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Design of Improved Electrosurgical Unit with Pad Plate Design

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Abstract: ***Diathermy is an electrosurgical unit which is frequently used in surgical operation for cutting purpose. It is an advanced method which overcomes the drawback of scalpel blade. Scalpel blade leads to cutting injuries and heavy blood loss during the surgical operation. This problem can be rectified using diathermy. Diathermy procedure is done by electrical spark, which require deep tissue cutting. Now a day's most of the surgeons prefer diathermy than scalpel blade, but present surgical unit creates few problems like burning and scaring due to improper construction of grounding (pad) plate. This paper proposes to reduce the electrical burning effect, the pad plated coated with silver material and hyperbolic shape pad plate. Mechanical stuck in the footswitch avoided by using parallel connection of micro switch. The implementation of pad plate design and footswitch model minimizes the electrosurgical burn during the operation.***

***Keywords*: Electrosurgical unit, surgical burn, pad plate footswitch model.**

I. INTRODUCTION

In natural science the term diathermy means "electrically induced heat". The heat is induced by using high frequency electromagnetic current. Diathermy is most commonly used for muscle relaxation. It is also a method of heating tissue electromagnetically or ultrasonically for therapeutic purpose in medicine. Electrosurgical units were introduced to facilitate the cutting of tissues during surgical procedures. This is achieved by passing normal electrical current through a diathermy machine and converting it into a high frequency alternating current. The high frequency alternating current produces heat within the body tissues. The alternating current is used to coagulate the bleeding vessels and cut through tissue. Due to high risks of injury permanent disfigurement or death may occur for both patients and staffs. The earlier procedure was carried out by surgeon cutting the blood vessels arteries and veins will also get damaged by scalpel blade. That time the blood loss is very high .That system should be systematically cleaned by gauss chocked with sterile water. The blood vessels are knotted with sterilized silk thread. To minimize the blood loss the diathermy is introduced. In operation rooms, electric devices are commonly used in surgical procedures for cutting and haemostasis (stop bleeding). The electric devices used for this purpose are known as electro cautery apparatuses. The apparatus is used to destroy a tissue through desiccation and stop bleeding by coagulation of blood. This is done by using a radio frequency spark. The RF spark damages the tissue by localized heating. The spark is produced between the probe and the tissue. The electrosurgical generator is the source of electron flow and voltage. The circuit consists of the generator's active electrode and patient's return electrode.

In diathermy, high frequency electrical current is used to heat deep muscular tissue. Diathermy is an essential modern electrical device in surgical procedure which is carried out by a surgeon in operation theatre. This device is Invented by GRHARD in the year of 1988.The process involves application of radio frequency spark produced between probes controlled by foot switch .Radio frequency range between 250-2000 kHz. Diathermy cut the tissues in deeper part of the dermis. This is used for cutting and coagulation of tissues. There are three method of diathermy .In each, energy delivered to the deep tissues, where it is converted to heat.

II. PRINCIPLE OF DIATHERMY

The block diagram explaining the principle of electro surgery is shown in figure 1. In diathermy, RF spark damages the tissue by localized heating. The power to produce the spark is generated from a high power high frequency generator. The power is generated as frequency energy source from an AC power supply 220 volt and 50 hertz.

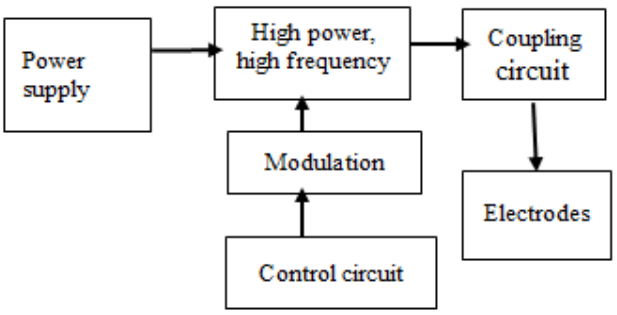

Fig .1 Principle of Electro surgery

Here the output of the generator is controlled by a modulator circuit.

