INTRACARDIAC ELECTROGRAPHY IN CARDIAC CATHETERISATION

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INTRODUCTION

The first report on intracardiac electrography in man came from the French workers in 1945. It has been extensively studied since then by Hecht (1946), Sodi Pollares (1947), Levine et al (1949). These studies contributed a great deal to the understanding of standard electrocardiography and the electrophysiology of the heart; however they were largely academic. Its application in diagnostic cardiology was subsequently popularised by Elmslie-Smith and Elmslie-Smith et al (1955, 1956). In the earlier days, the electrode catheters used did not allow for recording of pressure pulses and the sampling of blood. Later on, standard catheters of all sizes with built-in electrodes overcame the earlier drawbacks, and with this development the use of intracardiac electrography in diagnostic work received considerably wider attention.

The purpose of the present communication is to record the experience with intracardiac electrography in the cardiovascular laboratory in Singapore since it began to function in February 1964. It has been used in selected cases and not routinely for the following reasons (1) Its diagnostic value is confined largely to catheterisation of patients with congenital heart disease, (2) Electrode catheters are more expensive than ordinary catheters, (3) Electrodes within the heart are not without danger for if the recording machine is not properly earthed ventricular fibrillation may be induced. Admittedly, this risk is very small today with the availability of properly constructed electronic devices. (4) Lastly, the internal diameter of the electrode catheter is smaller than that of a standard catheter for the same external diameter. This is due to the fact that the spiral wire embedded in the wall of the catheter necessitates a thicker wall. For instance, it is extremely difficult to withdraw blood through a No. 5 electrode catheter whereas no such difficulty is encountered with a No. 5 ordinary Cournand catheter.

METHOD

The electrode catheter used is the ordinary Cournand catheter with a built-in platinum electrode 1 m.m. from the tip manufactured by the United States Catheter and Instrument Corporation. The electrode is connected by a spiral wire embedded in the wall to a metal piece on the proximal end. The praecordial lead is connected to this end by a wire lead with crocodile clips. Ideally, a scalar E.C.G. lead should be used as standard for comparison. However, the 4 channel N.E.P. recording machine used has only one E.C.G. channel. In general, the standardisation of the intracardiac electrogram is 2 millivolt for 1 cm. deflection. Pressures were recorded with P23DG Statham Strain-gage on to Gevaert Oscilloscript D paper. The lines were touched with black ink.

THE NORMAL INTRACARDIAC ELECTROGRAM

The electrogram in each chamber of the heart and in the great vessels is fairly typical. Within each chamber characteristic variations occur according to the site and the direction of the catheter tip. This knowledge facilitates exact localisation of the catheter tip during cardiac catheterisation.

The atrial depolarisation wave is often referred to as the auriculogram, and this corresponds with the P in standard E.C.G. The ventricular depolarisation and repolarisation waves are referred to as the ventriculogram, corresponding to the QRS and T in standard ECG. Fig. 1 is a composite diagram showing the more typical auriculograms and ventriculograms. The auriculogram (or P) is most prominent in the atria and becomes insignificantly small in the ventricles, aorta and pulmonary artery. It is negative at or near the sino-auricular node from where atrial impulse originates.

Fig. 2 shows a typical mid-right atrial tracing where the auriculogram is biphasic. The intrinsic deflection of the right auriculogram occurs in the early part of P whilst that of the left atrium occurs in the second half of P.

Fig. 3 illustrates a withdrawal record from mid-right atrium to high-right atrium to superior vena cava. The P is large in the upper part of the right atrium; in the superior vena cava the P is entirely negative, reminiscent of aVR in standard ECG.

