INTRODUCTION

The first planned laparoscopic colon operations were performed by Franklin[1], Jacobs[2], Foweler and White[3] in 1990, and since that time innumerable procedures have been performed. [4]

Improved laparoscopic skills and introduction of new instruments have led to broad application of laparoscopy in benign and malignant diseases. [5]

Laparoscopic colorectal surgery for benign diseases has met with great enthusiasm and widespread acceptance. Many surgeons have been reluctant about its application in patients with inflammatory bowel disease. Randomized and comparative studies have been reported to compare laparoscopic-assisted ileocolic resection with the open procedure for Crohn's disease, indicating the feasibility of the laparoscopic procedure in selected patients. [6]

Laparoscopic colon surgical techniques have been applied to segmental resections, total colectomy, and proctocolectomy over the past decade. While the use of minimally invasive techniques was once restricted to benign colorectal conditions, the recent Clinical Outcomes of Surgical Therapy **(COST)** has demonstrated the feasibility, oncologic adequacy, and long-term safety of laparoscopy in malignant disease of the colon. This is in addition to well-characterized short, and intermediate-term clinical benefits, including less post-operative pain and narcotic requirements, faster recovery of bowel function, and shorter stay in hospital. [7]

The postoperative complications associated with laparoscopic colorectal surgery are essentially the same as those for open surgery. Certain other complications, such as port site hernia, and recurrence are specific to the laparoscopic approach. Abdominal abscess and anastomotic leak occur in 1.1% and 0.7% of cases, respectively. Other complications include fever, dehydration, pulmonary embolus, wound infection, and cardiac arrhythmias. [8]

Septic shock with diffuse peritonitis and carcinoma in the end stage are absolute contraindications of laparoscopic colectomy, while morbid obesity, advanced cirrhosis, and multiple operations with severe adhesions are relative contraindications. [9]

AIM OF THE ESSAY

The aim of this essay is to review the recent advances in laparoscopic colectomy and to discuss the new equipments, techniques, advantages, disadvantage of laparoscopic colectomy and the role of laparoscopic colectomy in the management of benign and malignant lesions.

EQUIPMENT AND INSTRUMENTATION

Equipment and instrumentation have a much greater impact and importance in laparoscopic surgery. This is a fact that visualization and tactile exploration of the operative field is always only indirectly achieved through optical systems and instruments. [10]

The engineering and design of the equipment used for laparoscopy have been changing rapidly. [11]

The following list summarizes the fundamental instrumentation necessary to initiate laparoscopic colorectal surgery:

1. Image processing system

• Laparoscopes (10 mm 0^0, 30^0 and 5 mm 0^0, 30^0).

• Laparoscopic camera — single- or three-chip camera.

• Monitor.

2. Gas insufflation

• High-flow C02 insufflator (>6 L/min) with digital intra-abdominal pressure, volume, and gas display.

• CO_2 reservoir as a tank or a connection to a “wall” reservoir.

3. Instruments

• Standard surgical instruments to incise the skin, establish trocar sites and minilaparotomy, and perform emergent laparotomy, if needed.

• Laparoscopic 5-mm bowel graspers (two per case).

• Laparoscopic 5-mm dissector.

• Laparoscopic 5-mm scissor.

• Laparoscopic 5-mm needle holder.

• Suction/irrigation cannulae (5 and 10mm). [12]

Types Of Staplers Used In Laparoscopic Surgery

There are two types of staplers used in laparoscopic surgery:

***Linear staplers.* [Figure 2.1]**

*** *Circular staplers.*** (13)

Delivery of three rows of staples without cutting the tissue is used to close defects such as an enterotomy. Combined with a cutting knife in between two to three stapler rows, the staplers allow one to cut and close off the tissue on both cutting edges at the same time. Spillage of luminal contents (blood, stool, etc.) can therefore be avoided. The optimal staple size and depth vary according to the tissue that it is being used for. (14)

While linear stapling devices have been adapted for use in laparoscopic surgery, circular staplers (21-33 mm diameter) are essentially the same as those used during open surgery **[Figure 2.2].** Their standard application is the creation of a safe intestinal anastomosis in the pelvis after recto-sigmoid resection. The long and curved stapler body is inserted transanally, and the anvil is centrally deployed under direct vision, next to the staple line on the rectal stump. The stapler head, on the other hand, is inserted into the proximal bowel end after resection of the specimen; the bowel is subsequently returned into the peritoneal cavity, where the anvils of the stapler head and body are connected with an audible click either in hand-assisted or in purely laparoscopic technique after reestablishing the pneumoperitoneum. Firing the stapler results in an inverting anastomosis and should result in two intact tissue rings and an air-tight anastomosis. (15)

Figure 2.1 Laparoscopic Straight Linear Cutter **(SLC)** stapler.[13]

