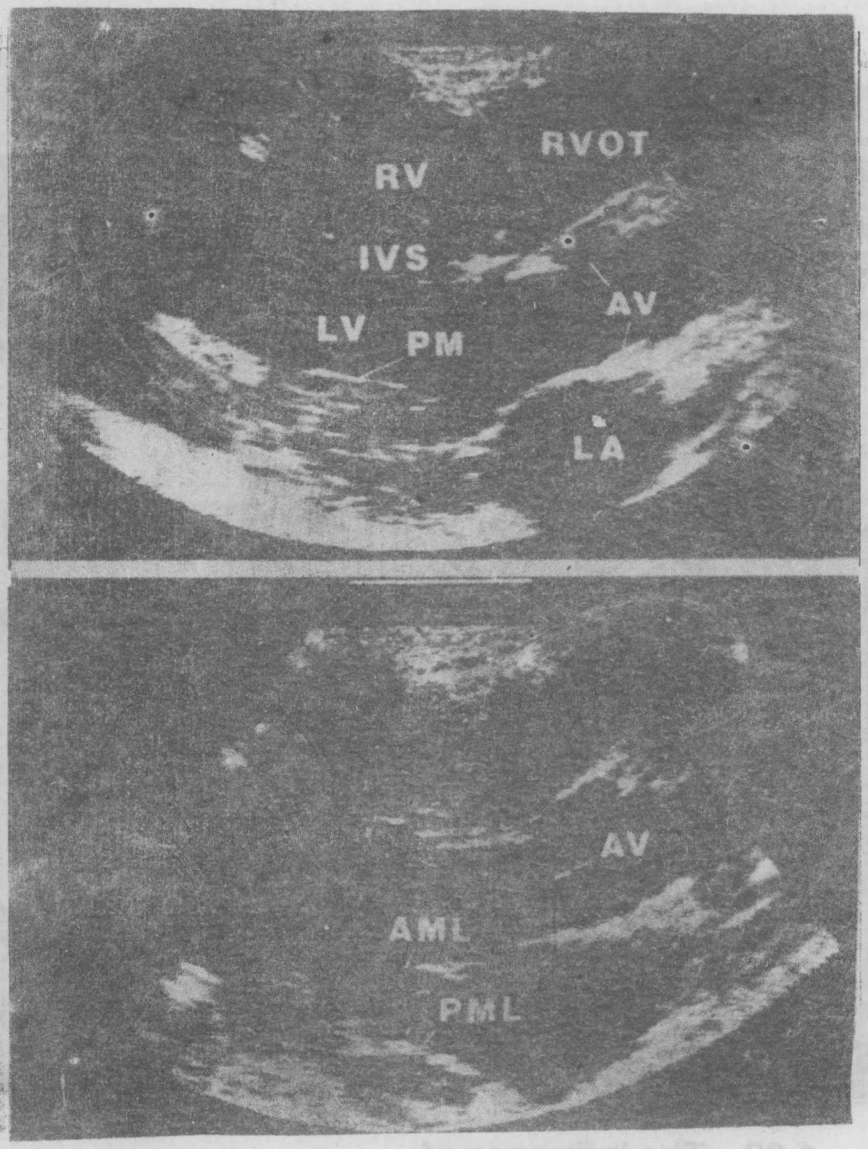
ACW	**Anterior chest wall**
AR	**Anterior wall of right ventricle**
IVS	**Interventricular septum**
AML	**Anterior mitral leaflet**
PML	**Posterior mitral leaflet**
EN	**Endocardium**
MY	**Myocardium**
EP	**Epicardium**



1.03 The Influence of Recording Speed on the Mitral Valve

(a) 50 mm/sec
(b) 100 mm/sec
IVS Interventricular septum
AML Anterior mitral leaflet
PML Posterior mitral leaflet

