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Energy Delivery Systems used in Onco-Surgery: A Comparative Analysis

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Abstract : In this paper we are going to discuss about different types of Energy Delivery Systems used in Onco-Surgery for the treatment of cancer. Surgical oncology is a branch of Oncology which emphasizes on removal of the cancerous tissue(s) through surgical procedure, in order to prevent its further spread. Different energy systems can be used, which differs in their principle of operation depending upon the type of cancer and area affected. We will also present a comparative analysis of these systems regarding their efficiency and effectiveness, and will also cover some of the recent advancements aimed at enhancing these techniques in order to achieve desired output in terms of patient recovery.

IndexTerms - Onco-Surgery, Cancer, Energy Delivery Systems

1. INTRODUCTION

Cancer is a disease in which some of the body's cells grow uncontrollably and spread to other parts of the body. Cancer can start almost anywhere in the human body, which is made up of trillions of cells. Normally, human cells grow and multiply (through a process called cell division) to form new cells as the body needs them. When cells grow old or become damaged, they die, and new cells take their place [1].

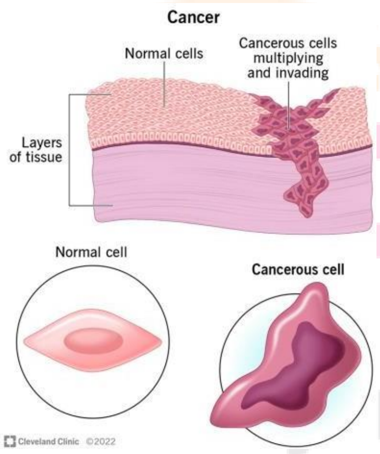

Fig 1. Normal vs Cancerous Cell

Fig1 shows how normal cell turns into cancerous cell due to uncontrolled growth and multiplication. Cancer is not just one disease but rather a group of diseases, all of which cause cells in the body to change and grow out of control. Cancers are classified either according to the kind of fluid or tissue from which they originate, or according to the location in the body where they first developed. In addition, some cancers are of mixed types. Few of the most common examples are: Melanoma, Basal cell carcinoma, squamous cell skin cancer, Merkel cell carcinoma, etc. Staging is the process of determining whether cancer has spread and, if so, how far. There is more than one system used for staging cancer [2].

2. RESEARCH METHODOLOGY

There are many types of cancer treatment. The types of treatment that one has will depend upon the type of cancer they have and how advanced it is. Some people with cancer will have only one treatment. But most people have a combination of treatments. Surgical oncology is a field of medicine that uses surgery to treat cancer. Its main goal is to find harmful tumors in the body and remove them. Doctors who practice surgical oncology can also see if one has cancer or find out if the disease has spread to other parts of the body. This includes the tools and techniques you used (like experiments, computer simulations, or surveys) [3]. Different energy systems are used depending upon the principle of operation, as given below:-

2.1 Electrosurgical Systems

An electrosurgical system consists of an electrosurgical unit, sometimes referred to as a generator or an ESU. The active electrode, the patient, and (as needed) the dispersive electrode sometimes referred to as the grounding pad. The generator takes current from the outlet and speeds it up. At this frequency, muscles and nerves are not affected, and heat is created at the cellular level. The heat created is responsible for the cutting and coagulation effect that is experienced. Electrosurgery works by cutting or coagulating tissue via a high-frequency electrical current that is generated from an electrosurgical unit or ESU. The electrical current travels through an attached device (active electrode) and creates localized heating to allow for precise cuts or coagulation of the tissue which helps to reduce the risk of bleeding. By adjusting the method, mode, and power settings (wattage), physicians can customize the unit output setting for a variety of procedures. There are several modes or settings on electrosurgical generators that can allow the physician to create a desired tissue effect. These may also be referred to as outputs. By adjusting the power setting and modes within the electrosurgical unit, physicians can determine the precise cut and coagulation current needed for the procedure. Electrosurgical units produce currents to cut and coagulate tissue during endoscopic procedures. Most units can support both monopolar and bipolar methods. The difference between monopolar and bipolar electrosurgery is how the electrical current travels and completes the circuit. Every electrosurgery manufacturer has their own names for the different outputs, but they generally range from a cut to a soft coagulation, with blended outputs in between. By adjusting the power setting and modes within the electrosurgical unit, physicians can determine the precise cut and coagulation current needed for the procedure.

