Laparoscopic Dissection Techniques

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INTRODUCTION

Dissection is defined as the separation of tissues with hemostasis. It consists of a sensory visual and tactile component, an access component involving tissue manipulation, and instrument maneuverability. These are combined to achieve exposure, i.e., developing a suitable space for seeing and handling target structures.

Precision and meticulous hemostasis is essential requirement in minimal access surgery (MAS). Endoscopic dissection, in contrast to dissection in conventional surgery, possesses several limitations. Three-dimensional direct visions are replaced by two-dimensional indirect visions in laparoscopic surgery. Illumination and the video image quality are still limited despite recent advances in video systems such as digitization and three-chip endocamera. Movement of the functional tip of laparoscopic instruments is restricted along with the kinematics response. The loss of tactile sensation in endoscopic surgery is yet another limiting factor.

Endoscopic dissection and manipulation of tissue within a confined space require a two-handed approach, assisting and dissecting both task are performed by surgeon himself. A passive assisting instrument (usually a grasper) provides countertraction and exposure for the active dissecting instrument. The active instrument may be nonenergized (e.g., scissors and scalpel) or energized with electricity (diathermy), ultrasound, or light energy.

TYPES OF LAPAROSCOPIC DISSECTION

A variety of mechanisms have been used to divide tissue and enable hemostasis. They all involve some form of physical energy being applied to the appropriate tissue. The amount of energy required for dissection depends on the type and constituency of the tissue. The properties of tissues may vary in different directions and for different disease states. This in totality influences the choice of the modality for dissection.

The ideal dissection technique requires a modality that can accomplish meticulous hemostasis and will be tissue selective without causing inadvertent tissue damage. It must be safe for both patient and surgical team when in regular use and when inactive in storage. In this respect, built-in safety measures are mandatory. An ideal dissecting modality should be efficient in both power delivery and in space requirement. The modality must be cost-effective also. The initial expenditure needed to acquire and setup the necessary equipment must be taken into account along with subsequent operational and maintenance costs.

In reality, there is no single “ideal” dissecting modality for entire minimal access surgical procedures. In actual practice, a combination of energy forms is applied with selection of the most appropriate one at each particular phase or type of the operation.

The available modalities for dissection in MAS include:
- Blunt dissection
- Sharp scalpel and scissors dissection
- High-frequency radiowave electrosurgery
- Radiofrequency ablation
- Ultrasonic dissection
- High-velocity and high-pressure water-jet dissection
- Laser surgery

Blunt Dissection

Instrument Used

- Closed scissors tips used as blunt dissector
- Scissor points used to separate by spreading the jaw
- Grasper—straight and curved
- Inactive suction cannula
- Heel of inactive electrosurgery (hook or spatula)
- Pledget

Methods

- Distraction
- Separation
- Teasing
- Wiping

Pledget Dissection

Endoscopic pledget dissection was first introduced in the University of Dundee in 1987. A special endoscopic pledget or peanut swab 5.0 mm ratcheted holder, manufactured by Storz (with strong jaws and inward facing tongs at the end of the jaws for security), is used in a manner similar to that employed in open surgery. The holder grasping, the pledget, is introduced inside a reducer tube through an 11.0-mm cannula. The blunt dissection is safe and is used to open planes and expose structures especially when the anatomy is obscured by adhesions. The movement consists of forward and backward wipes accompanied by clockwise/counterclockwise rotation of the pledget swab. It is also useful for controlled small bleeder by compressions before this is secured by clipping or electrocoagulation. The pledget swab is particularly useful for blunt dissection in Calot's triangle during cholecystectomy. It is economical, simple to use, and maintains a dry operative field while performing dissection. This type of dissecting modality is also utilized in hemostatically separating gallbladder from its bed, bladder from the uterus, or the rectum from the sacral attachment **(Fig. 1)**.

Removal of pledget must be carried out under vision to ensure that the swab is inside the reducer tube before withdrawal of the instrument, otherwise there is a real risk of losing the small pledget swab in the peritoneal cavity.

The pledget is an invaluable tool for the rapid dissection of loose areolar planes when it is wiped or pushed against the line of cleavage to separate the tissues.

Pledget is useful in maneuvers to control minor hemorrhage. The pledget can be placed over the bleeding point to apply pressure. When used on an oozing operative field, it adsorbs some of the blood and may clarify the anatomical position.

It is important to follow routine practice to minimize loss of the peanut swab inside the abdomen:

- Always use a reducer tube to insert and remove the swab.
- Employ a safe system (ratchet and elastic band) to maintain the grip of instrument used for insertion.
- Keep the pledget in view from insertion to retraction into the introducer tube. Be sure it is retrieved into the introducer, not the cannular end.

Tissue Stripping and Tissue Distraction

These are other safe and effective forms of blunt dissection. The latter is applied for seromyotomy. Insignificant hemostatic capability is the main disadvantage of blunt dissection **(Fig. 2)**.