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The surgeon controls the high frequency power through a control circuit. The surgeon determines the power that has to be applied to the electrodes in order to carry out a particular task. A coupling circuit is placed in between the generator output and the electrode.

This is done in order to maintain the output from the high frequency generator at various levels for various operations. Based on the different modes of action the electric waveforms generated by the electrosurgical unit vary.

When electrons move from one atom to an adjacent atom, electric current flows through the circuit. Heat is produced when electron encounters resistance. A continuous circuit is required in order to make a current flow. This continuous circuit consists of the patient, the electro surgical generator, the active electrode and the return electrode. The voltage for this is provided by the electrosurgical unit. As the tissue resists the flow of current from the electrode, electrical energy is converted into heat in tissue. This results in three tissue effects which are possible; they are cutting, desiccations and fulguration. Achieving these effects depends on various factors. The factors are current density, time, electrode size, tissue conductivity and current waveform.

A block diagram of a typical electrosurgical unit is shown in figure 2. The RF oscillator produces a high frequency signal, which is further modulated and amplified to produce the coagulation, cutting and blended waveforms. The RF sine wave has a nominal frequency of 250 to 2000 KHz and is usually pulsed at a rate of 120 per second, open circuit voltage from 300 to 2000 V and power into a 500 ohm load range from 80 to 200W.The magnitude of both voltage and power depends on the particular application.

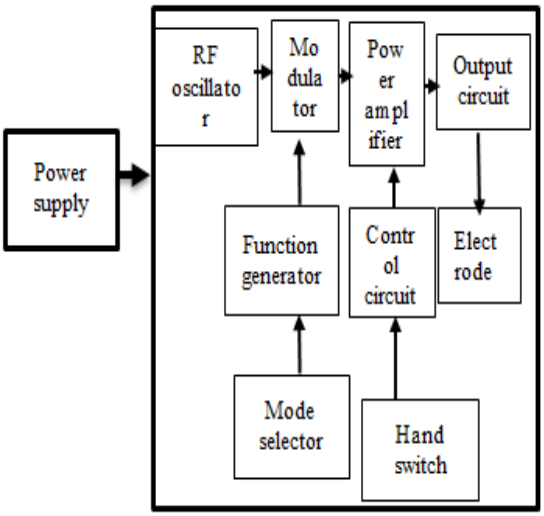

FIG .2.BLOCK DIAGRAM ELECTRO SURGICAL UNIT

III. COMPONENTS OF DIATHERMY

A. *Hand Tool*

Hand tool is replaced by a surgical pencil. The surgical pencil has two modes ie, cutting and coagulation. A high frequency, voltage and power is required for cutting since the heat produced by the spark destroys the tissue instead of just desiccating it. In coagulation the frequencies ranges from 500 KHz to 2.5MHz, with open circuit voltage as high as 9 kV. The Power level varies from 100 to 750W, depending on the type of application.

TABLE I
Various power levels of cutting and coagulation

TYPE	POWER
Pure cut	300 watt
Blend	250watt
Point of coagulation	120 watt

'Bloodless' cutting is required by the surgeon since at the place of incision, the cutting current usually results in bleeding. The various types of cuttings are available. Pure cut, blend cut, point of coagulation and spray bipolar.

B. *Pure Cut*

Pure cut is used only for dissection. In pure cut the surgeon has little control over bleeding since the instrument performs more like a stainless steel scalpel.

C. *Blend*

The frequency of blend waveform is generally same as the frequency of cutting current. The blend cut allows the surgeon to cut and coagulate at same time. In case of a pure cut the cell vaporizes due to large heat energy. But in a blend cut, cooling periods slows down the action to a dehydrating crawl. are replaced by The slow dehydration of cellular fluid and protein replaces the cell wall explosions and vaporization. Hence when the cut is actually made this stops bleeding for a particular time. In order to seal off small bleeders when cutting through soft tissue a blend cut is appropriate.

