## ELECTIVE (SSC5a) REPORT (1200 words)

**A report that addresses the above four objectives should be written below. Your Elective supervisor will assess this.**

**OBJECTIVE 1: (2) To understand the aetiology of cardiac arrhythmias, (2) To understand how to evaluate a patient with an arrhythmia in a safe and professional manner.**

**To understand the aetiology of cardiac arrhythmias:** cardiac arrhythmias can be described as fast, slow, or irregular rhythms that are mediated by problems in the underlying conduction of electrical signals in the myocardium [1]. Bradyarrhythmias can include the following examples e.g., sinus node dysfunction and atrioventricular block and are typically classified as pathologies with a rate that is <60 beats per minute. Tachyarrhythmias are defined as supraventricular arrhythmias or ventricular arrhythmias and a heart rate of >100 beats per minute. Supraventricular arrhythmias, in terms of pathology, originate between the sinus node and the atrioventricular node. Ventricular arrhythmias arise from a location that is typically below the atrioventricular node, resulting in a widened QRS complex.

With respect to bradyarrhythmia, **sinus bradycardia** (with atrial origin) may be caused by (1) physiological factors (e.g., in patients that are very athletic), (2) sinus node dysfunction, and (3) drug (e.g., beta-blockers and calcium channel blocker medication) [2]. **Atrioventricular block** (with AV node origin) may be defined as (1) first degree, (2) second degree, (3) or third degree. First degree pathologies may be caused by an increase in vagal tone or via certain pharmacological agents (e.g., beta-blockers and calcium channel blocker medication) and a persistently prolonged PR interval >200ms is characteristic. Second degree pathologies may be caused by e.g., drugs (e.g., digoxin), sinoatrial conduction disease, or right coronary infarction. It may be classified as Mobitz type I (i.e., Wenckebach): an increase in length of the PR interval until a beat of the heart is missed, or Mobitz type II: the abnormal dropping of beats of the heart. Third degree pathologies i.e., complete block indicates that there is an absence of electrical communication between the atria and the ventricles. This is demonstrated by the presence of AV dissociation on an ECG i.e., there is no connection between the P wave on an ECG and the subsequent QRS complexe [2].

With respect to tachyarrhythmias, supraventricular arrhythmias include sinus tachycardia, atrial flutter, atrial fibrillation, atrioventricular/AV node re-entry tachycardia, and junctional tachycardia. Ventricular arrhythmias include premature ventricular beats, ventricular tachycardia, torsade de pointes tachycardia, and ventricular fibrillation [3]. **Atrial flutter** is caused by macro re-entry rhythms within the atria and the presence of sawtooth P waves on ECG. **Atrial fibrillation** is the most common sustained tachyarrhythmia for which the underlying pathophysiological mechanisms are incompletely understood. However, they are believed to result from various risk factors. ECG signs include an irregularly irregular rhythm and indiscernible P waves. **Premature ventricular beats** are ectopic contractions originating from a ventricular focus and caused by hypoxia, hyperthyroidism, or an electrolyte imbalance (and thus resulting in a premature and widened QRS which is not proceeded by a P wave on ECG). **Ventricular tachycardia** may be caused by coronary artery disease, myocardial infarction, or structural heart disease. ECG features include wide QRS complexes (e.g., monomorphic or polymorphic VT) and AV dissociation. **Ventricular fibrillation** may be caused by myocardial infarction or structural heart diseases, and are characterised by arrhythmic, fibrillatory baseline with erratic undulation with indiscernible QRS complexes [3].

**To understand how to evaluate a patient with an arrhythmia in a safe and professional manner:** The diagnosis of an electrical disturbance of the heart requires a comprehensive history, physical examination, and investigations [4]. These tests can include:

- **Electrocardiogram (ECG):** to detect the electrical activity of the heart via a series of electrodes and leads.
- **Holter monitor:** an ECG device that can be worn for multiple days to record electrical rhythm and activity during normal day-to-day activities.
- **Echocardiogram:** a non-invasive test that uses a transducer and sound waves to assess size, structure, and motion.
- **Implantable loop recorder:** implanted beneath the skin to continually record the electrical activity of the heart.

