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PERCUTANEOUS LEFT VENTRICULAR PUNCTURE IN THE ASSESSMENT OF AORTIC STENOSIS

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In the assessment of cases of aortic valve disease with a view to operation, the standard methods of investigation are of limited value. Right heart catheterization gives some indirect information by measuring the cardiac output and the pulmonary capillary pressure. Some information can be obtained from a study of the peripheral arterial pulse wave, but this too cannot always supply a definite answer. Two questions have to be answered in assessing a case of aortic valvar disease. The first is whether, in a patient with signs of pure aortic stenosis, symptoms such as angina or dyspnoea are due to the aortic stenosis or due to associated coronary disease or pulmonary disease. The second is whether aortic stenosis or regurgitation is dominant, in a patient who has a mixed lesion. These questions cannot be answered by indirect methods of investigation.

Further information in such cases might be obtained by measurement of the systolic pressure gradient across the aortic valve. This has been a standard procedure in the case of pulmonary stenosis for many years. Measurement of the systolic gradient across the aortic valve is a routine procedure at operation for aortic stenosis. We have now developed a method by which this information can be derived from pre-operative left ventricular pressure measurements.

PREVIOUS METHODS

LEFT ATRIAL PUNCTURE.—Björk, Malmström, and Uggla (1953) developed a technique of left atrial puncture through the right hemithorax in which, by passing a fine catheter down the needle through the mitral valve, the left ventricle was entered. This technique has also been used by Fisher (1955) and by us, but, while it is easy to puncture the large left atrium in mitral stenosis, the difficulties are much greater in cases of aortic stenosis and the lung is likely to be transgressed. In a small series of 24 cases of left atrial puncture we have noted a number of unpleasant complications and there have been three deaths, possibly precipitated by the procedure. Haemoptysis occurred in five patients. In two a small haemothorax developed. Pneumothorax was produced four times and one patient developed a tension pneumothorax. In addition the procedure caused hypotension and a shock-like syndrome in most of the patients who were orthopnoeic or had been in left ventricular failure. Haemopericardium sufficient to cause significant increase in the size of the heart shadow was a frequent complication, and many patients developed post-operative pericarditis with substernal pain and some fever. Two patients also complained of dysphagia. For these reasons we have now abandoned this procedure.

LEFT VENTRICULAR PUNCTURE.—In order to find an alternative method for measuring the aortic valve gradient we decided to investigate the possibilities of direct puncture of the left ventricle through the intact chest wall. It was realized that there were many possible dangers in this procedure. Insertion of the needle into an irritable hypertrophied ventricle might precipitate ventricular fibrillation and bleeding might occur either from the ventricular cavity or from puncture of a coronary vessel. As we have had considerable experience of puncture of the left ventricle at operation and are familiar with the management of the complications which may arise during cardiac surgery, we felt that it was logical and reasonable for us to investigate the possibilities of this method and that our experience would enable us to deal with any untoward situation which might arise.

Puncture of the left ventricle in this way is not an entirely new concept, but it has not previously been used for assessing the gradient across the aortic valve. Previous workers have been concerned with its application to angiocardiography. Nuvoli (1936) first performed left ventricular

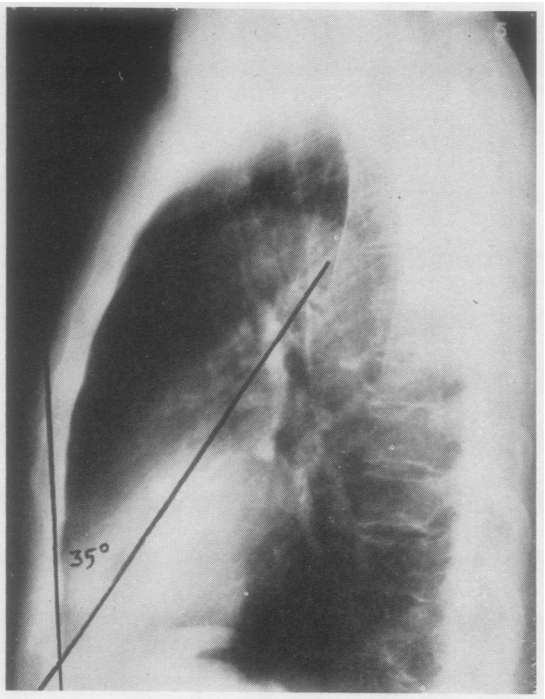

FIG. 1.—Lateral chest radiograph showing a line drawn from the apex of the heart through the calcified stenotic aortic valve. This makes an angle of 35° with the vertical plane.

puncture in man by the left parasternal route in order to outline an aortic aneurysm. The patient developed temporary syncope and bradycardia. A pioneer effort was made by Buchbinder and Katz in 1943, when they inserted needles into the right and left ventricles of a moribund patient in order to measure the intraventricular pressure. With considerable foresight they predicted its potential value in cardiological diagnosis (Buchbinder and Katz, 1949). Ponsdomenech and Nuñez (1951) and Nuñez and Ponsdomenech (1951) developed a method of puncture of the right or left ventricle by the subxiphoid route and performed 56 punctures without mortality. This was for the purpose of angiocardiography and the ventricular pressure was measured in only one case. Smith, Wilson, Cregg, and Klassen (1954) performed left ventricular puncture on six patients by the subxiphoid route for cardiangiography. They encountered ventricular extrasystoles in all cases; one patient developed asystole and another ventricular fibrillation, but it seems that these complications were attributable to the effects of the injected material rather than to the puncture itself.