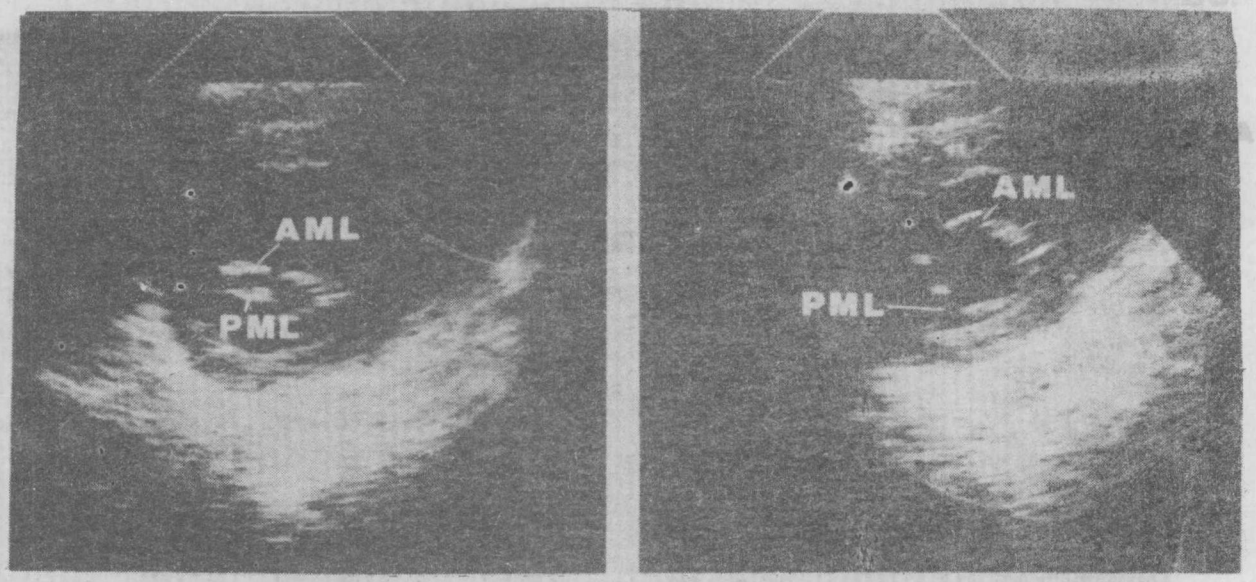
Although the upstroke of the anterior mitral leaflet at the beginning of diastole and the downstroke at the beginning of systole is more vertical in (a) than in (b), the calculated rate of opening and closing is in both cases over 500 mm/sec. The diastolic closing movement is clearly seen on the right hand fast tracing to be rounded (*single arrow*), but on the slower trace at 50 mm/sec on the left side it appears to be straight. Calculations of the diastolic closure rate (DCR) probably should be made at the maximum rate of closure (*double arrows*). Although the correlation of the DCR with the rate of ventricular filling is not linear, the DCR is a useful guide to left ventricular filling rate. Note that in normal subjects mitral opening occurs at minimum left ventricular dimension.



1.04 Long Axis Two-dimensional View—Normal Subject

The upper illustration was taken in systole and the lower in diastole. The scan is recorded through the heart from the aortic root on the right to the apex of the heart on the left. The separated open aortic cusps are visible on the systolic trace but they are in apposition on the lower trace. Posterior to the aortic valve is the left atrium. Anterior to the interventricular septum lies the right ventricle and the right ventricular outflow tract.

(a)	Systole
(b)	Diastole
RV	Right ventricle
RVOT	Right ventricular outflow tract
IVS	Interventricular septum
AV	Aortic valve
LV	Left ventricle
PM	Papillary muscles
AML	Anterior mitral leaflet
PML	Posterior mitral leaflet
LA	Left atrium



