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REVIEW ARTICLE

THERMAL KNIFE - ELECTROSURGERY

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Abstract: *This article reviews various aspects of physics of thermal knife. High frequency low amperage pure sinosoidal current is used in surgical diathermy. Damp sinosoidal wave is used for coagulation, preferably bipolar forceps should be used to avoid damage to surround tissues. Undamped current with pointed electrode in monopolar mode is used for cutting. Inactive electrode & circuit should be checked before starting surgery to avoid burns & electric shocks.*

Key words: Thermal knife, Electrosurgery, Electrocautery, Sinosoidal wave.

Diathermy is a term derived from the Greek words 'dia' meaning through and 'thermy' meaning heat. It means performing any task with the help of heat. When low voltage, low density electric current is used it is termed as medical diathermy and employed in physiotherapy. High frequency current is used in surgery and it is usually of more than 30000Hz. At 10000Hz or more neuromuscular system does not respond to individual stimuli[1] most of the modern units convert incoming high amperage 60 Hz's current to low amperage current of 500 to 1000 KHZ. Hence electric shock chances are rare in comparison to electricity current from mains of 50-60 Hz leading to intense activation of muscles and various other complications of electricity. An indispensible tool of operation theatre used almost in every operation has been hardly discussed in conferences and rarely taught in post graduate programmes. It is also unethical to work on human beings with an electric machine without having sound knowledge of its working and acquaintance with its various modes. Hence this article will review the various aspects of Electrosurgery.

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HISTORY

Historical evidence shows that Egyptians used the heat to treat tumors in 3000 BC[2] and Hippocrate used it for treating suprapubic abscess and Celsius was the first to use it for haemostasis. In the sixteenth century William Gilbert used electric current without causing electric shock and was known as the father of Electrosurgery[3]. In 1897 Franz Nagal Schmidt nominated the name 'Diathermy' and Reverie used it for the first time for destruction of small tumors with high frequency current. Doyen introduced the concept of bipolar diathermy in1907 and observed temperature as high as 600°C. The term fulguration was given by Pozzi in1909. He used high frequency and voltage but low amperage current to treat malignancies. In 1910 Clark introduced the term electrodesiccation. The first practical electrosurgical unit was designed by Bovie in 1928 with three phases of cutting, coagulation and desiccation. In 1931 Clark demonstrated the use of high frequency current for these modes and since 1950 Electrosurgery units are routine part of OT establishments.

TERMINOLOGY

Diathermy means generation of heat in tissu-

es. Surgical diathermy a synonym of Electrosurgery is a cutting tool, achieved by localised vaporization of tissue as a result of absorption of high frequency current while medical diathermy is high frequency current of low density and low voltage used in therapeutic heating of tissue. When it is used for coagulation, mainly to control bleeding, is termed as electrocoagulation accompanied by conversion of electrical energy to thermal energy at tissue level. Fulguration is derived from a Latin word which means lightening and is a process by which tissue is divided and destroyed by electric spark using high frequency current. The term electrodesication is also used synonymously.

Cautery is the term used for destruction of tissue by a caustic agent including corrosives and when electricity is used, it is termed as electrocautery. Sometime electrocautery and electrosurgery are used synonymously but in electrosurgery low frequency low voltage current is used to heat the tip while in diathermy cautery high frequency current is used.

Thermal knife is cutting by application of intense local heat vaporizing body fluids and pyrolyzing constituent biological compounds.

PRINCIPLES OF ELECTROSURGERY

Heat application to body leads to biochemical changes, cell wall damage, DNA and RNA denaturation and enzyme in cells leading to molecular death. Threshold level is 44°C above which irreversible tissue damage starts ranging from mild erythema to deep burn and tissue necrosis. The rate of irreversible tissue/cell injury increases with the rise in temperature with complete epidermal necrosis occurring after 5 minutes, 5 second & one second exposure to 50°C, 60°C and 70°C and for deep burn higher temperature is required for same duration[2].

As a result of heat inter cellular coagulation of protein occurs at approximately 60°C termed as pyrolysis that is dissociation of primary structure of tissue.

While cellular changes take place upto 100°C, tissue vaporization starts above 100°C, water contents vaporize at and above 100°C,triglyceride dissociation at approximately 300-400°C and protein dissociation at 600°C.

