THE SPECTRUM OF CARDIAC ARRHYTHMIAS.

The aim of this chapter is to provide a background to cardiac arrhythmias for a lay audience, to be built upon in the following chapters.

KEY POINTS

1. The electrical system of the heart consists of a sinus node, an atrioventricular node/His bundle complex and the left and right bundle branches. All of these structures are composed of heart muscle cells that have undergone special development into discrete structures for the purpose of activating the heart electrically for each heart beat.
2. Bradyarrhythmias can be subdivided into sinus bradycardias and those due to heart block.
3. Tachyarrhythmias are caused either by rapid firing of “rogue” myocytes or by abnormal conduction pathways within the heart that can be congenital or acquired.
4. Sinus tachycardia is usually a normal response to situations such as fever or exercise.
5. Atrial fibrillation and flutter are common and are an important cause of stroke and other embolic events. Atrial fibrillation consumes 1% of the NHS budget, and there are thought to be 50,000 new cases of atrial flutter every year in the UK.
6. Junctional tachycardias are usually caused by extra electrical pathways present at birth and usually occur in the absence of other heart disease.
7. The Wolff-Parkinson-White syndrome is a common cause of junctional tachycardias and can be life-threatening in about 1% of cases per annum.
8. Ventricular tachycardias usually occur in the setting of ischaemic heart disease, and previous myocardial infarction, but may also occur in otherwise normal hearts. When this happens it is commonly referred to as “idiopathic ventricular tachycardia”.
9. Ventricular fibrillation results in loss of all effective pumping function of the heart and rapidly leads to death unless a defibrillating shock is administered.
10. Other causes of ventricular arrhythmias include inherited and genetic causes as in hypertrophic or dilated cardiomyopathies, right ventricular dysplasia, the long QT and Brugada syndromes.

CORE PRINCIPLES OF CARDIAC ARRHYTHMIAS

Cardiac arrhythmias[1,2] , are caused by abnormalities in the normal electrical activation of the heart (Figure 1.). A slow arrhythmia is known as a bradyarrhythmia, and a fast arrhythmia is known as a tachyarrhythmia.

The normal heartbeat is generated by a group of specialised heart muscle cells in the top section of the heart (right atrium) referred to as the sino-atrial node. This group of cells beat at a rate of between 60 and 100 beats per minute under normal circumstances. This rhythm is transmitted initially through the rest of the cells in the atria before being transmitted through a specialised nerve called the atrioventricular (AV) node/His Purkinje complex to the ventricles (the main pumping chambers of the heart) via the bundle branches. These are also heart muscle cells, but they develop a little differently, and are capable of very rapid conduction of electrical impulses.