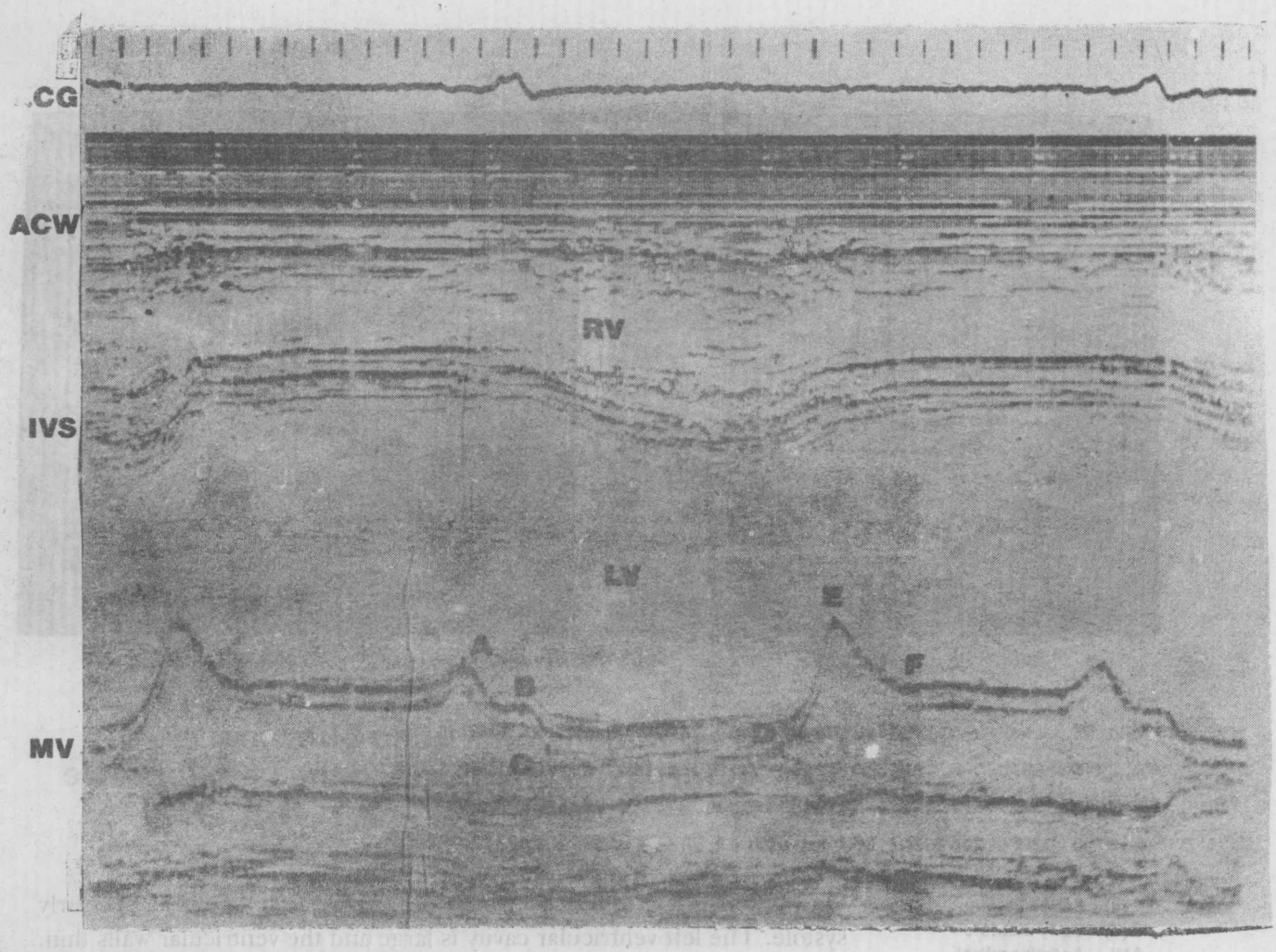
a b

1.05 Two-dimensional Echo Showing Short Axis View through the Left Ventricle

(a) Early systole
(b) Early diastole
AML Anterior mitral leaflet
PML Posterior mitral leaflet

On the left is a cross-sectional scan through the left ventricle in early systole. The left ventricular cavity is large and the ventricular walls thin. The anterior mitral leaflets are almost in apposition. The absence of complete apposition indicates that the recording is taken slightly towards the mitral ring rather than exactly in the free margin of the valve.

On the right, in early diastole, immediately following mitral valve opening, the ventricular cavity is still small and the ventricular walls thick. The anterior and posterior mitral leaflets are widely separated.

