Grammar Formalism for Medical Data Analysis

Grammar Formalism for Medical Data Analysis:

Its Application in ECG, Scintigraphy and Tomography

By

Salah Hamdi, Asma Ben Abdallah
and Mohamed Hedi Bedoui

Cambridge Scholars
Publishing

Grammar Formalism for Medical Data Analysis: Its Application in ECG, Scintigraphy and Tomography

By Salah Hamdi, Asma Ben Abdallah and Mohamed Hedi Bedoui

This book first published 2022

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-8429-1
ISBN (13): 978-1-5275-8429-7

CONTENTS

CHAPTER 1

INTRODUCTION

The heart is the essential representative of the cardiovascular system and it can be prone to many diseases. According to annual statistics from the World Health Organization (WHO), cardiovascular pathologies are the most common cause of death in the world. As a result, the diagnosis of cardiac pathologies appears and imposes itself as a vital task. Doctors have powerful tools at their disposal to observe the functioning of the heart muscle and thus make their diagnosis based on the continuous development of resources and techniques. Among the possible techniques: electrocardiography, scintigraphy and tomography.

The most common test done is electrocardiography because it is quick to perform, inexpensive, and non-invasive. With the help of the electrocardiogram (ECG), important indicators can be determined. In general, the shapes and durations of the different peaks and waves are examined as signs of true heart abnormalities.

Cardiac scintigraphy, one component of nuclear imaging, is an additional test used by nuclear physicians to assess heart function. Scintigraphy is a technique that carries useful information to affirm or deny chest pain by recognizing the state of perfusion of the myocardium. The technique is performed following a stress test to achieve maximum heart rate for a satisfactory time or to stop the test due to pain or exhaustion.

In addition to taking a medical history of symptoms and risk factors, the doctor may perform certain tests to judge the quality of the carotid arteries using the technique called angiography. In the case of medical imaging, tomography is a technique that reconstructs the volume of an object in the human body from a series of sections obtained from the exterior of the object in question. The result is a reconstruction of the real properties of the interior of the object. In this examination, an iodinated contrast medium is used to increase the density of the blood in the arteries and thus enhance the vascular bed in the images. These images are obtained from different angles, which allow 3D reconstruction.

Several usual approaches to processing 1D and 2D medical data have been proposed. However, few works have been based on grammar. Grammar and language theory began in 1950. To this day, grammar involves analyzing programming languages, describing natural languages, and modeling logical circuits. However, grammatical rigor can be extended to cover other areas of application such as signaling and medical imaging. The main advantage of these methods concerns the representation that it can make available. Syntactic approaches can powerfully represent object structures and therefore make it easy to retrieve information. The input data appears to be a structured scene having a hierarchical order because grammars can clearly represent hierarchical structures using non-terminal and terminal nodes. In addition, syntactic approaches are able to describe a large set of complex objects using small sets of simple primitives and grammatical rules. Compared to statistical methods, the use of grammars offers more flexibility in applications.

It is in this context that our thesis topic arises and finds its interest. We offer 1D and 2D medical data processing techniques based on grammatical formalism. The idea is inspired by language theory and word recognition. Grammatical formalization can represent semantic patterns and patterns found in the signal or in the image. Indeed, we used syntactic methods to interpret the ECG signals from the MIT-BIH standard base and measure the associated parameters (R peaks, RR distances, QRS durations and QTc corrected intervals). Also, we will show how the idea of grammar is applied to medical 2D images such as scintigraphic image and tomographic image. The proposed method makes it possible to detect the contours of the epicardium and endocardium. In addition, quantitative information can be deduced such as the area and radius of each organ as well as the thickness of the epicardial muscle. Indeed, this type of work will certainly help physicians during a medical examination and during a decision-making process.

This report is mainly composed of four chapters.

The first chapter briefly introduces the basics of cardiology and the functioning of the cardiovascular system. It helps to understand in particular the origin of the electrical signals recorded by the ECG signal. Then, the first chapter presents cardiac scintigraphy and explains different types of scintigraphic images held in states of exertion and rest. Also, a part will be devoted to present tomography and more precisely of the carotid arteries using tomography angiography. As the second part of the chapter, we briefly report basic notions of grammatical formalism and the

different types of grammar. It makes it possible in particular to focus on the first two types which are regular grammar and grammar out of context. We focus more precisely on the basics in terms of languages, automata, vocabularies, rules, lexical analysis and syntactic analysis.

The second chapter details the state of the art of different ECG signal processing methods. It presents several techniques reported from the literature for the analysis and processing of ECG and the extraction of certain characteristic elements of the signal such as QRS complexes, P and T waves, R peaks, etc.

The third chapter presents the method we have developed for the detection of QRS complexes and cardiac cycles and illustrates the results obtained on several types of real ECG signals from the MIT-BIH standard database and those obtained from our exploration partner service in Sahloul University Hospital in Tunisia. The algorithm quantifies various indicators of the ECG signal such as RR distance, QRS duration and the corrected QTc interval. In addition, we added two parameters: the standard deviation of the RR distances denoted σRR and the standard deviation of the QRS durations denoted σQRS. These standard deviation parameters reflect the regularity of RR distances and QRS durations.

The fourth chapter details the state of the art of the different grammar-based image segmentation methods. It presents several techniques cited in the literature that are based on grammatical formalism to do image processing in general. This fourth chapter presents the method we have developed for the segmentation of medical images. An application on scintigraphic images and tomographic images has been established. For a scintigraphic image, the algorithm can detect the contours of the epicardium and endocardium. In addition, quantitative information can be deduced such as the area and radius of each organ as well as the thickness of the heart muscle. For a tomographic image, a region of interest (ROI) segmentation technique is proposed. A large series of segmented regions of interest allowed us to do the 3D reconstruction of the objects. The image base comes from our second partner service, the Nuclear Medicine Service of the Sahloul University Hospital in Tunisia. The manuscript ends with a general conclusion.

