

New Look at Arrhythmias

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The changing scene of modern cardiology opened new avenues to explore old problems. Intensive coronary care units, cardiac surgery, pacing, the exploration of the intimate mechanism of impulse production and impulse conduction by micro-electrodes have given a renewed impetus to investigate cardiac arrhythmias. In this short article this new knowledge will be considered under the following aspects: (1) ventricular tachycardia and fibrillation, (2) junctional rhythms and AV conduction, (3) heart block and pacing, and (4) treatment.

VENTRICULAR TACHYCARDIA

The old diagnostic criteria were the presence of ventricular extrasystolic complexes following in rapid succession, but above all, a complete dissociation, with a slower atrial and a more rapid ventricular rate. This accepted clinical definition (Wenckebach and Winterberg, 1927) was at variance with the electrophysiological criteria described by Lewis (1925). He agreed that the faster rhythm of the ventricle and the slower rhythm of the atria might remain independent, "for a short or long period", but he emphasized the frequent retrograde conduction from ventricle to atria: "falling with each ventricular complex is an anomalous auricular complex: it is anomalous because the course of the contraction wave in the auricle is abnormal". Lewis's statement that the dissociation between atria and ventricle cannot be considered as a critical feature of ventricular tachycardia has been successively demonstrated with the help of oesophageal and right atrial leads. In induced ventricular tachycardias by right ventricular stimulation, retrograde conduction to the atria, with varying degrees of ventricular-atrial (VA) block, was produced in two-thirds, ventricular tachycardia with 1:1 VA conduction in

one-third, and runs with independent atrial rhythm (AV dissociation) in one-quarter of the patients. Retrograde VA conduction was rate dependent. At a rate above 200 varying VA block was seen, and at a rate of 160-200 there was 1:1 VA conduction (Kistin, Tawakkol, and Massumi, 1967).

The greatest difficulty in differential diagnosis is caused by aberrancy of ventricular complexes in supraventricular tachycardias. When supraventricular tachycardia is associated with aberrancy its presence is suggested by ectopic or premature P waves preceding the arrhythmia or appearing intermittently; if retrograde P is present—and this is best seen in intra-atrial or oesophageal leads—an R-P' distance of less than 0.1 sec. suggests AV junctional rhythm, while a distance greater than 0.11 sec. suggests retrograde VA conduction of ventricular tachycardia; QRS configuration similar to that seen in isolated supraventricular beats suggests supraventricular tachycardia; if the run starts with a short cycle which follows a long cycle, and if the pattern is that of right bundle-branch block, supraventricular tachycardia is probable; carotid sinus pressure will slow the tachycardia and remain ineffective in ventricular tachycardia; fusion beats are a clear indication of ventricular tachycardia. The rate may be irregular in both conditions, and independent atrial rhythm may be a feature of both. In spite of all these criteria, differential diagnosis may be impossible: fortunately, DC shock is equally effective in both supraventricular and in ventricular tachycardia.

The onset of ventricular tachycardia and fibrillation in myocardial infarction is not necessarily related to the extent of myocardial damage, but may be the expression of electrical instability set up by the impact of coronary occlusion. Larger infarcts through intracellular loss of potassium are more likely to be responsible than smaller ones.

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Psychological and biochemical stress-induced secretion of both free adrenaline and free noradrenaline has been proved by the increased content of these hormones in the urine (Valori, Thomas, and Shillingford, 1967). Of these two hormones, adrenaline, "the fight and flight hormone", is the one secreted in a state of anxiety and apprehension, while the role of noradrenaline is to uphold the vasomotor tonus (von Euler, 1968). Out of 11 patients with high urinary free adrenaline content (above 4 $\mu\text{g.}/24$ hours), dangerous arrhythmias during the first few days after infarction were found in 9, while out of 8 with normal urinary free adrenaline content arrhythmia was seen in one only. Increased urinary noradrenaline content was significantly higher in myocardial infarction accompanied by shock or heart failure (Januszewicz *et al.*, 1968). Serious arrhythmias were also more frequent in patients with high serum free fatty acid levels, a biochemical finding possibly related to increased catecholamine secretion (Oliver, Kurien, and Greenwood, 1968).