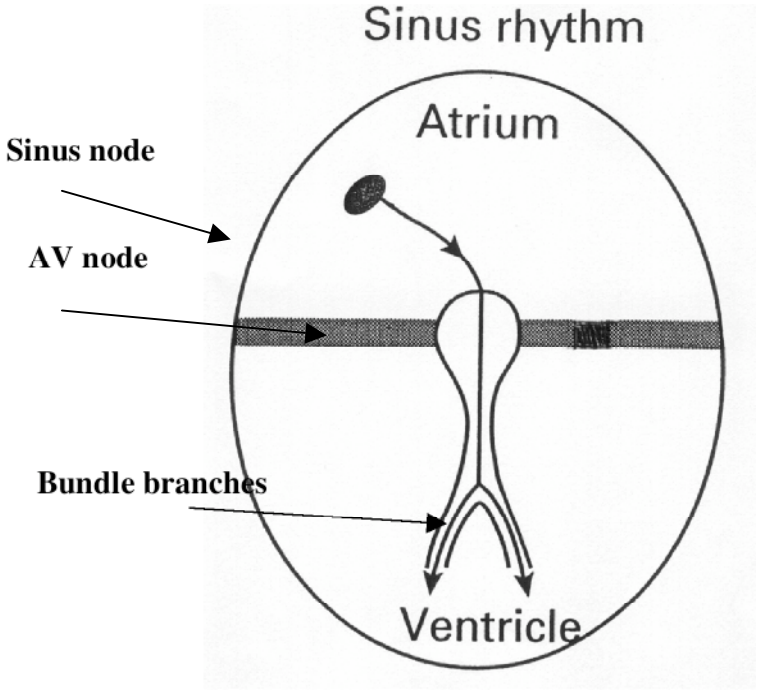

Figure 1. Schematic representing the conducting system of the heart. Note that in reality there are left and right atria, and left and right ventricles.

BRADYARRHYTHIAS

These occur when either the sino-atrial node is not generating an adequate heart rate (so-called sinus bradycardias) or when the AV node is not conducting the generated impulse properly through to the ventricles (so-called heart block).

Sinus bradycardia can be caused by a number of external factors and in many cases cause no deleterious effects (for instance in athletes and those taking beta-blocking tablets). However some patients, particularly the elderly, can develop a condition called sino-atrial disease in which the sinus node becomes progressively damaged by an with

scarring and death of the cells generating the normal heartbeat.[3] In this condition the heart rate may remain very slow and give rise to symptoms of dizziness and transient loss of consciousness, especially if there are longer pauses between beats. In younger patients this form of persistent bradyarrhythmia is less common, because the sinus node is healthy. However, the simus node has influences upon it that account for it's ability to speed up with exercise and slow down during sleep. The "brake" on the heart rate is the "vagus nerve". This may become transiently very overactivated causing a sudden drop heart rate (see Figure 2.). This condition is sometimes referred to as vasovagal syndrome and is a variation on the events occurring in a simple faint. Other terms that are used for this or similar conditions include cardioneurogenic syncope and reflex asystolic syncope (in this case the bradyarrhythmia may be sufficient to cause lack of oxygen to the brain, leading to a fit which resembles that occurring in epilepsy).[4] In most of these situations the events are also accompanied by changes in blood vessels in muscles that cause an accompanying abrupt drop in blood pressure.

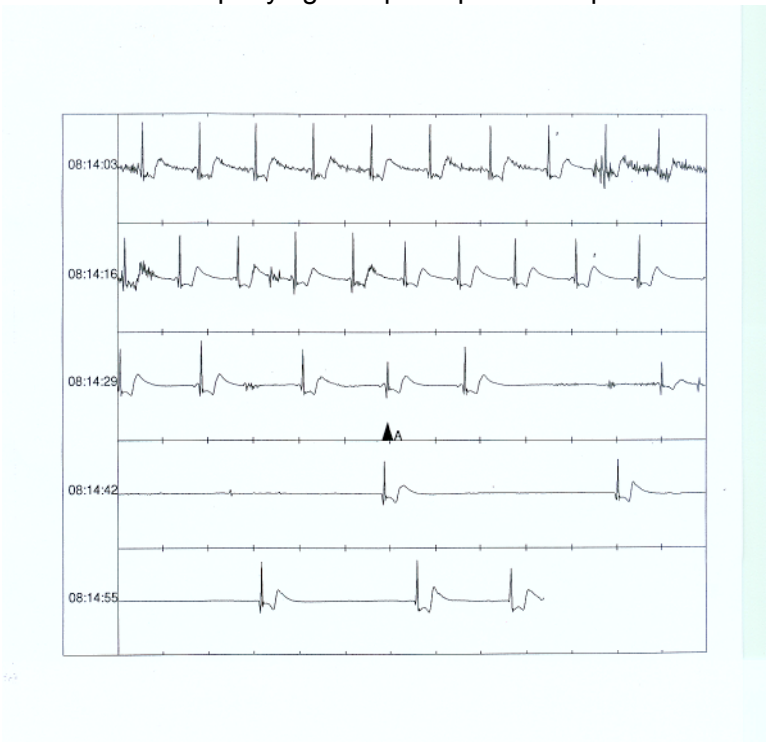

Figure 2. An ECG recording showing slowing of the heart rate due to overactivation of the vagus nerve