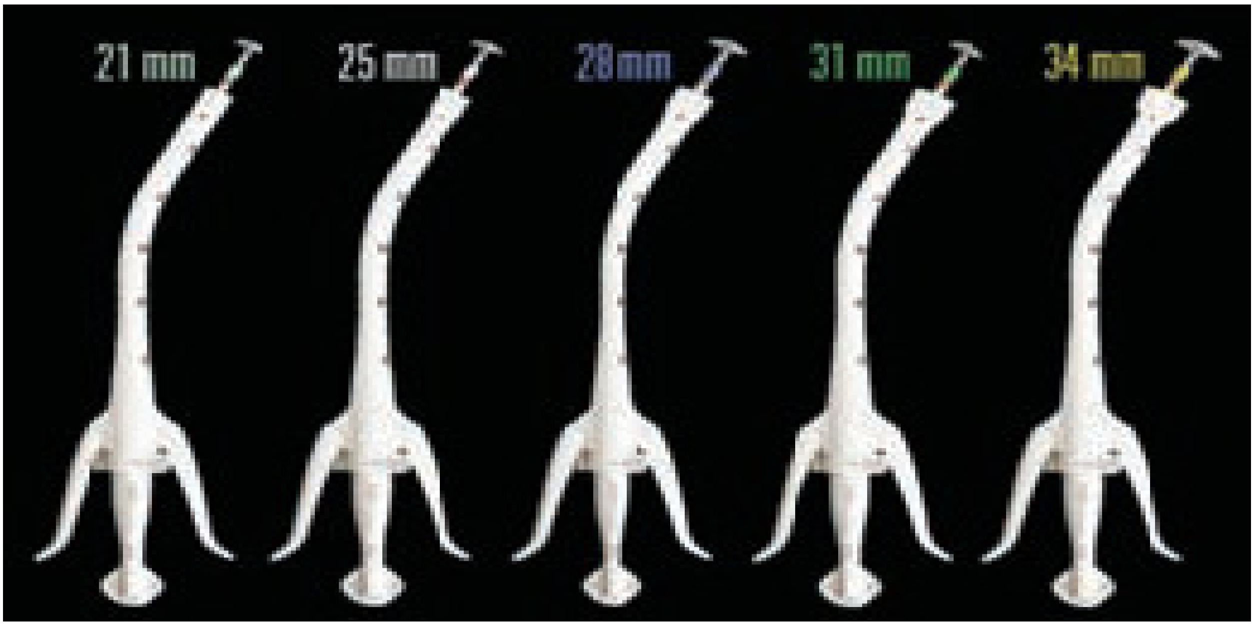


Figure 2.2.Various sizes of circular staplers. [15]

A significant change in the means whereby staples are delivered in intestinal tissues is being developed. Using a 170-cm long computer-driven cable, which attaches to a wide variety of stapling cartridges, this equipment permits the surgeon to pass certain linear staples through laparoscopic ports and angle the stapler tip over a wide range of angles (up-down and right-left). The staplers may be fired using push-button technology with a hand-held remote controller. In addition to the **SLC** stapler, there is a right-angled linear cutting device **(RALC 45mm)** that fires four rows of staples, cutting automatically between the second and third rows. There is also a circular stapler technology, similar in some ways to the commercially available models in sizes 25, 29, and 33mm. Advantages of this circular stapler are that it can be fired using a remote device, and also it can be passed transanally high into the large intestine, so that theoretically even right-sided end-to-end anastomoses could be made **[Figure 2.3].** [16]

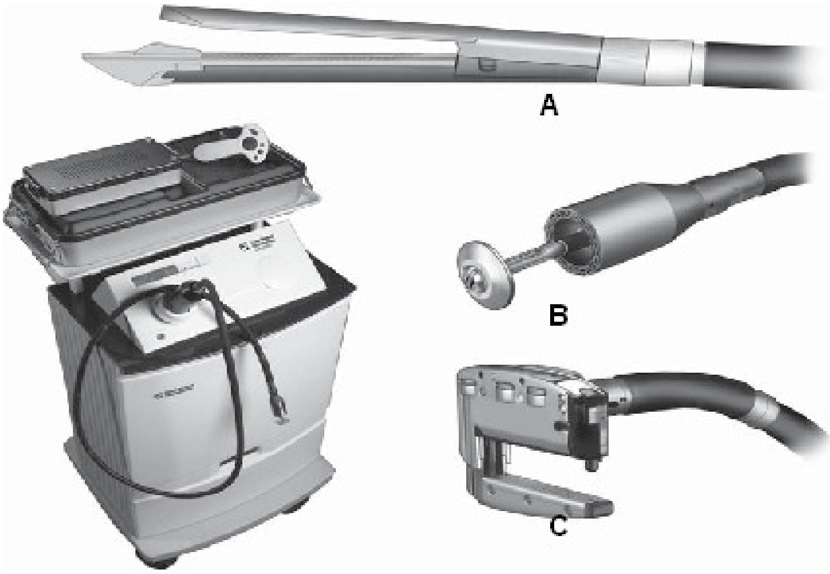


Figure 2.3. Computerized gastrointestinal stapling devices **A** Straight linear cutter (SLC) 55 and 75 mm, **B** circular stapler (CS) 25, 29, and 33 mm, **C** Right-angled linear cutter (RALC) 45 mm, which places four rows of stapler, cutting between the second and third rows. [16]

Clip Appliers

Clip appliers were developed to facilitate ligation of small ductal structures approximately 3 to 8mm in diameter. The most common disposable clip appliers contain up to 20 clips and are available in 5- and 10-mm-diameter instruments. They are manufactured from a variety of materials, including absorbable polyglycolic acid and polydioxane, stainless steel, and most often, titanium. [17]

The clip appliers may be single load or multifire **[Figure 2.4].** Generally, the single load is reusable and the multifire are disposable. In a colon resection, multiple clips are needed, so a multifire clip applier is appropriate. [18]

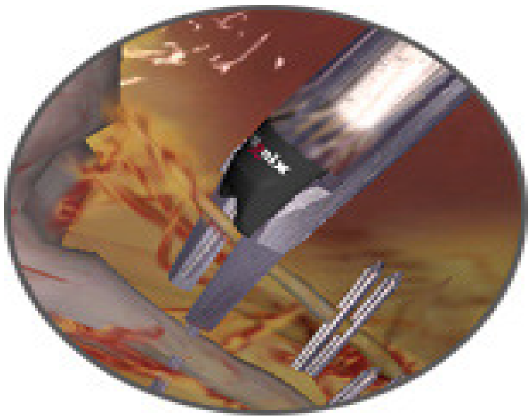


Figure 2.4. Clip Applier. (18)

Hand-Access Devices for Colorectal Hand-Assisted Laparoscopic Surgery

Because the intracorporeal manipulation is more extensive and multiquadrant in colorectal procedures compared with other general surgical procedures, the device should be durable and flexible so that a wide range of movement of the surgeon's hand causes neither gas leakage nor device malfunction. Among several commercially available products, the Gelport™ is preferred **[Figure 2.5].** (19)