CHAPTER 2

BASICS OF CARDIOLOGY AND GRAMMATICAL FORMALISM

I. Introduction

Through this chapter two aspects will be exposed:

- An overview of the cardiovascular system is given, followed by a general description of physiological cardiac activity. This presentation is particularly limited to the various parameters describing the Electrocardiogram (ECG) signal, the scintigraphic images and the tomographic ones for a better understanding of the work presented in this thesis. The chapter ends with a general description of cardiac pathologies. Readers interested in more in-depth approaches will be able to consult the numerous available medical books [Deb'97, Fis'02].
- A presentation of grammatical formalism basics will shed light on the theory that will be adopted later for the processing of medical data resulting from the techniques that have been described in this chapter.

II. Cardiovascular system

The cardiovascular system ensures the continuous circulation of blood in the organism. The circulatory system therefore supplies oxygen to cellular tissues and transports wastes to the kidneys and carbon dioxide to the lungs. The cardiovascular system is made up mainly of the heart and a network of continuous and closed conduits that allow the transport of blood to the arteries and veins.

II.1 Heart

The heart is a concave and muscular organ equivalent to a pump which allows the circulation of blood to the arteries and veins. The shape of the

heart is comparable to an inverted cone. The heart is placed in the mediastinum which represents the middle part of the rib cage bounded by the following organs: the two lungs, the breastbone and the spine. The heart is located to the left of the center of the thorax and is able to pump four to five liters of blood, at relaxation, per minute. The heart is subdivided into four chambers: two atria and two ventricles [Obr'68] (Figure 2.1), allowing blood to be pumped to the cells of the human body. The two atria and the two left and right ventricles constitute the left heart and the right heart respectively.

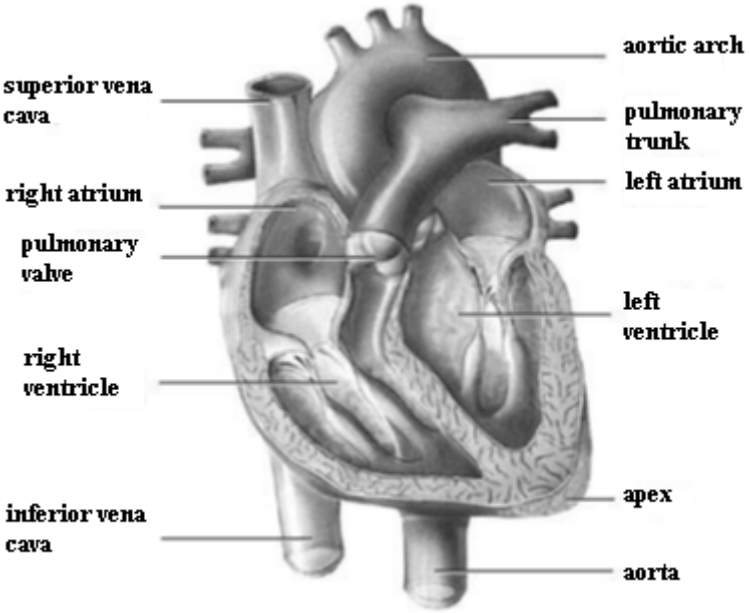

Figure 2.1: General diagram of heart [Fis'02]

II.2 Blood circulation

The right atrium picks up oxygen-poor blood from the upper and lower vena cava and throws it to the right ventricle after a phase of contraction. This phase is called systole. The systole is followed by another phase of diastole, making it possible to propel, through the pulmonary arteries, the blood in the lungs. Carbon dioxide carried by the blood will be cleaned by the lungs out of the body. Then the blood will be recharged with oxygen

and returns to the heart through the left atrium. After that, it circulates in the left ventricle and then to all the organs in the network of arteries through the aorta (Figure 2.1) [Fis'02].

III. Cardiac electrophysiology

The heart is an organ which automatically possesses all the tools for its functioning. This automatism is connected to the crucial tissue, and the heart contracts following a stimulus which originates from the posterior wall of the right atrium. This excitation passes through both atria and then passes to both ventricles. Consequently, the heart admits an intrinsic network of conductive cells which shape and retransmit electrical impulses vis-à-vis the cells that respond to impulses by phases of contractions. To better understand the origin of mechanical and electrical events in the heart, the electro-physiological properties of cardiac cells will be described first.

III.1 Electro-physiological properties of cardiac cells

The cells of the human heart are surrounded by a membrane which allows the passage of ions of different types, which produces differences in concentration on either side. Sodium is ten times less concentrated inside than outside the membrane, so the intracellular concentration of potassium is thirty times greater than outside. The concentration of calcium is much more concentrated on the outside than on the inside. Indeed, these differences in concentrations electrically generate potential differences between the outside and inside of the membrane [Deb'97, Fis'02].

Upon relaxation, the interior of the membrane is negatively charged with a -90mV potential difference, also called the resting potential. When the cell membrane is stimulated by chemical, mechanical or electrical excitation, momentary changes in the cell membrane will result in a cruel influx of sodium and calcium and an outflow of potassium. The potential level thus progresses from -90mV to +20mV, which is called the action potential. During the contraction of the cell membrane, exchanges of ions are transferred and thus induce an action potential, as described in Figure 2.2. The five resulting phases are represented as follows:

Rapid depolarization, or phase 0: After an electrical stimulus beyond the activation threshold, a rapid flow of sodium ions enters the cell and suddenly changes the polarity of the cell.

Early repolarization, or phase 1: It is characterized by short and rapid repolarization, due to the flow leaving the potassium ions and sodium inactivation.

Plateau, or phase 2: It represents slow repolarization. The phase is due to the slow entry of calcium ions into the membrane, which reduces the influence of potassium and consequently slows down the repolarization phase.

Repolarization, or phase 3: This phase corresponds to the final repolarization, and it is characterized by the closure of ion channels hence bringing the cell to a resting potential. Along this phase, potassium ions are continuously exiting, while the potential of the cell membrane tends towards a relaxation threshold.

Phase 4: This last phase describes the resting potential, in which the cell is no longer excitable.

