CHAPTER 1
INTRODUCTION

1.1 An Introduction to heart

Human heart is a muscular organ which pumps blood to the entire body with the help of circulatory system. The human heart consists four chambers: Two upper chambers called atria and two lower chambers known as ventricles which is separated through wall or septum. Atria and ventricles are attached by non-conductive tissues that separates ventricles from the atria. Circulation of blood to the lungs is possible with the help of right atrium and right ventricle. Deoxygenated blood is received with the help of large vein termed as vena cava and flows into the right atrium which further contracts and pushes blood into the right ventricle for maximizing the pumping efficiency. Whereas oxygenated blood pumps to the lungs by right ventricle and similarly the left atrium and left ventricle together form a pump for circulating oxygen enrich blood obtained from the lungs to the rest of the body (Dahlstrom, 2005; Laukkanen & Virtanen, 1998). The anatomy of heart is shown in Figure 1.1 (Levkov, 1987).

For pumping of the blood several muscles of heart are responsible. The actions generated from pace maker cells are arises from the two portions of the heart called the Sino Atrial (SA) and the Atrio Ventricular (AV) nodes like the example of myocardial muscle cell contraction. The action potentials are randomly generated by the cells of SA pacemaker at 60-80 times per minutes. SA node is responsible for generating the action potentials in heart. Sometimes, AV node performs this task in case of failure of SA nodes (Peskin, 1977). Steps involved in normal cycle of a heartbeat (Law et al., 1994) are as:

![Anatomy of Heart](image)
a) With the help of both atria, SA nodes creates action potentials
b) These action potentials generates contractions in arteries
c) Internal nodes of conducting system passes these potentials to AV node within 40 m sec
d) The contractions arises in atria pushes the blood to ventricles
e) The atrial system is responsible for pumping of blood via both ventricles
f) Systematic atrial system manages the left ventricle, while as right ventricle manages the pulmonary system for oxygenating blood via lungs
g) The elastic recoil of the arterial walls is responsible for continuing blood flow after the relaxation of heart muscles
h) Meanwhile atria and ventricles again fill with blood with the help of venous system
i) For determining the way of blood flow, a sequence of one way valve is used

1.2 An Electrocardiograph

In the heart, there are several spreading action potentials which generates an electrical current in human body (Sudarshan & Mukunda, 2016). With the help of voltage measurement system, this electrical current is determined by fixing electrodes on specific positions at the body surface between ±2mV and bandwidth range from 0.05 to 150 Hz.

Tracing electrical activity of the heart on standard graph papers over a certain interval of time is called electrocardiogram (ECG). The ECG recordings have a very stable output in terms of direction, amplitude and duration hence it is considered as an important tool for healthcare professionals (Hadzievski et al., 2004).

The pattern recognition is one of the major domain for analysis of ECG signals. The pattern recognition aims at automatically dividing the input data into different classes. By seeing an ECG waveforms printout, an experienced cardiologist can easily determine the status of heart. In few cases, ECG analyzers provide better accuracy in comparison to traditional manual visual inspection. To accurately identify the specific disease in a pool of several waveforms is a tedious task that can be simplified with the help of computer based automated tool. Few analyzers available in the market are able to produce a diagnosis, while rest produces a limited number of features which can be used for manual interpretation by experts (Reinstadtler, 2010).

Graph tracing based ECG recorder is one of the most popular and oldest instrument used in medical field. The breakthrough step in ECG recording was wearable monitoring devices which lead to high resolution recording, analysis and interpretation (Davie et al., 1996). An ECG provides following information about human heart:
1.3 Components of an ECG

The pattern of ECG waveform represents repolarization and depolarization of atrium and ventricles (Franke et al., 1962). Both electrical activities cause other different muscular activities in heart. The electrical cells generate impulse which leads the ions to cross the cell membrane causing some action potentials called depolarization. Depolarization occurs in four chambers of the heart, firstly in atria and then in ventricles. When these ions return to their resting state in the myocardial muscle, it is called repolarization (Yan et al., 2003). Waveforms generated below the baseline are called negative deflections whereas above the baseline is called positive deflections. Figure 1.2 represents the various components of an ECG (Hsieh & Hsu, 2012) and Table 1.1 shows the duration of ECG components (Reynolds et al., 1967; Arthur et al., 1972).