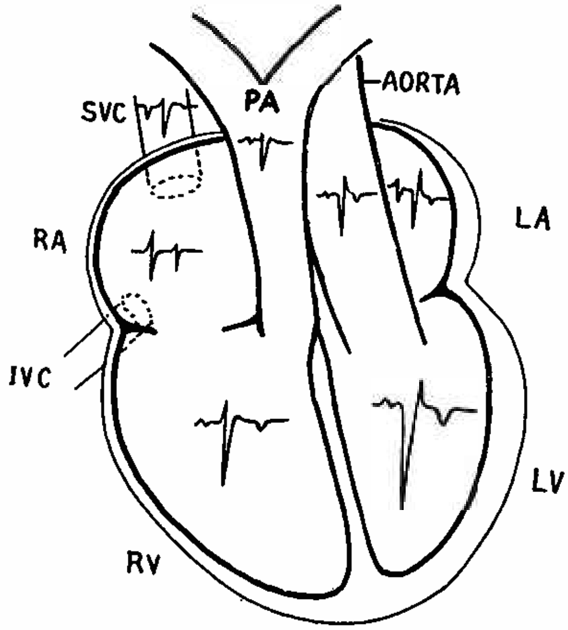

Fig. 1.

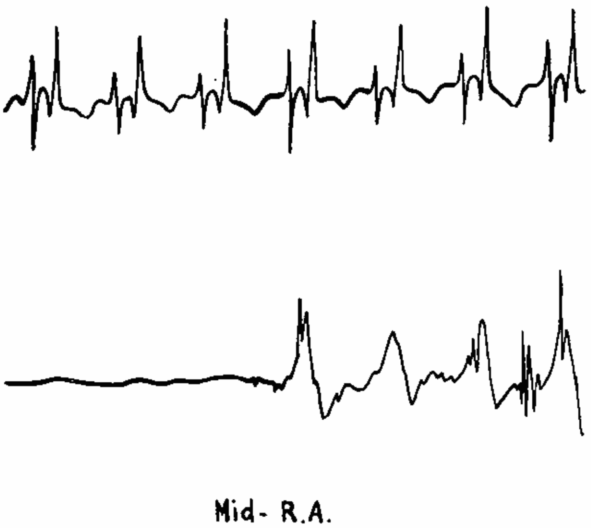

Fig. 2.

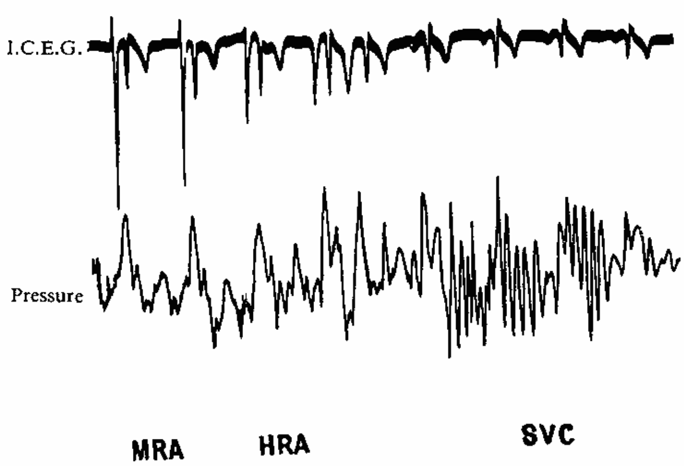

Fig. 3.

The ventriculogram in the right ventricle generally has a small early r followed by a deep S. Occasionally QS complexes are seen. On the ventricular aspect of the tricuspid valve and pulmonary valve it may show a tall, delayed R. In the left ventricle, left atrium and aorta the ventriculogram invariably takes the form of Qr complexes with small delayed r and inverted T, like the pattern of myocardial infarction in standard ECG. Not shown in fig. 1 but equally characteristic is the auriculogram and ventriculogram recorded in the coronary sinus. The auriculogram is of the left atrial variety with a biphasic pattern; the QRS is of the left ventricular variety, showing a deep Q, a late R and an upright T of the epicardial surface of the left ventricle (Elmslie-Smith 1955).

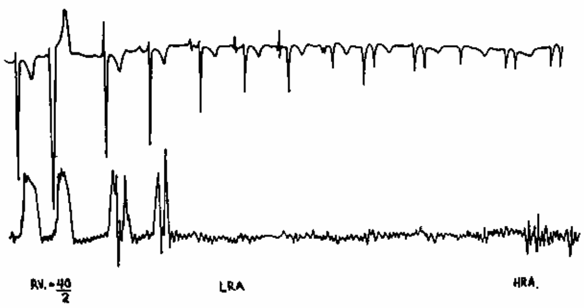

Fig. 4.

