2 Biomedical signals

Chapter: 2
Biomedical signals

Biomedical signals like Electrocardiogram (ECG/EKG), Electroencephalogram (EEG), and Electromyogram (EMG) are important from clinical point of view.

2.1 Electrocardiogram (ECG/EKG)

The electrocardiogram (ECG) is a graphic recording of the electrical potentials produced by cardiac tissue. The heart is unique among the muscles of the body in that it possesses the properties of automatic impulse formation and rhythmic contraction.

Electrical impulse formation occurs within the conduction system of the heart; excitation of the muscle fibers throughout the myocardium results in cardiac contraction. Formation and conduction of these electrical impulses produce weak electrical currents that spread through the body.

Applying electrodes to various locations on the body surface and connecting them to a recording apparatus record the ECG. The connections of the apparatus are such that all upright deflection indicates positive potential and a downward deflection negative potential.

ECG being the most prominent bio-signal [1] has enjoyed maximum attention of the researchers. In 1903, William Einsthoven developed his string Galvanometer and recorded ECG from the limb leads, which was replaced by amplifier and electronic circuitry, strip chart recorders. Currently a computerized ECG analyzer is used. The signals are acquired and studied.

The computerized data acquisition quantifies data at a predefined frequency and resolution is termed as **Quantitative Electrocardiogram**.

The rhythmic movements of the heart and the generated bio-potentials are definable. The features of the ECG are initially defined as P.Q.R.S.T and U, the intrinsic features of the waveform can be further defined **as per Figure 2.1.**

Based on the past experience, treatment and other ECG independent tests, various conditions of the heart have been studied for the reflections in the electro-cardiogram.

The physical shape and location, local nutrition, conduction, Harmon, Mental status, blood constitution, physical state and various diseases affect the ECG.

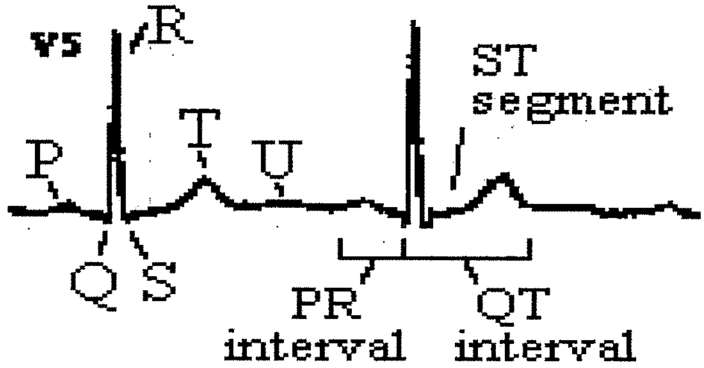

Figure 2.1 Sections of a typical ECG

2.1.1. ECG recording

Applying electrodes to various locations on the body surface and connecting them to a recording apparatus record the ECG. The connections of the apparatus are such that all upright deflection indicates positive potential and a downward deflection negative potential.

The standard 12-lead ECG (placement shown in **Figure 2.2** is composed of 12 leads that record the electrical activity in the heart from 12 different views. Each ECG lead provides a unique picture of the electrical impulses transmitted from the heart to the surface of the body.

Of 12 leads .....

- six are designated as **limb leads**. They are derived from electrodes placed on or adjacent to the four limbs. The limb leads are designated **I, II, III, aVR, aVL and aVF**.
- The other six leads are designated **chest** or **precordial leads** because they are derived from six electrodes placed on specific areas of the chest overlying the precordium (heart). The chest leads are designated **V1, V2, V3, V4, V5 and V6**. The recording limb electrodes are placed on the right

arm (RA), left arm(LA) and left leg(LL). The right leg (RL) electrode is a ground or neutral electrode.