Sharp Dissection

Sharp scalpel is used mainly for division by cutting. Although inexpensive, its use is restricted in laparoscopic surgery. The lack of hemostasis, the potential of injury from the tip when inserting through the port, and the kinematics problems restrict its use to common bile duct division.

Scissors Dissection

It is one of the most frequent methods in laparoscopic surgery. It offers the benefits of being cheap, safe, and precise operator determined action. However, being nonhemostasis renders it far from ideal as a dissecting modality **(Fig. 3)**.

Electrosurgical Dissection

Electrosurgery is the most convenient way of dissection in MAS combined with most risky method of dissection. Most of the complication in laparoscopic surgery is due to use of energized instrument (1%) **(Fig. 4)**.

Before understanding the principle of electrosurgery, following definitions should be known:

- *Current*: Flow of electrons
- *Circuit*: Pathway for flow of electrons
- *Voltage*: Force that causes electron to flow
- *Resistance*: Obstacle to the flow of electron.

There are two basic principles of electricity:

1. Electrical current ultimately flows to ground
2. It always follows the path of least resistance.

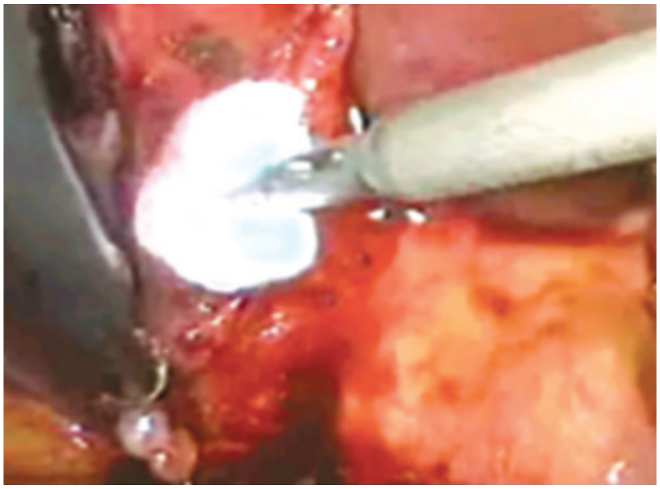


Fig. 1: Pledget dissection.

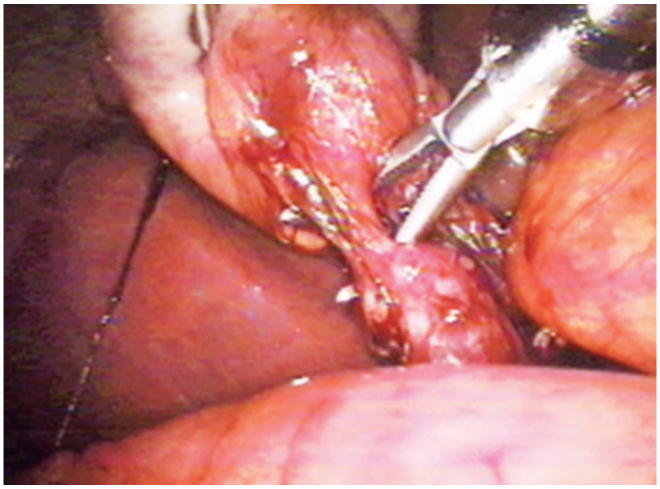


Fig. 2: Tissue stripping and dissection.

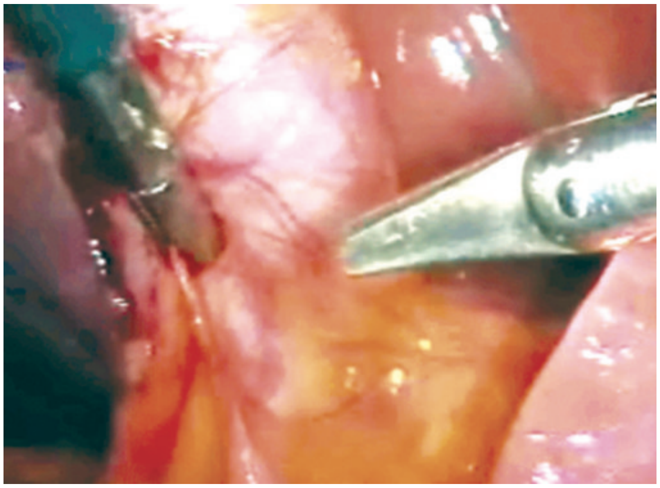


Fig. 3: Scissor dissection.

Fig. 4: High-frequency electrosurgical generator.

High-frequency Electrosurgical Dissection

Our household appliances have the 50–60 Hz frequency. This frequency is beneficial because if faulty instrument has current and inadvertently someone touches, then he will be thrown away and the person getting shock will be safe. If the frequency is >100 kHz, muscle and nerve stimulation ceases whereas all other property of electric current is still there. High-frequency electrosurgery is the application of high-frequency currents (in the frequency range of 300 kHz up to several MHz) to coagulate, fulgurate, spray coagulates, or ablates tissue. Knowledge of how this and other physical modes interact with biological materials is becoming increasingly important to the surgeon for safe and consistent surgery **(Fig. 5)**.