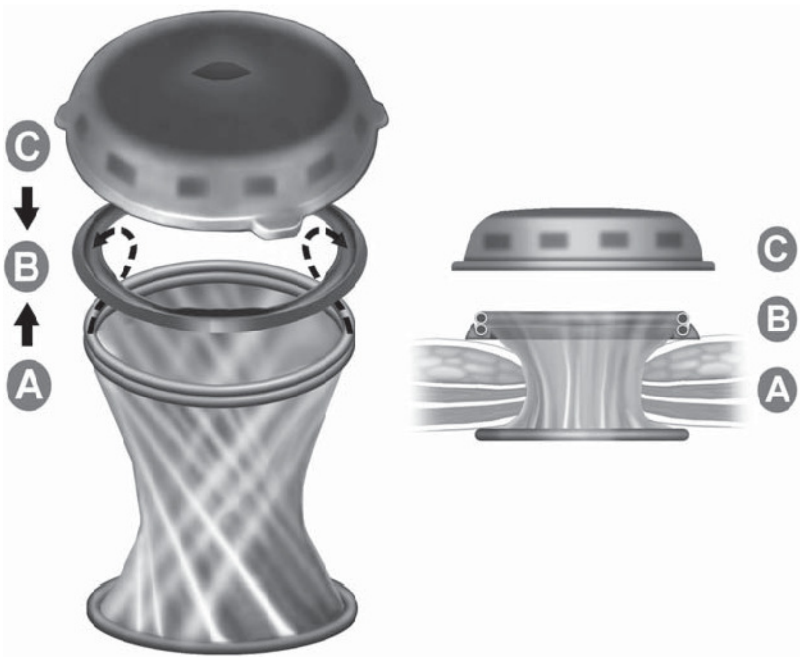


Figure 2.5. Gelport™ hand-access device. (19)

Using a new generation of hand-access devices that extend the options for hand-assisted techniques, these devices facilitate hand insertion, protect the wound, act as the retrieval site for the specimen and serve as the portal for construction of extracorporeal anastomoses. [20]

Specimen Bags

A specimen bag is very useful for laparoscopic retrieval for colorectal malignancy to isolate the resected specimen from the peritoneal cavity. This may reduce the possibility of seeding tumor cells into the peritoneal cavity and abdominal wall. In general, a bag has to be inserted into the peritoneal cavity in a compressed manner and then opened. The bulky specimen may then be placed in the bag, and the bag completely closed before bringing it through the abdominal wall. The ideal endoscopic bag for delivering the intra-abdominal specimens should have the following properties:

- It should be fluid-impermeable and be strong enough so that it cannot be damaged inside the abdominal cavity or when being removed.
- It should fit through a cannula 15 mm or smaller.
- It should open easily.
- It should be large enough so the entire intestinal specimen, including mesentery, can easily be placed in it in one piece.
- It should have a mechanism to quickly close the bag to prevent spills **[Figure 2.6].**[21]

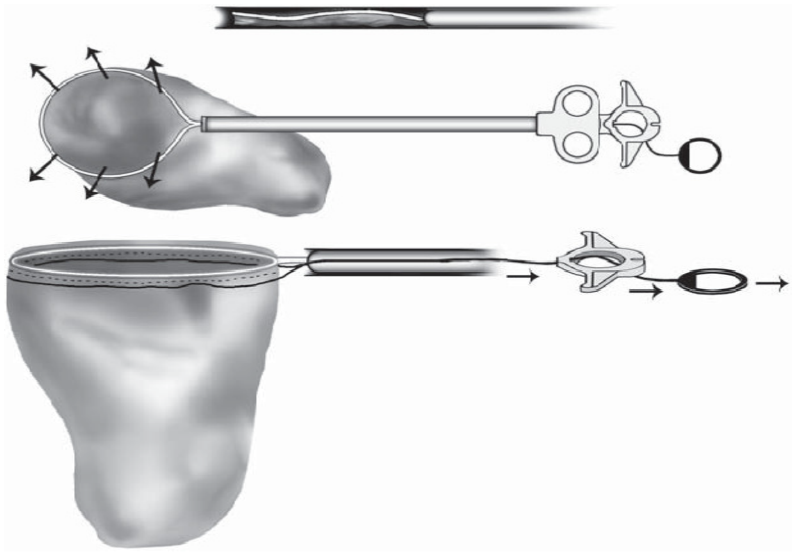


Figure 2.6. Endo Catch™ II. (21)

Trocar Wound Closure Devices

Closing small fascial defects left by trocars can be a difficult, time consuming, and occasionally hazardous task especially in obese patients. Inadequate closure of those wounds can lead to significant morbidities such as evisceration, incisional hernia, and at worst, incarcerated (Richter) hernia. Trocar wound closure devices are commercially available in both disposable and reusable fashion **[Figure 2.7].**(17)

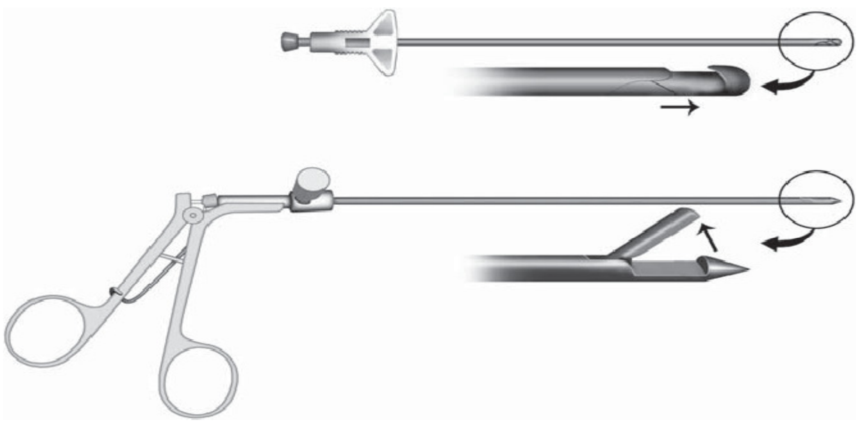


Figure 2.7. Endo close ™ and Suture Passer (abdominal wall closure devices). (17)

Sterilization and Maintenance of Instruments & Equipment

The laparoscopic instruments **(LI)** are more prone to lodging of bioburden (micro organisms and debris). Sterilization is the absolute elimination or destruction of all forms of microbial life.Optimal processing of LI involves several steps that reduce the risk of transmitting infection from used instruments and other items to health care personnel, These are 1) Dismantling, 2) Decontamination, 3) Precleaning, 4) Cleaning and rinsing, 5) Drying 6) Sterilization and 7) Storage. For proper processing, it is essential to perform the steps in correct order. [22]