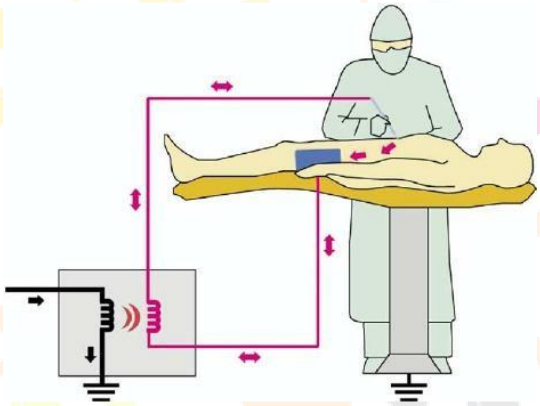

Fig 2. Electrosurgery : Basic Principle

Fig 2 shows the basic principle of electrosurgical systems. Electrosurgical units produce currents to cut and coagulate tissue during endoscopic procedures. Most units can support both monopolar and bipolar methods. The difference between monopolar and bipolar electrosurgery is how the electrical current travels and completes the circuit. In monopolar electrosurgery, the current passes through the connected device (active electrode) directly to the affected tissue where the desired tissue effect occurs. It then passes through the patient’s body to where a dispersive pad electrode is placed. The dispersive electrode receives the current and then transmits the energy back to the electrosurgical unit to complete the circuit [4].

2.2 Ultrasonic Generators

Surgical ultrasound equipment is a medical device that uses ultrasound technology to perform tissue cutting and hemostasis. It cuts tissue through high-frequency ultrasound vibration, while using the generated heat to coagulate blood vessels, achieving hemostasis. The main function of the generator is to provide electrical energy with ultrasonic frequency, and control the output of the electric power to the hand piece handpiece by activating the foot switch or hand piece switch. Set output energy by operation of the front panel of the generator, and observe the working condition of the system, providing different energy at different gear. An USG makes the transducer oscillate at the ultrasonic frequency of 55.5khz ± 1KHz, and then the amplitude is amplified by the shaft, so that the water in the tissue vaporizes, the protein hydrogen bond in the tissue breaks and the cells disintegrate, thus cutting the tissue. At the same time, the protein coagulates causing that the small lumen and the large lumen are closed to achieve coagulation.

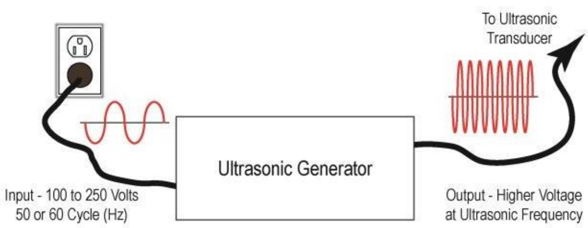

Fig 3. Ultrasonic Surgical Generator

Fig 3 shows an Ultrasonic Surgical Generator. The generator main controller adopts DSP, CPLD and ARM controllers. CPLD realizes complex logic transformation. DSP realizes data calculation processing such as current, voltage and impedance and controls the waveform producer to generate basic output waveform. It outputs the required power signal through the power drive circuit and output transformer, and outputs it to the handpiece for converting electrical energy to mechanical energy. The conversion ultimately drives the scalpel vibration to achieve cutting and hemostasis. At the same time of output, the DSP monitors and feedback the current and voltage signals whether it reaches the preset value, and changes the drive signal by calculating the error and a certain algorithm, thereby achieving stable output. The system is mainly comprised of five parts: Ultrasonic Surgical Generator, Ultrasonic Surgical Handpiece, Disposable Ultrasonic Surgical Scalpel /Ultrasonic Open Surgery Scissors, foot switch and cart (optional). The generator supplies the handpiece with electrical energy and facilities selection of power levels, system monitoring and system diagnostics. Power is delivered by activating the foot switch or instrument switch.