D. *Point of Coagulation*

Current density, period of contact, and surgical technique are the various factors which affect the pinpoint of coagulation. Therefore the time that the electrode remains in contact with the tissue is very important in pinpoint coagulation. Only a light contact should be made by the tip on the surface. Power should be sufficient in order to deliver a desired clinical effect. This is done to stop local bleeding.

E. *Spray Bipolar*

Fulguration is defined as a non-contact type of coagulation. In this current jumps from the active electrode to the tissue. Fulguration is used to locate and seal off small hidden bleeders which are difficult to be found. Apart from this, for areas with large bleeders fulguration is very useful.

F. *Electrodes*

Electrodes are considered to be an important part for destruction (or) construction for the physiological condition of body. It uses transmitting signal as a sensor, releasing electrical energy to cells or tissues. In the case of electrosurgical unit, electrodes are used for destruction purpose to damage the dermis of the skin surface either superficial, epidermis. They are available in different sizes and shapes, according to the application of surgery that is to be carried out.

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In general an active electrode is similar to a scalp blade. Whereas the needle connected to a probe used with electronic instrument is similar to an oscilloscope to study the nature of the waveform displayed in the screen visibly.

In the case of mechanical surgical blade it has a sharp edge but it is difficult to understand the mechanical power. This is totally eliminated in bipolar pencil which has got selection of cutting and coagulation. Similarly a pointed metallic probe fits into the handle, which is considered to be a surgical bipolar pencil. This is considered to be magic or miracle to latest instrument in medical world. The current density differs for each tip based on the size and shape of the tip-electrode. There are three types of electrode tip

- Needle Tip
- Blade Tip
- Ball Tip

These Electrode tips are manufactured from stainless steel possesses increased resistance and it can become a fire hazard if it interacts with the desired tissue effect. Scratch pad is used to clean these tips have to be cleaned frequently. Electrode size and shapes varies depending on the manufacture and application. Electrosurgical unit have two types of electrode one is active electrode another one is return electrode. The active electrode is a flat blade electrode it is used for cutting and coagulation purpose. A pointed metallic probe is inserted into an insulating handle and is held by surgeon like how one would hold a pencil.

IV. DIFFERENT CONFIGURATIONS OF DIATHERMY

A. Bipolar

In bipolar configuration electrode is used to apply voltage to the patient. The intervening tissue gets heated when a high frequency electric current flows from one tip of forceps to the other while holding the tissue with forceps. The active and return electrodes are located at the place of surgery in this type of surgery, within the instrument tip. It Avoids damage to adjacent tissue by sparking and used for delicate highly conductive tissue.

B. Monopolar

In the mono polar configuration, to the return electrode of the AC source a large metal plate pad or a flexible metalized plastic pad is connected. Contact is made with the tissue by using a pointed tip electrode. Through the return electrode, the electric current flows and it is then returned back to the electrosurgical generator.

Risk of electrosurgical unit:

- Improper contact of pad plate.
  This type of burn occurs due to improper grounding of pad plate.
- Mechanical struck in footswitch.
- Insulation failure of active electrode.

IV. IMPLEMENTATION OF FOOTSWITCH MODEL

The implementation of a footswitch model is shown in figure 3.The radio frequency power output is turned on and off by using a control circuit connected to a footswitch .The footswitch is operated by the surgeon.