Dismantling

Instruments that cannot be dismantled completely are liable to harbour blood **/** debris within the shafts and compromise safety of the patients. [22]

Decontamination

Decontamination is the process used to reduce bioburden on reusable medical devices. Instruments should be placed in a container containing a disinfectant solution such as 0.5% chlorine and allowing them to soak for 10 minutes **[Figure2.8].**[22]

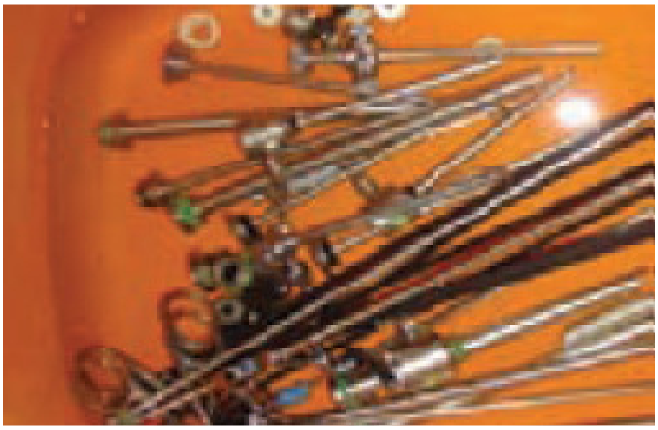


Figure 2.8. Instruments soaked in a disinfectant for decontamination.[22]

Precleaning

Precleaning treatment with an enzymatic product is recommended. A number of enzymatic products are available, protease, lipase, and amylase, which are effective in enhancing the cleansing process for difficult-to-clean instruments. These break down blood and other protein soil and facilitate cleaning. (22)

Cleaning

Any instrument designed for autoclaving requires specialized cleaning prior to sterilization. For laparoscopic instruments this is best carried out using soft brushes that allow the inner surfaces of the instruments to be cleaned thoroughly.(22)

Rinsing

Laparoscopic instruments are best rinsed in running water The jet of water is able to clean these instruments far better than rinsing them in stagnant water.(22)

Ultrasonic Cleaner

This method is, by far, the most efficient and effective available today. ultrasonic cleaning is 16 times more efficient than hand-cleaning. The instruments are placed in the ultrasonic unit for 10-15 minutes and use a neutral ph solution. (22)

Drying

This is ideally achieved by using an air gun that blows all the water droplets off the surfaces of instruments or by using an oven. (22)

Sterilization

There are three sterilization processes available; steam, ethylene oxide and peracetic acid.

Steam sterilization

Steam sterilization in an autoclave is one of the most common forms of sterilization used in health care facilities. Laparoscopes may be sterilized by flash or vacuum steam sterilization.Flash sterilization is carried out at 135°C at **30 psi** pressure for 60 minutes.[22]

Gas *sterilization*

Using ethylene oxide **(EO)** is suitable for all disposable instruments. The advantages of E0 are that the items are not damaged, it is non-corrosive to optics and it permeates porous material. Its main disadvantages are its cost, toxicity, the need for aeration and being a longer process. [22]

High level disinfection

When sterilization is not available or feasible, high-level disinfection **(HLD)** is used for instrument processing. HLD eliminates bacteria, viruses, fungi, and parasites but does not reliably kill all bacterial endospores, which cause diseases such as tetanus, gas gangrene and atypical mycobacterial infections. Agents that are used for HLD include 2% glutaraldehyde, 6% stabilized hydrogen peroxide and per acetic acid (acetic acid/hydrogen peroxide).Formaldehyde is extremely irritating to the skin, eyes, nose, and respiratory tract. Therefore, routine use of formaldehyde for sterilizing instruments and other items is not recommended.[22]

ENERGY SOURCES IN LAPAROSCOPY AND THEIR OPTIMAL USE

Energy sources are classified as electrical, laser, ultrasonic, and mechanical. Precise dissection with minimal bleeding is especially important in laparoscopic surgery. Even minor oozing compromises the laparoscopic view and clearing blood from the field of vision with suction and irrigation may be tedious. Although many different coagulation and dissection devices are available, they all divide and coagulate tissue by converting various types of energy into heat. Therefore, the effect on tissue is thermal and depends on exposure time and the amount of energy applied to the tissue. [23]

ELECTROSURGERY

The application of diathermy and electrosurgery is based on the fact that with a radiofrequency current >10,000 cycles per second, stimulation of muscle and nerve does not occur. [24]

The terms electrocautery and electrosurgery are often used interchangeably in modern surgical practice. However, these terms define two distinctly different modalities. Electrocautery is the use of electricity to heat a metallic object which is then used to coagulate or burn. Electrosurgery, on the other hand, uses the electrical current itself to heat the tissues. As a result, the electrical current must pass through the tissues to produce the effect. The current then flows through the tissues to produce heat from the excitation of the cellular ions. [25]

PHYSICS

The basic principle of electrosurgery is that current flowing through the body takes the path of least resistance which in the body means tissues with maximal water thus electrical resistance is in inverse proportion to water content. The most conductive is blood followed by nerve, muscle, adipose tissue and finally least conductive is the bone. (25)

Tissue reaction to thermal injury depends primarily on the temperature used **[Figure 3.1].** An increase in tissue temperature up to 60°C results in almost indiscernible changes to the naked eye. Coagulation begins at temperatures above 60°C; it is characterized by shrinkage and blanching caused by the denaturation of proteins, particularly collagen. When the tissue temperature reaches 100°C, the cell water boils, water is converted to steam, and the cell wall ruptures. When the water has evaporated and heat is still applied, the tissue temperature increases rapidly until it reaches 200°—300°C. At this point, the tissue carbonizes and begins to vaporize and smoke. At temperatures more than 500°C, tissue burns and evaporates. (26)