Fig. 4 illustrates the change in the electrogram from the right ventricle to the right atrium. The ventriculogram in the right ventricle takes the form of rS complexes. The potential of the QRS complex is much less in the right atrium and the P waves become progressively more negative the higher they are recorded in the right atrium.

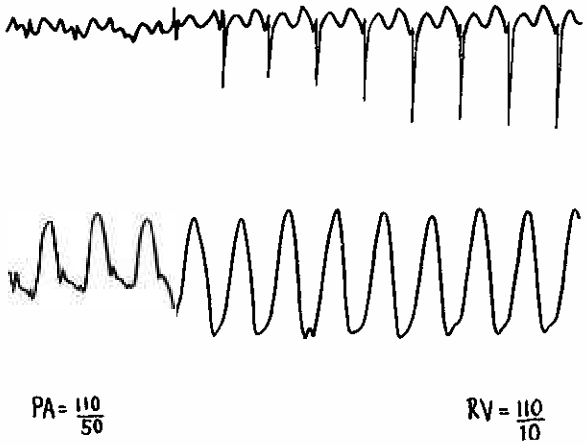

Fig. 5.

Fig. 5 illustrates a withdrawal tracing from the pulmonary artery to the right ventricle. There is no pressure gradient between the right ventricle and the pulmonary artery. The change in the QRS complexes is at the level of the pulmonary valve; it is abrupt and easily recognisable. This enables exact and instantaneous localisation of the position of the pulmonary valve.

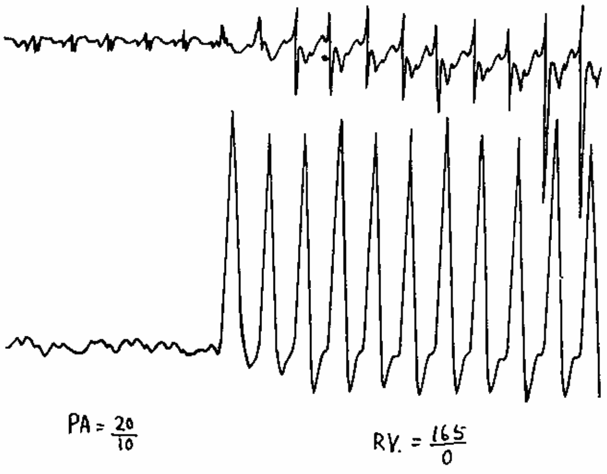

Fig. 6.

Fig. 6. In pulmonary valvular stenosis, the sudden jump in pressure when the catheter tip is withdrawn across the pulmonary valve from the pulmonary artery to the outflow tract of the right ventricle coincides with the abrupt change in the intracardiac electrogram. It is noteworthy that the voltage of the QRS complexes is greater in the body of the right ventricle than in the infundibular chamber. Selective angiocardiography proved the stenosis to be at valve level.

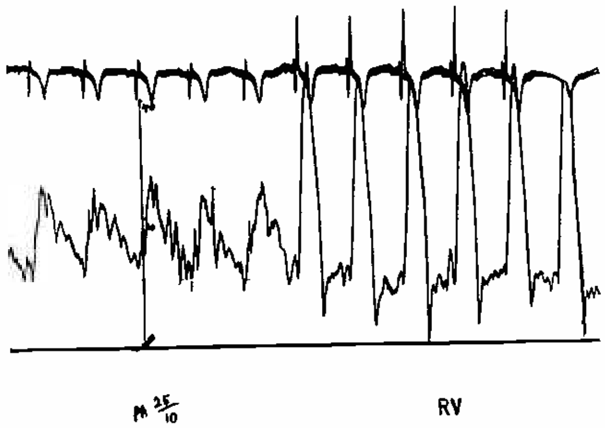

Fig. 7.

Fig. 7 illustrates another example of pulmonary valvular stenosis of a milder degree in which the obstruction was localized at valve level by the change in QRS complexes.