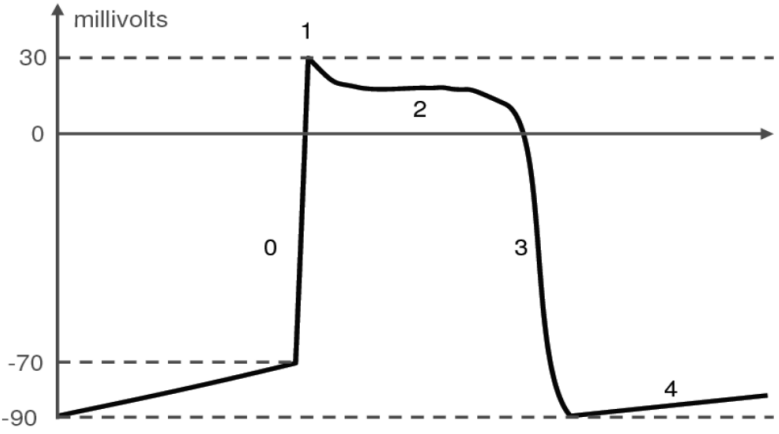

Figure 2.2: Five phases describing the action potential of cell membrane: phase 0 of depolarization, phase 1 of onset of repolarization, phase 2 of slow repolarization, phase 3 of rapid repolarization, and phase 4 of rest.

III.2 Electrical functioning of heart

The heart has an electrical system that keeps beating automatically. The heart muscle contracts and is governed by an electrical impulse in the

sinus node located in the superior vena cava, as shown in Figure 2.1, in the right atrium. The sinus node is formed by a set of automatically excitable cells which generate an electrical current of depolarization 60 to 100 times per minute.

Electrical self-excitation is transmitted to both atria causing atrial systole and occurs at the Atrioventricular (AV) node. The latter is the only point of passage between the ventricles and the atria located in the interventricular septum. At this stage, the self-excitation induces a short pause and consequently induces the phase of ventricular systole.

This pause is largely cruel to cause delayed stimulation relative to the atria and thus allows both ventricles to be fully filled during the atrial contraction phase. Consequently, the electrical system develops the conformity of the heart rhythms and so allows the coordination of the phases of the AV contractions.

IV. Electrocardiography

IV.1 History

In 1842: Carlo Matteucci was an Italian physicist who discovered that an electric current would follow every heartbeat.

In 1887: John Burden was an English physiologist who published the first ECG of a human being.

In 1897: Clément Ader was an engineer in electronics who adapted the galvanometer, which was an amplification system for telegraphic communications under marine.

In 1903: Einthoven managed to collect the electric currents by using an assembly called the Wheatstone bridge.

In 1924: Einthoven won the Nobel Prize for his activities on electrocardiography.

In 1932: Chest leads were used for medical diagnosis.

In 1942: Unipolar leads were used for medical diagnosis.

IV.2 Presentation

Electrocardiography is a slightly expensive technique, following a simple and non-invasive examination, controls the good functioning and progress of the cardiovascular pump.

This method was created in 1887 for the first time following the work of Waller [Wal'87]. Then it was reinforced by the invention in 1901 of the string galvanometer [Ein'88] vis-à-vis the medical community. In 1924, Dr. Wilhem Einthoven was awarded the Nobel Prize in Medicine. Since then, electrocardiography has been transformed into a primordial, essential and indispensable technique in cardiology.

The human body is observed as an electrical conductor. Therefore, the values of potentials generated at the levels of heart cells during mechanical activity can be recovered using metal electrodes arranged on the skin. The graphic recording obtained following the electrical activity of the human heart is always called “the ECG”.

The electrodes used are positioned for recording the ECG signal and they are known by electrocardiographic leads. The standard ECG signal is obtained on 12 leads (six precordial and six peripheral leads).

IV.3 System of electrocardiographic derivations

An electrocardiographic bypass is defined by two points of hearing from which the electrical activity of the heart is measured and the difference in the electrical potential is calculated. Often, EKG machines can record many potential differences simultaneously depending on the number of electrodes distributed and their locations on the body. Each value of these measured potentials is suitable for a lead of the ECG. The electrodes are located to better explore the full range of cardiac electrical fields produced by the contraction of the heart muscle and myocardium.

IV.4 Peripheral derivations

The peripheral leads provide the study of the electrical activities of the human heart on the frontal plane. Peripheral leads are obtained using four electrodes placed on the left arm, the right arm and the left leg. In order to eliminate the parasites, a neutral electrode is placed on the right leg. This arrangement was determined in 1912 by Dr. Wilhem Einthoven under the name “bipolar peripheral derivations” and subsequently completed in 1942

by Dr. Goldberger under the name “unipolar peripheral derivations” [Deb'97, Fis'02].

IV.4.1 Bipolar peripheral leads

Bipolar leads were decided by Einthoven in 1912, and they have also remained in use up to now (Figure 2.3). In fact, the leads are based on three electrodes distributed over the body. These electrodes are installed on the left and right arms and on the left leg in order to establish the Einthoven triangle. They are called bipolar derivations because we calculate the potential difference between each two electrodes. Any side of Einthoven's triangle symbolizes a lead by using two separate electrodes for each lead. The set of three derivations is:

- DI with DI = VL - VR
- DII with DII = VF - VR
- DIII with DIII = VF - VL

where V L is the potential value on the left arm, VR is the potential value on the right arm, and VF is the potential value on the left leg.

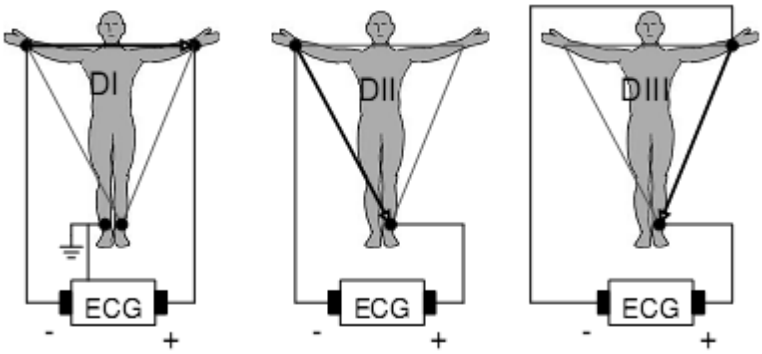

Figure 2.3: Einthoven triangle setup for recovery of bipolar leads.