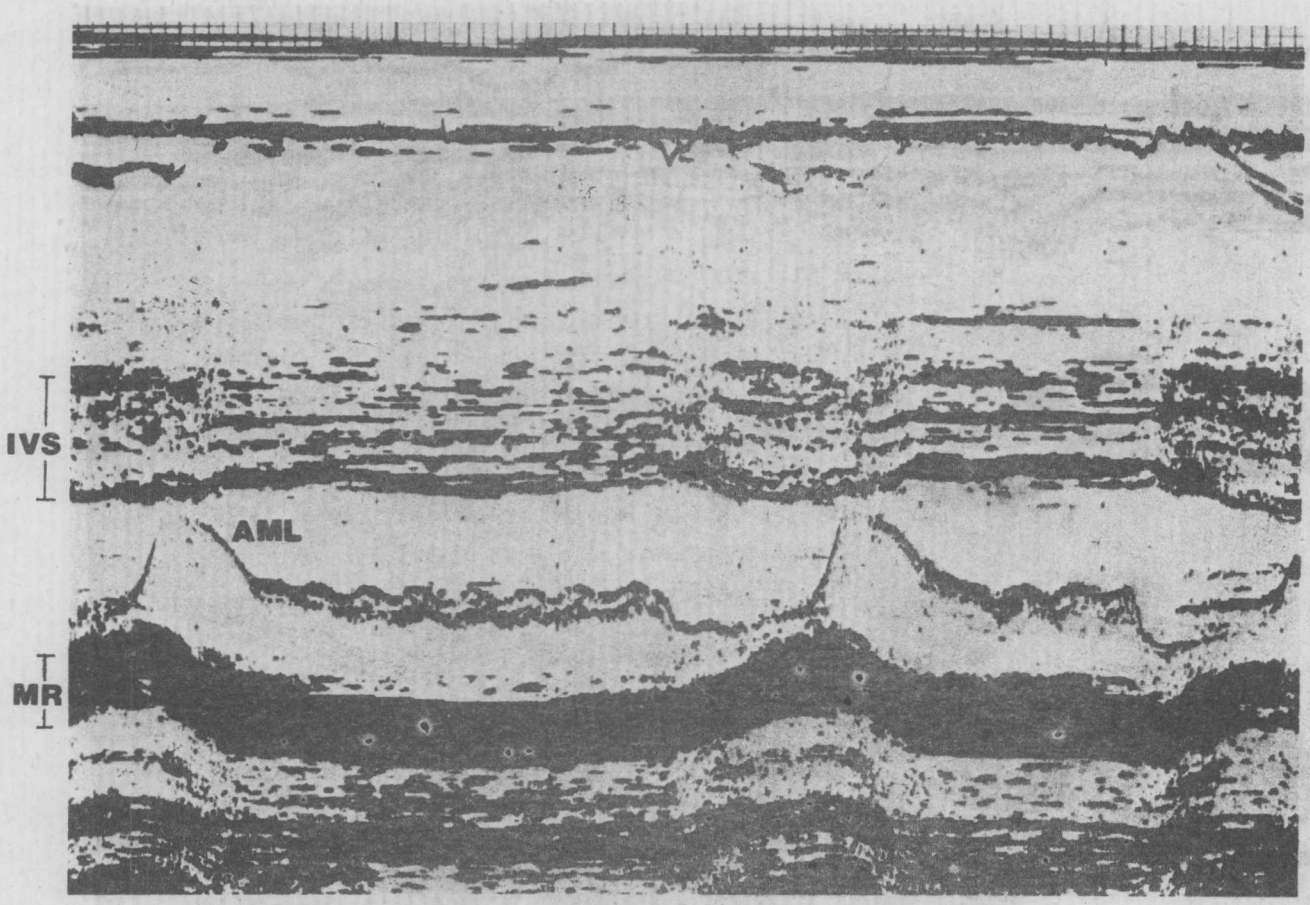


1.06 Anterior Mitral Leaflet with Prominent 'B' Point

ACW Anterior chest wall
RV Right ventricle
IVS Interventricular septum
LV Left ventricle
MV Mitral valve

When echocardiography of the mitral valve was first introduced by Dr Edler, he labelled a number of points on the normal trace. The most anterior movement of the anterior mitral leaflet after the P wave of the electrocardiogram, he labelled 'A'. This corresponds to the maximum opening after atrial systole. The valve then closes again to a mid-way position, where it remains until the onset of ventricular systole. The point at which mitral systolic closure starts he labelled 'B'. Complete apposition of the cusps occurs at 'C', 'D' is the opening of the mitral valve, 'E' is the point of maximal opening following the onset of ventricular diastole and 'F' the point at which the early rapid diastolic closure finishes.

