Republic of Iraq Ministry of Higher Education and Scientific Research
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Biomedical Signals Recorders and Monitors

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ELECTRODES FOR ECG:

Limb Electrodes

The most common type of electrodes routinely used for recording ECG are rectangular or circular surface electrodes Figure 1. The material used is German silver, nickel silver- or nickel-plated steel. They are applied to the surface of the body with electrode jelly. The typical value of the contact impedance of these electrodes, which are of normal size, is nearly 2 to 5 kΩ when measured at 10 Hz. The electrodes are held in position by elastic straps. They are also called limb electrodes as they are most suitable for application on the four limbs of the body. The size of the limb electrodes is usually 3 × 5 cm and they are generally made of German silver, an alloy of zinc, copper and nickel. They are reusable and last several years.

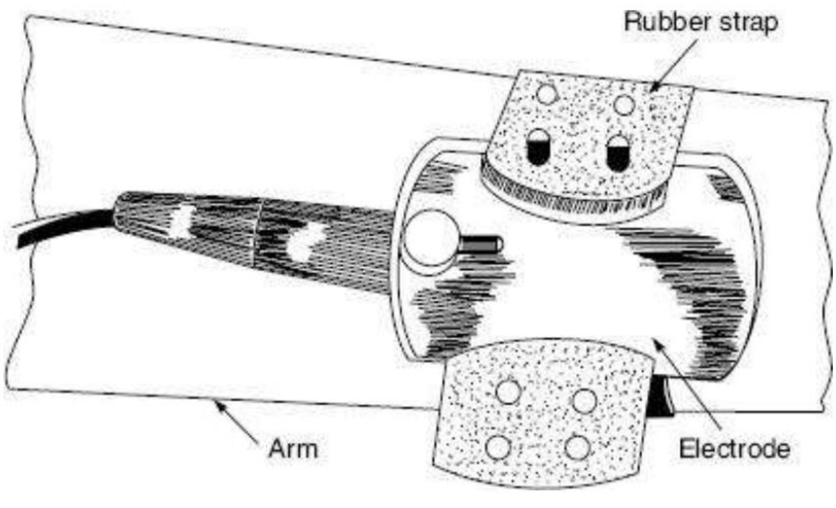

Figure1: ECG plate electrode. The electrode is usually fastened to the arm or leg with a perforated rubber strap which keeps it in position during ECG recording.

Limb electrodes are generally preferred for use during surgery because the patient's limbs are relatively immobile. Moreover, chest electrodes cannot be used as they would interfere with the surgery. Limb electrodes are not suitable for use in long-term patient monitoring because the long flowing leads are inconvenient to the patient. Also, the electromyographic voltages generated by the activity of the limb muscles makes them unsuitable for use when monitoring conscious and semi-conscious patients.

Welsh Cup Electrode:

Welsh Cup Electrode or suction electrode Figure 2 is a metallic cup shaped electrode which is used for recording ECG from various positions on the chest. It is commonly used to record the unipolar chest leads. It has a high contact impedance as only the rim of the electrode is in contact with the skin. The electrode is popular for its practicality, being easily attachable to fleshy parts of the body. Electrode jelly forms the vacuum seal. However, they are now being gradually replaced with disposal electrodes, as they are liable to infection due to inadequate cleaning procedures.