PRELIMINARY STUDIES

Observations were made at operations for aortic stenosis and at post-mortem examination with a view to determining the line of the outflow tract of the left ventricle in the antero-posterior and lateral planes. Further information was obtained from a study of radiographs in which the position of the calcified aortic valve was clearly visible (Fig. 1). The axis of the outflow tract is found to correspond with a line drawn from the apex of the heart to the second right costochondral junction (Fig. 2a and b) and inclined backwards at an angle of about 35° to the sternum (Fig. 3). A needle inserted in this line has a better chance of entering the left ventricular chamber than one passing across the outflow tract. This is particularly true in aortic stenosis where the ventricular muscle is very thick and the cavity small, especially in systole. It also seems likely that there is less chance of damage to a coronary vessel since these are small in the region of the apex of the ventricles. In any case the warnings of possible damage to the coronary vessels during puncture of the pericardium seem to have been greatly exaggerated and few references can be found to this accident in the literature (Paget, 1896; Ballance, 1920).

These observations on the line of the outflow tract were checked by taking radiographs of the needle in position in the heart during left ventricular puncture (Fig. 4a and b).

TECHNIQUE

The patient is given premedication as for a cardiac catheterization and lies supine. The procedure can be carried out just as easily with the patient elevated at an angle of about 30° if he is orthopnoeic. An electrocardiograph is connected in every case and instruments are available for emergency thoracotomy, cardiac resuscitation, and aortic valvotomy. A percutaneous brachial artery puncture is performed. In addition the right heart has been catheterized at this stage in 15 cases. This last manœuvre gives a figure for cardiac output and enables the aortic valve area to be estimated in cases of pure stenosis.

The front of the chest is draped with sterile towels to expose the area from the right of the sternum to the mid-axilla and from the clavicle to the costal margin. The position of the apex beat and of the second right costochondral junction is then marked on the skin. In some patients it may be found that after premedication the apex beat is no longer palpable. It is therefore convenient to mark the position of the apex beat indelibly on the skin the day before the puncture. The position of the apex may also be determined from a study of an antero-posterior radiograph of the chest.

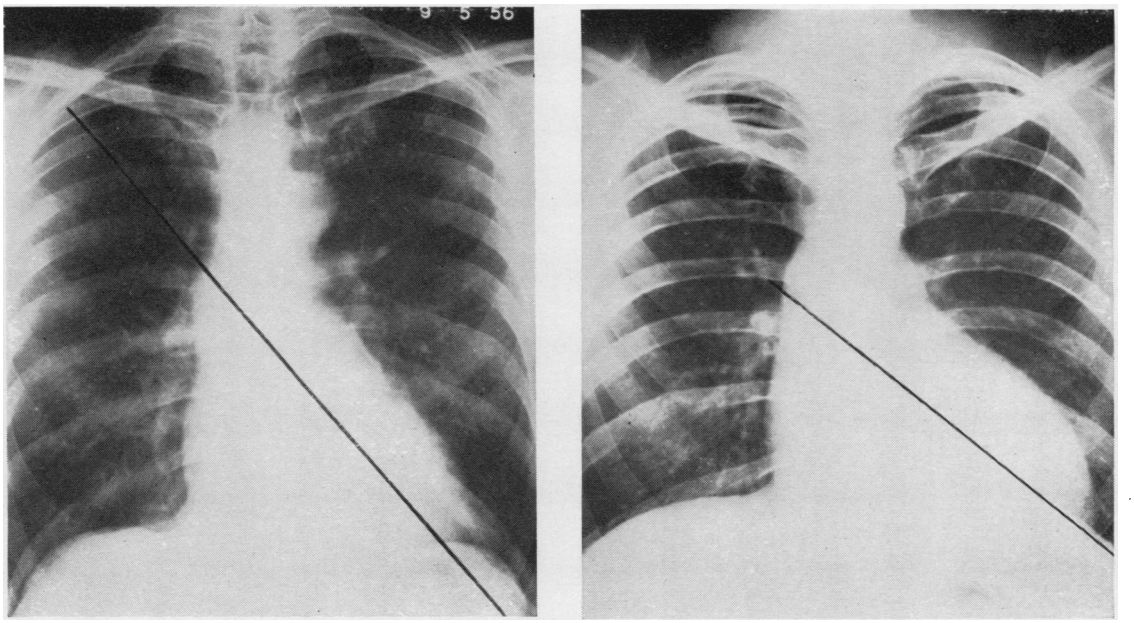

FIG. 2a FIG. 2b

FIG. 2.—Radiographs of two hearts showing that a line drawn from the apex through the area of valve calcification passes through the second right costochondral junction.