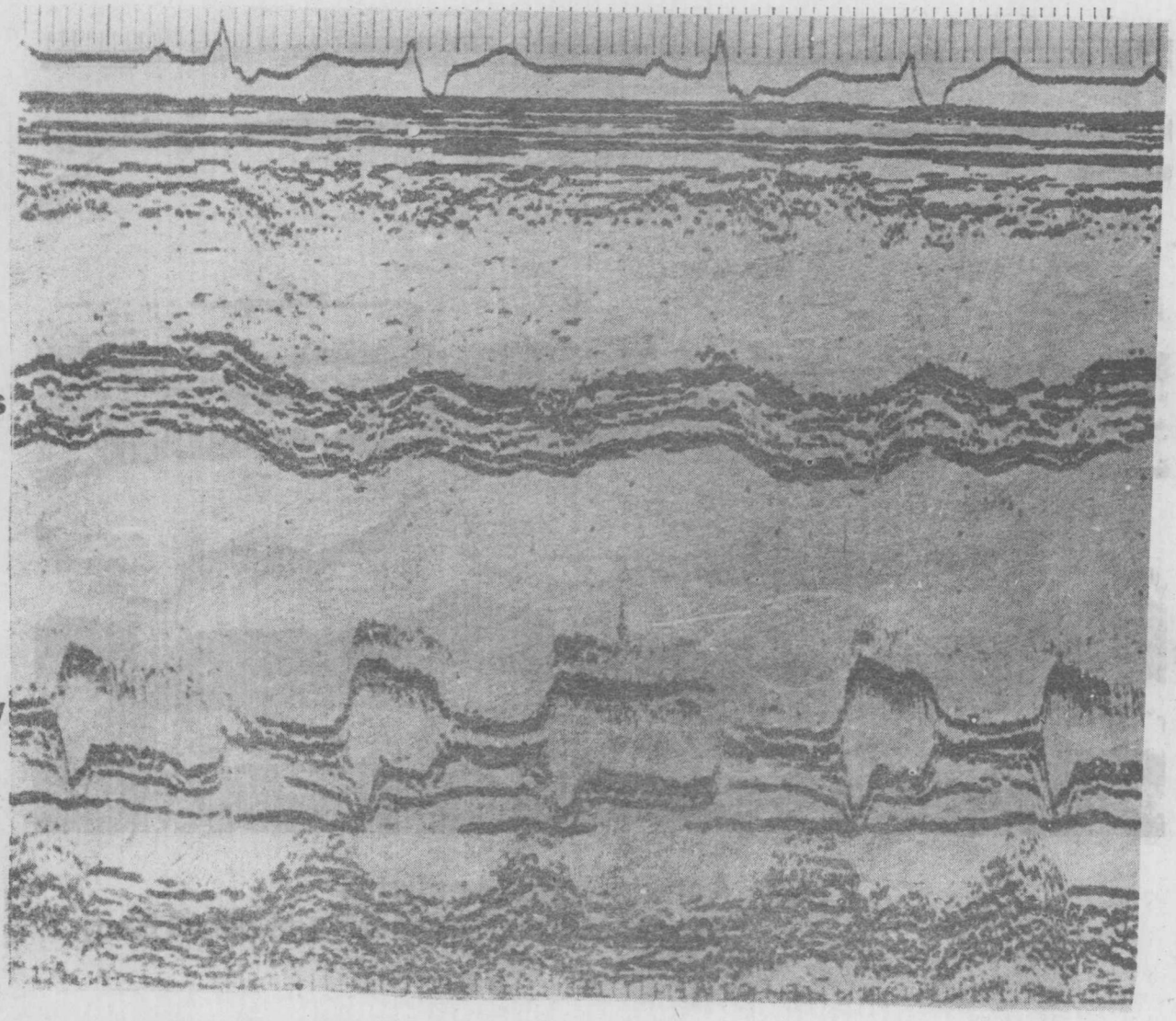
Routine records for valve movement are usually made at 50 mm/sec. Unless the P–R interval is lengthened, the mitral closure from the 'A' point appears to be continuous until the two cusps are in apposition, and the 'B' point is not always seen. A prominent 'B' point is said to occur when there is a significant rise in left ventricular end diastolic pressure, but it is an unreliable sign [4, 5]. This recording is taken at 100 mm/sec to accentuate the 'B' point in a patient with a dilated left ventricle.