Heart block, like sinus bradycardia, can also be caused by a number of external factors ut most commonly occurs in elderly people as a result of a progressive scarring of the atrioventricular node, the underlying cause of which remains uncertain.[5] Heart block can be recognised in several levels of severity referred to as first-degree block, second degree block or third degree block (the latter is more commonly known as complete heart block). Although the underlying problem can develop slowly, once complete heart block is present then symptoms of dizziness or loss of consciousness are very likely and indeed sudden death may occur.

TACHYARRHYTHMIAS

Tachyarrhythmias are most often caused by “short-circuits” in various parts of the electrical system of the heart caused either by extra conduction pathway that is present from birth, or damage caused to heart cells as a result of heart attacks or other diseases. More rarely they are caused by overactivity of “rogue” cells or cell groups within the heart. Tachyarrhythmiaias are usually classified according to their presumed site of origin and it is usual to refer to 3 broad groups based on whether they originate in the atrium, the AV node or AV junction, or the ventricles.

TACHYARRHYTHMIAS ORIGINATING IN THE ATRIUM

These tachycardias can be divided into sinus tachycardia, atrial tachycardia, atrial flutter, and atrial fibrillation.

Sinus tachycardia is due to an increase in the rate of beating of cells in the sino-atrial node and in general is the normal response to stimuli such as exercise, anxiety, fever, low blood pressure and other medical conditions rather than any intrinsic problem with the heart’s electrical system. As a consequence it is very rarely a problem in itself and no specific treatment is necessary or appropriate. Atrial tachycardia is usually due to the presence of rapidly firing cells in specific locations in the atrium[6],(see Figure 3.) including the pulmonary veins[7], Atrial tachycardia can also occur following surgery for congenital heart disease[8].

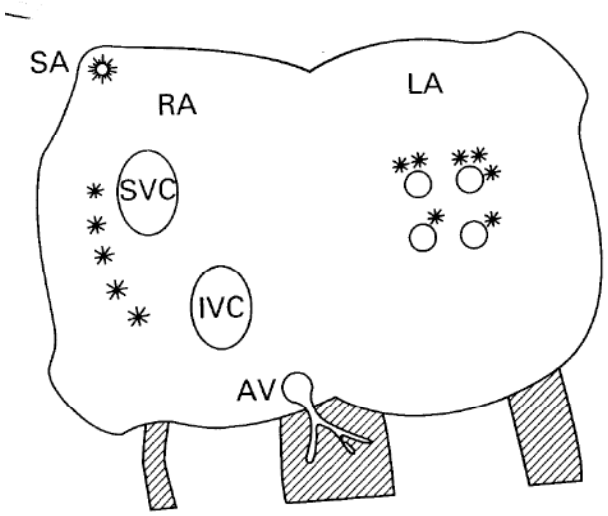

Figure 3. In this figure the ventricles have been removed from the drawing and the atria are shown opened out

Atrial flutter is a tachycardia that originates from a “short-circuiting” of the electrical system in the right atrium, usually as a consequence of enlargement or damage of this chamber secondary to some other heart condition such as disease of the heart valves. Instead of normal orderly activation of the atrium from the sino-atrial node, the right atrium is activated very rapidly in a circular fashion[9] (see figure below). As well as causing palpitations this can lead to the development of clots in the atria of susceptible

individuals, with an associated risk of stroke.[10,11] In the short term atrial flutter can be treated by electrical shock treatment (cardioversion) and in the long term catheter ablation treatment is usually curative (see Figure 4).