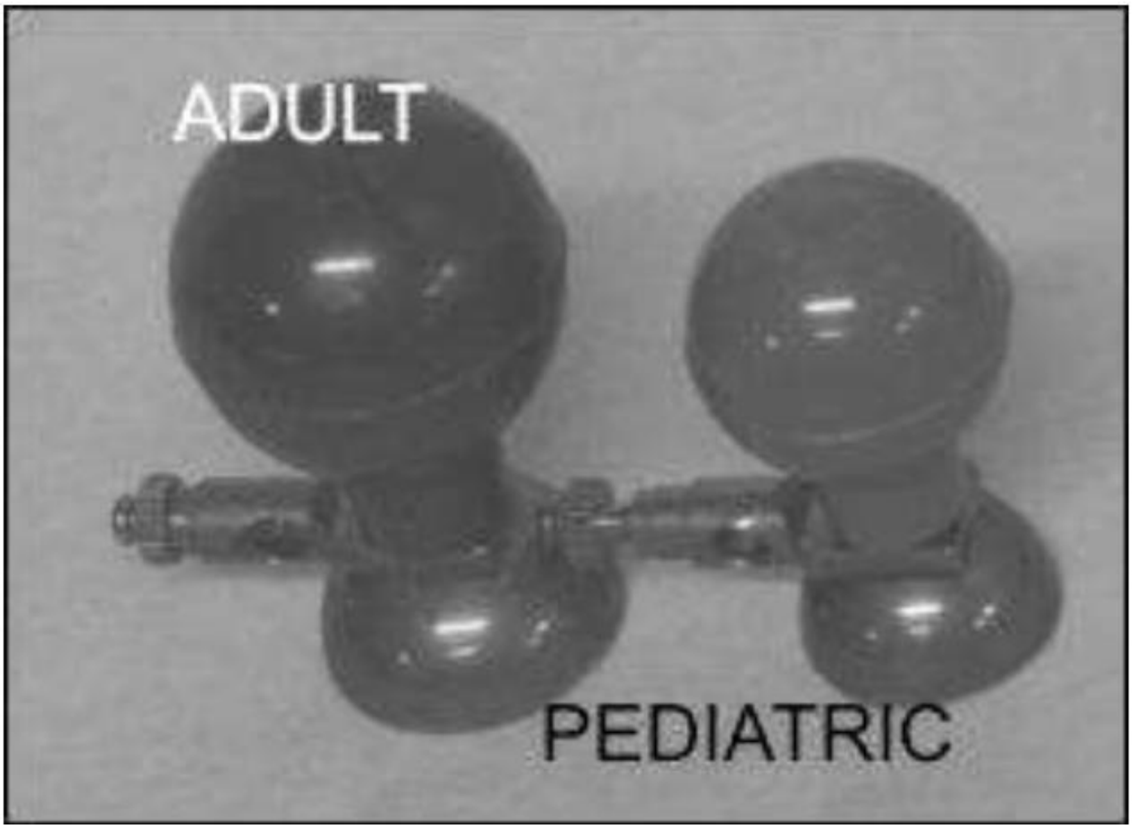

Figure 2 : Suction cup electrode.

Floating Electrodes

Limb electrodes generally suffer from what is known as motion artifacts caused due to the relative motion at the interface between the metal electrode and the adjacent layer of electrode jelly, Kahn (1965) and Boter *et al.* (1966). The interface can be stabilized using floating electrodes in which the metal electrode does not make direct contact with the skin. The electrode (Figure 3) consists of a lightweight metaled screen or plate held away from the subject by a flat washer which is connected to the skin.

Floating electrodes can be recharged, i.e., the gel in the electrodes can be replenished if desired. These electrodes were made of silver impregnated silastic rubber and were found to be comfortable to wear. They were also evaluated for use during exercise or prolonged monitoring as may be necessary in an intensive care or coronary care unit.

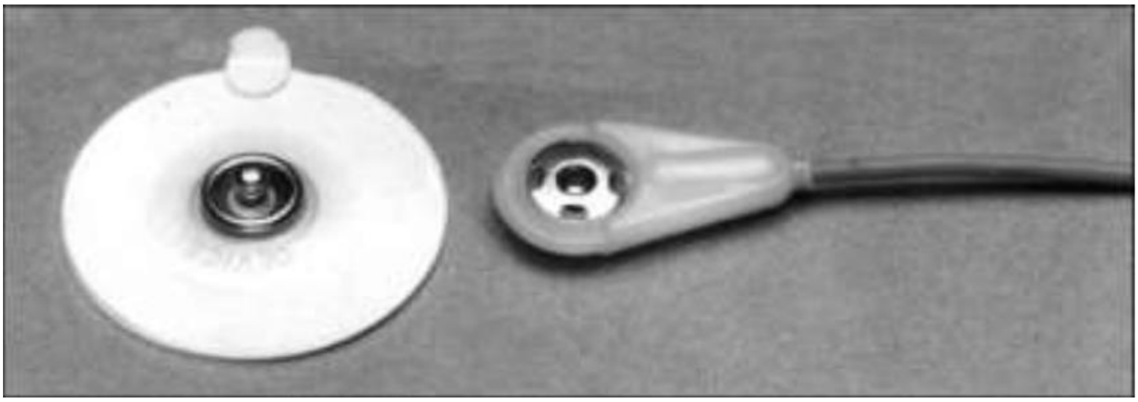

Figure 3: Light-weight floating electrode with press stud for long term monitoring of ECG.