If an arrhythmia is not identified during the above investigations, the following may be used:

- **Cardiac stress test:** since some arrhythmias can be associated with triggers, this test can be used to monitor patients whilst on e.g., a bicycle or treadmill, to detect irregularities.
- **Electrophysiological testing and mapping (e.g., EP study):** via a catheter, this study is used to map the spread of electrical impulses through the heart.

Appropriate use of these investigations, alongside a comprehensive and detailed history and examination, are vital to evaluating a cardiac patient in a safe and professional manner.

**OBJECTIVE 2: To understand the underlying basis and fundamentals of the procedures performed in cardiac electrophysiology.**

Cardiac electrophysiology offers various treatment options. Cardiac implantable devices are a form of medical technology that can be implanted beneath a patient's skin in the chest to detect and/or control conduction disorders or help with the management of heart failure [5-6]. Examples of such devices includes pacemakers, implantable cardioverter defibrillators (ICDs), cardiac resynchronisation therapy (CRT) devices and left ventricular assist devices (LVADs) in addition to implantable cardiac monitors i.e., loop recorders for monitoring purposes. Artificial cardiac pacemakers (i.e., anti-bradycardia pacing) can monitor the electrical activity and rhythm of the heart in order to facilitate the delivery of an electrical pulse that acts to maintain a normal rhythm. It can also be used to synchronise the ventriculus e.g., in atrioventricular block. Pacemakers come in several configurations, including single chamber device (i.e., one electrode) or dual chamber (i.e., two electrodes) [5]. In contrast, ICDs (i.e., anti-tachycardia pacing) can deliver synchronised and/or un-synchronised cardioversion via the delivery of a shock [5]. Additionally, the main aims of CRT therapy are to help with the synchronisation of left- and right-ventricular contractions. While CRT-P (i.e., pacemaker) is used for resynchronisation and pacing, CRT-D (i.e., defibrillator) is used for resynchronisation, pacing, and defibrillation [6].

In addition to devices, catheter ablation is an invasive procedure that works via the application of radiofrequency energy that is used to help remove or inactivate areas of the heart that are responsible for an arrhythmia [7]. In atrial fibrillation, this is achieved via pulmonary vein isolation. At present, a variety of energy modalities can be used for catheter ablation, however radiofrequency and cryoablation are the most common. In radiofrequency ablation, a frequency is generated and transmitted between a catheter tip and an electrode patch positioned on the skin. This results in conductive heat and the formation of a lesion

within the heart. In cryoablation, there are three distinct phases: (1) freezing-thawing phase with freezing of tissue and intracellular ice formation, followed by thawing and the fusion of ice crystals with microthrombi and platelet aggregation, (2) haemorrhagic phase where localised tissue inflammation and oedema occur, and (3) replacement-fibrosis phase which results in the formation of a fibrotic scar.

**OBJECTIVE 3: (1) To understand how arrhythmia affects patients on a global scale. (2) To understand how the delivery of patient care with respect to cardiac electrophysiology differs between countries (e.g., in the UK and US). (3) To understand the various public health interventions that can be used to raise awareness of rhythm disorders.**

**To understand how arrhythmia affects patients on a global scale**: normal aging is associated with a multitude of cardiovascular system changes, including decrease blood vessel compliance, mild concentric left ventricular hypertrophy, and an increased incidence of cardiac arrhythmias. Conduction disorders may be asymptomatic or may cause haemodynamic changes that require treatment. At present, arrhythmias affect approximately 1.5-5% of the population, with atrial fibrillation being the commonest. In the United Kingdom (UK), arrhythmic events occur in over 2 million individuals [8]. In the United States (US), approximately 12.1 million individuals are expected to acquire AF by 2030 [9]. As a result, cardiac arrhythmias are responsible for causing a significant public health and economic burden worldwide.