IV.4.2 Unipolar peripheral leads

The unipolar leads were determined by Wilson (Figure 2. 4). In this type of lead, the values are measured between an exploratory electrode installed at the crest of the Einthoven triangle and a second central terminal. The latter is a neutral electrode whose potential value is equal to the average of the potentials of the three peaks of the triangle. This determines the

unipolar leads known by VL, VR and VF. Goldberg [Gol'42] changed the installation of Wilson's unipolar leads to extract three other unipolar leads called the augmented unipolar derivations aVL, aVR and aVF, as shown in Figure 2.4. The word augmented indicates that the Goldberg leads amplify the potential values of the old Wilson leads by a coefficient of 1.5.

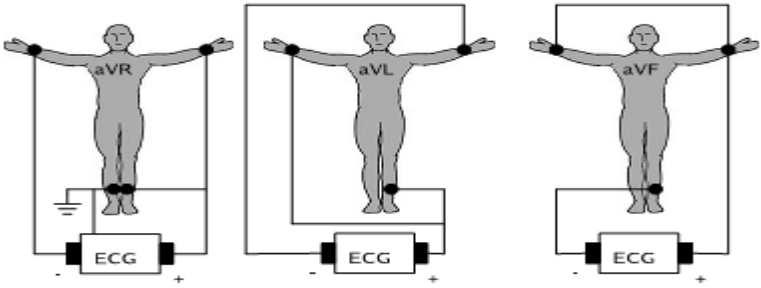

Figure 2.4: Goldberg system for recording unipolar leads

IV.4.3 Precordial derivations

To measure variations in potentials near the heart, Wilson proposed six new derivations of the horizontal plane V1, V2, V3, V4, V5, and V6 located on the left side of the thorax. The variations are measured from a positive pole in the form of an exploratory electrode located on the thorax and a negative pole in the form of a reference electrode connected to the central Wilson terminal. These leads are connected since the position of the exploration electrode is close to the left and right ventricles [Fis'02].

IV.5 ECG signal

As we have quoted before, an EKG is obtained from a machine called an EKG machine, which transforms the mechanical activity of the heart into a form of an electrical signal. The electro-physiological signal is obtained using metal electrodes located on the skin. The morphology of the ECG signal is presented in the form of a series of electrical waves which repeat with each cardiac cycle with particular shapes. In fact, the waveforms explain different phenomena relating to the levels of the action potentials of cardiac excitation and whose stages are illustrated in Figure 2.5 in successive ways. Figure 2.5 depicts the morphology of the normal single cardiac cycle ECG signal.

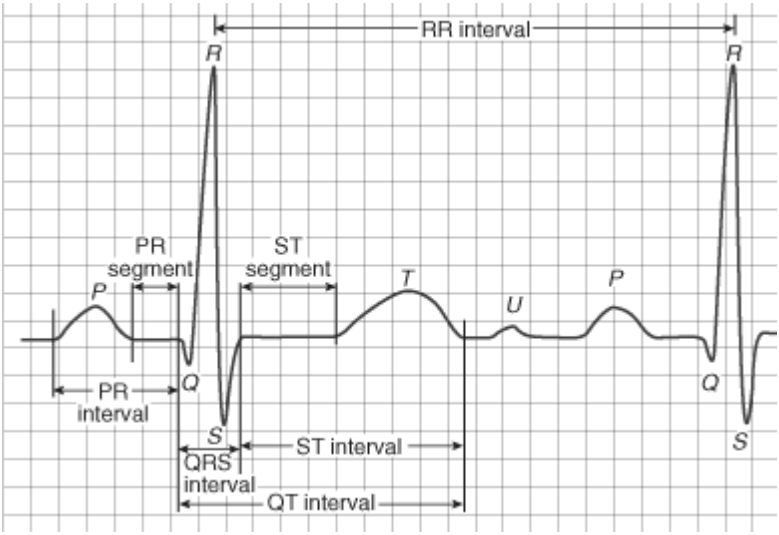

Figure 2.5: Morphology of normal ECG signal in single cardiac cycle

IV.5.1 Morphology of ECG signal

In an ECG signal, we notice that the phenomenon of the contraction and relaxation of the myocardium is exhibited in the form of a sequence of negative and positive deflections superimposed on a baseline of a zero potential which is suitable for the absence of cardiac events, as depicted in Figure 2.5. The letters P, Q, R, S, T and U are successively assigned to the waves of the ECG signal.

P wave: This is the first-order detectable wave. It appears when the electrical impulse is distributed through the sinus node in order to depolarize the atria. Muscle mass is partially light and results in a potential value of less than 0.25 mv. In the atria, the propagation of the depolarization wave is much lower than in the ventricles. Indeed, the place of the atria around the sinus node is depolarized very quickly compared to distant places. In addition, the repolarization front holds the same direction as the depolarization front and the result vector is directed towards the sinus node. Consequently, this phenomenon produces a repolarization wave in reverse of the depolarization P wave. Then, the repolarization phase of the atria explains the QRS complex. When this pulse is much stronger than the first, the repolarization wave will be hidden.

QRS complex: It is the set of negative and positive deflections which are suitable for the contractions of the two ventricles. For a normal case, the QRS complex has an amplitude between 5 and 20 mV and it lasts less than 0.12 seconds.

The QRS complex is often made up of three waves:

¬ L ' Q-wave: the first negative deflection.
¬ L ' R-wave: the first positive deflection.
¬ L ' S-wave: the second negative defection following peak A.

The shape of the QRS complex is variable depending on the positions of the electrodes as well as the leads used.

T wave: It comes after the QRS complex following a return to the basic power line. This wave is suitable for ventricular repolarization. Practically, it has a slight amplitude and does not confirm any mechanical phenomenon.