In spite of intensive care units and early warning, ventricular tachycardia and fibrillation were present in half of the patients who died (Thomas, Jewitt, and Shillingford, 1968). The arrhythmia arises during the first few hours after infarction, without warning in the majority of patients, whereas in those who developed the arrhythmia after 48 hours, premonitory ventricular ectopic activity was present (Lawrie *et al.*, 1968). Multifocal ectopic beats or the "R on T extrasystoles" are particularly ominous: this is expressed by Büchner and Effert (1968) as the "ectopic index"—the product of the Q-T period of the extrasystolic beat divided by the Q-T period of the preceding beat. If this is less than 0.7, complicating ventricular tachycardia or fibrillation is highly probable. Arrhythmias arising one to three weeks after the original infarct are due to renewed infarction (Spracklen, Besterman, and Litchfield, 1968).

Tendency to ventricular tachycardia or fibrillation more often arises in posterior or basal infarct caused by occlusion of the right coronary artery which supplies almost always the AV node and, in half the cases, the sinus node as well. Loss, even temporary, of the pacemaker control makes the ventricle more liable to abnormal depolarization. Atrial fibrillation with AV block followed by a short burst of ventricular tachycardia passing immediately into fibrillation without premonitory extrasystoles was the mechanism in a personal case of posterior infarction. Sudden, unexpected death in cardiac infarct is thus almost always caused by ven-

tricular fibrillation, and the reduction of hospital mortality from 30 to 19 per cent in the intensive care units has been achieved through immediate resuscitative measures.

AV JUNCTIONAL RHYTHMS AND AV CONDUCTION

The term "junctional", intending to replace upper, middle, and lower nodal rhythm, was proposed by Pick and Langendorf and has been adopted. The reasons for the change were that the low excitability of the node casts doubts upon its automaticity, that the relation of P to QRS is not only dependent upon the location of the pacemaker but also upon the speed of impulse conduction, and that, contrary to belief, retrograde atrial activity may produce an upright P in II-III and aVF (Pick and Langendorf, 1968). This led also to reviewing the often misapplied term of AV dissociation which was used in the past as a diagnosis to be opposed to AV block when the ventricular rate was faster than the atrial rate. According to recent views, AV dissociation should never be used as a diagnosis but as a qualifying term added to a primary disturbance affecting impulse production or impulse propagation. It may arise through slowing of the primary pacemaker, through acceleration of the secondary pacemaker, sino-atrial or atrioventricular block, or a combination of all these factors. The complex arrhythmias that may result if AV dissociation is incomplete, with total or partial capture of the ventricles with reciprocating beats or interpolated junctional extrasystoles, led to reappraisal of AV conduction. Scherf (1941), in an experimental study of reciprocating rhythm, assumed two functionally separate pathways in the AV node to explain impulse conduction. An impulse travelling in VA direction, finding one pathway blocked, will reach the atrium through the open pathway. If this impulse is sufficiently delayed, it may spill over in the node and re-enter the, meanwhile recovered, pathway, and reach the ventricle producing a reciprocal beat. Kistin (1963), studying interpolated ventricular extrasystoles, found that the ventricular systole following it was not, as hitherto assumed, a sinus beat but a reciprocating beat. Thus, the idea of longitudinal dissociation in the AV node, the original hypothesis of Scherf, was again resumed on the ground of different conduction times for the interpolated ventricular extrasystoles and the reciprocating beat.