**To understand how the delivery of patient care differs between countries (e.g., in the UK and US):** the healthcare systems of the United States (US) and United Kingdom (UK) differ significantly. For example, healthcare in the US is provided predominantly via private sectors and patients are required to purchase health insurance beforehand. This is in contrast with the UK, where is has what is recognised as one of the largest public sector systems and, generally, medical care is free at the point of access. While is it recognised that both systems have very good patient outcomes overall, the UK system on one hand has less disparity in patient health outcomes throughout the population. Although health insurance is a legal requirement in the US, healthcare is generally ranked quite highly with respect to responsiveness by the world health organisation (WHO) [10]. The system in the US is financially unconstrained and is also able to respond to the needs of its citizens. This contrasts with the system in the UK, which is under much tighter control with respect to funding and resources as well as the presence of lengthy waiting times for healthcare that is classified as non-urgent.

**To understand the various public health interventions that can be used to raise awareness of rhythm disorders:** creating policies on public health programmes that are aimed at raising awareness of the risk factors and symptoms that are affiliated with heart rhythm disturbances is important. First, we must develop policies that educate the public on the symptoms to look out in the event of a heart rhythm disorder, and of what therapies are available for these conditions. Second, we must promote cardiovascular health via public channels (e.g., online) to help minimise the incidence of major associated risk factors (e.g., which are associated with atrial fibrillation). Third, we must strengthen public health agencies to ensure that they develop and manage health data systems that can effectively monitor patients for heart rhythm disturbances.

**OBJECTIVE 4: To understand the clinical and professional paths that can be taken to pursue a future career in cardiac electrophysiology in the UK and US.**

**Cardiology training in the UK:** Prior to the completion of medical school, a student must apply to the Foundation Programme. This is a 2-year training programme that must be completed to obtain full registration with the GMC (i.e., to obtain a medical license). This programme consists of 6 different medical and surgical rotation, with each year taking place in a different hospital. Once complete, the trainee will then apply via national selection to Internal Medicine Training (IMT) which is a 3-year programme. This aims to provide trainees with exposure to a variety of medical specialities and can include cardiology. During this, the trainee must pass the MRCP (Membership of the Royal College of Physicians) exam. After IMT, the trainee will then be given the opportunity to apply to speciality training specifically in cardiology (i.e., ST3 cardiology). This typically runs from ST3 to ST8 (i.e., 'speciality training year 3' to 'speciality training year 8', and therefore 6 years in total), however many trainees interrupt their training to pursue other interests or to complete e.g., a PhD. During the last 2 or 3 years of this programme, the trainee will focus on their specific subspeciality interest e.g., cardiac electrophysiology. Once complete, the trainee may wish to undertake a fellowship in cardiac electrophysiology in order to broaden their clinical and procedural skills and knowledge. Following the completion of all training, and given that all exams have been passed, the trainee can then apply to consultant (i.e., attending) jobs within the country.

**Cardiology training in the US:** Prior to the completion of medical school, a student must apply via the 'match' process to apply for residency in their chosen speciality. In order to apply to this, the student must have completed their USMLE 'steps' i.e., Step 1 and Step 2. If pursuing cardiology, then a residency programme in internal medicine should be selected. Residency is a clinical training programme that takes approximately 3 years to complete. During this, state licensing is also required in addition to Board Certification in Internal Medicine, which is a pre-requisite for Board Certification in Cardiology. After completion of a residency programme, the trainee can choose to become an attending in internal medicine or to further specialise in an area of medicine. If pursuing cardiology, a cardiology fellowship must be completed, and is typically a 3-year programme. Depending on the hospital, the structure of this programme will differ. However, this generally includes further training in the prevention, diagnosis, and management of various cardiac conditions. Overall, it gives the trainee the opportunity to diversity their skillset in cardiovascular disease management. Once completed, the trainee can then take the Cardiovascular Disease Certification Examination. Cardiologists may then elect to specialise in one of the field's subspecialities, including cardiac electrophysiology. After completing a subspecialty fellowship, clinicians will then have the option to complete advanced certification via the American Board of Internal Medicine.

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