1.07 Anterior Mitral Leaflet in Bradycardia. Calcification of Mitral Ring

IVS	Interventricular septum
AML	Anterior mitral leaflet
MR	Mitral ring

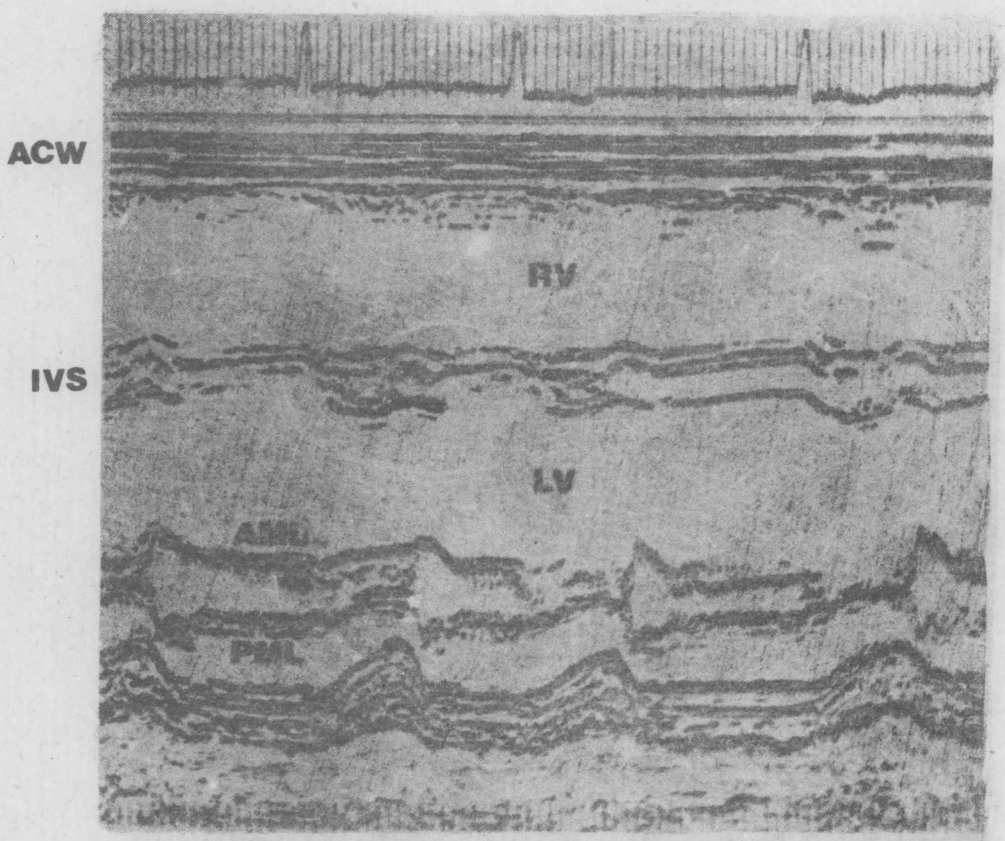
In patients with a long diastole the anterior mitral leaflet can be seen to undulate. In the present tracing there are a number of oscillating movements following the initial relatively rapid diastolic closure rate. The patient is in slow atrial fibrillation and behind the anterior mitral cusp there is a heavy echo, which represents calcification in the mitral ring. The movements of the anterior mitral cusp can sometimes be seen to correspond in time with 'flutter' waves on the electrocardiogram.



1.08 Mitral Valve Fluttering in Aortic Regurgitation

IVS Interventricular septum
MV Mitral valve
Arrow indicates rapid oscillations

In aortic regurgitation the anterior mitral leaflet, instead of remaining relatively static throughout diastole, will frequently show very rapid oscillations (*arrow*). These are due to turbulence caused by the regurgitant jet passing in front of the thin anterior mitral leaflet and the normal jet passing behind the anterior mitral leaflet from the left atrium [6]. The amount of oscillation has no quantitative relationship to the amount of reflux, which is better gauged from the left ventricular wall movements [7]. In the present illustration the ventricle is dilated with an end systolic diameter of almost 6 cm and an end diastolic diameter of over 7.5 cm. Rapid oscillation of this amplitude (over 1 cm) denies significant anterior mitral thickening, and by implication excludes mitral stenosis as a cause of the mid diastolic murmur, which is frequently indistinguishable from the Austin Flint murmur of aortic regurgitation.

