Heart Rhythm and Related Cardiac Conditions

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Heart Rhythm and Related Cardiac Conditions

by

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# Table of Contents

Abstract 4

Introduction 5

Section 1: The Heartbeat, an Electrical Mechanism 6

Section 2: How Heartbeat May Be Altered and Common Types of Arrhythmias 9

Section 3: Lethal Forms of Arrhythmia, and What Can Be Done About Them 12

Conclusion 15

Reference List 16

Additional Figures/Illustrations 19
Abstract

When discussing the cardiovascular system, a key mechanism for its function that needs to be understood is the heartbeat, which uses electrical impulses to regularly send blood throughout the body. Aside from learning and research, heartbeats are commonly measured in a clinical context, often being an important measure even for patients with conditions that primarily affect other systems. As far reaching as this mechanism is, it can be altered in a number of ways by disease or overall health conditions, which are often monitored via electrocardiography. The following thesis would be a paper focusing on normal sinus rhythm, common arrhythmias, and other medical conditions where the heart's beat or measurement on an electrocardiogram is irregular.

The thesis will be divided into segments covering the function and mechanism of the pulse, concepts involved in heart arrhythmia, and certain lethal forms of arrhythmia. One section will involve examples of regular electrocardiogram recordings and the electrical signals responsible for maintaining the heart's rhythm. The second will focus on tachycardia, bradycardia, and the most common type of arrhythmia which is atrial fibrillation. The third section will center around four conditions, these being ventricular fibrillation, ventricular tachycardia, and asystole.
Introduction

For those either studying the heart or working in the field of cardiology, the centerpiece of the organ’s function that needs to be understood to grasp the impact of various conditions or injuries is the heartbeat. The function of the heart is crucial because it affects how well the body can function, and likewise electrical activity of the heart, and any disturbances, affects how well the heart as a whole can function. The heartbeat is the electrical mechanism that allows the heart to contract and relax at a steady rate, and as such may be measured and separated into parts using an electrocardiogram. Because of how critical its normal function is, it is equally important to understand common alterations from the regular heartbeat and the numerous reasons why they may occur, especially in contexts where distinguishing between acute and chronic conditions is both important for deducing cause and deciding potential further treatment. More urgently, especially for those certified for CPR and AED or those planning on becoming certified, the heartbeat can become destabilized in ways that can effectively shut down the body in ways that are either subtly different or completely distinct from others.
1: The Heartbeat, an Electrical Mechanism

When electricity is mentioned in the body, two specific cell types are front and center. These are the neurons and the muscles, with the most notable of those being the cardiac muscle. In the cardiac muscle, an electrical signal sent throughout the heart controls when the atria and ventricles contract and relax. This signal is generated by the sinoatrial (SA) node (Silverthorn 2019), located in the top of the right atrium, and is sent through the internodal pathway starting with the internodal atrial muscle and junctional fibers. The internodal atrial muscle conducts the impulses from the SA node to the atria, while the junctional fibers continue to transmit the signal to the atrioventricular (AV) node, where the impulse is delayed by approximately 0.1 seconds to allow the atria time to finish contracting. After the delay, the impulse is conducted from the AV node to the AV bundle, or bundle of his, then rapidly between the SA node and bundle branches, and finally from the bundle branches to the purkinje fibers, which extend from the part of the interventricular septum closest to the apex around the ventricles. This pathway, in practice, causes the atria to contract shortly after the SA node generates the impulse, then causes the ventricles to contract 0.1 seconds later, and finally the heart relaxes.

As mentioned previously, the sinoatrial node is responsible for generating the electrical impulse that other parts of the heartbeat's electrical pathway conduct. This node is composed of specialized myocardial autorhythmic cells, or cardiac pacemaker cells, which function via action potentials. The potential of the cell becomes less negative due to sodium inflow until reaching threshold, causing its potential to quickly rise into positive values while calcium channels open. At the peak of depolarization,
those calcium channels close, and potassium channels open so the membrane potential can go back to its resting state, and the impulse has been sent to the rest of the heart to complete one cardiac cycle. While the heartbeat can function on its own, some of its methods of control involve the nervous system. These nerves surrounding the heart are known as the cardiac plexus, and allow the heart to receive signals from both the vagus nerve of the parasympathetic nervous system and the cardiac nerves of the sympathetic nervous system. Sympathetic signals are associated with an increase in heart rate and parasympathetic signals decrease the heart rate, aligning with the overall function of the SANS guiding the fight or flight response and the PANS guiding a rest and digest response.