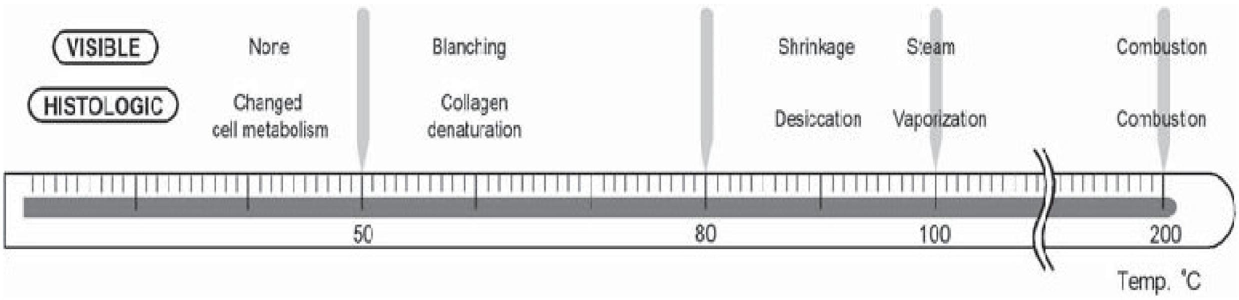


Figure 3.1. Visible and histologic alterations of tissues as related to tissue temperature.(26)

Electrosurgical Techniques

The effect of heat on tissue depends not only on the absolute amount of heat applied to tissue but also on the exposure time to heat. If heat is applied over a very short time (less than 1—2 seconds), the effect is localized because the heat is not conducted to surrounding tissues even when the heat is great enough to vaporize the tissue, the vaporization is localized. If, however, the same amount of heat is applied for a longer period (greater than 2 seconds), the heat is conducted to the surrounding tissue, thus increasing thermal necrosis and broadening the vaporization area.(23)

In clinical use electrosurgery consists of electrocuting, electrocoagulation, and fulguration. Electrocutting is the severing of tissue by a blade electrode energized by a highfrequency electrosurgical unit. Electrocoagulation is the heating, desiccation, and destruction of tissue at the point of contact, using a needle-tip, ball-tip, or blade electrode **[Figure 3.2.1] and [Figure. 3.2.2A).** [27]

Fulguration is a method of coagulation in which the active electrode is held some distance (e.g.1-10 mm) away from the tissue and the energy is dissipated in the area by sparking **[Figure.3. 2.2B]**. Thus fulguration requires the application of a relatively high voltage to ionize the gas between the electrode and the tissue. Fulguration gives greater depth of penetration and produces more dehydration of the tissue than does electrocoagulation. [27]

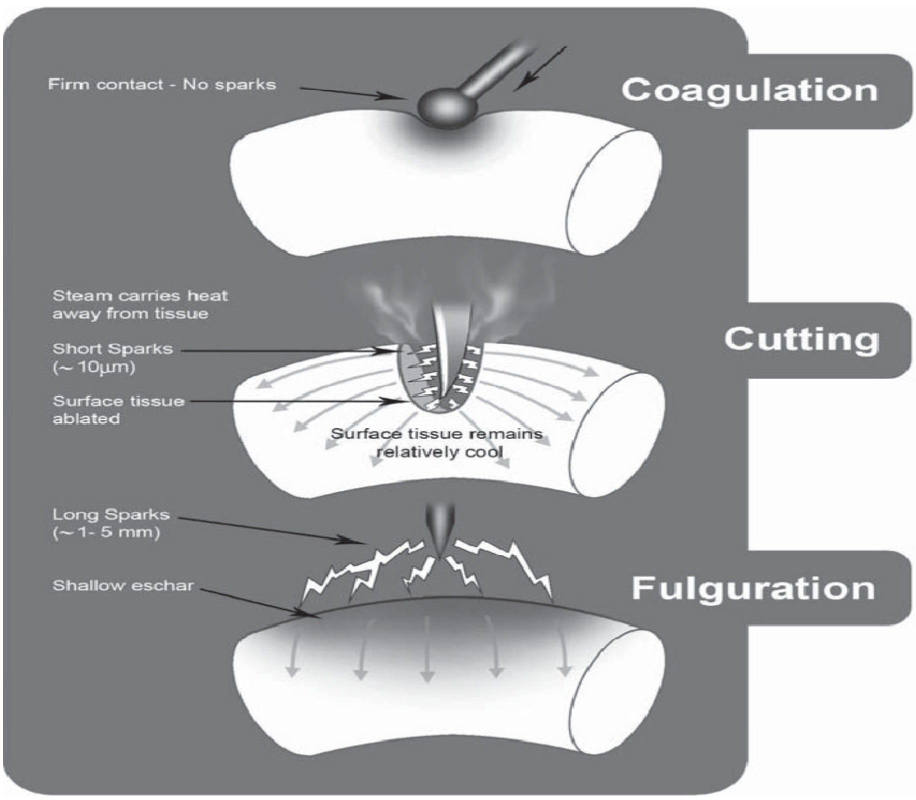


Figure 3.2.1 Effects of coagulation, cutting, and fulguration. [27]

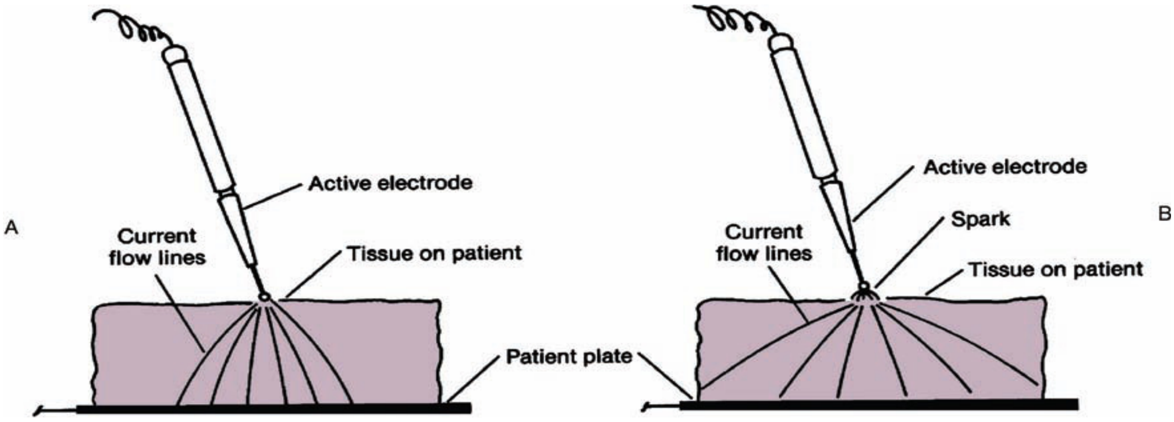


Figure 3.2. 2. (A) Electrocoagulation. (B) Fulguration. (27)