The skin about two centimetres below and lateral to the apex beat is infiltrated with local anaesthetic solution and the infiltration is carried down to the pericardium. The electrocardiograph tracing should be carefully watched at this stage. The appearance of one or two extrasystoles means that the needle has penetrated the myocardium. If these are seen no more procaine should be injected at this depth and the needle should be withdrawn a short distance if it is required to inject any more. The injection of procaine into the myocardium may precipitate ventricular fibrillation. A No. 18 gauge needle 12.5 cm. long is connected to the electromanometer and heparinized saline run slowly through it. The needle is inserted at the apex and directed towards the second right costochondral junction with a backward inclination of about 35°. It is advanced until the left ventricle is just felt impinging on the needle tip and it then enters the ventricle. Precautions must be taken to avoid air embolism, which we regard as a possible serious hazard, although it has not occurred in our cases. The needle is lightly supported between the fingers while synchronous or immediately consecutive left ventricular and brachial artery tracings are recorded. The needle is then withdrawn and the skin puncture covered with a simple dressing. The needle is not as a rule in the heart for more than three to four minutes, and, apart from one or two extrasystoles as the ventricle is penetrated, there are no further arryhthmias while the needle is in position so long as the needle is kept still (Figs. 5 and 6). In one case it was necessary to elevate the patient's shoulders while the needle was in position, and the angulation of the needle on the heart which resulted caused a series of ventricular extrasystoles. There is no distress, and little sensation of pain or discomfort is experienced by the patient. Recently we have been successful in passing a fine catheter through the needle and into the aorta and have secured a withdrawal tracing.

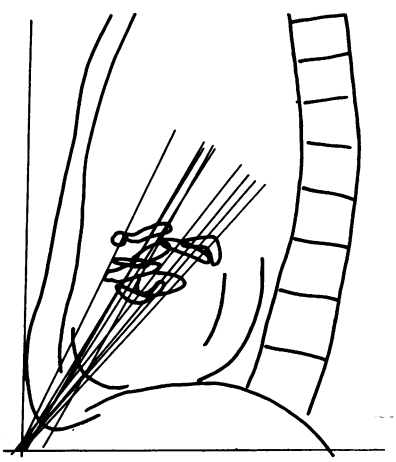

FIG. 3.—Composite drawing of lateral views of nine hearts from cases of aortic stenosis. A line has been drawn from the apex through the centre of the area of valve calcification in each case. The angle varies from 24 to 42° with a mean of 35°.

A radiograph of the chest is taken routinely before the patient is returned to the ward to exclude

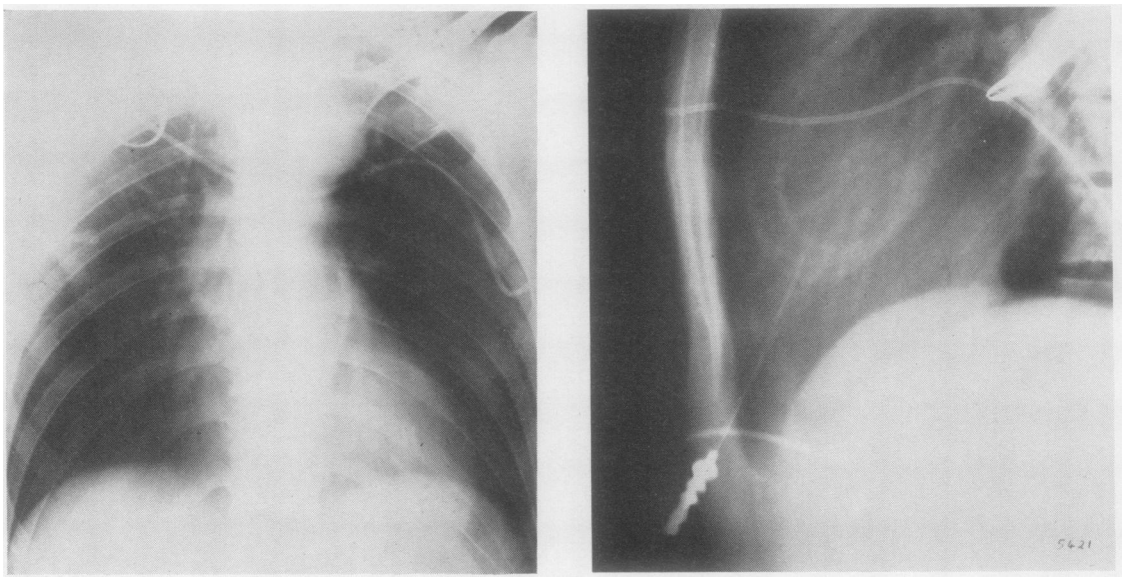

FIG. 4a FIG. 4b

FIG. 4.—Antero-posterior and lateral radiographs taken during left ventricular puncture and right heart catheterization. The ventricular needle and cardiac catheter can be seen. Note that in the antero-posterior view the needle is directed towards the second right constochondral junction. In this case the posterior angulation of the needle is about 30°.