BASIC PHYSICS

Alternating current sinosoidal is used in diathermy for producing circuit (fig.I) is utilized where 'v' is wave speed, speed with which energy propagates through medium, 'λ' is wave length traversed by the wave during one vibration, 'f' is frequency number of vibration per second. This circuit also produces pure sinosoidal waves of frequency.

$$F = 1/2\pi\sqrt{1/LC}$$

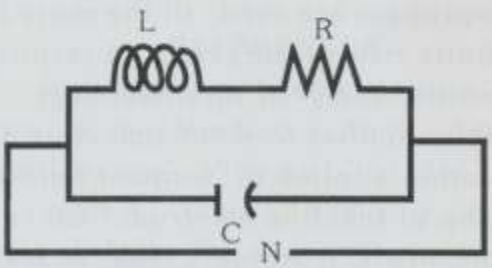
If amplitude remains same, pure sinosoidal wave is generated. Current variation effect is more in waves of large wave length i.e. low frequency, higher the frequency lesser is the dispersion, greater is the energy generated because varying current always produces an induced current in the medium in which it travels. Higher the frequency, lesser is the induced current and greater is net current or energy produced.

Large frequency waves are more energetic(electromagnetic waves like X-rays Gamma rays, radiowaves, light waves). All these propagate with the speed of light and their wave length is small because λ = speed / frequency leading to quite rapid current variation providing larger net current, hence suitable for cutting or uniform heating.

Heat developed through the medium due to current flow is $H = I^2 Rt$ where 'R' is resistance, 't' is time, 'I' is current. In heavily damped wave 't' is negligibly small (~2μs) though 'I' and 'R' are large, hence heat produced is small. In heavily damped sinusoidal waves, wave pulse generates only for a short (~2μs) interval and wave propagates with the damped pulse at regular intervals.This interval is significantly large(20μs)as compa-

red to the interval of wave pulse, hence used for coagulation purpose but poor cutting capability since heat produced is negligibly small.

If frequency and wave length variation could be avoided by filters, more sharp & intense energy beam can be produced & higher the frequency more precise is the tissue approach.The electric currents when passed through the body leads to heat production due to impedance of body tissue which is measured as resistivity and expressed in ohm.cm., resistance is directly proportional to the length of the tissue and inversely proportional to the cross sectional area. Thus higher the resistance and current density greater the local heating so more is the tissue damage. Electric current at low frequency from 50 to 3000 Hz causes intense nerve stimulation leading to muscle contraction and significant ventricular fibrillation stopping the surgeon and a plateau reaches at 5000 Hz. While above 10000 Hz neuromuscular system does not respond to electric impulses.



AC cicuit

Fig. I

The power delivered by the unit determines the power of coagulation when current is increased by 2x and subsequent heating is increased by 4x.

The second factor which affects the result is wave form and depending upon it current can cut, coagulate or do both simultaneously. It has been observed that undamped continuous sinosoidal waveform is best for cutting of tissue and damped sinosoidal is for coagulation but cutting can hardly be performed. By varying the on to off time, different degree of cutting versus coagulation can be achieved.

For cutting, an electric arc has to be produced between tissues and electrode by significant electrical voltage on a single precise point leading to intense temperature rise and tissue water evaporation which explodes the cells and divides them. Remember density of current is inversely proportional to the size of electrode. With pure cutting current a thin line of tissue destruction made primarily of fine carbon particles with the adjoining broad layer contais coagulated tissue and destroys adjacent tissues depending upon the duration and power of current again.

For coagulation the electrodes have to be in actual contact, the heat and area depends upon the size and shape of the electrode. With the application heat is generated water evaporated, coagulum formed & pyrolysis takes place. Obliterative coagulation leads to shrinkage of vessel wall and occlusion of lumen by the coagulum of tissue and thrombosis. Coaptive coagulation results from mechanically apposing the edge of vessel by forceps and applying current on forceps to seal the vessel, erythrocytes are affected first by the heat. Venous walls are thin and pressure is less. Hence low current is required and early haemostasis can be achieved.