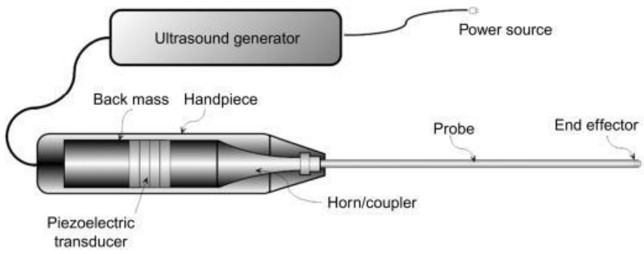

Fig 4. Ultrasonic Handpiece

Fig 4 shows an Ultrasonic Handpiece. The handpiece contains an electroacoustic transducer that converts the electrical energy supplied by the generator to mechanical motion. The transducer is connected to an amplifier which amplifies the motion produced by the transducer and relays it to the scalpel/scissors. The mechanical motion from the handpiece advance to the scalpel/scissors, transmitting ultrasonic energy which enables hemostatic cutting and/or coagulation of tissue. The foot switch is optional. The foot switch is required if the system will be used with coagulating shear or instruments without the hand switching adaptor. The cart is optional. It is designed to put on Ultrasonic Surgical Generator. The cart requires assembly; instructions are included with the cart [5].

2.3 LASER Surgical Systems

Laser therapy uses a very narrow, focused beam of light to shrink or destroy cancer cells. It can be used to cut out tumors without damaging other tissue. Laser therapy is often given through a thin, lighted tube that is put inside the body [6]. A Laser is constructed from three principal parts: An energy source (usually referred to as the pump or pump source), a gain medium or laser medium, and Two or more mirrors that form an optical resonator. The pump source is the part that provides energy to the laser system. Examples of pump sources include electrical discharges, flash lamps, arc lamps, light from another laser, chemical reactions and even explosive devices. The gain medium is the major determining factor of the wavelength of operation, and other properties, of the laser. Gain media in different materials have linear spectra or wide spectra. Gain media with wide spectra allow tuning of the laser frequency. The optical resonator, or optical cavity, in its simplest form is two parallel mirrors placed around the gain medium, which provide feedback of the light. The mirrors are given optical coatings which determine their reflective properties [7].

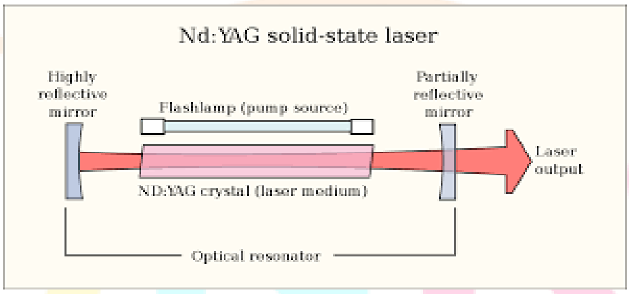

Fig 5. Nd: Yag Solid State Laser Generation

Fig 5 shows Nd: Yag Solid State Laser Generation. The most common lasers for treating cancer are: Carbon dioxide (CO2) Lasers, Argon Lasers and Nd:Yag Lasers. Carbon dioxide (CO2) Lasers remove thin layers of tissue from the surface of the body and the lining of organs inside the body. They can treat basal cell skin cancer and cancers of the cervix, vagina, and vulva. Argon Lasers can treat skin cancer and are also used with light-sensitive drugs in a treatment called photodynamic therapy. Nd:Yag Lasers are used to treat cancer of the uterus, colon, and esophagus. The laser- emitting fibers are put inside a tumor to heat up and damage the cancer cells. This treatment has been used to shrink liver tumors. Thin fibers at the end of the tube direct the light at the cancer cells. Lasers are also used on the skin. Laser therapy uses an intense, narrow beam of light to remove or destroy cancer and abnormal cells that can turn into cancer. Tumor cells absorb light of different wavelengths (or colors) than normal cells do. So, tumor cells can be targeted by selecting the proper wavelength of the laser. Laser therapy is a type of local treatment, which means it treats a specific part of your body. Lasers can also be used in other types of local treatment, including photodynamic therapy and a treatment that is like hyperthermia, called laser interstitial thermal therapy, or LITT. Lasers are most often used with other types of cancer treatment such as radiation and chemotherapy [8].

2.4 Cryosurgical Systems

Cryosurgery is a treatment that uses extreme cold produced by liquid nitrogen or argon gas to destroy cancer cells and abnormal tissue. It is a local treatment, which means that it is directed toward a specific part of your body. Cryosurgery is used to treat tumors on the skin, as well as certain tumors inside the body. Cryosurgery may also be called cryotherapy or cryoablation. Cryosurgery freezes tissue, causing cells in the treated area to die. For tumors on the skin, the doctor applies liquid nitrogen directly to the abnormal area with a cotton swab or spraying device. For tumors inside the body, the doctor may use a device called a cryoprobe to freeze the tumor tissue.