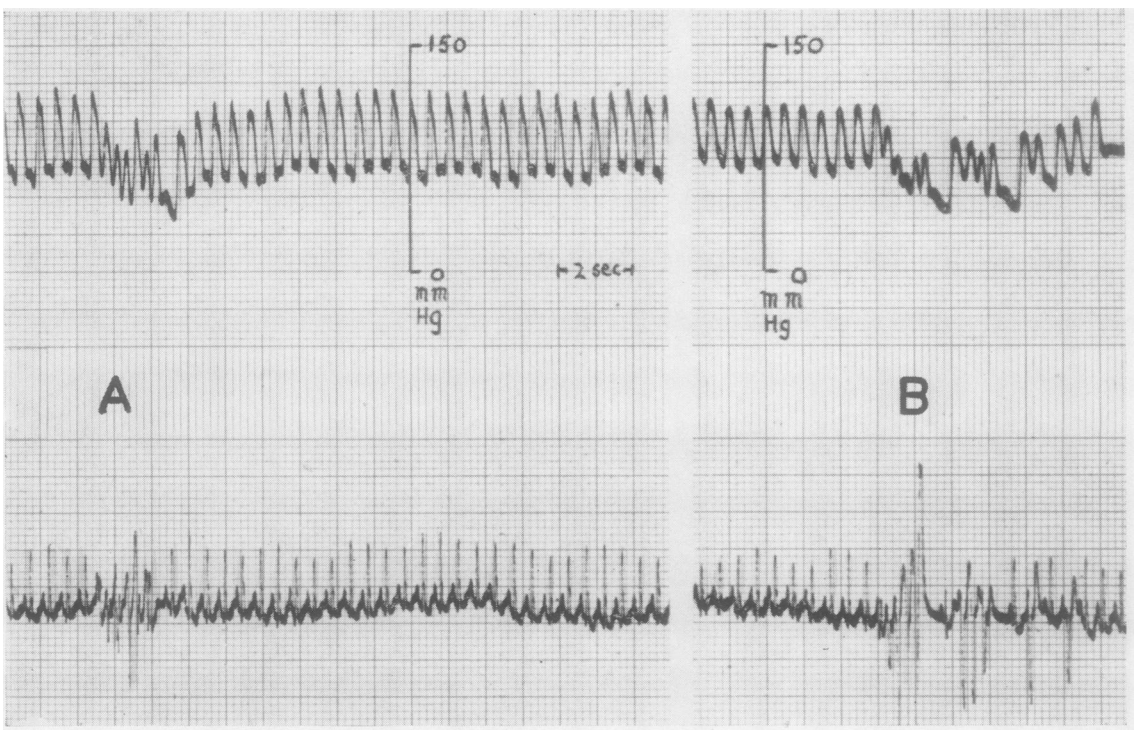

FIG. 5.—Continuous electrocardiogram and arterial tracing during left ventricular puncture. At A the infiltration needle penetrated the myocardium causing a few ectopic beats. At B the puncture needle was advanced through the myocardium.

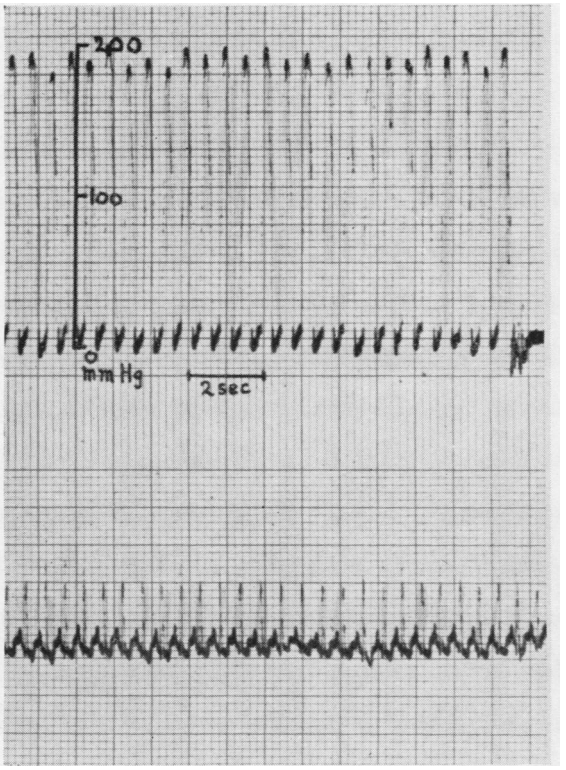

FIG. 6.—Tracing during withdrawal of needle from the left ventricle. Regular rhythm is seen throughout.

pneumothorax or blood in the pleura or pericardium. Figs. 7 and 8 show pressure readings obtained by this technique.