Figure 1.2 Components of an ECG

P Wave: The left and right atrial depolarization is represented as the first positive deflection known as P wave. P waves have amplitude of 0.05 to 0.25 mV which represents the initialization of QRS complex. If an ECG signal has high SNR then it is difficult to recognize the P wave. Unclear or absent P wave shows the presence of atrial fibrillation.
<table>
<thead>
<tr>
<th>Component</th>
<th>Duration (Sec)</th>
<th>Amplitude (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P Wave</td>
<td>0.08 to 0.10</td>
<td>0.1 to 0.2</td>
</tr>
<tr>
<td>T Wave</td>
<td>0.12 to 0.16</td>
<td>0.1 to 0.3</td>
</tr>
<tr>
<td>QRS Complex</td>
<td>0.06 to 0.10</td>
<td>1</td>
</tr>
<tr>
<td>TP Segment</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ST Segment</td>
<td>0.08 to 0.10</td>
<td>-</td>
</tr>
<tr>
<td>PR Interval</td>
<td>0.12 to 0.20</td>
<td>-</td>
</tr>
<tr>
<td>QT Interval</td>
<td>0.30 to 0.40</td>
<td>-</td>
</tr>
<tr>
<td>RR Interval</td>
<td>0.6 to 1.2</td>
<td>-</td>
</tr>
</tbody>
</table>

T Wave: Repolarization of ventricles is shown by T wave which is the most unstable wave in an ECG. The T wave starts at the end of ST segment. Some diseases known as Ischemia and Hyperkalemia possess large T waves.

QRS Complex: This is made up of the combination of three graphical waves known as Q wave, R wave and S wave which occurs due to the existence of depolarization of right and left ventricles having duration of 0.06 to 0.10 sec. Q wave occurs from any negative deflection shown after P wave. R wave possess positive deflection whereas S wave is any negative deflection after the R wave. These three waves together are considered as QRS complex. It ranges from 0.08 to 0.10 second. Few ventricular problems while conduction such as bundle branch block may determine by analyzing the duration of QRS complex.

J Point: This is the meeting point of QRS complex and ST segment. At this area a sharp angle is formed by the last part of the upstroke of S wave.

TP Segment: This segment represents the isoelectric interval on the ECG. It is the region showing end of T wave and starting of P wave. This is the time period when the muscles of the heart are electrically silent.

ST Segment: This is the flat horizontal area where QRS complex ends and T wave begins. ST segment is isoelectric in nature with the baseline.

PR Interval: It occurs from the starting point of P wave to the starting point of QRS complex. Its duration is usually between 120 to 200 ms.
QT Interval: This is calculated between starting of QRS complex to T wave finishes. It reflects time between repolarization and depolarization of ventricles. It ranges from 0.4 to 0.43 sec and varies differently in males and females with age.

RR Interval: RR Interval is between the consecutive RR’s and the variability of the heart period. It ranges from 0.6 to 0.10 sec.

1.4 The 12 Lead Standard ECG System

The standard ECG is measured with the help of 12 leads. They are three limb and augmented leads, and six precordial leads shown in Table 1.2. Some functions of these leads (Daniel et al., 2001) are defined as:

- Records the electrical activity of the heart at different angles
- Shows positive and negative components
- Monitors the desirable positions of the heart

<table>
<thead>
<tr>
<th>TABLE 1.2 12 Lead ECG system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIMB LEADS</strong></td>
</tr>
<tr>
<td>Bipolar Leads</td>
</tr>
<tr>
<td>Lead I – Lateral</td>
</tr>
<tr>
<td>Lead II – Inferior</td>
</tr>
</tbody>
</table>

Each lead have a pair of electrodes called positive and negative, placed on a specific locations of a human body for recording the electrical signals which is connected to an ECG machine (Chaitman et al., 1978).

Bipolar Leads: Records generated potential difference between the positive and negative poles.

Unipolar Leads: These leads are also known as nine wires which records the electrical potentials at a specific points. The three augmented leads looks directly into the heart with tunnel
vision. The precordial leads displays the three dimensional view of the integral vector while using with the combination of limb leads.

1.5 Functions of 12 lead

Lead descriptions and its functions are as follows (Edenbrandt & Pahlm, 1988):

- **Limb Leads (Einthoven Leads)** shown in Figure 1.3 (Dower et al., 1988).
  These leads records the potentials between
  - Lead I- The right and left arm
  - Lead II- The right arm and left leg
  - Lead III- The left arm and left leg

![Figure 1.3 Limb Leads](image)

- **Augmented Leads** are displayed in Figure 1.4 (Garvey et al., 2006).
  These leads puts the positive electrode on
  - Aug. VR means right arm
  - Aug. VL means left arm
  - Aug. VF means left leg
  
  And puts the negative electrode on the combination of electrodes places on the
  - Aug. VR means between left arm and left leg
  - Aug. VL means between right arm and left leg
  - Aug. VF means right arm and left arm
• Precordial Leads are also known as Wilson Leads are shown in Figure 1.5 (Haraldsson et al., 2004).