Pre gelled Disposable Electrodes:

Electrodes which are employed in stress testing or long-term monitoring, present additional problems because of the severe stresses, perspiration and major body movement encountered in such studies. Both design considerations and application techniques of electrodes used in electrocardiography are necessary to prevent random noise on the baseline, baseline wandering and skin contact over extended periods causing a loss of signal. To overcome problems due to prolonged application, special disposable electrodes have been developed. Figure 4 (a) illustrates the principle of a pre jelled electrode while Figure 4 (b) shows a cross-section of such an electrode. The main design feature of these electrodes which that helps in reducing the possibility of artefacts, drift and baseline wandering is the provision of a high-absorbency buffer layer with isotonic electrolyte. This layer absorbs the effects of movement of the electrode in relationship to the skin and attempts to maintain the polarization associated with the half-cell potential constant. Since perspiration is the most common cause of electrode displacement, the use of an additional porous overlay disc resists perspiration and ensures secure placement of the electrode on the skin even under stress conditions. Figure 5 shows a typical pre gelled electrode.

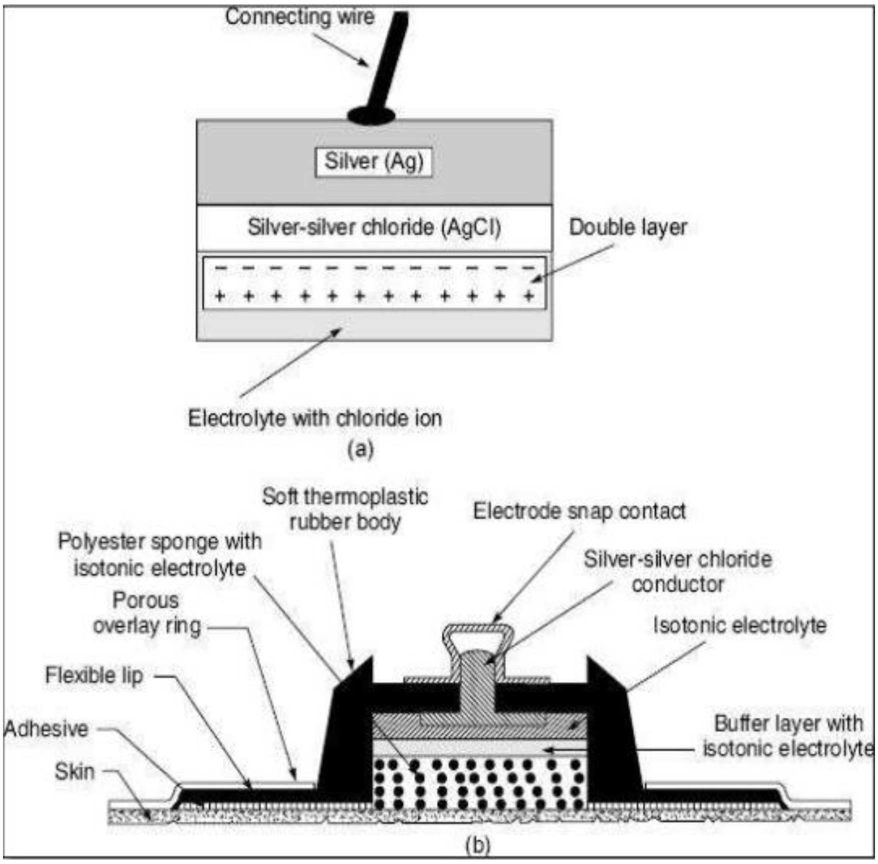

Figure 4: (a) Principle of pre-gelled ECG electrode made of silver-silver chloride. The electrode has electrolyte layers that are made of a firm gel which has adhesive properties. The firm gel minimizes the disturbance of the charge double layer. (b) Cross-section of a typical pre-gelled electrode.

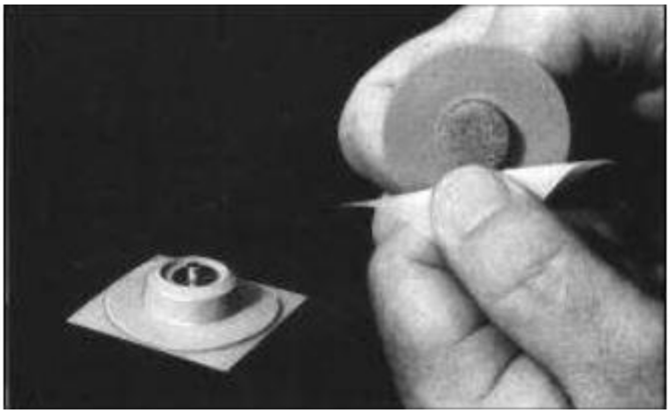

Figure 5: Disposable pre-gelled ECG electrode. A porous tape overlaying ring placed over the electrode resists perspiration and ensured positive placement under stress conditions (Courtesy: DelMarAvionics, U.S.A.)