RESULTS

Twenty-four patients have been submitted to direct left ventricular puncture and of these 15 have had right heart catheterization in addition. In 12 cases the diagnosis has been confirmed at operation when the gradient was compared with the figure obtained at left ventricular puncture (Table I). It will be seen that there is, in general, reasonably close correlation between the observations made before and at operation. We are unable, therefore, to agree with the objections made by some authors (Bailey, Bolton, Nichols, Jamison, and Litwak, 1956 ; Matthews, Medd, and Gorlin, 1955) that pressure readings made at operation are inaccurate and misleading. These statements seem to have been made with no practical observations at all to support them.

There have been no deaths in this series.

TABLE I

PRESSURES AT VENTRICULAR PUNCTURE AND AT OPERATION (in mm. Hg)

Case No.	Left Ventricular Puncture			Operation		
	L.V. Pressure	B.A. Pressure	Gradient	L.V. Pressure	Aortic Pressure	Gradient
1	165/10	130/70	35	155/10	70/45	85
2	145/10	100/45	45	155/10	65/30	90
5	220/10	100/60	120	195/25	80/45	115
6	170/10	95/60	75	135/15	70/50	65
9	255/10	130/90	125	165/15	55/30	110
12	245/15	185/105	80	250/30	200/100	50
15	150/12	115/75	35	175/25	150/100	25
16	220/15	100/60	120	200/20	80/50	120
18	200/25	80/50	120	200/45	95/60	105
19	205/20	140/80	65	160/20	80/45	80
20	260/40	150/70	110	175/35	85/65	90
22	170/15	95/45	75	145/15	75/45	70

HAEMODYNAMIC EFFECTS OF LEFT VENTRICULAR PUNCTURE

For this investigation to be of value it must be established that it does not cause any profound disturbance in cardiovascular physiology. We have attempted to settle this point by studying the electrocardiograph for rhythm changes and by recording the blood pressure, pulse rate, and cardiac output before and during the puncture. The results are recorded in Table II.

The only rhythm changes seen were ventricular ectopic beats. Bundle branch block was encountered in only one case in which it appeared transiently during the preliminary right heart catheterization.

TABLE II

HAEMODYNAMIC CHANGES DURING VENTRICULAR PUNCTURE

Case No.	At Rest			During Ventricular Puncture		
	Cardiac Output (l./min.)	Blood Pressure (mm. Hg)	Pulse Rate	Cardiac Output (l./min.)	Blood Pressure (mm. Hg)	Pulse Rate
1	5·7	95/50	78	—	130/70	100
2	4·7	110/50	61	—	100/45	56
3	5·9	95/70	97	—	95/65	116
4	6·0	90/40	71	—	55/25	71
5	10·9	95/55	88	12·9	100/60	98
6	5·0	110/60	85	6·3	95/60	100
7	3·7	80/60	90	4·3	80/55	72
8	6·0	130/85	85	10·2	105/65	80
9	5·1	130/90	83	5·9	130/90	108
10	7·3	110/60	70	8·3	125/70	97
11	—	100/45	69	—	110/45	76
12	—	135/85	125	—	185/105	114
13	8·0	120/65	115	7·3	130/90	130
14	4·0	120/75	82	5·0	100/70	75
15	—	105/70	75	—	115/75	75
16	6·6	100/55	100	5·5	100/60	100
17	—	145/75	75	—	160/80	100
18	—	115/70	115	—	80/50	120
19	—	150/75	75	—	140/80	90
20	—	135/75	100	—	150/70	100
21	—	160/80	70	—	200/100	100
22	—	95/50	60	—	95/45	50
23	—	125/65	75	4·8	125/70	100
24	—	150/80	60	4·8	155/75	60