That functional changes should be confirmed by structural ones is uncommon: usually it is the other way round. However, in this case, studies by electron microscopy confirmed that longitudinal

dissociation of impulse conduction in the node and common bundle is a "distinct possibility". James and Sherf (1968), studying the ultrastructure of the AV node, found that it contained four types of cells: (1) "P" cells, similar to the ones present in the sinus node thought to be the pacemaking cells; (2) "transitional" cells, possibly connected with delaying and filtering the impulses reaching the node; (3) Purkinje cells; and (4) cells of "working" myocardium, forming the margin of the node. The longitudinal order of cells in the node interwoven with fibrous septa makes, in addition to its impulse-delaying function, longitudinal dissociation possible. The inhomogeneity of the cell structure does not only determine the speed of impulse conduction but also the depolarizing wave entering the bundle of His where longitudinal dissociation may be a normal physiological phenomenon.

A double AV pathway, one of which may have a shorter refractory period and a slower conduction time, may give a simpler interpretation to complex arrhythmias hitherto explained by concealed or supernormal AV conduction. The WPW syndrome in its acquired form may also be the expression of such a dissociation, with one part of the impulse being delayed, the other accelerated on its arrival to the ventricle, the latter replacing the accessory bundle present in the congenital variety. Circus movement responsible for paroxysmal tachycardia may arise as much through a dissociated bundle as through an accessory pathway. The puzzling electrocardiographic pattern of the upright "P" sandwiched between a junctional and a conducted beat in AV dissociation caused by sinus depression can now be easily explained. It is not the ventricular contraction which reactivates the "flagging" sinus causing AV dissociation (Papp, 1958), but the retrograde conduction through one nodal pathway: the re-entry of the impulse into the other one gives rise with some delay to the reciprocating beat. Whether the impulse spills over at nodal or at atrial level is immaterial: P will remain upright in both circumstances.

HEART BLOCK AND PACING

Pacing a heart with chronic complete heart block is a vastly different proposition from pacing one with acute heart block after cardiac infarction. Chronic heart block, though a condition common in the old, is infrequently due to coronary heart disease. Clinical observations of the rarity of persistent heart block after coronary thrombosis and the uncommon occurrence of angina in this group of patients (Zoob and Smith, 1963) received pathological confirmation (Davies, Redwood, and Harris,

1967). Out of 53 hearts with chronic complete heart block, only 8 (15%) were caused by coronary heart disease, and the common cause was fibrosis of the "cardiac skeleton"—the pars membranosa, central fibrous body, and aortic ring—a wear-and-tear manifestation of unknown origin, not related to ischaemia (McNally and Benchimol, 1968). The right branch of the bundle being more exposed because of its long isolated course is more vulnerable than the left which fans out early. In fact, bilateral bundle-branch block is the common underlying lesion of chronic complete heart block. The slow rate favours the emergence of ectopic centres which are not suppressed by a faster rhythm, and ventricular tachycardia may alternate with ventricular standstill. Pacing is commonly required because of Adams-Stokes attacks. In fact it is astounding how often the healthy "working" myocardium is able to increase the stroke volume to compensate for a bradycardia of 36–40 in patients aged 70 to 80 who may lead a reasonably active life. When Adams-Stokes attacks or failure sets in, pacing for these patients prolongs life and makes effective failure treatment with glycosides possible.

Cardiac infarction may injure the conducting system in different ways according to the affected areas. AV nodal involvement in 80–90 per cent of cases is caused by inferior or diaphragmatic infarction. Given the abundant blood supply of the node, it is hardly ever primarily involved, but invaded by oedema or inflammatory changes from the surrounding myocardium. These changes subside within days or weeks, and the block is almost always transitory. The average mortality in 100 consecutive cases of posterior infarction was 20 per cent, and of the 14 cases with heart block, 12 recovered and 2 died. However, out of 11 patients with postero-anterior infarction, heart block, and arrhythmias, 6 recovered and 5 died (Papp and Smith, 1952). Though the numbers are small, this early report of premonitoring days proved what recent publications have confirmed, i.e. that AV block associated with posterior infarction is not *per se* fatal (Lassers and Julian, 1968). It is the extension of the infarct, particularly its association with anterior infarct, bundle-branch block, arrhythmias, and heart failure, which weighs heavily upon mortality. Pacing in complete heart block from basal infarct is unnecessary unless bradycardia, which is often a feature causing heart failure, cannot be corrected by atropine. Adams-Stokes attacks are a clear indication, though they are infrequent, in posterior infarction where the nodal rate may be as high as 50. The effect of steroids is unconvincing as the block has the tendency to revert within