These six leads consists positive electrodes and these are strategically placed on the chest of a human body. These leads are necessary for accurate recording of ECG. These are as follows:

- V1- IV intercostal space i.e. right sternal line
- V2- IV intercostal space i.e. left sternal line
- V3- In middle of electrodes between V2 and V4
- V4- V intercostal space in middle portion of clavicular edge
- V5- Inside of anterior axillary line horizontally
- V6- In the mid axillary line horizontally, middle of clavicular line and Anterior axillary line
1.6 ECG Arrhythmias

Normal rhythm of the heart is termed as Normal Sinus Rhythm (NSR) when the human ECG morphology is found free from any disease or disorder. The NSR rate of heart is normally between 60 to 100 beats per minute. The RR interval is sometimes irregular with the breathing cycle (Huikuri et al., 2001).

An Arrhythmias is a type of disorder having too fast, too slow and sometimes irregular rate or rhythm of the heart. The occurrence of arrhythmia is based on the non-functioning stage of the electrical impulses which directs and regulates the human heart beat. Almost every human being experiences an abnormal heart beats once in their life time. Normally, arrhythmias are harmless but sometimes it becomes problematic when it disturbs the flow of blood in human body that can lead to the destruction of brain, lungs or many more other vital organs of the body. If not treated properly it can lead to sudden death (Cranefield et al., 1973).

1.7 Causes of Arrhythmias

Any type of disturbances to the electrical impulses of heart contraction, leads to arrhythmia. In the resting state, a normal person should have 60 to 100 beats per minute (London et al., 2007). But too fast, too slow and sometimes absence of beats also leads the occurrence of arrhythmias. Some important reasons (Yada et al., 2007) for improper functioning of heart are:

- Diabetes
- Excessive usage of drugs
- Coffee consumption is too high
- Hypertension
- Sometimes mental stress
- Intake of dietary pills
- Involvement in herbal treatments
- Involvement in Medications

1.8 Symptoms of Arrhythmias

An individual having arrhythmia, can have these symptoms (Lacefield & Simon, 1981):

- Too slow heart beats called Bradycardia
- Too fast heart beats called Tachycardia
• Irregular, uneven and sometimes skipped heart beats

There is no time or month for the occurrence of arrhythmias. It can happen at any time or all the time. An individual may or may not feel arrhythmic as the symptoms may be very light. Following are the list of some common symptoms when the presence of arrhythmias is found (Kent, 1985):

• Heavy sweating
• Pain in the chest
• Laziness
• Shorten breath
• Head pain

1.9 Types of Arrhythmias

Table 1.3 illustrates the four types of arrhythmias (Prasad & Sahambi, 2003)

<table>
<thead>
<tr>
<th>CARDIAC ARRHYTHMIAS</th>
<th>PREMATURE BEATS</th>
<th>SUPRAVENTRICULAR ARRHYTHMIAS</th>
<th>VENTRICULAR ARRHYTHMIAS</th>
<th>BRADY ARRHYTHMIAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a) Atrial Fibrillation (AF)</td>
<td>b) Atrial Flutter</td>
<td>a) Ventricular Tachycardia (VT)</td>
<td>a) Wolff Parkinson White Syndrome (WPWS)</td>
</tr>
<tr>
<td></td>
<td>c) Paroxysmal Supraventricular Tachycardia (PSVT)</td>
<td>d) Wolff Parkinson White Syndrome (WPWS)</td>
<td>b) Ventricular Fibrillation (VF)</td>
<td></td>
</tr>
</tbody>
</table>

1.9.1 Premature Beats

It is one of the most common type of harmless arrhythmia having no symptoms. But, sometimes shows light pain in the chest or skipped heart beats, but this needs no treatment. If they occur in upper area of heart (atria), termed as premature atrial contractions (PAC’s) or occurs in lower area of heart (ventricles) termed as premature ventricular contractions (PVC’s). Mostly it occurs naturally, but any type of heart disease can cause premature beats. The main causes of the
occurrence of these beats are the excessive use of coffee and stress. Figure 1.6 and Figure 1.7 represents premature ventricular contractions (PVC’S) and Premature Atrial Contractions (PAC’S) respectively (Rensma et al., 1988).