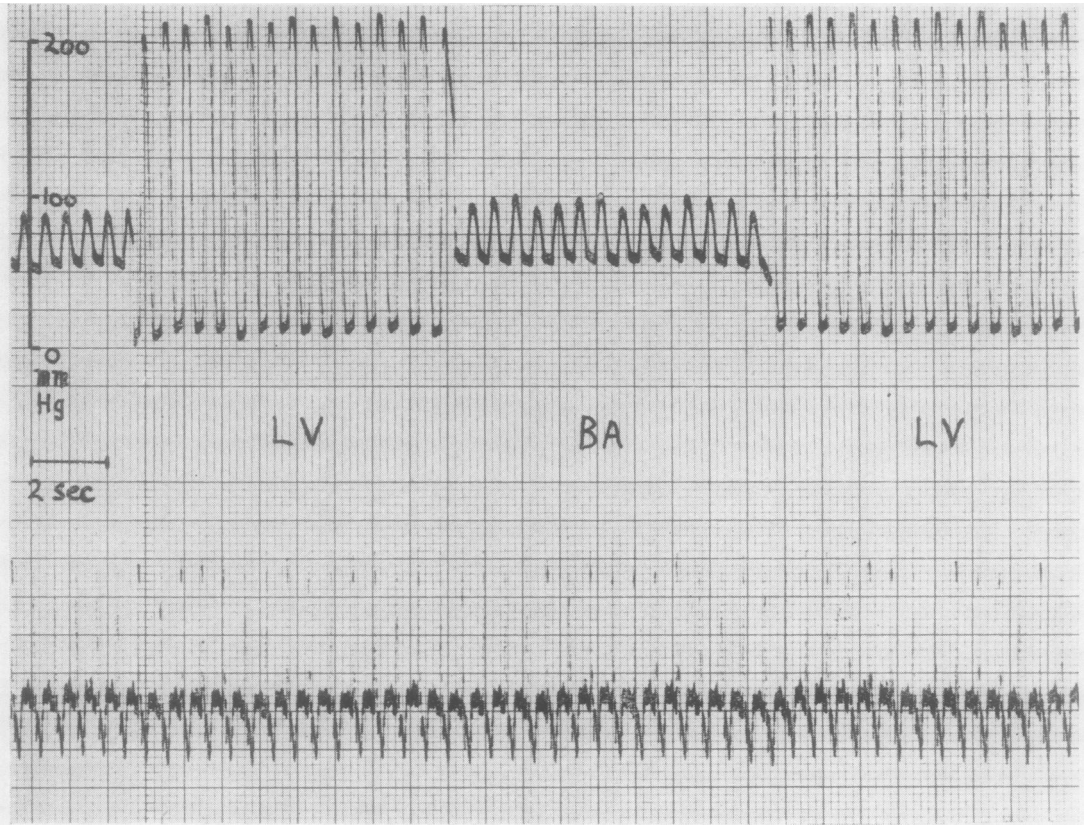

FIG. 7a

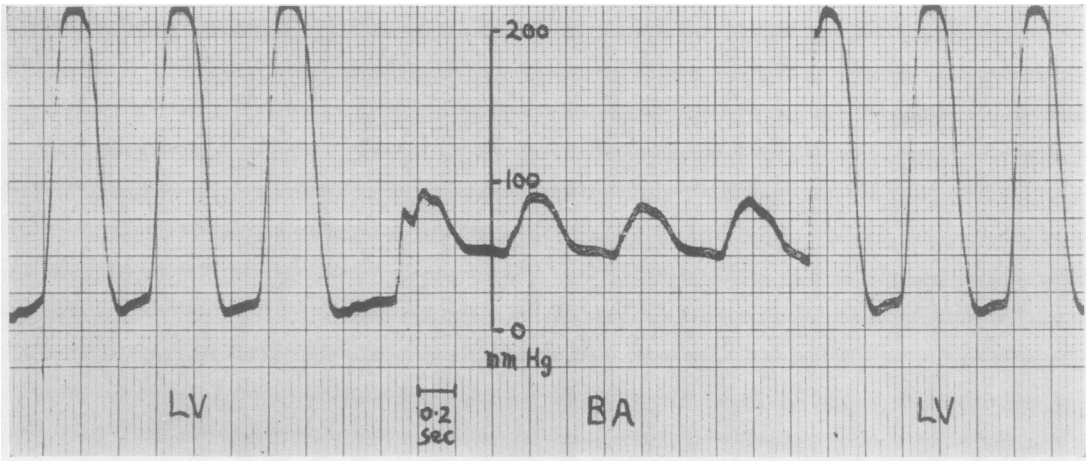

FIG. 7b

FIG. 7.—Immediately consecutive left ventricular and brachial artery pressure records showing an aortic systolic gradient of 120 mm. Hg, thus demonstrating severe aortic stenosis; a is at slow speed and includes the electrocardiogram; b is at fast speed to show the form of the curve.