hours or days to normal conduction through low degree and latent block.

While chronic heart block in posterior infarction usually goes through premonitory phases of Mobitz I type, e.g. Wenckebach periods, and gradual reduction of conducting ratios, in high, transmural extensive antero-septal infarct, its appearance is sudden, the rate is low, and Adams-Stokes attacks are the first manifestation of impending doom. The severe damage of both bundle-branches by transmural septal infarction is a manifestation of extensive infarct accompanied by shock and cardiac failure. In patients with pre-existent left bundle-branch block or posterior infarct, a less extensive septal infarct may interrupt conduction in the right bundle, with fatal results. The sudden low ventricular rate may give rise to ectopic activity, and impulses falling in the vulnerable phase of the basic beats may set up ventricular arrhythmias. Pacing by the experienced British team (Sutton, Chatterjee, and Leatham, 1968) proved ineffective and mortality was 100 per cent.

Pacing has no place in the treatment of acute complete heart block after severe cardiac infarction. Isolated cases may be saved but the method itself is not without danger. Ventricular arrhythmias may be caused by the intracardiac pacemaker, though demand pacemakers are less likely to do so, and in inexperienced hands ventricular perforation is a real danger.

TREATMENT

The greatest achievement in the field of arrhythmias was their successful treatment with direct-current shock (Lown, 1967). The subject has been recently reviewed in detail, and indications and contraindications have been clearly stated (Resnekov and McDonald, 1968).

DC defibrillation is the quickest, best, and probably the safest treatment so far available for atrial flutter, atrial tachycardia, atrial fibrillation, ventricular tachycardia, and ventricular fibrillation. Except for arrhythmias caused by digitalis toxicity or electrolytic imbalance, there are no contraindications. The disappointing feature is that a 90 per cent immediate success shrinks to 15-20 per cent after one year; but this is not due to the method but to the underlying pathology. If the arrhythmia persisted for 3 years or more, if the heart and, particularly, the atria are enlarged because of valvular or myocardial disease, sinus rhythm will be restored for a short time only or not at all. Where the underlying cause can be eliminated before irreversible

damage sets in (thyrotoxicosis, successful valvotomies, or valve replacements), the success will persist. The exception is lone atrial fibrillation, but here the slow rate and the normal cardiac output do not need to be improved by reversal to sinus rhythm. Embolism in little more than 1 per cent indicates the necessity for anticoagulant treatment only for those at risk.

With such an excellent method available, it is astonishing that search for new antiarrhythmic drugs continues. Quinidine, which proved disappointing in maintaining sinus rhythm after DC reversion, is having a particularly bad press which may astonish those who used the drug for 30 years and were fortunate enough not to see serious toxic manifestations. May it not be that too energetic diuretic treatment and consequent potassium depletion (not always shown in the plasma) increases the depressing effect of the drug?