Fig. 8. This is a tracing fiom a patient with pulmonary valvular and infundibular stenosis. Where the QRS complexes changes abruptly there is a jump in pressure indicating valvular stenosis. Between the infundibular and the body of the right ventricle, the pressure increases progressively. Concomittantly the voltage of the QRS complexes also increases.

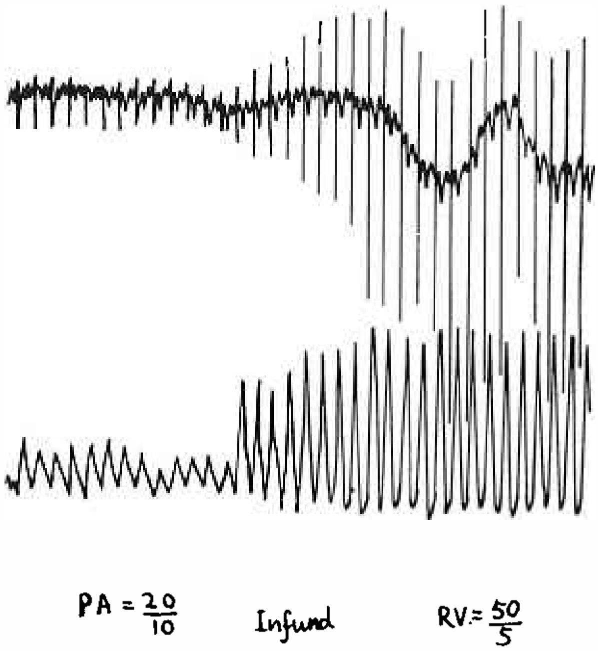

Fig. 8.

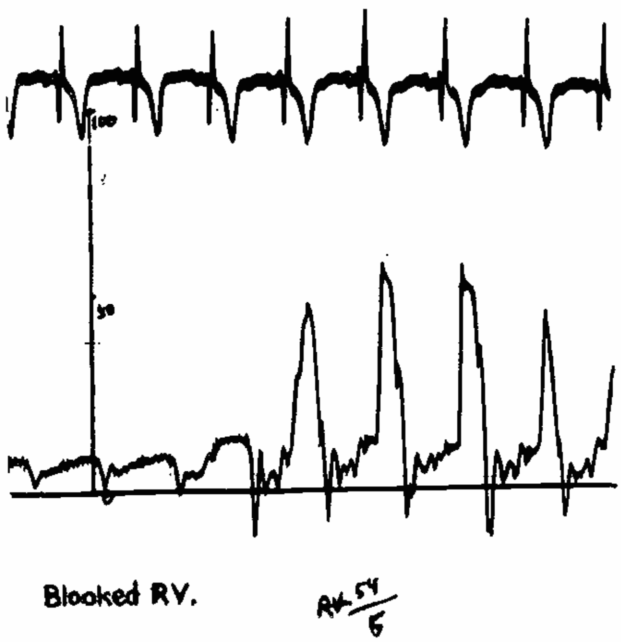

Fig. 9.

Fig. 9. This tracing was recorded with the catheter tip initially at a position which on fluoroscopy was thought to be either at the root of the pulmonary artery or in the right ventricular outflow tract just below the valve. On withdrawing the catheter to the body of the right ventricle, ventricular pressure pulse forms were recorded. Superficially, there appears to be a pressure gradient between the right ventricle and the pulmonary artery. But inspection of the intracardiac electrogram reveals no change in form or voltage. The explanation for the low pressure pulses first recorded is that they represented blunted right ventricular pressure pulses due to the catheter tip jamming against the wall

of the outflow tract. In other words, the catheter tip was never above the pulmonary valve at any time.