- Standard electrical current alternates at a frequency of 50 cycles per second (Hz)
- Nerve and muscle stimulation ceases at 100,000 cycles per second (100 kHz)
- Electrosurgery can be performed safely at frequencies above 100 kHz.

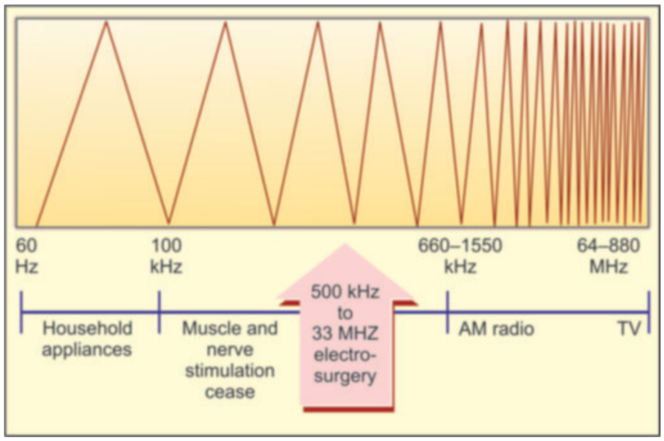


Fig. 5: Frequency range of electrosurgery.

High-frequency Monopolar Electrosurgery

The monopolar circuit is composed of the generator, active electrode, patient, and patient return electrode. The patient's tissue provides the resistance, producing heat **(Fig. 6)**.

Monopolar diathermy is used in endoscopic surgery for coagulation and for dissection (cutting). During monopolar diathermy, current is conducted from the instrument through the tissues to a skin pad (neutral electrode) connected back to the generator. Heating occurs at site of small cross-section and low electrical conductivity. A high current density occurs in the tissue in immediate contact with the instrument and heat is generated.

$$\text{Burn} = \text{Intensity of current} \times \text{Time/area}$$

Burn is directly proportional to the intensity of current. Intensity of current can be adjusted by the knob provided in the generator's control panel. If the intensity setting is more, the burn will be more. Intensity actually denotes ampere or number of electrons that flows through the pathway.

Burn is also directly proportional to time. Time is paddle application time. Surgeon should always keep in mind that continuous activation of paddle can result in many complications. Intermittent activation is always better than continuous activation **(Figs. 7 and 8)**.

Burn is inversely proportional to area. One of the major problem in electrosurgery is patient will get burn at the site where area is narrowest. This may cause remote injury with the use of monopolar diathermy. The surgeon should hold the tissue with the point of instrument to catch the minimum amount of tissue at one time. If a bunch of tissue is caught, there is always fear of remote injury.

Patient return electrodes: Silicon and metal patient return plates are available. The silicon is better because it does not have any sharp edge and the resistance is less **(Fig. 9)**. Patient return electrode is required only in unipolar electrosurgery because the patient's body is a part of circuit and the patient return plate will take the current back to the generator. If the patient return plate is not attached properly

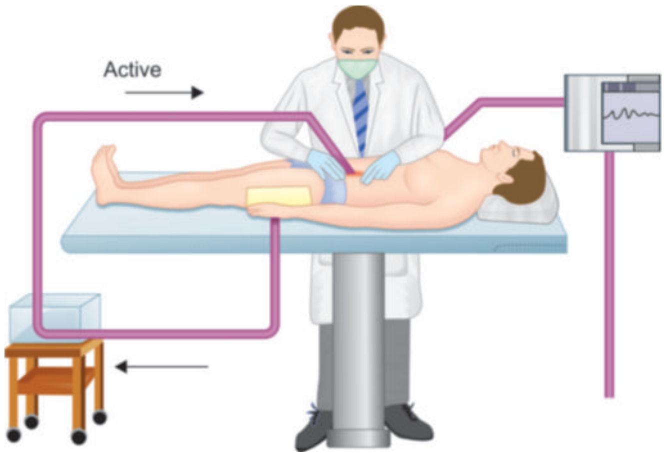


Fig. 6: Circuit of monopolar current.

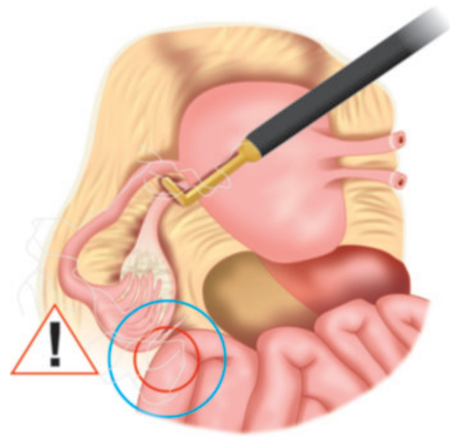


Fig. 7: Remote injury.