The mode of operation (cutting or coagulation or a combined effect) depends on the waveform of the current. Coagulation current is a high-frequency damped sine wave **[Figure. 3.3].** When applied to tissue, the current produces oscillation of the molecules, with heat generation resulting in tissue coagulation and dehydration. This action seals blood vessels. (28)

Cutting current is a high-frequency sine wave similar to that of coagulation current, but it is undamped. The action of this cutting current on tissue produces a very focused heat build-up, resulting in tissue rupture. There is no coagulating hemostatic action with pure cutting current. A "blend" of cutting and coagulating currents allows execution of the cutting current and obtains the additional benefit of hemostasis. (28)

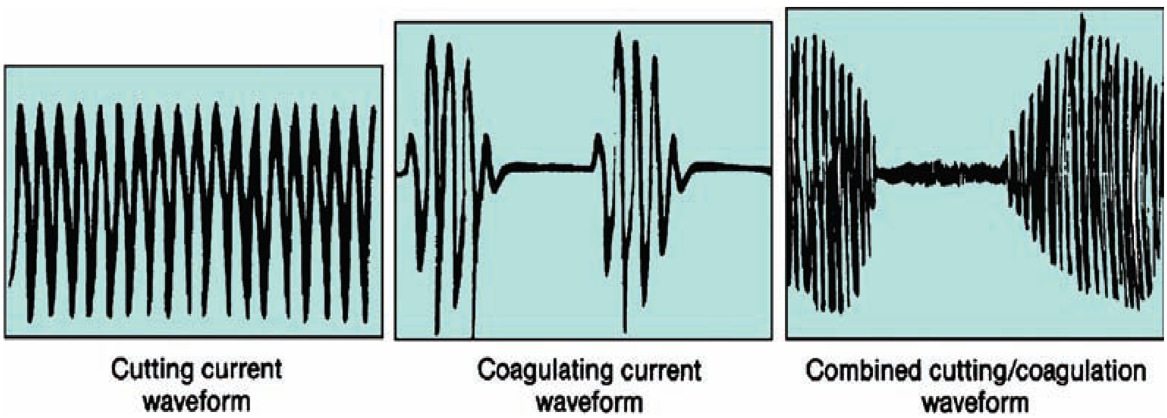


Figure 3.3 Different waveforms of current. (28)

Cutting quality and coagulation quality are inversely related, regardless of the dissection device used **[Figure 3.4].** Good cutting quality depends on rapid local vaporization of tissue with minimal lateral heat damage. No coagulation will occur because the lateral heat damage is not wide enough to seal the blood vessels. In contrast, the quality of coagulation depends on the width of lateral heat damage: the wider the lateral heat damage, the better the hemostasis. Because as cutting quality improves, the coagulation quality worsens, simultaneously combining excellent cutting qualities with excellent hemostasis is impossible. [(23)]

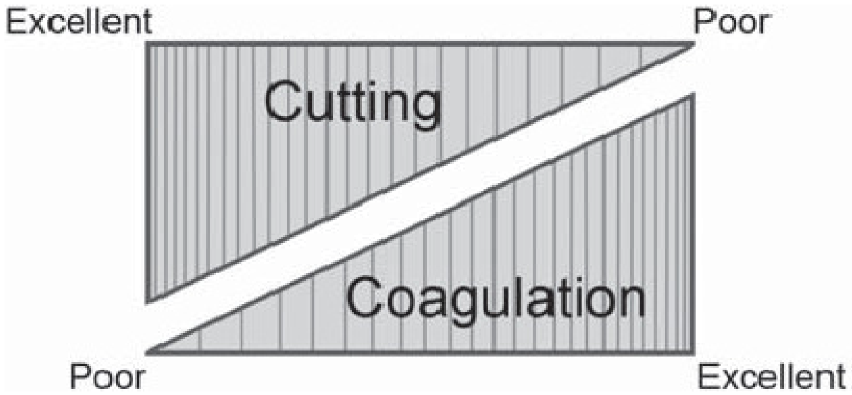


Figure 3.4. Inverse relationship between cutting and coagulation qualities of electrosurgery. [(23)]

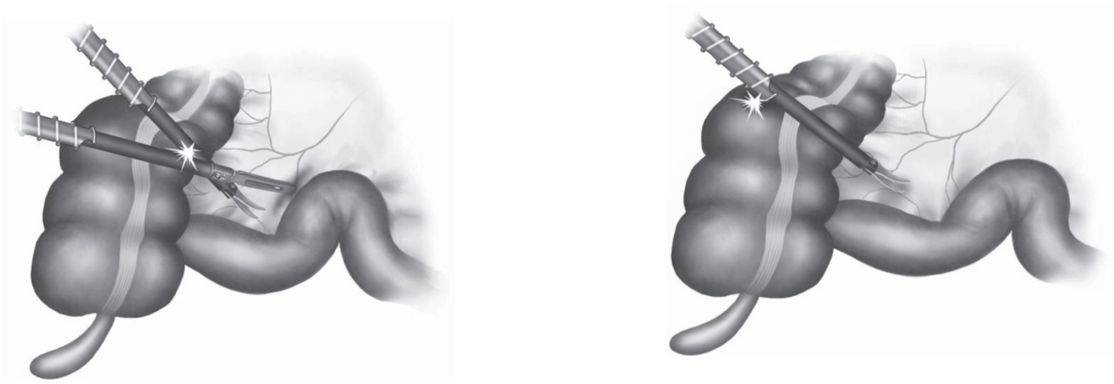
Electrosurgery in Laparoscopic Surgery

Both monopolar and bipolar electrosurgery are currently widely used in laparoscopic surgery. Although bipolar electrosurgery is safer than monopolar, its application is limited to tissue desiccation, so most laparoscopic surgeons still prefer monopolar electrosurgery. The combination of bipolar electrosurgery with an endoscopic scissor is used by some surgeons. Monopolar electrosurgery for laparoscopic procedures is advantageous because: 1) it is a familiar dissecting method, 2) it provides excellent hemostasis, 3) it is universally available in operating suites, and 4) it is inexpensive. The disadvantages of monopolar electrosurgery are extensive smoke development and risk of thermal injury during dissection. Smoke development can be extensive in laparoscopic colorectal surgery because of the unique need to dissect through the fatty mesentery. [23]