Understanding the typical structure of sinus rhythm on an electrocardiogram is integral to understanding any abnormalities that cardiac arrhythmia causes. A standard ECG wave consists of 3 main components, the P wave, the QRS complex, and the T wave. The P wave is the first component of the wave, and represents the depolarization of the atria after the pacemakers generate an action potential. The QRS complex represents the depolarization of the ventricles, and additionally is when repolarization of the atria occurs, but this event is often masked. The T wave represents the end of the individual cardiac cycle when the ventricles repolarize, and cells return to their resting potential before the next heartbeat. There are additional intervals and segments related to the P wave, QRS complex, and T wave which can describe certain aspects of someone’s heart rhythm. The P-R interval covers the time between the onset of atrial depolarization and the onset of ventricular depolarization, the Q-T interval which represents the refractory period of the ventricles, and the R-R interval not shown in the
below figure which may be used to measure the time between two successive ventricular depolarizations. For segments shown, the PR segment shows the time it takes for the AV node to conduct an impulse to the ventricles, and the ST segment represents a period early in ventricular repolarization where the ventricles are still electrically excited. These components of one cardiac cycle and the electrical pathway covered in this section that they represent typically need to be understood to describe the changes associated with cardiac arrhythmia.

Figure 1: One PQRST wave, including visual representations of the PR and QT intervals as well as the PR and ST segments.
2. How Heartbeat May Be Altered and Common Types of Arrhythmias

While all forms of arrhythmia are important to understand, some symptoms such as tachycardia and its opposite, bradycardia, are commonplace. Sinus tachycardia and bradycardia are not conditions in themselves, but symptoms of conditions. As an example of their status as symptoms, both may be present in cases of sleep apnea (Muller et al. 2023). Additionally, tachycardia is a symptom of many conditions in which the heart beats irregularly or experiences a flutter, including the most common form of heart arrhythmia, which is atrial fibrillation.

Any heart rate slower than 60 beats per minute is considered bradycardia, and those with it may experience dyspnea or shortness of breath, and lightheadedness due to less oxygen being available throughout the body. In both bradycardia and tachycardia the heart rhythm may still be considered regular, as the heart is beating normally but at either an abnormally high or abnormally low rate. In the case of bradycardia specifically, diseases and conditions that can cause this change in heart rate tend to involve damage to the heart tissue, such as lupus and some cases of myocarditis in multisystem inflammatory syndrome (Ciccarelli et al. 2021). It is also important to consider that some athletes’ bodies may have been conditioned into a lowered resting heart rate, and thus what may be considered unusually low heart rate in others may be normal for them. In tachycardia, the heart rate is elevated above its resting maximum of 100 beats per minute, and it has its own symptoms of patients feeling that increase with a racing heartbeat. In the case of tachycardia, it may be caused by different forms of heart fibrillation and flutter, ventricular and supraventricular tachycardia. As tachycardia
describes a high heart rate for any reason it may be the result of high levels of caffeine, alcohol, or smoking, as well as abnormal blood pressure.

Atrial fibrillation is the most common type of heart arrhythmia in a clinical practice (Jost et al. 2021), and while not as immediately dangerous as other forms of arrhythmia that will be covered, it does contribute significantly to mortality in elderly people with this condition. Atrial fibrillation, sometimes referred to as afib, will occur when abnormal heart beats trigger a repeated impulse from the pacemaker, which effectively causes the atria to contract at irregular intervals. Common symptoms for those with atrial fibrillation include dyspnea, chest pain, and heart palpitations. What triggers these sudden heartbeats can vary from case to case between causes such as coronary artery disease and high blood pressure, and some people may be at risk of atrial fibrillation for hereditary reasons. The threat of this disease comes from its contribution to stroke risk via thromboembolism and congestive heart failure, as well as the potential for prolonged cases of atrial fibrillation to cause atrial remodeling, in which the heart attempts to respond to the irregular beat. Composed of electrical, contractile, and structural forms of remodeling, this mechanism is responsible for the progressive nature of this type of arrhythmia, where action potentials grow shorter, more calcium than usual flows into cells, and fibrosis is promoted in the heart. The spontaneous beats that afib causes appear on an ECG as a wave where individual QRS complexes and T waves may be mostly intact and allow blood to be pumped to critical areas of the body such as the brain, but the P wave has an inconsistent and often coarse shape. Figure 2, located on page 19, displays these qualities as well as how atrial fibrillation often involves tachycardia. With this in mind, an electrocardiogram is a common method for detecting
atrial fibrillation, in addition to other exams that examine someone's pulse. Additionally, people who potentially have atrial fibrillation may receive blood tests to determine whether thyroid dysregulation is the cause, as thyroid disease and atrial fibrillation are often associated with each other. Atrial fibrillation and its clear indicators on an electrocardiogram is an example of how dramatically arrhythmia can differ from sinus rhythm, tachycardia, and bradycardia, which also illustrates the importance of ECGs when discussing how they are detected and diagnosed.
.3. More Lethal Forms of Arrhythmia, and What Can Be Done About Them

Unlike atrial fibrillation, which was discussed in the previous section, some forms of arrhythmia can lead to sudden cardiac arrest following their onset. These have been categorized as lethal rhythms, including ventricular fibrillation, ventricular tachycardia, and asystole. Sudden cardiac death, which is primarily caused by ventricular arrhythmias, accounts for 50% of global cardiovascular deaths (Wan et al. 2021). In the event of cardiac arrest, two actions are typically used to provide immediate care, which are cardiopulmonary resuscitation, or CPR, and defibrillation. CPR allows the recipient’s heart to continue to pump blood throughout the body with proper execution, and a defibrillator’s purpose is to send an electric impulse through the heart all at once to potentially correct the arrhythmia.