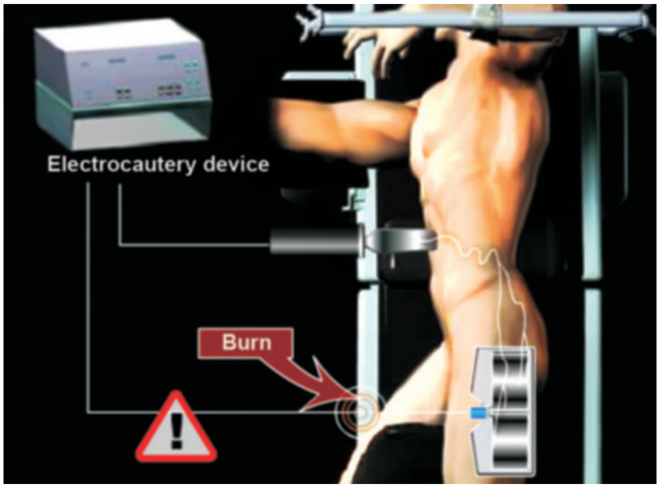


Fig. 8: Remote injury with electrocautery device.

Fig. 9: High-quality patient return plate.

to the body of the patient or the size of the patient return plate is very small, patient can get electric burn at the point of attachment of this patient return plate. Ideally, the size of patient return plate should not be <100 cm^2.

At the time of location of patient return plate attachment, surgeon should keep in mind the following points **(Fig. 10)**:

- *Choose*: Well-vascularized muscle mass to have more area of contact.
- *Avoid*:
  - Vascular insufficiency should be avoided because of high resistance
  - Irregular body contours can prevent plate to be in firm contact
  - Bony prominences will not allow the surrounding skin to be in contact.
- *Consider*:
  - Plate should be nearer to incision site
  - Plate should be placed according to patient's position, so it should not be displaced
  - Plate should be away from other equipment such as cardiac monitor.

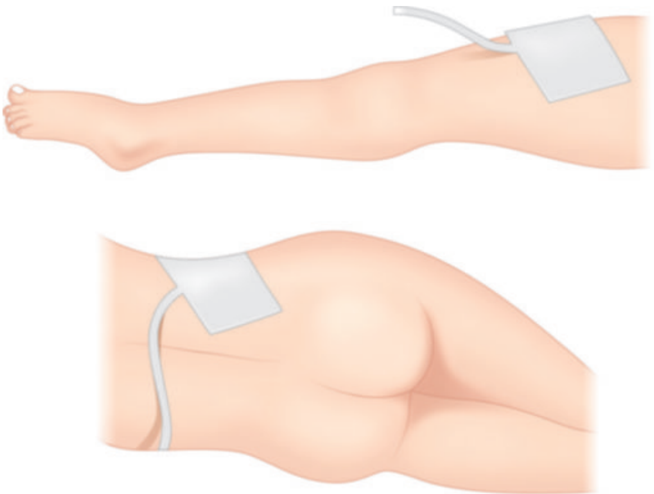


Fig. 10: Patient return plate.

The effect of high-frequency current on the tissues depends on:

- Temperature generated
- Shape and dimensions of the contact point (broader damage with broader contact)

- Time of activation (short bursts reduce depth and charring)
- Distance from the electrode **(Fig. 11)**
- Conductivity of the tissue (bleeding results in a change in conductivity)
- Power output from the generator (voltage)
- Amplitude and current wave form time curve of the signal (cutting or coagulating settings).

Bipolar Diathermy

A bipolar system is inherently safer as the interaction is restricted to the immediate vicinity of contact and the current does not pass through the patient, but instead returns to the generator via the receiving pole after passage through the grasped tissue **(Fig. 12)**.

Bipolar Electrosurgery

- Active output and patient return functions both are at the site of surgery
- Current path is confined to tissue grasped between forceps **(Fig. 13)**
- Return electrode should not be applied for bipolar procedures.

Tripolar Electrosurgery

Bipolar probes are now available for coagulation as well as for cutting. The cutting system is not strictly bipolar and is hence referred to as tripolar **(Fig. 14)**.

It has four functions in one and the same instrument namely:
1. Dissecting
2. Grasping
3. Bipolar coagulation
4. Bipolar cut

Use of the Diathermy Hook

These are generally L-shaped or open C-shaped, blunt ended rods mounted on an insulated handle. The active, noninsulated part is limited in size. The hook is a delicate

Fig. 11: Effect of cutting current.

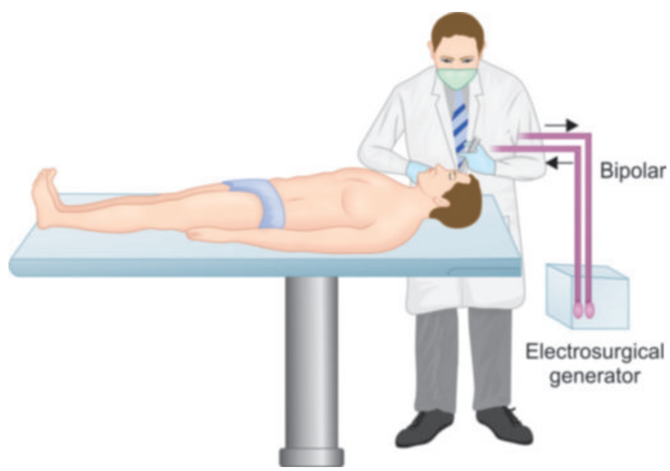


Fig. 12: Circuit of bipolar current.