Extent of Tissue Damage

The tissue temperature many centimeters from the operative area may increase substantially when using proper electrosurgical technique. Although bipolar instruments may help confine the effects of electrosurgery to the structures grasped, extensive coagulation may also damage surrounding tissue. For instance, ureter injuries have been reported after using bipolar electrocoagulation near the ureters in gynecologic surgery.[29]

In laparoscopic surgery, closely monitoring the effect of electrical current on tissue is mandatory because the laparoscope provides only a limited view during dissection. Inadvertent injuries using monopolar electrosurgery occur primarily at the active electrode and the return electrode. Near the active electrode, injuries can occur in any part of the instrument: the handle, the insulated shaft, or at the uninsulated tip. These inadvertent injuries occur by direct coupling, or capacitive coupling **[Figure 3.5].** [30]



A B

Figure 3.5. Insulation Failure can occur by two major means when performing electrosurgery. **A)** Direct coupling between two instruments. **B)** Capacitive coupling when the charged instrument is being used with a metal cannula that is insulated from the abdominal wall by a non conducting anchoring device**.**[30]

Recent Advanced Technology And Instrumentation In Electrosurgery

The Ligasure System

Ligasure vessel sealing system **(LVSS)** utilizes a new bipolar technology for vascular sealing with a higher current and lower voltage (180 V) than conventional electrosurgery.[30]

It is capable of sealing vessels up to 7 mm in diameter **[Figure.3.6].** By grasping the tissue with the device and activating the energy source, both physical pressure and electrothermal energy are delivered to the vessels. The elastin and collagen of the wall of the vessel are partially denatured, and then allowed to cool briefly as a seal intrinsic to the vessel wall forms. The newly sealed tissue, which is often transparent, can then be divided using a cutting knife built into the LigaSure™ device **[Figure 3.7].** This device makes laparoscopic surgery immensely easier, especially in the handling of mesentery and omentum.[31]

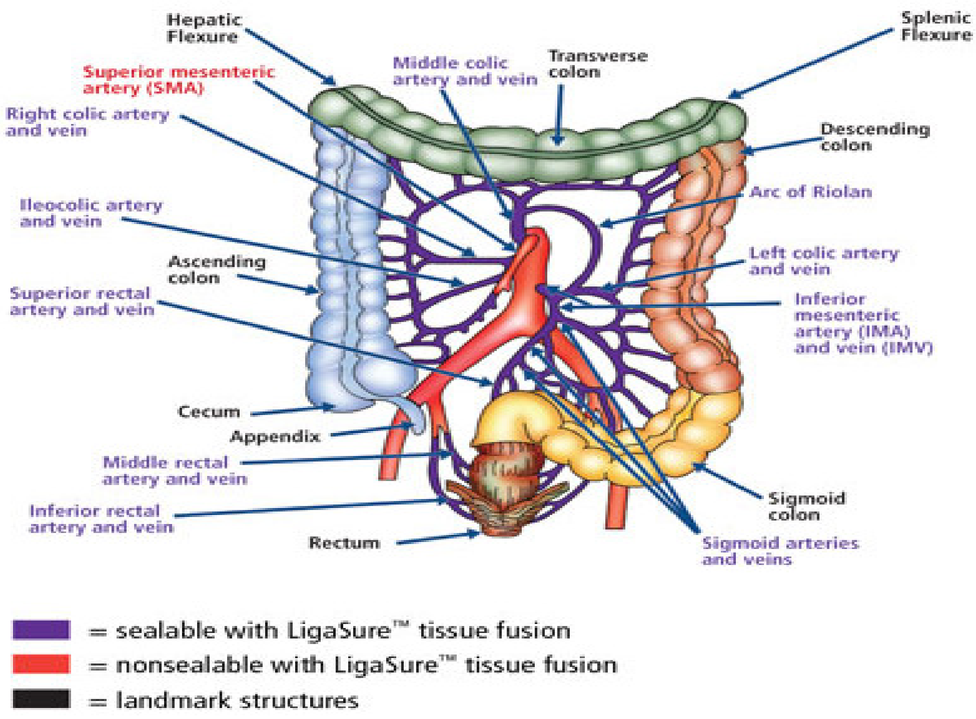


Figure 3.6. Vessels sealable and nonsealable with LigaSure™ .[31]

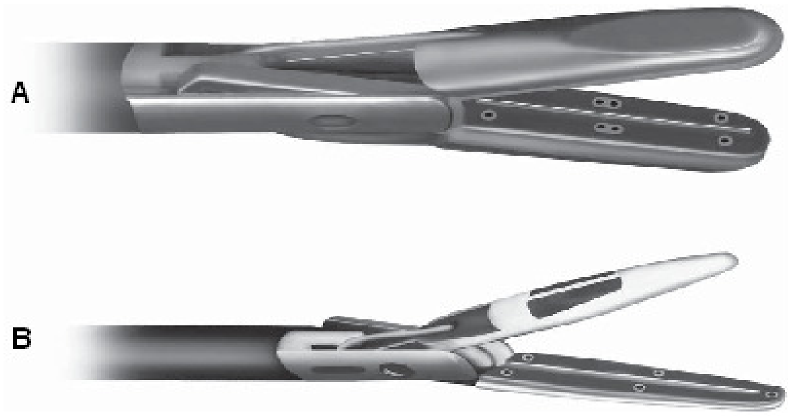


Figure 3.7. Vessel sealing devices (Ligasure™) **A,** 10 mm and **B,** 5 mm, each with a cutting mechanism. [31]