One learns by experience the duration and amount of current required to be used in individual patients and in various tissues. Insufficient current or duration will create a weak bond and coagulation will be in a bigger surrounding area which may not withstand arterial pressure leading to post operative

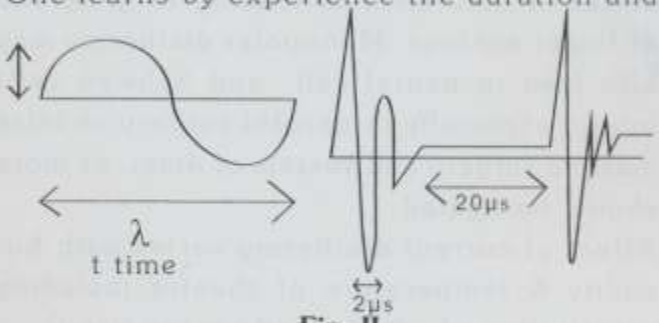


Fig. II

bleeding while high voltage will explode the tissue by boiling the fluid and blood without successful control of bleeding. Usually discoloration of tissue suggests an optimal stage to achieve coagulation; further current will lead to spark and surrounding tissue necrosis resulting in delayed wound healing, infection, secondary haemorrhage and aggravated scarring. Remember that haemostasis and thermal damages are interdependent and care should be taken of the surrounding tissues. If used judiciously crushing of tissue by clamps & ligating them is no less than thermal knife. Even[5,6,7] histopathological changes in electrodesication are not significant.

In blending of cutting and coagulation though tissue, damage is more by cutting mode but considering the safety, cleanliness blood less surgical field and grossly reduced blood loss and decreased duration of surgery justifies its use[4]. It is wise to identify and isolate large vessels and coagulate them individually. Vessels more than 3mm. should be painted first in long axis to achieve better haemostasis.

Surgical field should be kept clean,as body fluid and blood disperse current. Remember monopolar cautery is not used in peripheral parts as it leads to deep burns affecting the vessels. Current is conducted better in fluid medium leading to gangrene of finger and toes. Monopolar diathermy may also lead to neural cell and Schwan cells injury, especially in parotid surgery or intra mastoid surgery and vessels of 4mm. or more should be ligated.

Affect of current diathermy varies with humidity & temperature of theatre including constitution of patient and season itself.

HAZARDS

1. Electrocution of the patient or of the surgeon due to faulty circuits though now solid state digital diathermy machines have got micro chip circuits which automatically stop working.

2. Superficial to deep burn on return (in different) electrode due to its faulty position on bony prominences or dry electrode or poorly conductive gel application. Electrode should be applied in long axis nearest to active electrode and on broad base away from pressure points, scars and keloids low intensity should be used in paediatric patients due to less connective area.

3. Explosion may take place if volatile or inflammable anaesthetic agents like ether or cyclopropane are used, all the more there is a definite risk in surgeries of respiratory tract (tonsillectomy[8] or turbinectomy).

4. Burn injuries from inflammatory prepatory solution applied in surgical field or in the region of inactive electrode[9] on cutting epidermis in electrosurgery leads to scarring and thicker scars. Only indication is in coagulation deffects or when suturing is not required (drainage of an abscess).

5. Electric current in body interferes with the working of cochlear implants and pace makers[10] causing arrhythmias.

6. Smoke produced by electrosurgery specially in electrodesication when tumours of suspected viral etiology are burnt off, contain viruses, intact cells, carbonized particles and carcinogenic gases[2].

7. Necrotic granulomas of peritoneum, uterine cavity have been reported and necrosis of inferier turbinate has been observed as a frequent complication by using 7.5cm long needle monopolar electrode in subepithilial connective tissue.

8. Grisel syndrome is a non traumatic atlantoaxial subluxation after an inflammatory process in the upper and peripheral cervical region. With Monopolar Electrocautery following adenoidectomy an increased incidence of Grisel's syndrome has been observed. (Author has been successfully using bipolar cautery for last 15 years without any complication).

CONCLUSION

Needle electrode is used for cutting

due to its precise intense supply of energy leading to minimum surrounding tissue damage with pure sinuosoidal undamped current.

Thicker (broad) electrode is used for slow and deeper coagulation or touching the current to haemostats (artery forceps).

Bipolar forceps deliver low intensity currents avoiding injury to surrounding tissue. Minimum intensity with just sufficient current is used till the change of colour of tissue.

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