Fig. 13: Bipolar forceps used in laparoscopically-assisted vaginal hysterectomy (LAVH).

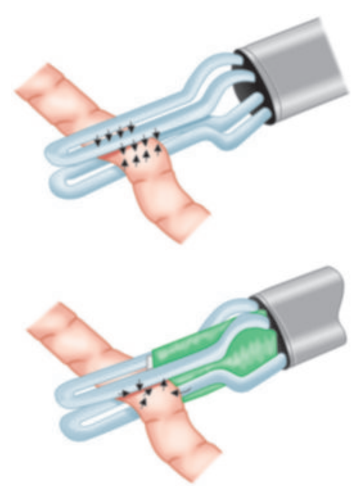


Fig. 14: Tripolar device.

instrument and should be protected during insertion by manual opening of the cannula valve or use of a reducing tube. As electrosurgery generates smoke (which is harmful), many handles of electrosurgical hooks have a suction attachment at the other end of the handle.

Electrosurgical Hooks (Fig. 15)

Electrosurgical instruments such as the hook are useful as blunt dissectors prior to activation. They are used to isolate the tissue to be divided by the current. The tip is passed into or under a layer of the tissue being dissected, which is then hooked and tented up (to increase its impedance and thus limit the spread of current when applied). Small portions of tissue are tackled, so that an assessment of the tissue caught on the hook can be made before coagulation or cutting current is applied to the instrument. The hook can be used to clear unwanted tissue beside linear structures by passing the hook into the tissues parallel to the structure and then rotating it to hook up strands of unwanted tissue. The tissue to be divided is held away from underlying tissue to prevent inadvertent damage. Short bursts of coagulating current can be followed by the use of cutting current, if the tissue has not already separated. The use of the hook can be summarized as “hook, look, and cook”.

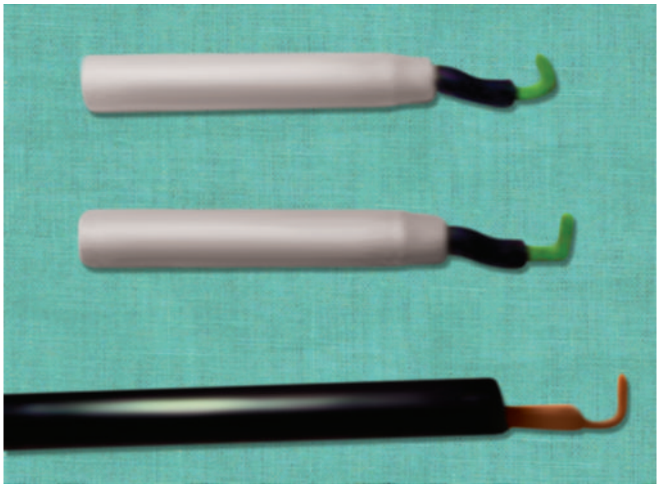


Fig. 15: Different types of hook.

The hook or the spatula may be used to mark out and coagulate a line for division. The heel of the hook is used with the high-frequency current set to soft coagulation. Short bursts are applied and the hook moved along to create a “dotted” line of coagulated tissue. When deeper penetration is desired, the hook is appropriate instrument. This type of contact is best reserved for situation where no significant damage can be caused by current penetration **(Fig. 16)**.

Monopolar electrosurgery has become the most widely used cutting and coagulating technique in MAS. It has proven to be versatile, cost-effective, and demonstrated superior efficacy for coagulation. By varying the voltage, current, or waveform, tissue can be cut cleanly (pure cut); coagulated to achieve hemostasis (coag mode) or a “blend cut” that combines these two functions can also be produced. Finally, a dispersed coagulation mode known as fulguration allows coagulation of diffuse bleeding **(Fig. 17)**.

Cutting current is low-voltage high-frequency current. Due to high frequency, the ions inside the cell get turbulence and cells brust (explode or evaporize). Cutting current can be obtained by pressing the yellow paddle of electrosurgical generator. To cut any structure, it is important that surgeon should apply the sharp tip of electrosurgical instrument and the tissue should not be held firmly. At the time of cutting, it is wise that tissue should be under tension. Ideally, direct touch with the tissue should be avoided in case of cutting current. It should be spark wave from some distance **(Fig. 18)**.

Electrosurgical coagulation is achieved by high-voltage low-frequency current. This low frequency is not sufficient to cause the explosion of cell, but heat inside the cell is increased.