Depending on the thickness of the tissue, the sealing time varies between about 2 and 10 seconds. Depending on the thickness of the pedicle that is to be ligated, and the presence or absence of major vessels, multiple firings can be done before division. Typically, two to three applications per major vascular structure or with thicker bites of tissue,are used to divide the tissue **[Figure 3.8].** These multiple applications provide an increased length of tissue seal, and also allow for direct inspection of the sealed area, which is often translucent, adding confidence in the hemostasis before cutting. [32]

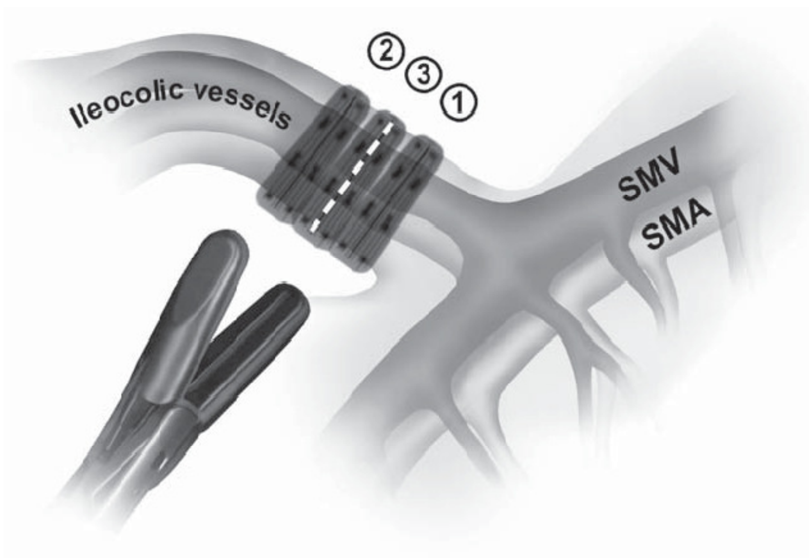


Figure 3.8. Ligation of the ileocolic vessels using the LigaSure™ 10 mm instrument.[32]

Ultrasonic Energy

The high-power ultrasonic dissection devices have become an integral part of current laparoscopic surgical instrumentation. Today virtually all laparoscopic procedures can be performed safely and efficiently without electrosurgery by using ultrasound. Furthermore, ultrasonic surgery has also replaced mechanical surgical clips and scissors in many laparoscopic procedures [**Figure 3.9**]. (33)

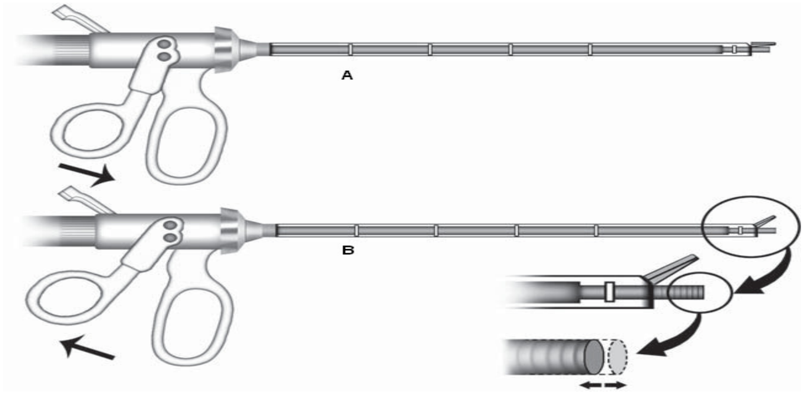


Figure 3.9. Longitudinal cut- way view of ultrasonic Shears in the opened **A** and closed **B** position. (53)

Ultrasonic cutting, coagulation, and cavitation:.

Basic mechanism for coagulation of bleeding vessel ultrasonically is similar to that of electrosurgery or lasers. Vessels are sealed by tamponading and coapting with a denatured protein coagulum. Electrosurgery uses electrons and lasers use photons to excite molecules in the tissue. This in turn releases heat and protein is denatured to form a coagulum. Ultrasurgical devices denature proteins by mechanical energy of the vibrating probe. Ultrasurgical hook or spatula blade can coagulate blood vessels in the 2mm diameter range without difficulty and the scissors can coagulate vessels up to 5mm in diameter, small- to medium-size arteries can be appropriately occluded and divided by LCS-type ultrasonic dissection devices.(34)

Although coagulation produced by ultrasonic surgery is slower than that observed with either electrosurgery or laser surgery, nonetheless, it is as effective or even more effective. The ultimate goal of surgery, is faster with the LCS or hook scalpel than with other energy modalities. The cutting mechanism for the ultrasonically activated scalpel is also different from that observed with electrosurgery or laser surgery. At least two mechanisms exist. The first is cavitational fragmentation in which cells are disrupted. This occurs primarily in low protein density areas such as liver. This mechanism is similar to that observed with the ultrasonic aspirating device (CUSA), The later device is composed of an ultrasonic generator that vibrates at 23000 Hz, When coupled with powerful aspiration device ,the ultrasonic aspirator fragments cells and aspirates the resulting cellular debris and water. This action leaves collagen rich tissues such as blood vessels, nerves, and lymphatic intact. Thus, there is no cutting or coagulation with the ultrasonic aspirator. (25)

In marked contrast, the ultrasonically activated scalpel not only coagulates and cavitates, it also cuts high protein density areas such as collagen or muscle rich tissues. This occurs via the second cutting mechanism ,which is the actual “power cutting” offered by a relatively sharp blade vibrating 55500 times per second over a distance of 80 um. A major advantage of the ultrasonically activated scalpel coagulation ability, is the absence of melting and charring of tissues. This allows the tissue planes to be clearly and sharply visualized at all times. As a result surgeons can be more precise because they can see better than with other energy forms. Ultrasonic surgical dissection allows coagulation and cutting with less instrument traffic (reduction in operating time), less smoke and no electrical current.(25)

In summary, the ultrasonic dissection device is a useful tool in laparoscopic colorectal surgery. Less thermal spread is practically valuable when dissecting significant structures from fatty tissue: e.g., taking down the ureter and gonadal vessels below the inferior mesenteric artery pedicle, and skeletonizing the vascular pedicle during pelvic lymph node dissection. (23)