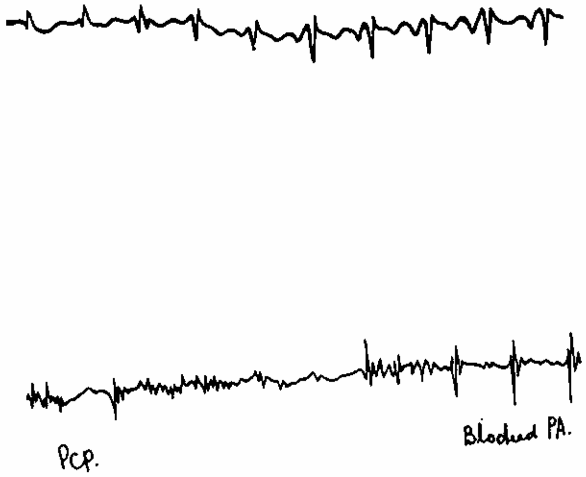

Fig. 10.

Fig. 10 shows a withdrawal recording from the pulmonary arterial wedged position to the main pulmonary artery. The intracardiac electrogram showed an abrupt change from the wedged position to the pulmonary artery position. The pulmonary artery pressure pulses were partially blocked hence producing an appearance not unlike the wedged pressure tracing. But fluoroscopy revealed that the catheter tip was definitely in the pulmonary artery.

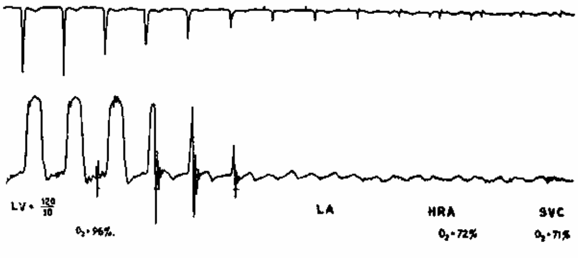

Fig. 11.

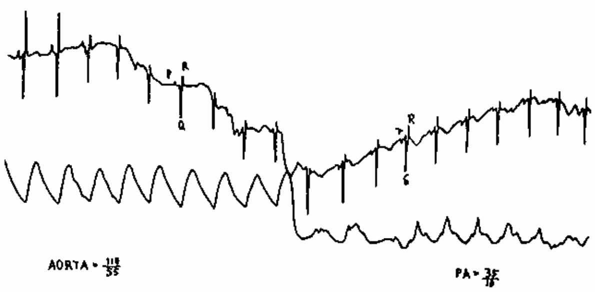

Fig. 12.

Fig. 11. It was stated earlier that the ventriculogram in the left ventricle always takes the form of QS complexes. This figure illustrates a withdrawal tracing from left ventricle to left atrium and through a septal defect to right atrium and, finally, to the superior vena cava. The QS complexes are deep in the left ventricle and diminish in voltage at the atrio-ventricular valve. The intracardiac electrogram in the left atrium has a biphasic P followed by a relatively small QS. In the upper part of the right atrium and in the superior vena cava, the P is negative and the voltage of the QRS is considerably diminished.

Fig. 12. In this case, the catheter was withdrawn from the aorta through a patent ductus arteriosus to the pulmonary artery. Note the fall in pressure from the systemic circulation to the pulmonary circulation and the sudden shift of the ECG baseline which is often seen when the catheter tip passes through a communication. The Qr pattern of the left ventricle is seen in the aorta. Once the catheter tip enters the pulmonary artery, the ventriculogram changes abruptly to the familiar rSR pattern most commonly seen in right-sided tracings.

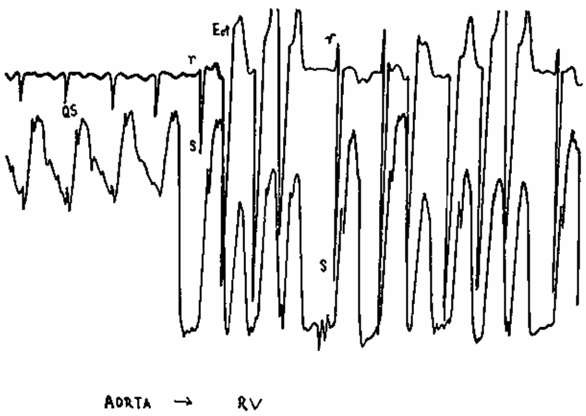

Fig. 13.