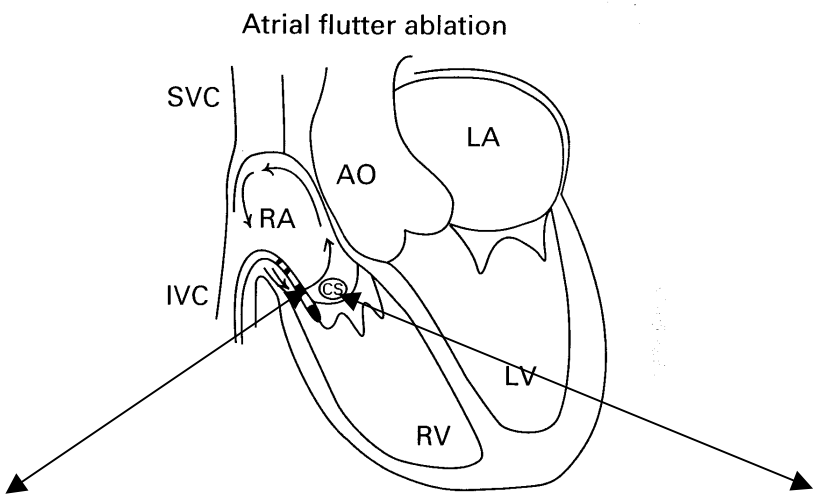

Figure 4. A catheter can be passed up from the vein in the leg to where the critical atrial flutter "circuit" passes behind the main valve between the right atrium and right ventricle

Atrial fibrillation (AF), like atrial flutter, usually (but not always) occurs in patients with enlarged or diseased atria. This tachycardia differs from atrial flutter in that it is caused by rapid *irregular* activation of the atria (see Figure 5) but has many similarities in terms of both its causes and consequences. In the presence of other risk factors, AF significantly increases the risk of stroke and warfarin is frequently prescribed to prevent this complication.[12,13] Atrial fibrillation occurs more frequently than atrial flutter however and is the most common tachycardia worldwide with an overall prevalence approaching

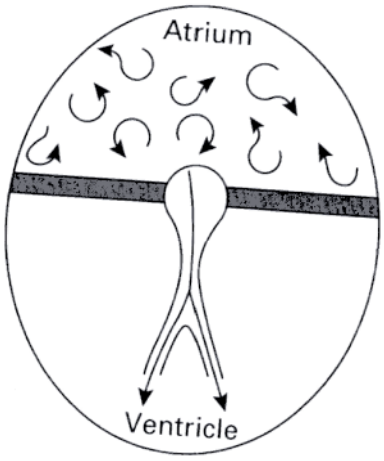

Figure 5. Multiple circuits exist during atrial fibrillation which come and go in largely random patterns

1% of the population, rising to 4% in the over 65s.[14] It is also more difficult to treat in the long-term with patients often receiving a sequence of different types of medications with varying success.[15,16] Two different types of catheter ablation treatment are in relatively common use for this tachycardia (see later chapters).

TACHYARRHYTHMIAS ORIGINATING AT THE AV JUNCTION.

These junctional tachycardias are also commonly called supraventricuilar tachycardias (SVT). Junctional tachycardias are usually caused by the presence of an abnormal conduction pathway within the heart that has been present from birth. They are not normally associated with other forms of heart disease.

These extra pathways may be only a millimetre across and a few millimetres in length but can lead to a "short-circuiting" of the heart's electrical system and the development of a rapid, circular activation of the heart. This rapid activation results in tachycardia and the sensation of palpitations for the patient. The abnormal conduction pathway may be sited close to the normal AV node (see Figure 6), (resulting in AV nodal reentrant tachycardia[17]) or away from the AV node, in which case the nerve is referred to as an accessory pathway[18]. Some patients with an accessory pathway have a specific pattern recognisable on their electrocardiogram (ECG) during normal rhythm and these patients are said to have the Wolff-Parkinson-White syndrome after the 3 doctors who described the condition.[19] Patients with either of these forms of junctional tachycardia suffer from recurrent palpitations but these (except very rarely with the WPW syndrome[20]) are not life-threatening. These tachycardias are amongst those most amenable to catheter ablation treatment[17,18]