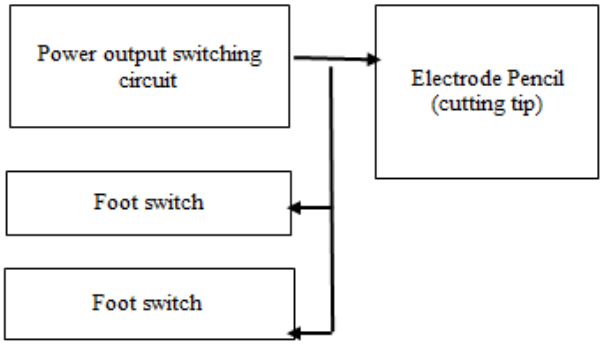

Fig.3.Implementation of footswitch model

Conventional footswitch unit has only one footswitch for the control circuit purpose. Frequently the footswitch will be affected by mechanical stuck due to high frequency. The footswitch failure affects the whole circuit model. This will lead to electrical burns on human body since the footswitch controls the active electrode during the surgical procedure. To avoid the mechanical stuck, the proposed type accommodates the one more micro switch with parallel connection in footswitch model.

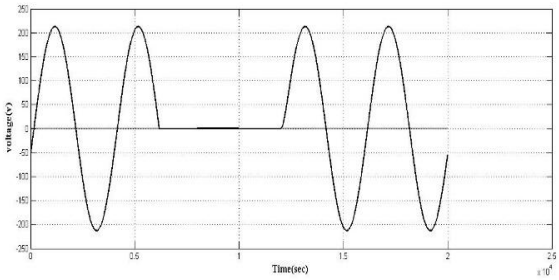

Fig.4.Conventional footswitch model output during mechanical stuck

Fig.4 explains the conventional footswitch affected by mechanical strike when high voltage occurs. During the mechanical stuck the footswitch must not be active. To avoid the mechanical stuck one more micro switch is added in parallel to the conventional model.

V. PAD PLATE (RETURN PLATE)

The return electrode present is the mono polar type. The return electrode provides the return path to the electro surgical current during the electro surgery. There are different types of return electrode used for electro surgical procedure. Cup size metal plate was placed and contact with patient was used in early days. But electrical burn and tissue damage occurred at the return plate due to improper contact. After few days, the return plate was placed on the thigh. This provided good contact area when compared to cup size return plate. But still burning effect occurred during electro surgery.

To avoid the surgical burn the return electrode shape and metal construction is modified in this paper.

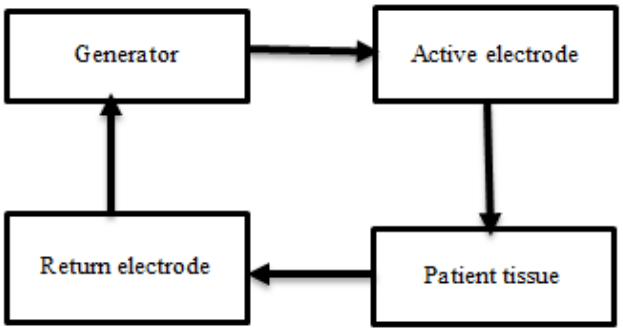

Fig.5. Working of pad plate

In mono polar electrodes, the generator produces a radio frequency current which flows through the active electrode. This active electrode acts as a medium which passes the current into the tissue which is then passed through the patient and returns back to the generator via pad pate. This is a process cycle of electro surgery. When the return electrode is grounded the circuit will be complete.

VI.RISK OF PAD PLATE DESIGN

There are certain criteria's to look into while using a pad plate. Unintended burns will be produced if the pad plate is not large or completely in contact with the skin. Hence in order to disperse the current without generating much heat, the return electrode should have a low resistance with a large surface area.

VII.SOLUTION TO PAD PLATE BURN

To avoid the pad plate burn, plate size should be modified. Another important thing is electroplating material should be changed. Generally SS316 is widely used but it is not advisable and it should be replaced with best one. Here electroplating material is changed by using silver due to low resistivity and good conductivity .To overcome this problem the pad late surface is coated by using copper with silver material.