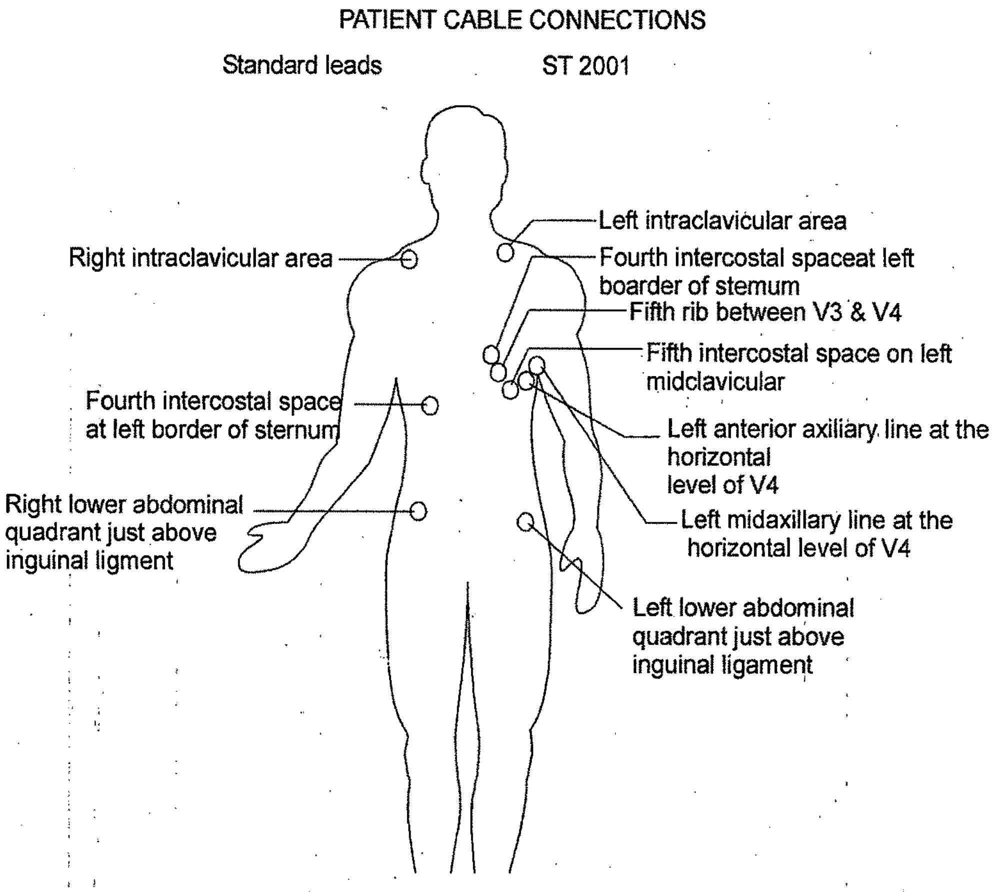

Figure 2.2 Conventional lead placements

In the hospital setting, continuous bedside monitoring of the ECG is often performed. One or more leads may be monitored continuously from bedside. A **three-electrode monitoring** system uses one electrode designated as positive, one electrode as negative and the third as ground. One limb lead (I, II, III) may be monitored at a time. Modified chest lead (MCL) is possible by placing positive electrode in appropriate chest electrode location. A five-electrode monitoring system uses the four limb electrodes (RA, LA, RL, LL) in the conventional locations, with the fifth at desired V1 through V6 position [2].

2.1.2 Diagnostic importance of ECG

The ECG is of diagnostic value in the following critical circumstances:

- Artial and ventricular hypertrophy

- Myocardial ischemia and infarction
- Pericarditis
- Systemic diseases that affect the heart
- Determination of the effect of cardiac drugs, especially digitalis and certain anti arrhythmic agents
- Disturbances in electrolyte balance, especially potassium; and
- Evaluation of function of cardiac pacemakers.

The ECG has considerable diagnostic value in assessing conduction delay of artial and ventricular electrical impulses & determination of the origin and behaviour of dysrhythmias. The important amplitudes and durations of ECG waveform for diagnostic use are described in [3], [4].

Visual Evoked Potential (VEP) [5], [6] is the response that is obtained when the occipital cortex of the brain is stimulated. Visual evoked response helps in study of disease of the eye, retinal lesions, chaismal and retro-chiasmal lesions.

The PC based visual evoked potential system records the potentials generated in the occipital cortex of the brain in response to visual stimulus. The visual stimulus is provided by the reversing the checkerboard pattern.

The evoked potentials are generally superimposed on the EEG, which is related to the spontaneous activity of the brain. The potentials from five channels are picked up using electrodes and amplified in an amplifier module.

An ADC card is used to interface this module with the computer. The computer averages the digitized signal to extract the evoked potential. The amplitude and latency at each point of the waveform also displayed. The frequency spectrum of the VEP signal sequence is determined by Fast Fourier Transform (FFT). The majority of the signal appears to be in the range of 0-70 Hz and signal amplitude reduces to a minimum at frequency of 500 Hz.

2.2 Electroencephalogram (EEG)

The electro-encephalogrtam (EEG) [7] is the recording of the electrical activity of the brain. EEG can be divided into two segments:

a) Potential related to the spontaneous activity of the brain.
b) Potential generated by the events.

If an external stimulus is given to the body, the corresponding sensory area of the brain responds to it by producing an electrical potential known as evoked potential.

Evoked potential are generally superimposed over EEG that is related to the spontaneous activity of the brain.

2.3 Electromyogram (EMG)

Electromyogram (EMG) is an electrophysiological recording of muscle potentials that measures the amount and nature of muscle activity at the site from which the recording is taken.