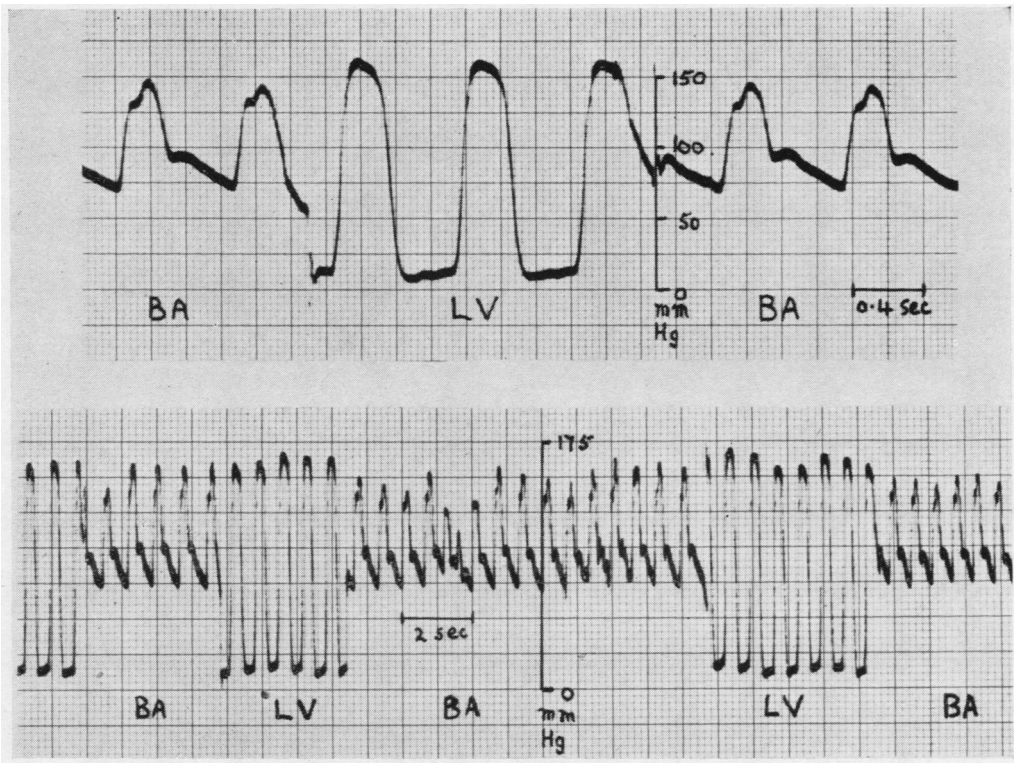

FIG. 8.—Immediately consecutive left ventricular and brachial artery pressure records showing an aortic systolic gradient varying from 5 to 15 mm. Hg, thus excluding significant aortic stenosis.

The blood pressure rose in 11 cases, fell in six, and was unchanged in seven. The rise was about 20 mm. Hg on the average, with a maximum of 50 mm. Hg.

The pulse rate rose in 11 cases, fell in 10, and was unchanged in three. The change was small in most cases and the highest rate recorded during the puncture was 130 per minute.

The cardiac output rose in seven cases and fell in two. The increase was about 20% with one exception in which there was a rise from 6.0 to 10.2 l./min.

These findings indicate that in the majority of cases the procedure does not alter the haemodynamics to any degree which would render the information obtained unreliable.

ILLUSTRATIVE CASE REPORTS

The value of this method can be judged by the following two brief case reports.

CASE 20.—A. L., a man aged 43, had had dyspnoea on exertion for 10 years. He was found to have asthma and chronic bronchitis. He had had attacks of congestive cardiac failure two years and six months before admission. Since the last attack he had been confined to bed with severe left ventricular failure and emphysema.

Examination revealed central cyanosis and dyspnoea at rest. Both ventricles were enlarged. There was a grade 3 aortic systolic and grade 2 diastolic murmur. The aortic second sound was absent. There was considerable aortic valve calcification. The arterial oxygen saturation was 85.7% and the plasma CO_2 content 64.0 vol.%.

Left ventricular puncture revealed a systolic gradient across the aortic valve of 110 mm. Hg, the pressure in the left ventricle being 260/40 and in the brachial artery 150/70. In spite of the severe emphysema and cor pulmonale it was considered that aortic valvotomy was unavoidable in view of the very high pressure in the left ventricle.

At operation the gradient was 90 mm. Hg and valvotomy reduced it to 15 mm. Hg.

CASE 24.—C. G., a man aged 67, had had increasingly severe angina pectoris for six years. For three months he had had to rest at home and could walk only a few yards.

Examination revealed evidence of aortic stenosis with some anomalous features and the electrocardiogram showed gross left ventricular hypertrophy. It