U wave: It is rarely observed. This wave is denoted U and can be observed after the T wave. It is a low amplitude wave and it is appreciable in some leads, especially in athletes. This wave is frequently associated with the phases of delayed ventricular repolarization.

Accordingly, a study of a normal EKG is shown in Fig.2.5. The characteristics of an ECG signal relate to the morphology of the P and T waves and of the QRS complex, the durations, the amplitudes, and other temporal indicators which are the PR, RR and QT intervals as well as the ST and PR segments.

IV.5.2 ECG intervals and segments

In addition to the different waves mentioned above which are the basic elements that characterize the ECG, there are other segments and intervals which support very essential information on the speed of the conduction of the impulse in the different organs of the body heart [Lim'09].

The most used segments and intervals are:

RR interval: This interval is very important and it corresponds to the time between two successive depolarizations of the ventricles. The RR interval is used to calculate the heart rate (1 / RR).

PR segment: This segment represents the time between the end of depolarization of both atria and the start of depolarization of both

ventricles. This is the time period in which the depolarization wave is surrounded at the AV node.

PR Interval: This PR interval represents the delay in the propagation of the depolarization wave from the sinus node to the ventricular cells.

QT interval: The QT interval corresponds to the duration of the ventricular systole, which begins at the onset of the excitation of the ventricles and stops at the end of their relaxation.

ST segment: This segment describes a phase during which all ventricular cells are depolarized; the segment has become isoelectric.

A detailed description of these characteristics of the normal ECG signal, physiological interpretation and numerous methods [Bro'98] for the calculation of the electrical axis of the QRS complex are available.

IV.5.3 Cardiac arrhythmias

In a state of rest, the heart is between 60 and 100 heartbeats per minute, often called beating heart. Acceleration in the number of beats is called tachycardia. A slowdown in the number of beats is called bradycardia. An irregular change in the heart beat is called an irregular rhythm. All these forms are the basic forms of arrhythmia [Joh'15].

Arrhythmia occurs when an electrical excitement manifests itself elsewhere than in the sinus node. In other words, the electrical impulse is registered in the AV node or in the ventricles, or the electrical excitation no longer propagates in normal paths.

Arrhythmia is sometimes accompanied by palpitations of beats. These palpitations cause you to feel the heartbeat and do not necessarily symbolize a heart rhythm disorder. This most often occurs when the pulse is beating faster or irregularly. On the other hand, a patient can have arrhythmia without necessarily feeling palpitations. There are different forms of arrhythmia. The main forms are as follows:

a) Extrasystole

It is very common arrhythmia. Extrasystole is an advanced heartbeat or excess that is perceived as an irregular or missing beat. A lot of people have this type of arrhythmia and do not even feel it. In most cases, this arrhythmia is not accompanied by other symptoms. This abnormality is mild and can even occur in a healthy heart. Sometimes extrasystole is

accompanied by little dizziness, but this case is not serious. The following figure describes the atrial extrasystole where the second and sixth complex occur in advance [Joh'15].

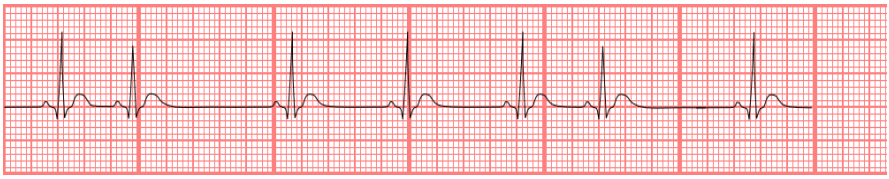

Figure 2. 6: Example of atrial extrasystoles

b) Atrial flutter

In this type of arrhythmia, abnormal depolarization propagates into the right atrium in a looping path and endlessly (Figure 2.7). The frequency of rotation is in the order of 300 beats / min. Depolarization occurs 300 times per minute at the entrance to the AV node and will cross the junction to the two ventricles only once in two or once in three. Indeed, the frequency of the ventricles will be a sub-multiple of 300 beats / min [Joh'15].

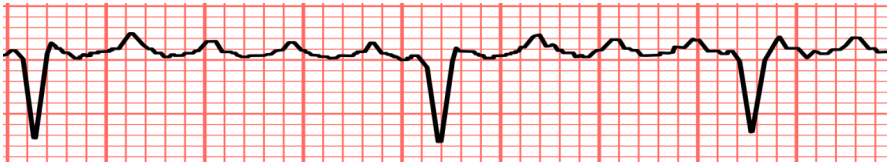

Figure 2. 7: Example of atrial flutter

Note that, in this type of abnormality, there is a major danger to the health of the patient due to disorders in the blood flow to the atria and the possibility of embolism occurring.

c) Atrial fibrillation

It is an atrial arrhythmia also called atrial fibrillation. The depolarization is divided into a set of fronts of different amplitudes and directions, ensuring a completely disordered electrical activity at the level of the atria. Often, this anomaly does not allow the atrial myocardium any phase of rest. Atrial fibrillation results in the absence of atrial waves in favor of a continuous irregular sinusoidal wave activity. The frequency of depolarization within the atria is often very high. Numerous depolarization fronts are consequently exposed at the AV node which acts as a filter by

allowing only a few fronts to pass at random. Generally, the rate of the ventricles is entirely irregular, between 90 and 140 beats / min depending on the state of the excitability of the node [Joh'15].