ECG pre gelled electrodes can be characterized electrically by tests developed by the Association for the Advancement of Medical Instrumentation (AAMI), USA to establish a reasonable safety and efficacy level in clinical use of electrodes. In abridged form the standards are as follows:

1. Direct-current offset voltage.
2. Combined offset instability and internal noise.
3. Alternating-current impedance.
4. Defibrillation overload recovery.
5. Bias current tolerance.

Capacitive Electrodes:

A metal plate electrode in direct contact with the skin though makes a very high resistive contact and has a considerable capacitive contact too with the skin (Stevens, 1963). By using a very high input impedance amplifier, it is possible to record a signal through the tissue electrode capacitance. Lopez and Richardson (1969) describe the construction of electrodes which can be capacitively coupled to the subject.

Paste less Electrode:

Traditional ECG monitoring electrodes, which use metal plates and electrode jelly, have several drawbacks. These include time-consuming skin preparation, poor signal quality, baseline drift, skin irritation, and discomfort from frequent jelly reapplication during long-term monitoring. Additionally, bacterial growth and electrode shifts during movement can cause further issues. The use of dry electrodes, which eliminate the need for skin preparation, offers a more convenient and comfortable alternative.

ELECTRODES FOR EEG:

Small metal discs usually made of stainless steel, tin, gold or silver covered with a silver chloride coating are generally used for recording EEG. They are placed on the scalp in special positions. These positions are specified using the International 10/20 system. Each electrode site is labeled with a letter and a number. The letter refers to the area of brain underlying the electrode e.g., F-Frontal lobe and T-Temporal lobe. Even numbers denote the right side of the head and odd numbers the left side of the head. Figure 6 shows EEG cables with disc electrodes to which electrode gel is applied to maximize skin contact and allow for a low resistance recording of EEG from the subject's scalp.

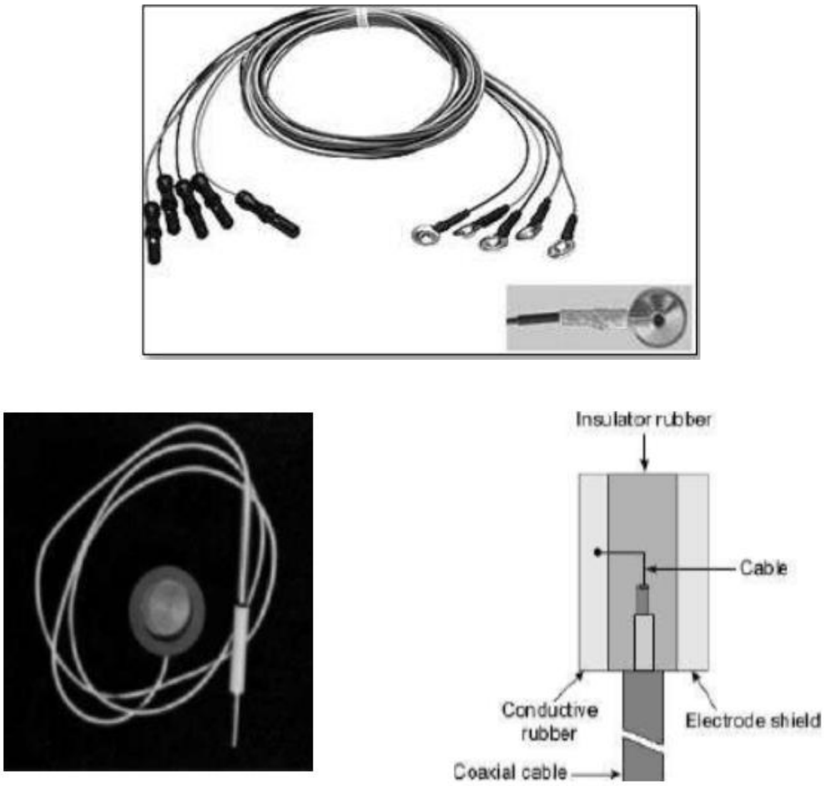

Figure 6: EEG cables with disc electrodes

The EEG electrodes can be classified as disposable, reusable disc and cup shaped, subdermal needles (single-use needles that are placed under the skin), and implanted electrodes. Needles are available with permanently attached wire leads, where the whole assembly is discarded. They are made of stainless steel or platinum. Some of EEG electrodes can be used for special applications. For example, implanted EEG electrodes also can be used to stimulate the brain and map cortical and subcortical neurological functions (Usakli, 2010).