![Figure 1.6 Premature Ventricular Contractions](image1)

![Figure 1.7 Premature Atrial Contractions](image2)

**1.9.2 Supraventricular Arrhythmias**

These types of arrhythmias have very fast heart rate, originating in the atria or atrioventricular (AV) node. This AV node consists large number of cells between atria and ventricles.

**1.9.2.1 Atrial Fibrillation**

This is one of the most hazardous type of arrhythmia. In this type of arrhythmia, the heart rate exceeds up to 350 beats per minute (Wolf et al., 1991). The uncoordinated activations and the contraction between different parts of atria may lead to AF. Figure 1.8 displays the difference between Atrial Fibrillation and normal signal (Sandercock et al., 1992).

![Figure 1.8 Atrial Fibrillation](image3)
1.9.2.2 Atrial Flutter Atrial

This arrhythmia shows very high heart rhythms from 240 to 400 beats per minute (Pappone et al., 2005). The regular fast occurrence of P wave resembles like saw tooth waveform images, known as flutter waves. Figure 1.9 displays the difference between Atrial Flutter and normal signal (Ruberman et al., 1977).

![Atrial Flutter Diagram]

Figure 1.9 Atrial Flutter

1.9.2.3 Paroxysmal Supraventricular Tachycardia (PSVT)

PSVT is a common heart disorder can originates in all age groups and persons but its treatment is quite challenging job. It is an episodic arrhythmic condition having unusual onset and termination. PSVT is somewhat similar to narrow complex tachycardia that has a regular but abrupt heart rhythms shown in Figure 1.10 (Scheinman et al., 1982). The complications due to this arrhythmia are myocardial infarction, syncope and sudden death.

![PSVT Diagram]

Figure 1.10 Paroxysmal Supraventricular Tachycardia

1.9.2.4 Wolff Parkinson White Syndrome (WPWS)

WPW syndrome arises due to several heart disorders in electrical system of heart. These are characterized as pre excitation syndromes having an abnormal extra electrical conduction pathway between the atria and the ventricles. This abnormal pathway is called as bundle of Kent that shown in Figure 1.11 (Newman et al., 1966).
1.9.3 Ventricular Arrhythmias

These are the abnormal heart beats originating from bottom portion of heart called ventricles which arises due to the abnormalities found in heart muscles. These rhythms of the heart may either be too fast or too slow (Zipes et al., 2006).

1.9.3.1 Ventricular Tachycardia (VT)

This Tachycardia arises due to the occurrence of continuously three irregular heartbeats at 100 beats per minute. It occurs due to improper functioning in heart’s electrical system. Figure 1.12 shows ventricular tachycardia ECG signal (Josephson et al., 1978).

1.9.3.2 Ventricular Fibrillation (VF)

It is one of the life threatening heart disorder occurs in lower portion of heart. In this arrhythmia heart cannot pump any blood that lead heart failure. Figure 1.13 shows ventricular fibrillation ECG signal (Lown & Verrier, 1976).
1.9.4 Brady Arrhythmias

When the rate of heart is too slow i.e. Bradycardia which affects important organs of body. In this arrhythmia heart rate is too slow around 60 beats per minute. Its main symptom is heart rate dropping below 40 beats per minute and there is a shortage in blood supply to brain. It is not dangerous for physically fit individuals having automatically slow heart beats and not showing any symptoms, while other persons with other conditions it may occur and show symptoms. Figure 1.14 shows Brady arrhythmia ECG signal (Myles, 1991). Brady arrhythmias occur due to several reasons. They are:

- Angina Attack
- Heart’s electrical activity is changed
- Chemical imbalance or the occurrence of other substances in blood
- Intake of some anti arrhythmic medicines

Figure 1.14 Brady Arrhythmia

1.10 Arrhythmias in Children

Heart rate reduces day by day in children as they get older. New born babies’ heart rate is varying from 90 to 160 beats per minute, whereas children heart rate having age of 6 to 9 years are 60 to 120 beats per minute (Trivedi & Kanter, 2011). Figure 1.15 shows the ECG signals acquired from Children (Kannan & Kumar, 2013).
The babies and children heart rhythm may be abnormal sometimes due to several reasons. As the children become active their heart beat is faster and it is noticed the rate of heart is slow during sleep hours (Jat et al., 2011). Some children are born with heart defects like arrhythmias and some other children with arrhythmias are in later childhood. Medical professionals are using same diagnostic methods and treatment in children or in adults. The treatment includes medicines, electric shock, surgically implantable devices and many more for managing the heart beats (Till & Ward, 1988).