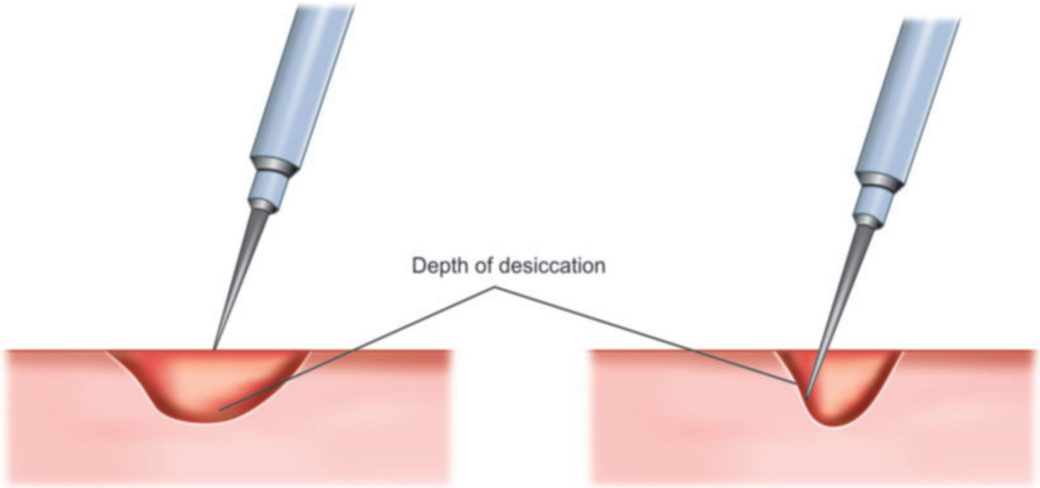


Fig. 16: Depth of desiccation is proportional to paddle application time.

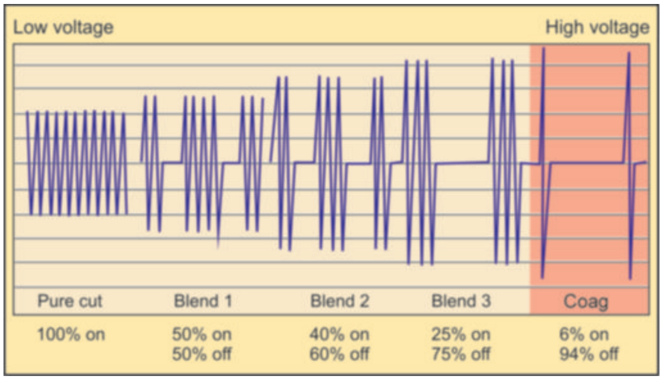


Fig. 17: Different types of electrosurgery.

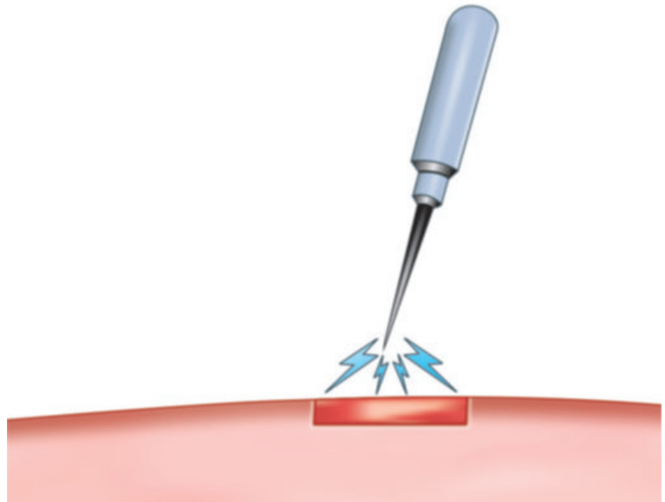


Fig. 18: Fulguration.

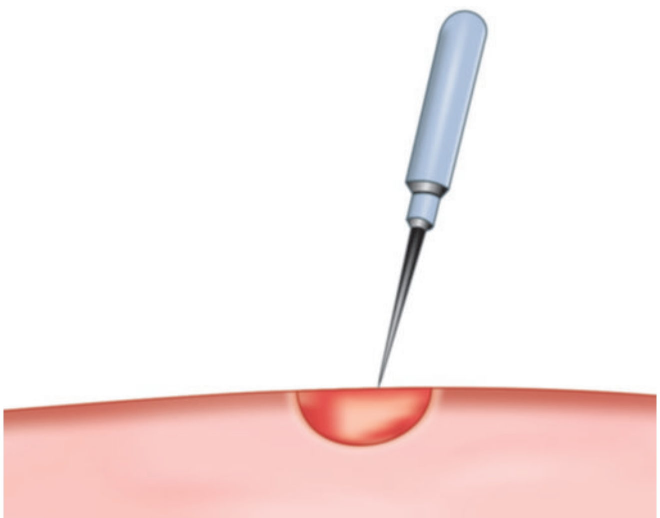


Fig. 19: Desiccation with more collateral damage.