ELECTRODES FOR EMG:

Electrodes for electromyography (EMG) are usually needle electrodes, commonly made from stainless steel. They are used in clinical EMG, neurography, and other tests to study muscles beneath the skin and in deeper tissues. Although stainless steel can create more noise compared to other materials, it is preferred for its strength and low cost. These electrodes are fully autoclavable, meaning they can be sterilized by high heat, and must always be thoroughly sterilized before use to ensure safety during procedures.

MICROELECTRODES:

To study the electrical activity of individual cells, microelectrodes are employed. This type of electrode is small enough with respect to the size of the cell in which it is inserted so that penetration by the electrode does not damage the cell. The size of an intracellular microelectrode is dictated by the size of the cell and the ability of its enveloping membrane to tolerate penetration by the microelectrode tip. Single-living cells are rarely larger than 0.5 mm (500 microns) and are usually less than one-tenth of this size. Typical microelectrodes have tip dimensions ranging from 0.5 to 5 microns. The tips of these electrodes have to be sufficiently strong to be introduced through layers of tissues without breaking.

Two types of microelectrodes are generally used: metallic [Figure 7.(a)] and glass microcapillaries (or micropipette) [Figure. (b)]. Metallic electrodes are formed from a fine needle of a suitable metal drawn to a fine tip. On the other hand, glass electrodes are drawn from Pyrex glass of special grade. These microcapillaries are usually filled with an electrolyte. The metal microelectrodes are used in direct contact with the biological tissue and, therefore, have a lower resistance. However, they polarize with smaller amplifier input currents. Hence, they tend to develop unstable electrode offset potentials and are therefore not preferred for steady state potential measurements. On the other hand, in case of glass microelectrodes, improved stability can be obtained by properly choosing the metal and the electrolyte so that the small current passing through their junction may not be able to modify the electrical properties of the

electrodes. Also, the glass microelectrode has a substantial current carrying capacity because of the large surface contact area between the metal and the electrolyte.

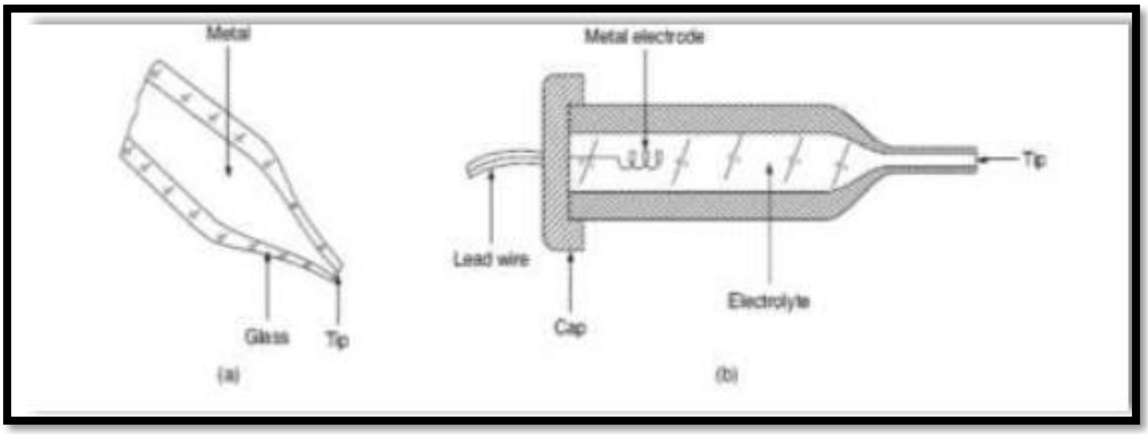

Figure7: (a) Micro-electrodes Metal (b) microelectrode Micropipette or microcapillaries electrode

The microelectrodes have very high impedance as compared to conventional electrodes used for recording ECG, EEG, etc. The high impedance of a metal microelectrode is due to the characteristics of the small area metal-electrolyte interface. Similarly, a micropipette tip is filled with an electrolyte which substitutes an electrolytic conductor of small cross-sectional area, which gives a micropipette its high resistance. Because of high impedance of microelectrodes, amplifiers with extremely high input impedances are required to avoid loading the circuit and to minimize the effects of small changes in interface impedance.