Interpretation of the electromyogram (EMG) is an important part of the clinical neurophysiological evaluation of patients with suspected neuromuscular disorders. The recent advent of computerized electro diagnostic equipment is making quantitative analysis of EMG signals more practical, with the expectation that this will lead to greater objectivity and increased diagnostic sensitivity.

Intramuscular EMG (the most commonly used type) involves inserting a needle electrode through the skin into the muscle whose electrical activity is to be measured. **Surface EMG (SEMG)** involves placing the electrodes on (not into) the skin overlying the muscle to detect the electrical activity of the muscle.

2.4 Electro oculography (EOG)

Monitoring eye movements is clinically important in diagnosis of diseases of the central nervous system. Electrooculography (EOG) is one method of obtaining such records, which uses skin electrodes and utilizes the anterior posterior polarization of the eye. There are many different types of instruments for the measurement of eye movements [8] that use various clinical techniques and clinical research methodologies in the assessment of the oculomotor ability of a subject, including non-contacting and contacting methods. Since the 1950s, one of the most commonly used techniques to record eye movements has been electrooculography (EOG).

2.5 Artifacts

There are various artifacts [9], which often contaminate electrocardiogram (ECG) signal. Some of them are power line interference, base line drift, random noise generated within the measuring instrument, cross talk, disturbances due to movement of recording electrodes, signal due to muscle-contraction: electromyogram (EMG) artifacts, etc. As a result the signal to noise ratio (SNR) of ECG or other biomedical signals is very low. **Table1** depicts summary of sources and types of artifacts.

Table 2.1 Summary of sources of artifacts

Arising due to Subject	Due to Recording Equipment/Environment
• Sweat artifact	• 50/60 Hz interference
• ECG/EKG artifact	• Salt bridge
• Pacemaker artifact	• Amplifier blocking
• Bi-metallic artifact	• Electrode popping
• Eye movements	• Electrodes of different metals
• Eye blinks	• Supply line transients
• Movement artifacts	• Static electricity
• Tremor	• Aliasing
• Muscle artifact	• Photonic interference
• Pulse artifact	• Telemetry
• Cardioballistic artifact	
• Respiration artifact	
• Genioglossal Artifact	

2.6 Recent trends in Biotechnology

Telemedicine is now a strategic tool for hard-eyed hospital administrators and entrepreneurial practitioners. In the last decade we have been witnessing a transformation-some call it a revolution-in the way we communicate, and the process is still under way. This transformation includes the ever-present, ever-growing Internet; the explosive development of mobile communications; and the ever-increasing importance of video communication. Data compression is one of the enabling technologies for each of these aspects of the multimedia revolution. It would not he practical to put images, let alone audio and video, on websites if it were not for data compression algorithms. Cellular phones would not be able to provide communication with increasing clarity were it not for compression. The advent of digital TV would not he possible without compression.

2.7 Biomedical signal processing

Essential tasks involved in conventional signal processing are Filtering, Prediction, Compression, Smoothing (averaging), Encryption, Decryption, Reconstruction, and Feature Extraction.

Since the bio signals are contaminated with various artifacts it is essential to remove them using filtering.

It is necessary to transmit these signals over the communication channels for analysis and diagnosis or for expert opinion. To enhance speed of communication and save storage space compression techniques must be employed. Encryption, Decryption, Reconstruction, and Feature Extraction are the operations desired for the secured communication.

Aim of this work is to develop ANN based techniques to carry out these tasks with better efficiency and better results as compared to conventional techniques with a view to improving its transmission reception and use for analysis /interpretation /diagnostics.

2.8 Test Signal Samples

The samples of bio signals consist of two ECG records and one EMG (noise) records. These are 8 channel records of two peripheral and 6 precordial leads, taken with respect to the left leg electrode. Sampling rate is 400 Hz, 12 bit ADC records (one byte least significant bits; 1 byte (half – full) most significant bits), with resolution of 4.88 mV/bit.

EMG signals were obtained from one ECG electrodes placed on one forearm. The ECG amplifier was used and the recordings were made during sustained voluntary effort. The artifacts thus obtained were weighted and additively mixed with the different ECG signals subjected to processing. Format for such ECG/ EMG files is shown in Figure 2.3.

patient data (name, age, etc.)	2048 bytes
initial lead L (Peripheral)	3200 Bytes
initial lead R (Peripheral)	3200 Bytes
initial lead C1 (Precordial)	3200 Bytes
initial lead C2 (Precordial)	3200 Bytes
initial lead C3 (Precordial)	3200 Bytes
initial lead C4 (Precordial)	3200 Bytes
initial lead C5 (Precordial)	3200 Bytes
initial lead C6 (Precordial)	3200 Bytes

Figure 2.3 File format