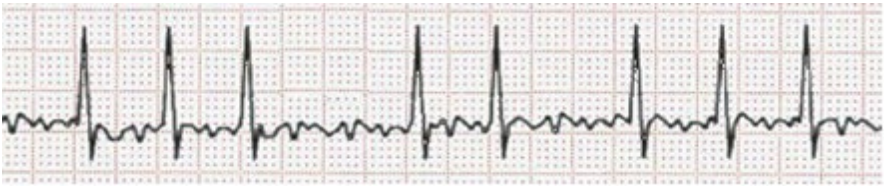

Figure 2. 8: Example of atrial fibrillation

However, the absence of atrial systoles results in a significant decrease in cardiac efficiency at two levels: first because the heart does not benefit from the atrial systole, which allows the ventricles to be filled with blood, and second because the average rate is often above 100 beats / min and can reach 200 beats / min. This arrhythmia is not serious, but the primary risk associated with this anomaly is flutter which is the possible transmission of emboli created in the atria. This major risk is probably low when atrial fibrillation is permanent, whereas it is immediately reinforced by episodes on a sinus background, especially during the change from one rhythm to another [Dal'07].

d) Supra-ventricular tachycardia

This atrial arrhythmia may have as its source a stimulation loop, an ectopic focus, or a pathway that closes the AV pathway, called the accessory pathway, with reentry by the AV node.

An ectopic focus is a case in which a group of cells placed in the atria depolarize naturally and as quickly as the sinus, thus taking its position. The depolarization of the atria is not of a sinus origin, the diffusion of the nerve impulse is different from that originating from the sinus, and a P wave of an exceptional shape is observed. The specific frequency characterizing this type of focus is between 120 and 200 beats / min and the ventricles operate at the same rate in the absence of conduction problems [Dal'07].

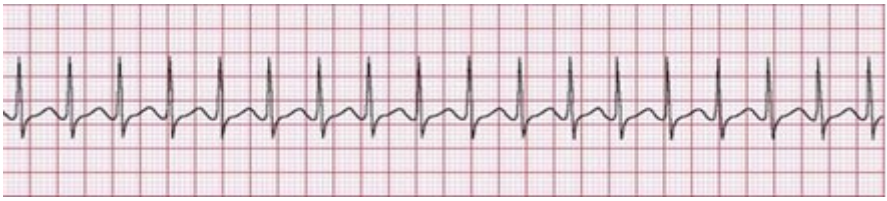

Figure 2. 9: Example of supra-ventricular tachycardia

In the event that the number of beats can reach 250 beats / min, periodic discharge from an ectopic focus located in the AV node can still be the cause of tachycardia, known as junctional or nodal tachycardia. Unlike atrial tachycardia, a P wave that precedes QRS complexes is never found, because there is no atrial activity that precedes the beat [Dal'07].

This type of pathology has a main risk which is the lack of efficiency of the ventricles; either forced to contract frequently, or because the ventricles do not have enough time to fill with blood properly. Thus, the body's supply of oxygen can be corrupted.

e) Ventricular fibrillation

Arrhythmia is equivalent to atrial fibrillation, but it affects the ventricles. The latter are therefore discharged in a completely desynchronized manner, and there is still no cardiac systole. The ECG signal records a disordered, irregular, rapid and oscillatory ventricular activity [Dal'07].

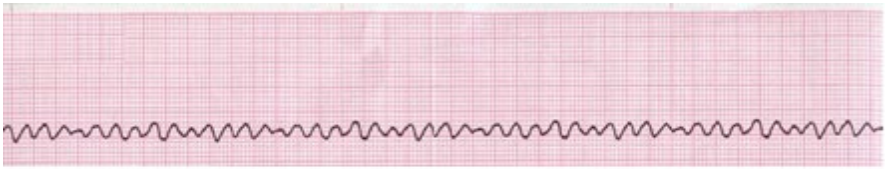

Figure 2.10: Example of ventricular fibrillation

Usually, ventricular fibrillation constitutes a serious arrhythmia, since it is a warning of sudden death. This is because the heart no longer functions at all its usual pumping activity and the blood no longer circulates, which causes the asphyxiation of all the tissues of the body. Without immediate defibrillation intervention, the depolarization of all myocardial cells are resynchronized and the cardiac movement restarts, hence ensuing death. A defibrillator allows people at risk of ventricular fibrillation to benefit from

its implantation. The defibrillator is located at the level of the thorax and it is accompanied by a probe capable of detecting the rhythmic abnormality and causing the device to give a strong electric shock [Dal'07].

f) Ventricular tachycardia

This type of arrhythmia has as source one or more ventricular ectopic foci which may in turn depolarize. Heartbeats take the form of tightly connected ventricular extrasystoles. If it is not treated by using a defibrillator, this pathology is dangerous because of its possible transformation into ventricular fibrillation, which can lead to the death of the patient within minutes of its appearance [Dal'07].

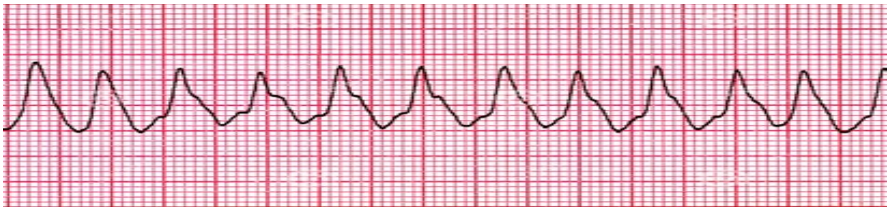

Figure 2.11: Example of ventricular tachycardia

V. Heart scintigraphy

V.1 Presentation

Scintigraphy is a non-invasive imaging technique. The images obtained from cardiac scintigraphy provide functional information. Scintigraphy is useful for studying myocardial perfusion. In this case, it is called cardiac or myocardial scintigraphy. This technique is still used at the level of the brain and the bone. Around the object in question, the acquisition heads are in rotation [Mar '00], and projections are successively acquired so dozens of images are obtained, each from a different angle. This way of acquisition ensures the distribution of the tracer in space and in 3D. Due to the tomographic reconstruction, a 3D representation of the left ventricle is made. Atherosclerosis is an anomaly characterized by a gradual obstruction of the arteries by a covering composed mainly of calcium and lipids, which generates a narrowing of one or certain coronary arteries. This is because the formation of thickening of the arterial wall and plaques causes stenosis. When this disorder affects the coronary arteries, then it irrigates less heart muscles, which become ischemic or necrotic. In this case, the technique of myocardial scintigraphy is useful to check the viability of the

myocardial tissue and to specify the ischemic territory. The patient is put on an activity and two groups of myocardial perfusion images are obtained by scintigraphy. A group is taken in the state of rest and another group in the condition of effort. The comparison between the art series of images allows having a distribution of zones in the myocardium in light of three degrees of intensity [Mar'00]:

- If the intensity value is normal in both images, then the area is normal.
- If the value of intensity is normal in the image rest and low in the image effort, then the area is reached by the ischemia effort.
- If a value of intensity is lower in both images, then it comes to a narrow stenosis of the coronary artery or there is a necrosis [Com'05].