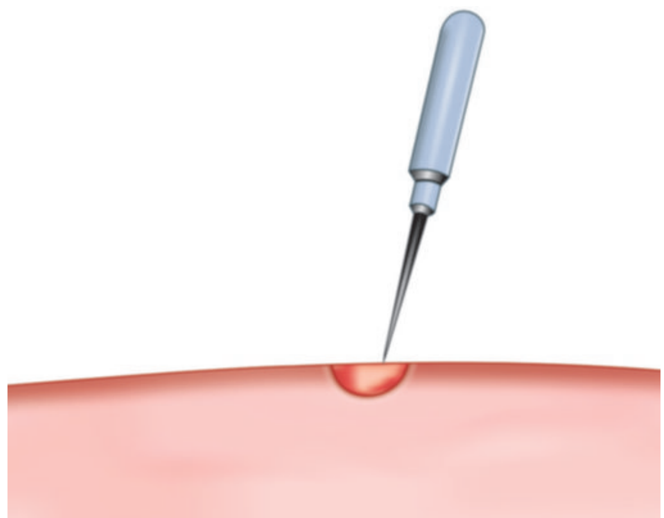


Fig. 20: Desiccation with less collateral damage.

Due to increased intracellular temperature, the protein inside the cell coagulates and shrinks. Shrinkage of protein will cause constriction in the lumen of bleeding vessels and the vessels are sealed. Permanency of coagulated tissue and its sealing effect depends upon melted collagen. At the time of electrosurgical monopolar coagulation, the temperature of tissue causes the collagen to melt. These melted collagens solidify again once the active instrument is off from the tissue. It is important to remember that if the tissue is burnt more than required, the melted collagen burns, turns into charcoal, and the sealing strength of the lumen of any vessel will decrease. Surgeons and gynecologists should always try to avoid overcooking of the tissue.

Electrosurgical coagulation is of two types:

1. *Fulguration*: Fulguration is coagulation current from some distance **(Fig. 18)**. It is also known as spray mode. At the time of fulguration, lateral spread of energy is more than depth. We want to use fulguration everywhere, where superficial burn is required and deeper injury may cause damage of underlying structure. The example of good use fulguration is ablation in cases of endometriosis and fulguration of gallbladder bed at the time of cholecystectomy, if there is generalized oozing from liver. Direct touch with tissue should be avoided to achieve maximum effect. Fulguration is coagulation current from some distance.
2. *Desiccation*: Electrosurgical desiccation occurs when the electrode is in direct contact with the tissue. Most of the time with the unipolar or bipolar electrosurgery, we do desiccation only. The tissue damage in depth and width is same in desiccation. The extent of collateral damage in desiccation is more compared to cutting current. The extent of collateral damage of desiccation can be minimized by minimizing the paddle application time **(Figs. 19 and 20)**.

However, monopolar laparoscopic electrosurgery can compromise patient safety under certain circumstances. Thermal injury to nontargeted internal organs may occur firstly, as a result of imprecise mechanical operation of a laparoscopic instrument and secondly, through diversion of electrical current to other paths. These stray current may be released either through insulation failure, direct coupling, or capacitive coupling. Other problems encountered include effect on pacemakers, return electrode burns, toxic smoke, charring of instruments, and minimal control of energy delivery **(Fig. 21)**.

Bipolar electrodes design although virtually eliminating complication from insulation failure, capacitive coupling, and direct coupling **(Figs. 22 to 24)**.

The primary electrothermal tissue effect is limited to desiccation, not cutting. It requires slightly more time than monopolar coagulation because of lower power settings and bipolar generator output characteristics. It is not an effective method of making a "pure cut".

Fig. 21: Overshooting should be avoided.

- Hemostasis over a large area is not possible
- Grasping dense tissue between both the active and return electrodes is difficult.