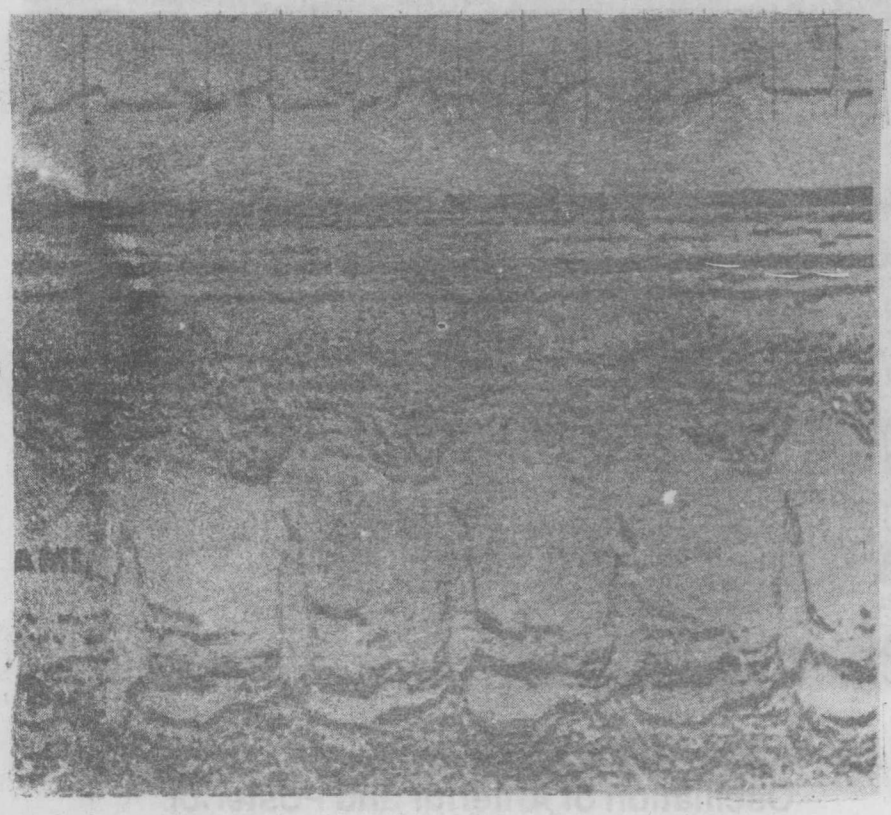


1.09 Aortic Regurgitation with Oscillation of Anterior and Posterior Cusps

ACW	Anterior chest wall
RV	Right ventricle
IVS	Interventricular septum
LV	Left ventricle
AML	Anterior mitral leaflet
PML	Posterior mitral leaflet

Both anterior and posterior cusps of the mitral valve oscillate rapidly. This suggests considerable turbulence, but again it does not necessarily mean that the aortic regurgitation is severe. No septal oscillation can be seen on this trace.

Similar but less marked flutter patterns may also be seen in patients with marked left ventricular dilatation and left ventricular failure without aortic regurgitation. The mechanism is presumably secondary to turbulence within the ventricular cavity.



1.10 Premature Mitral Closure in Acute Aortic Regurgitation

IVS	Interventricular septum
AML	Anterior mitral leaflet
PML	Posterior mitral leaflet

The tracing was taken from a young woman who had been unwell for only one week prior to admission. She had been febrile and had become acutely dyspnoeic shortly before admission. On auscultation an immediate diastolic murmur was audible. At operation a ruptured cusp due to endocarditis on a bicuspid aortic valve was found and the aortic valve was replaced. Mitral valve closure occurs before the P wave of the ECG, and this is only seen in acute aortic regurgitation. The pressure in the normal-sized left ventricle is increased in early diastole by the aortic regurgitation so that the atrioventricular gradient is reversed. If the patient survives, ventricular dilatation will abolish this diastolic pressure rise. Mitral closure before the P wave is pathognomonic of this condition. Premature closure of the mitral valve leaflets occurring after the P wave of the ECG may occur in heart failure from whatever cause.