Myocard scintigraphy is based on the muscle ability to accumulate different radioactive tracers. In fact, there are two types of cardiac tracers which are technetium products and thallium. Figure 2.12 shows the general principle of the technique of scintigraphy:

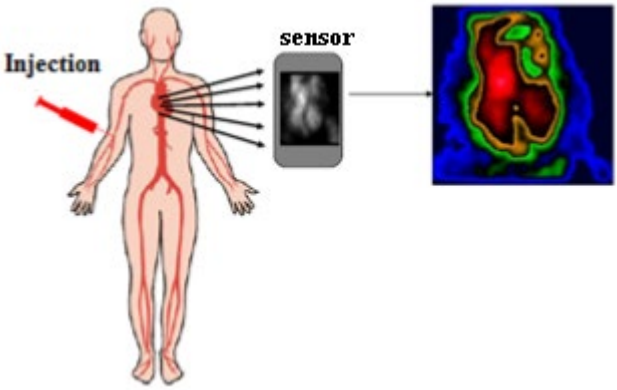

Figure 2.12: Principle of scintigraphy.

Myocardial perfusion provides series of 2D images that provide functional information and assess the irrigation of the heart muscle. The patient receives the molecules and sends out the radiation once they are received by the organ to be explored. In practice, the gamma-camera machine detects the radiation emitted by the body. Finally, the resulting image is

reconstructed. The inner wall is called endocardium and the outer wall is called epicardium.

In a single sequence, the E numbers are 2D images which vary according to the value of the inter–cross-section used. The more reduced the value of inter-cross-section the bigger the number of images (Figure 2.13) and the better the 3D reconstruction.

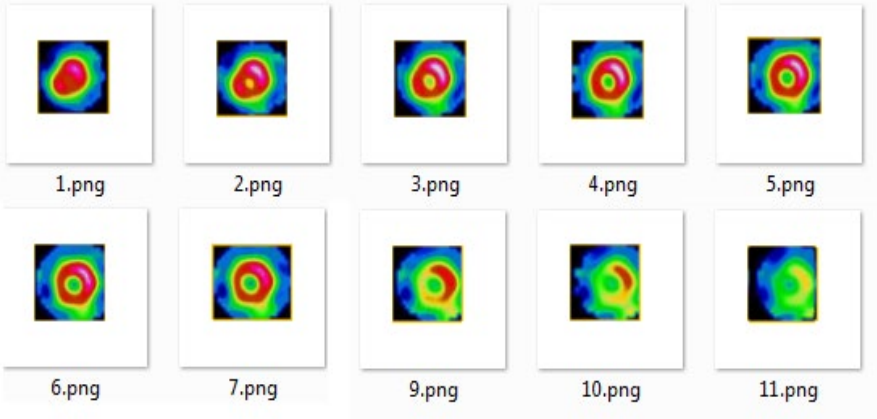

Figure 2.13: 2D scintigraphic cross-sections.

V.2 Ejection fraction

On echocardiography, the Ejection Fraction (EF) of the left ventricle can be calculated. The EF can also be measured by data provided by cardiac MRI, scintigraphy or coronary angiography. It indicates the degree and order of emptying of the ventricle. The EF is a useful indicator for efficiently estimating the contraction capacity of the heart. The normal EF is of the order of 60% in an individual. In the case of a contractility abnormality, the EF decreases. In case of a major dysfunction, the EF value may decrease by up to 20%. In case of heart failure, the EF level can distinguish between diastolic and systolic heart failure.

The formula for calculating the EF is defined by the ratio between the ejected volume (Vtd - Vts) and the telediastolic volume Vtd:

$$EF = \frac{Vtd - Vts}{Vtd} * 100 \quad (2.1)$$

Normally, the FE value is between 55 % and 75 %. The average value is of the order of 67%. If the value is more than 75%, then the efficiency of the cardiac system decreases. In this case, there will be an increase in the mechanical energy so that the myocardium is compressed to a systolic volume. The gain of the ejected volume is minimal, since the ventricular cavity becomes short tele-systole. The phase of diastole ensures a fair ventricular filling.

VI. Tomography

VI.1 Presentation

Tomography is technical imaging using contrast dye to highlight the carotid arteries in the captured image. The dye used is introduced into the blood vessel. When it goes to the carotid arteries, computed tomography forms radiographic images of the brain or the neck under many angles of observation.

3D tomography is based on techniques which make it possible to obtain the image of a volume at a given time by using a suitable acquisition system, with the possibility of. providing information on any volume in the shortest moment. Thus, the principle of computed tomography, also called computer-assisted voludensitometry, is used for the reconstruction of cross-sections and the reconstruction of the object volume in question.

Generally, the X tomography system permits the real 3D acquisition using a source of X-rays that rotates around the object. The reconstruction of the 3D image translates to each position, and the source acquires an X-ray radiography of the object which has a 2D projection (1.14). By rotating the detector-source system, it gathers a set of radiographs representing the entire set of projections under the different viewing angles, through which 3D reconstruction must be performed (Figure 2.15). Extensions have been proposed for other imaging modalities such as the MRI and the ultrasound. In a certain extent of formalism concerning tomography, X can be retaken [Com'05].