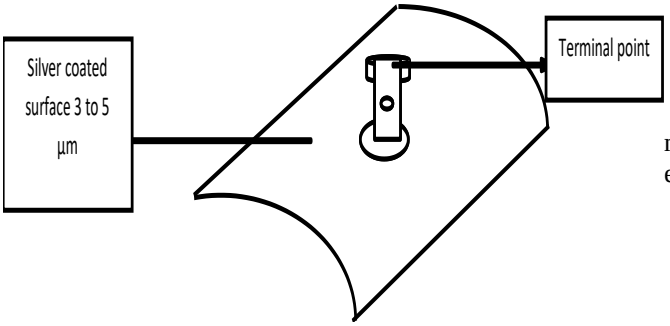

Fig.6.Modified pad plate

Fig.6 explains the implemented model of pad plate design. Area is increased in this pad plate and also silver coated material is used to reduce the resistivity value. This type of pad plate minimizes the burning effect. This paper is based on development of prototype design particularly in different metals electrodes which are considered being important part in a diathermy. This paper deals entire design aspects of diathermy besides physical properties of materials of the pad plate and lead wires.

Generally SS 316 is widely employed but it is not advisable since it is an alloy. It should be replaced with best one is Copper better than Aluminum and Nickel. The best one is silver. It has good conductivity, low resistivity compare with other metals. The resistivity of the various metals are:

1. Aluminium - 1.28Ω
2. Copper - 0.7Ω
3. Silver -0.6Ω
4. Stainless steel-70Ω

Pure silver cannot be used, because of the cost factor and more than that it is fragile but Copper is acceptable for pad plate. The only problem anticipated is that it will get oxidized easily. Oxidization is not advisable, as such in a pad plate a thin layer of copper oxide will formed, in order to overcome this problem pad plate surface is coated with thin copper and silver at the order of some microns (µ). Finally because of inherent characteristics based on material of construction a better result is obtained.

VIII.PROPERTIES OF METALS

A. Copper

Copper is an electrical conductor. It is employed based on property of the metal. It is a good conductor. It is widely used for various application based on its property.

Table.2.Copper

Atomic number	29
Atomic weight	63.46
Category	Transition metal
Group	2
Valance number	1
Melting point	1084.62^{o}C
Boiling point	2562
Specific gravity	8.96 grams/cm^{3}
Resistivity	1.7×10^{8}Ω

B. Stainless steel

There are 300 types of stainless steel are available. It is a multipurpose metal.SS304, SS316, SS 301 etc. are widely employed.

Table.3.Stainless steel

Density	7.89 gram/cm^{3}
Melting point	1350-1400^{o}C
Specific gravity	502 J /calorie

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C. Silver

Calculation of resistance

$$R=\rho L/A$$

L- Length in meter, A-area of the cross section

It has a resistance of 1.6×10^{8}. When temperature increases resistivity will also increase naturally.

IX. RESULTS AND DISCUSSION

A foot switch will play a major role in the handling of diathermy. Conventional surgical unit has only one footswitch for control circuit purpose. The footswitch failure affects the whole circuit model. This will lead to the electrical burn on human body as the footswitch controls the active electrodes during the surgical procedure.

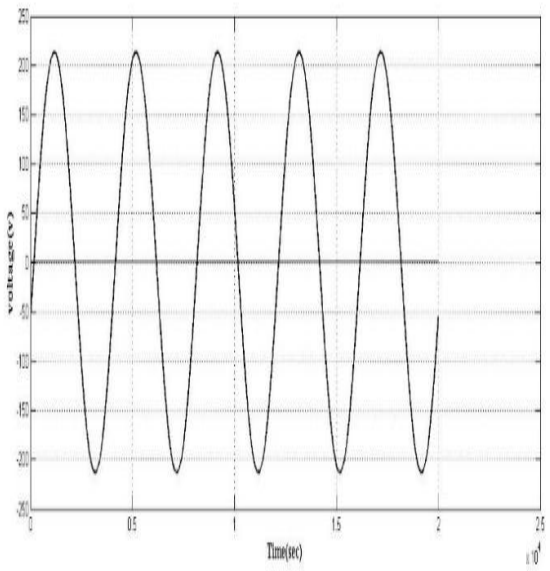

Fig.7. Implemented footswitch model output

Fig.7 explains mechanical stuck avoided by the implemented model. The implemented footswitch has one more parallel connection of micro switch. When mechanical stuck occurs in convention method the parallel switch gets active and gives continuous supply to the footswitch. If the conventional footswitch is active, parallel connection of footswitch will be in off state. When mechanical struck occurs another switch will be automatically turned on. One footswitch with two micro switch models is considered to have a minimum failure rate of the machine. Thereby control circuit will get an enhanced working quality.