Propranolol, because of its adrenergic blocking effect, has raised considerable interest as an antiarrhythmic drug. In addition to its β -blocking effect, it has a quinidine-like action upon the AV node, by increasing its refractoriness and by slowing conduction in atria and ventricles mainly through its action upon the Purkinje system (Rouse, 1965). Its only disadvantage is its depressing effect on cardiac contractility, whereby it may accentuate or provoke cardiac failure in diseased hearts. Here it has to be combined with digitalis which may then lead to excessive bradycardia by the β -blocking effect of the former and the vagal effect of the latter. Its main use is in reduction of cardiac rate in sinus tachycardia, flutter, or atrial fibrillation. It has a pronounced effect in repetitive tachycardias, atrial and ventricular, and in tachycardias caused by digitalis toxicity where DC shock is contraindicated. It was used successfully to reduce cardiac irritability after cardiac surgery, but has no prophylactic effect against arrhythmias occurring after cardiac infarction. Its main drawback is its negative inotropic effect which has been eliminated in its recent derivative (ICI 50172), which is still under study. The antiarrhythmic dose is but a third of the antianginal dose, which suggests a different pharmacological mechanism.

Lignocaine, a derivative of procaine, which has fallen into disuse as an antiarrhythmic drug, has the prophylactic effect against post-infarction arrhythmias that propranolol does not possess, and is also effective in digitalis-induced ventricular tachycardias. It has no deleterious effect upon cardiac output, arterial pressure, and systemic vascular resistance (Jewitt *et al.*, 1968). It can be given

by continuous intravenous infusion of 1–2 mg. per kg. in a 0.1 per cent solution, or by repeated slow intravenous injection of a 2 per cent solution, 5 ml. at a time, or 10 ml. if given by intramuscular injection. It has no effect upon sinus tachycardia and atrial fibrillation, and it should not be used in flutter where it accelerates AV conduction and removes the block (Spracklen *et al.*, 1968). Given the minimal side-effects, it may become the elective prophylactic drug to inject at the bedside early in cardiac infarction, except in bradycardia when *i.v.* atropine 0.6 to 1.2 mg. will be preferred.

With propranolol, lignocaine, atropine, procainamide, quinidine, digitalis, and potassium to correct electrolyte imbalance at one's disposal, there has not been much interest in antiepileptic drugs in this country. Phenytoin sodium (diphenylhydantoin) was found effective in supraventricular tachycardias, and abolished ventricular extrasystoles in varying clinical conditions. Fifty to 100 mg. can be given intravenously and repeated at 5- to 10-minute intervals, or orally up to 3.5 g. a day. Side-effects of the larger doses include hypotension, drowsiness, nystagmus, and nausea. There is no depression at junctional level, and the Q-T interval shortens (Bigger, Schmidt, and Kutt, 1968). Diazepam, 10–20 mg. *i.v.*, has also been effective in ventricular arrhythmias, but is now mainly used as an anaesthetic for DC shock.

The successful use of these drugs led to interesting speculations as to the nature of paroxysmal tachycardias in otherwise healthy hearts. Electroencephalographic studies in 45 of these patients revealed changes localized in the temporal zone in 30, while such changes were found only in 5 of 40 patients with various heart diseases but without paroxysmal tachycardia. The electroencephalographic changes are related to disturbances of electrical potentials in higher centres of the autonomic nervous system and paroxysmal tachycardia is considered as a form of visceral epilepsy: "cardiac epilepsy" (Pasini *et al.*, 1967). Relation to epilepsy and migraine has also been postulated by Parrow (1966).

Finally, let us look at new terms. "Junctional" to replace "nodal" is justified on physiological grounds, but "dysrhythmia" to replace "arrhythmia" is not. While abroad I was asked about the new arrhythmias discovered in England and described under this term. Another colleague, whose spoken English was evidently better than his spelling, thought this to be an excellent term to differentiate cardiac arrhythmias found in "disease" (e.g. flutter, fibrillation) from those found in health

(e.g. vagal arrhythmia, extrasystoles). I am sure that the pioneers of cardiac arrhythmias had as good or better classical knowledge as many of us—they were not disturbed by the verbal translation of arrhythmia which, for them, meant absence of *physiological* rhythm. Let us not sacrifice international understanding to false linguistic purism. Arrhythmia has the same meaning all over the world—the reason why it was used throughout this article.

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