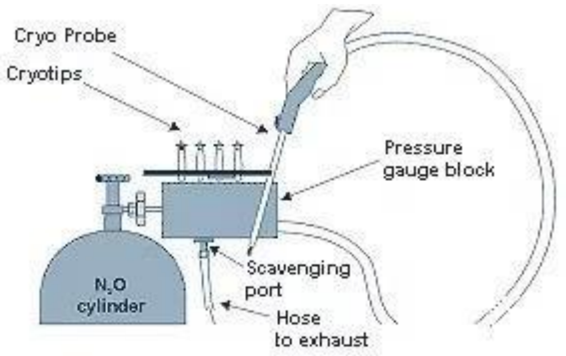

Fig 6. Cryosurgical System

Fig 6 shows a Cryosurgical System. Cryoprobes may be put into the body during surgery or through a small cut in the skin. As liquid nitrogen or argon gas flows through the cryoprobe, the doctor places it directly on the tumor. During this procedure, the doctor uses ultrasound or MRI to guide the cryoprobe to the correct spot, which helps limit damage to nearby healthy tissue.

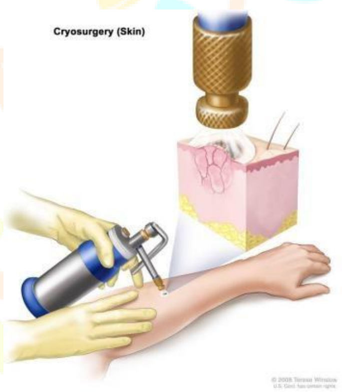

Fig 7. Cryosurgical Procedure

Fig 7 shows a Cryosurgical Procedure. When the frozen tissue thaws, the cells die. Tumors that were frozen inside the body will be absorbed. Tumors that were frozen on the skin will form a scab that will fall off as the damaged skin heals. Cryosurgery may be used with other cancer treatments such as hormone therapy, chemotherapy, immunotherapy, radiation therapy, or surgery. For example, the tissue remaining after a primary bone tumor has been removed by surgery may be treated with cryotherapy to help reduce the risk that the tumor will come back. Cryosurgery can be used to treat the following types of cancer: retinoblastoma, skin cancers, including basal cell and squamous cell carcinomas, skin lesions from AIDS-related Kaposi sarcoma, early-stage prostate cancer, liver cancer that is confined to the liver, bone cancer, mostly chondrosarcoma non-small cell lung cancer, skin growths called actinic keratoses that can turn into cancer [9].

3. RESULTS AND DISCUSSION

Electrosurgery provides numerous benefits including but not limited to: Minimizes bleeding at the application, Allows for greater precision with cutting and coagulation settings, Offers a relatively fast method for tissue resection or ablation [4]. Ultrasonic surgical dissection allows coagulation and cutting with less instrument traffic (reduction in operating time), less smoke, and no electrical current. Many surgeons claim that ultrasonic spine surgery leads to: Less disruption to bones, joints, and tissue. Pain alleviation. Faster recovery time than traditional open spine surgeries. Also, Cutting is very effective with less bleeding and less thermal damage to the surrounding tissues and, hence, less smoke [5]. The benefits of Laser Therapy are as follows: Takes less time, is more precise and causes less damage to tissues, Leads to less pain, bleeding, infections, and scarring, can often be done in a doctor's office instead of a hospital [6]. Cryosurgery has many benefits. For tumors inside the body, only a small cut or puncture is usually needed to insert the cryoprobe through the skin. As a result, pain, bleeding, and other problems that come with surgery are reduced. Cryosurgery can often be done with local anesthesia and may not require a hospital stay. Since cryosurgery is a local treatment and doctors can focus treatment on a precise area, damage to nearby healthy tissue can be reduced. Cryosurgery can be repeated safely and may be used with other cancer treatments. Cryosurgery may be used when tumors can't be removed with surgery or when people can't have surgery because of their age or other medical problems. Cryosurgery may be an option when the cancer does not respond to standard treatments [9].

Thus we conclude that each of these system has their own benefits, and therefore are equally significant in treating cancer. New advancements like NIR and Microsurgery are being largely incorporated in different healthcare facilities, which can help in treating cancer in a more optimized way in future.

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