A. Pad plate design using silver

Pad plate material is replaced by using silver due to resistivity of silver. The low resistivity of silver reduces the burning effect in human skin. The silver material gives the better result than other material. Stainless steel, copper, aluminium and silver resistance value are measured for various pad plate size.

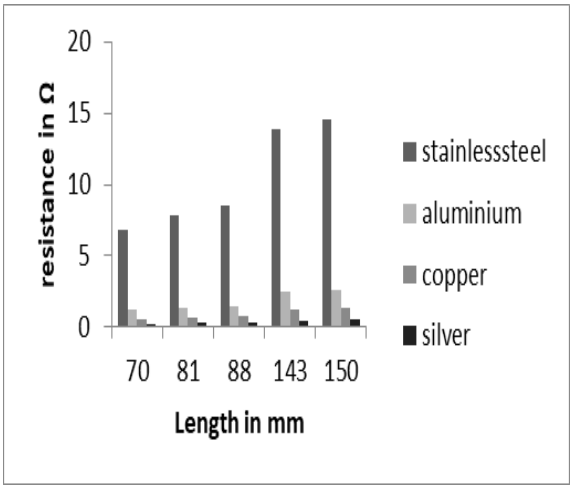

Fig.8.Comparision of resistance value

From the fig.8 it is inferred that depending upon length of the material the resistance is varied. It is calculated that silver has lower resistance compared to stainless steel, copper and aluminium. Stainless steel, copper, aluminium and silver current value are measured for various pad plate size.

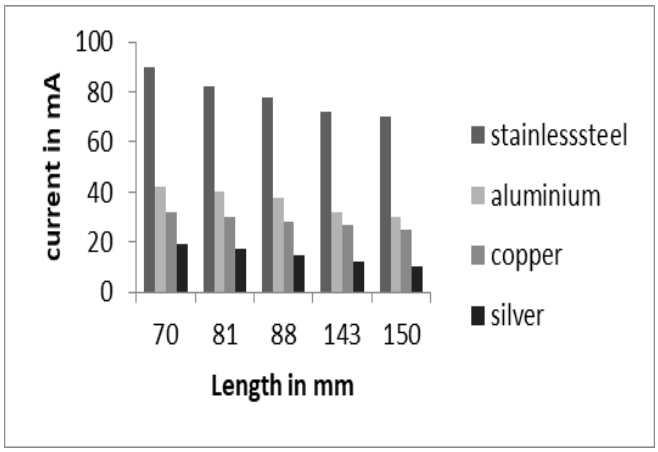

Fig.9.Comparison of current values

From the fig.9 it can be inferred that among the various metals, silver consumes minimum current. Therefore, by using silver burning effect can be avoided and thus it is preferred over the other metals in pad plate designing. Silver has been chosen in this work because of its high physical properties. Silver possess good electrical conductivity as well as high thermal conductivity in room temperature. In this work silver is coated on the substrate by using electroplating process.

X.CONCLUSION

Diathermy working quality is improved by using pad plate design. Footswitch model is designed to avoid the surgical burn during operation. Modified design of footswitch increases the working quality of surgical unit and also avoids mechanical stuck. Various metal properties are investigated to design the pad plate. Finally the copper plate coated with silver material is selected for the purpose of resistive property. It is concluded that copper with silver coated plates are the best material. Safety is an important goal of this work. Implemented diathermy will create impact on the society by avoiding side effects due to surgery.

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