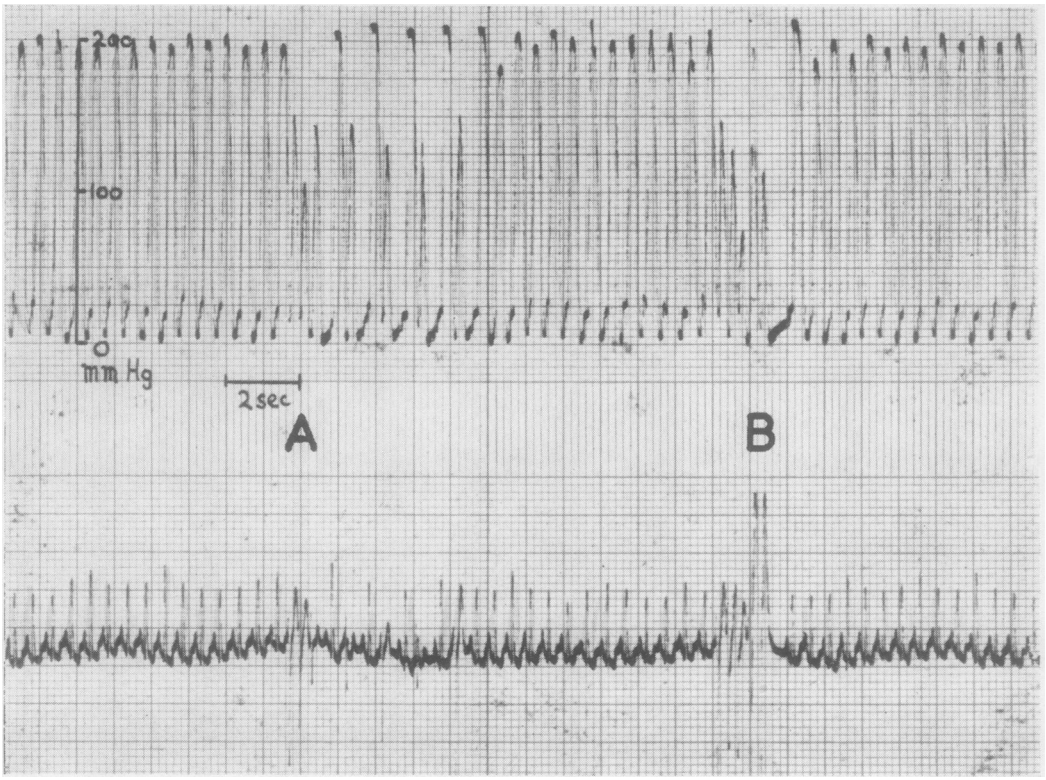

FIG. 9.—Pressure record and electrocardiogram during advancement of the needle 10 cm. into the left ventricle (from A to B). Ectopic beats at B are presumed to be due to the needle impinging on the septum at a depth of 10 cm.

seemed possible that the angina was due to the aortic stenosis and therefore he was considered for aortic valvotomy.

Right heart catheterization and left ventricular puncture were performed and these showed a systolic gradient of −10 mm. Hg between the left ventricle and the brachial artery with an output of 4.8 litres per minute. This demonstrated that there was no significant aortic stenosis. Aortic valvotomy was not advised.

COMPLICATIONS

Cardiac arrest and ventricular fibrillation have not been observed. No patient showed any evidence of pneumothorax or haemothorax and there has been no evidence of enlargement of the heart shadow such as would suggest a haemopericardium of any size. On two occasions a small quantity (20–50 ml.) of dark blood was found in the pericardium at operation, but this had not given rise to any symptoms. One patient complained of substernal pain for 36 hours and there was about 50 ml. of blood-stained fluid but no pericardial reaction. There has been no evidence of laceration of the myocardium. The puncture wound at the apex has only been visible on one occasion at subsequent operation. In one case there was renal pain and later haematuria which were probably due to a renal embolus. One patient had transient syncope after the procedure and one a mild degree of hypotension for a few hours. There has been no fever and the patients have been able to get up the next day.

DISCUSSION

The introduction of a needle direct from the anterior chest wall into the left ventricle sounds an alarming procedure. In investigating the possible use of this method we were aware of this and approached it very cautiously. However, we have found that the technique is simple and in fact in most cases the apex of the left ventricle seems to be almost subcutaneous. The ease with which the left ventricular pressure is obtained contrasts strongly with other less direct methods. Moreover, as a

large needle can be used a pure undamped tracing much superior to that obtained through a long fine catheter is recorded. This makes analysis of the record simple and more accurate. We have not failed to enter the left ventricle in any case. In one patient who had cor pulmonale as well as aortic stenosis with a very large right ventricle extending electrocardiographically as far as V6, the needle inserted at the apex entered the right ventricle and a second puncture further back was necessary to enter the left ventricle. In 10 of these cases the needle was advanced as far as possible up the outflow tract and it was found that it could be advanced for a further 10 cm. after the ventricle was first entered before extrasystoles appeared on the electrocardiograph, suggesting that the needle had again penetrated the myocardium (Fig. 9). Thus it seems that if the needle is passed along the line of the outflow tract it will remain in the ventricular cavity and there is a wide margin for error. The procedure is no more disturbing to the patient than the brachial artery puncture and certainly far less than puncture of the left atrium from the posterior chest wall. It clearly has wider possibilities as a method of investigation, for example, in the study of mitral valve disease. In the assessment of mitral valve gradients we now consider that a left ventricular puncture combined with a perbronchoscopic left *atrial* puncture is a much less disturbing method for the patient than left atrial puncture from the posterior chest wall and the passage of a catheter by this route into the left ventricle. We have thought it inadvisable to exercise patients while the needle is *in situ* because of the arrhythmias which would result from displacement of the needle. The interpretation of the data obtained by this investigation is to be described in a separate article (Gibson and Fleming, 1956).

Summary

The assessment of cases of aortic stenosis for operation necessitates the measurement of the gradient across the aortic valve.

A method of measuring the gradient by direct puncture of the left ventricle through the intact chest wall and simultaneous brachial artery puncture is described. The procedure is simple and safe, causes no disturbance to the patient, and has given rise to no serious complications. It has now been performed 24 times.

The value of the method and other possible applications in cardiological investigation are discussed.

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