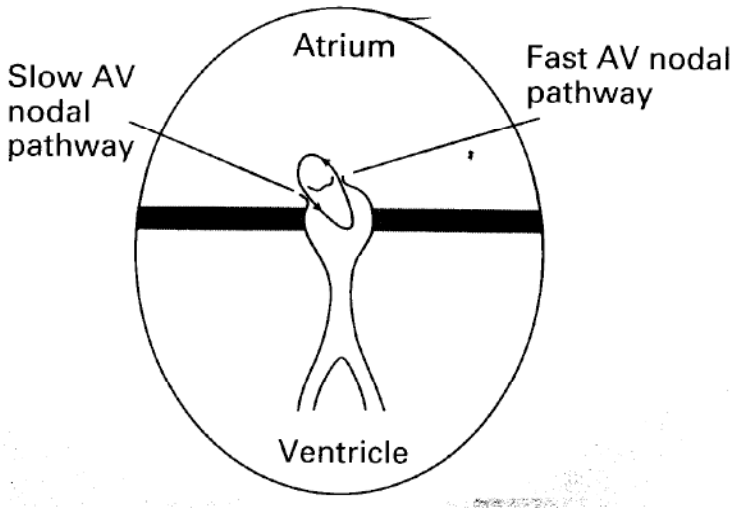

Figure 6. A schema representing AV nodal re-entrant tachycardia which is closely related to the normal compact AV node.

VENTRICULAR TACHYCARDIA AND FIBRILLATION

Tachyarrhythmias arising from the ventricles are referred to as ventricular tachycardias (VT) and most commonly occur in patients with previous heart attacks[21] (myocardial

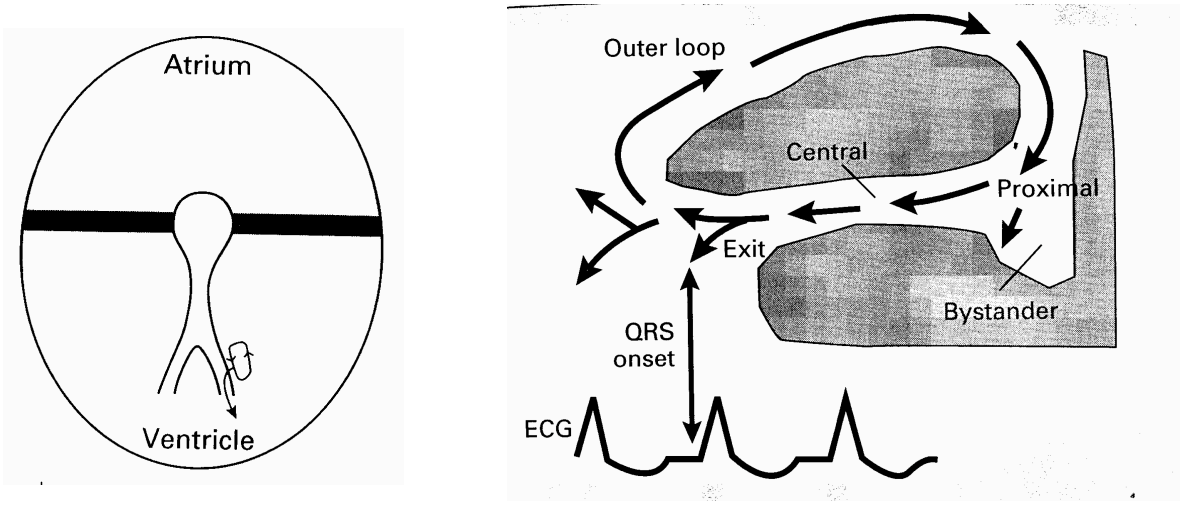

Figure 7. In ventricular tachycardia the higher conducting tissues of the atrium and AV node are not involved. Usually ventricular tachycardia develops because of acquired abnormal conduction pathways associated with scarring of ventricular muscle after a previous heart attack.