Ventricular fibrillation is similar to atrial fibrillation in name, but instead involves irregular and spontaneous electrical impulses in the ventricles. Unlike atrial fibrillation this form of arrhythmia is disruptive enough to quickly prevent blood from properly flowing throughout the body and leave a person without a strong pulse. Without blood flowing to the brain, someone with this condition may experience unconsciousness or death within minutes (Wan et al. 2021). The major disruption in electrical activity is apparent in an ECG of ventricular fibrillation, in which the wave pattern effectively destabilizes rather than having an irregular beat, which is a similarity between types of arrhythmia that cause sudden cardiac arrest. As ventricular fibrillation is an emergency condition and shockable, immediate therapy is often performed using CPR and a defibrillator, which may also be capable of detecting the ventricular fibrillation. This
treatment may be performed by certified individuals performing basic life support (BLS) or healthcare professionals providing advanced life support (ALS).

Ventricular tachycardia is a condition with multiple variants, but is characterized by being a tachycardia specifically in the lower chambers of the heart. Some variations of ventricular tachycardia include polymorphic ventricular tachycardia (Zaffran et al. 2023) which has variable peaks for each wave on an ECG, and idiopathic ventricular tachycardia, which is ventricular tachycardia in a structurally normal heart absent of typical structural changes such as ischemia (Ward et al. 2023). Episodes of ventricular tachycardia can vary in length, with any over 30 seconds long being considered sustained and any under 30 seconds being considered non-sustained. Ventricular tachycardia on an electrocardiogram is characterized by having regularly spaced waves, but with a lack of P waves and a QRS complex that is significantly widened compared to sinus rhythm and conditions that affect the atria rather than the ventricles. Possible treatments for ventricular tachycardia include ALS, but the decision on whether to use a defibrillator may vary depending on the circumstances, as “shocks in particular have been demonstrated to increase mortality and worsen patients’ quality of life” (Guarracini et al. 2023).

Asystole is an atypical form of arrhythmia due to precisely what it describes, a lack of electrical activity or contraction in the heart, in contrast to arrhythmia where the heart beats too often and at irregular intervals. Asystole is colloquially referred to as flatline, due to the electrocardiogram showing no electrical activity in a person’s heart, which displays as a flat line on a monitor with no waves and thus 0 beats per minute. Asystole as a condition is notable because while it may be the initial rhythm once it is
treated, it can be the result of another form of arrhythmia that has progressed toward cardiac arrest. BLS or ALS may be performed on asystolic patients, and normally ALS providers must initiate CPR without clear signs of irreversible death or a do not resuscitate order. However, this shutdown of electrical activity is what differentiates treating asystole from other arrhythmias that cause cardiac arrest, and that is that asystole is non-shockable (Jordan et al. 2022). What this means is that if asystole is noted on any cardiac monitor available, those providing life support will usually not attempt to defibrillate and instead minimize interruptions in CPR.
Conclusion

This paper was intended to work as a potential broad guide to the rhythm of the heart, its electrical nature, and how numerous conditions can be clearly identified using electrical information obtained from a person’s heart. This does not completely cover all conditions that may affect the results of an ECG, however, some more common conditions and patterns were the focus, as well as those that may require immediate attention for those trained to provide treatment. It is important to understand that due to the continued problem that sudden cardiac death has posed, there continue to be advancements in cardiology that may influence our understanding of the subject or change how professionals respond to certain diseases.
Reference List


https://www.heart.org/en/health-topics/arrhythmia/about-arrhythmia/tachycardia--fast-heart-rate

**Figures/Illustrations**

![Figures](image1.png)

**Figure 2.** An example of normal sinus rhythm from the American Heart Association (2022).

![Figures](image2.png)

**Figure 3.** An example of tachycardia from the American Heart Association (2022), note the shortened period between the T wave of one cardiac cycle and the next P wave, as well as the lowered R-R interval.
Figure 4. An example of bradycardia from the American Heart Association (2022), where lowered heart rate is illustrated by the extended period between heartbeats.

Figure 5. An example of atrial fibrillation from ACLS Medical Training (2023), with notable differences from sinus rhythm being irregular rhythm and less distinct P waves.

Figure 6. An example of ventricular fibrillation from ACLS Medical Training (2023), with a highly disorganized ECG where there is no pulse and a chaotic wave pattern.
Figure 7. An example of ventricular tachycardia from ACLS Medical Training (2023), characterized by widened QRS complexes, no P waves, and heart rate over 100 bpm.