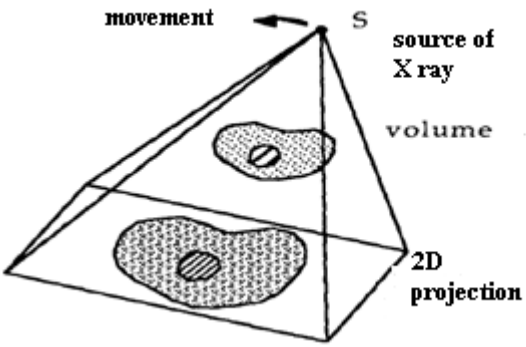

Figure 2.14: Principle of real 3D acquisition from conical sources of X-rays.

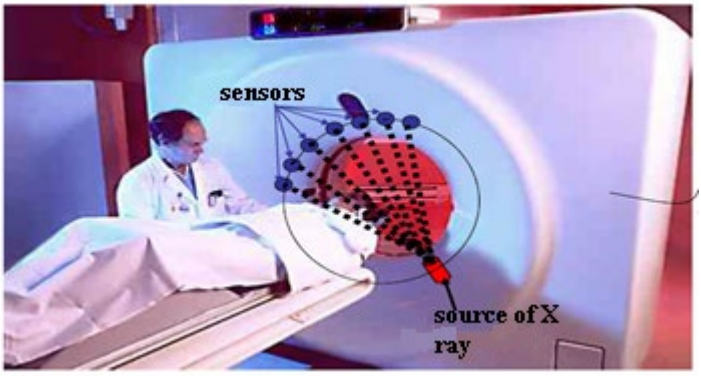

Figure 2.15: Emission scanner of X-rays

The Positron Emission Tomography (PET) technique is a method recognized in noninvasive functional nuclear medicine which ensures a clinic diagnostic of human cells by measuring the metabolic activity. It calculates the 3D distribution of a molecule pointed by a positron emitter. This method is experiencing a constant evolution as regards the used detector and the algorithms. A modern generation of PET scanners provides additional information that can rectify mitigation, delineate lesions and correct therapeutic procedures [Com'05].

PET acquisition can be done either in a 2D mode or in a 3D one. A PET camera is equipped with a system that has the appearance of a scanner but

works otherwise. In fact, the radioactive atom is decomposed by emitting a positron after a short course of one millimeter. This annihilation provides two gamma photons which emerge in the same direction but inversely, which makes the tomographic processing of the data easy. The photon sensors are located around the patient and detect the annihilation photons occurring at the same time, which makes it possible to know the line on which the photons are emitted. Then, a computer system reconstitutes, in the form of a 2D image or of a 3D object, the images resulting from the distribution of the tracer at the level of a part or of the whole body [Ber'08].

However, the problem of reconstructing 3D images from measurements corresponds to integrals of the volume on lines in space. This problem generalizes that of the reconstruction of 2D images from 1D projections. This leads us to recall the basic principles s of 2D tomography. The reconstruction problem was first dealt with in different ways, based on the general methodologies of the inverse problems of image restoration or the theory of the Radon transform.

Generally, the Radon transform is associated with function f (x) of n variables, and its integrals over hyperplanes of R^n. If f (x) is a function of R^n, then its Radon transform can be determined as a function of a real variable r and a unit vector θ as follows:

$$Rf(r,\theta) = \int_{\theta} f(r\theta + s)\, ds \qquad (2.2)$$

For n = 2, the Radon transform r means taking the integral of function f (x) on the straight lines of the plane.

For n = 3, the Radon transform integrates f (x) on the space planes. It can also be expressed by using the distribution of Dirac on R^n, denoted δ, as follows:

$$Rf(r,\theta) = \int_{\theta} f(x)\, \delta(x\theta - r)\, dx \qquad (2.3)$$

VI.2 2D computer-assisted tomography

In computer-aided tomography, 2D acquisition photons allow obtaining a series of 1D projections, which we state a usual parametrization. Let f (x, y) be the continuous function, infinitely differentiable, and to be reconstructed on a bounded support. The projection of an angle θ denoted

p θ (u) is equal to the integrals of function f (x, y) along a straight parallel in the same direction, and limited by the angle θ defined as follows:

$$p_\theta(u) = \int_{R^2} f(x,y)\, \delta(x\, cos\theta + y\, sin\theta - u) dx\, dy \qquad (2.4)$$

Figure 2.16 illustrates an example of a 2D section of an angiographic tomographic image of the carotid artery. The word carotid can refer to a carotid artery, but there is the primary carotid artery and the common carotid artery whose two branches form the internal carotid artery and the external carotid artery.

The internal carotid artery is an artery derived from the common carotid artery and the vascularis is a part the greater the brain, the eye and the inner ear. One of the two side branches of the common carotid artery is the external carotid artery. The latter ensures the vascularization of a good part of the face and the upper part of the neck.

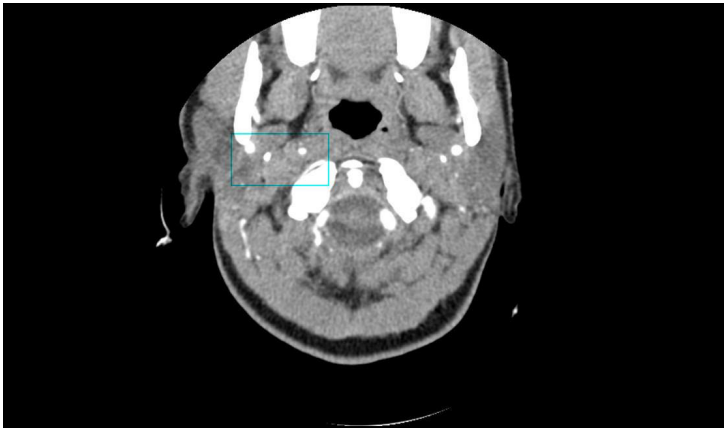

Figure 2.16: Example of 2D cross section of hagiographical tomographic image of carotid artery.

VI.3 Computer-assisted 3D tomography

3D computer-assisted tomography consists in determining variate function f (x, y, z) from its bivariate projections. However, there are two types of projections: divergent and parallel.

The following figure illustrates an example of a 3D image of a 3D computer-assisted angiographic tomographic image of the carotid artery.