infarction). Surviving heart cells in between areas of scar tissue resulting from these heart attacks lead to short-circuiting of electrical activity in the ventricle[22] and development of a rapid, circular activation of the heart that causes tachycardia and the sensation of palpitations (see Figure 7)). The fact that these patients have damaged hearts in the first place means that their hearts find it particularly difficult to deal with the increase in heart rate, leading to a fall in the blood pressure and possible collapse of the patient. For this reason VT is usually more dangerous than other forms of tachycardia. Possible treatments include drugs, catheter ablation and implantable defibrillators. Ventricular fibrillation (VF) may occur in these patients when the activation of the ventricles becomes completely irregular and incoordinated (see figure below) to the extent that the heart can no longer push blood into the rest of the body. In this situation the only possible treatment available is an electrical shock, which must be administered quickly if the heart is to be returned to normal rhythm and the patient to survive. In some patients these attacks can be recurrent and an implantable defibrillator is required (see later).

Although most VT and VF occurs in patients with previous heart attacks, these dangerous tachycardias can more rarely occur in association with other heart conditions

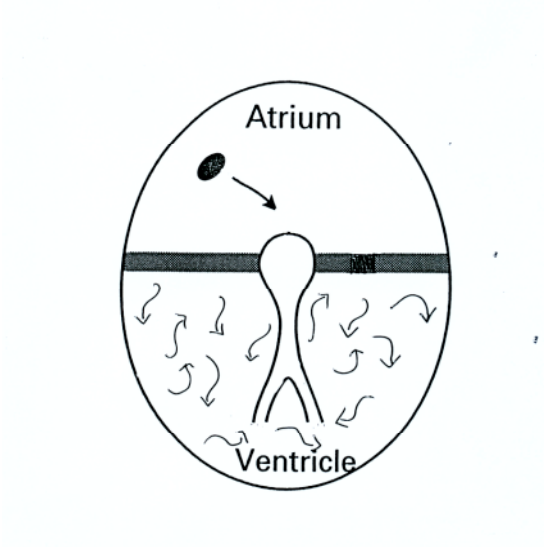

Figure 8. In ventricular fibrillation the muscle action is not unlike the action seen in atrial fibrillation, with random activation of electrical currents,and ineffective beating. The difference is that in ventricular fibrillation the situation is not compatable with life for more than a few short minutes because the heart can pump no blood around the body.

called cardiomyopathies including dilated, hypertrophic[23] and right ventricular cardiomyopathy[24] (the latter is sometimes known as right ventricular dysplasia) or rare congenital conditions such as the long QT syndrome [25] and the Brugada syndrome.[26]

LAY SUMMARY

The normal electrical system of the heart can be damaged in a number of different ways. This can lead to the development of either slow or fast heart beats.

Slow heart beats or bradyarrhythmias can result in dizziness or collapse and may require a pacemaker as treatment.

Fast heart beats or tachyarrhythmias results from “rogue” cells within the heart or from “short-circuits” within the electrical system.

Atrial flutter and atrial fibrillation occur due to rapid firing of the top part of the heart (atrium) and can lead to strokes.

Junctional tachycardias are due to extra conduction pathways present in the middle of the heart and can be effectively treated by “keyhole” operations performed under local anaesthetic.

Ventricular tachycardias are fast heart beats coming from the bottom part of the heart (ventricle) and are usually caused by a previous heart attack (called myocardial infarction). Often when ventricular tachycardia occurs in this setting, there is a significant risk to life due to sudden cardiac arrest.

Ventricular fibrillation causes cardiac arrest and an electrical shock is needed within a few minutes if the patient is to survive.

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