Fig. 13. The QRS complexes in a persistent truncus is identical with that recorded in the aorta (vide fig. 12). The moment the catheter was withdrawn from the truncus to the right ventricle, the pattern of the QRS changes to the rSR type. Numerous ventricular ectopics were recorded as the catheter entered the right ventricle. They have a bizarre pattern. The ventricular pressure pulses associated with these ectopics have a lower amplitude than the normal ones.

DISCUSSION

From the foregoing illustration it is clear that intracardiac electrography recorded during cardiac catheterisation is a useful adjunct in a diagnostic work-up of patients with congenital heart disease. By recognising characteristic patterns in the oscilloscope, the operator is able to tell where the catheter tip is lying. Watson (1964) emphasises the value and need for intracardiac electrography in cardiac catheterisation in small children in whom the anatomical relationship of the chambers and great vessels are not easy to recognise with certainty on fluoroscopy. For instance, in Eisenmenger complex the pressures are balanced in both ventricles and there is bidirectional shunting. Inspection of the pressure pulses and samples will not enable the operator to recognise which chamber the catheter is in. But the characteristic ventriculogram in the left ventricle will immediately solve the problem. In 500 cases where electrode catheters were used by Watson, no morbidity or mortality was encountered.

Studies of tracings following a procedure provided valuable information, such as the localisation of pulmonary stenosis and the detection of damped pressure pulses. In addition, the electrogram would enable one to pick up venturi effect mistaken for ventricular pressure pulse and to recognise artificially produced higher pulmonary pressure due to catheter flicker.

"Injury" pattern due to the catheter impinging on the endocardium is recognisable by a monophasic QRS with a grossly elevated ST segment. This is usually not reflected in the standard ECG. Hence lower ventricular pressures due to unduly firm contact with the endocardium as recognised by this "injury pattern" helps to exclude true gradients. Ventricular ectopics can be mistaken for "injury pattern" but they would be present in the standard lead as well. This emphasizes the need for the use of a standard lead simultaneously with the unipolar intracardiac lead.

In Ebstein's anomaly, the intracardaic electrogram is diagnostic. Developmentally, the tricuspid valve is situated lower down in the right ventricle. In other words, part of the right ventricle is "atrialised". The electrogram from this part is similar to that in the right ventricular cavity whereas in the atrium proper, the complexes show the typical right atrial type of electrogram. Hernandez et al (1958) emphasized the typical right ventricular pattern with low atrial pressure curves in the "atrialized" portion, and the right ventricular monophasic injury pattern in this part of the chamber. They further stressed that the production of right ventricular extrasystoles by pressure of the catheter tip against the distal part of the right atrium was highly suggestive of the condition. In a suspected case studied in our series, numerous right ventricular ectopics were recorded when the catheter was in the distal part of the right atrium. But as a result of the run of ectopics no typical right ventricular type of complex was recorded. Right atrial angiography subsequently confirmed the diagnosis of Ebstein's anomaly.

Apart from its value in diagnostic cardiology, studies of intracardiac electrography in dogs and in man have contributed a great deal to our understanding of the spread of electrical excitation in the heart. Furthermore, it has strengthened the ground of those who propounded the Dipole Theory explaining the electrical phenomenon of the heart's action. Although outside the scope of our present study, work on intracardiac electrography in bundle branch block, ventricular hypertrophies, Wolff-Parkinson-White Syndrome and in atrial arrhythmias have been interesting and most revealing. A Teflon-coated wire with an intracardiac electrode built in at the tip can be introduced blindly into the right atrium for detecting P waves in complex arrhythmias (Vogel et al 1964). Lastly, electrode catheters are also used for detecting left to right shunts with hydrogen gas or ascorbic acid solution as indicator.

The chief drawback of electrode catheters at present seems to be that when angiocardiography is required, they have to be changed to the thin wall angiographic catheters. However, it should not be long before the development of multipurpose catheters incorporating electrodes would solve this problem.

SUMMARY

The value of the electrode catheter in catheterisation of congenital heart disease is illustrated and discussed. It should be used whenever feasible. Its value in the study of intracardiac electrography in general is reviewed.

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