Safety during Electrosurgery

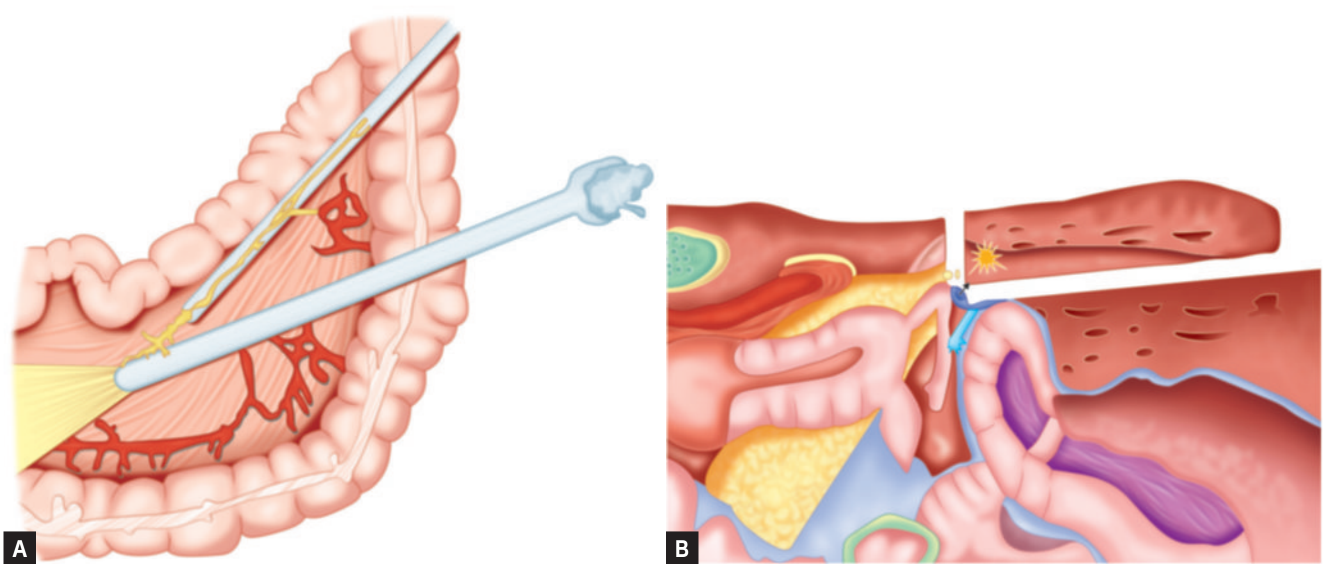
Laparoscopic dissection requires more extensive dissection and thus meticulous hemostasis becomes particularly important. Any loss of view will result in loss of control and hence decreased safety. Hemorrhage, even to a minor extent, tends to obscure their operative field and is to be avoided. This means that vessels of a size that in open surgery could be divided without particular attention need to be secured prior to division when working endoscopically. Dissection must be more meticulous to proceed smoothly to avoid any unacknowledged injury.

The magnification produced by the endoscope may initially confuse the surgeon as to the extent of electrical injury. However, an inexperienced endoscopic surgeon is well-advised to convert if he have any doubt about his ability to control the situation expeditiously.

Safety Considerations in Minimal Access Surgery

The potential for accidental damage with electrosurgery must always be borne in mind at the time of MAS. Following are the most commonly encountered problems specific to the MAS:

- Overshooting
- Overcooking
- Direct coupling
- Capacitive coupling
- Insulation failure



Figs. 22A and B: Direct coupling.

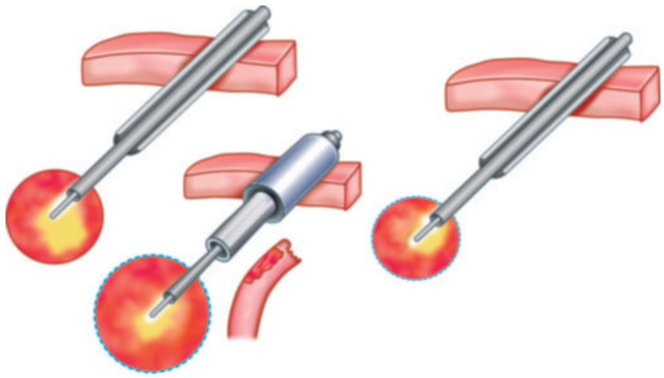


Fig. 23: Capacitive coupling.

Overshooting: Overshooting means the tip of energized instrument going beyond the field of vision during electrosurgery. Overshooting is one of the common mistakes done by beginners. Surgeon should be careful that if they are cutting any structure they should apply less force, otherwise their instrument will overshoot once the structure is cut and the energized instrument can heat any nearby viscera leading to perforation.

During initial learning phase of laparoscopy, the trainer surgeon should keep hold on the hand of trainee at the time of electrosurgery to prevent any inadvertent injury by overshooting. At the time of laparoscopic cholecystectomy, if hook overshoots, it may hit diaphragm or duodenum. If overshooting is not under the control of surgeon, he should try to keep the tip of hook toward the anterior abdominal wall, so that only peritoneum will be injured.

Overcooking: Proper hemostasis requires optimum application of energy over the tissue. Due to visual limitations and fear of impending bleeding, laparoscopic surgeons have a tendency of overcooking. It is important to remember that instead of more secure coagulation overcooking can create rebleeding. To understand the effect of overcooking, it is important to know physiology of tissue sealing.

Coagulation current is high-voltage low-frequency current. At this current, the ions inside the cell will move but it cannot explode. Due to increase in intracellular heat, the protein inside the cell will be denatured, coagulated, and shrink. Due to shrinkage of tissue, the lumen of small bleeder obliterates and bleeding stops. At the same time due to heat, the collagen of tissue melts and once the paddle of electrosurgical generator is off, the melted collagen will cool down and solidify.

Overcooking results in charring of melted collagen and the sealing strength of tissue is decreased. It could be understood just by the example of sealing of polythene over a flame of candle. If you want to seal the polythene bag but applying more temperature on polythene by putting it over direct flame, instead of getting sealed, the polythene will start burning. One should know the sealing temperature of polythene so that required temperature is applied, the polythene will melt and once cooled will solidify. Similarly, the burnt collagen does not have any tissue sealing property and bleeding may start again if it is overcooked.

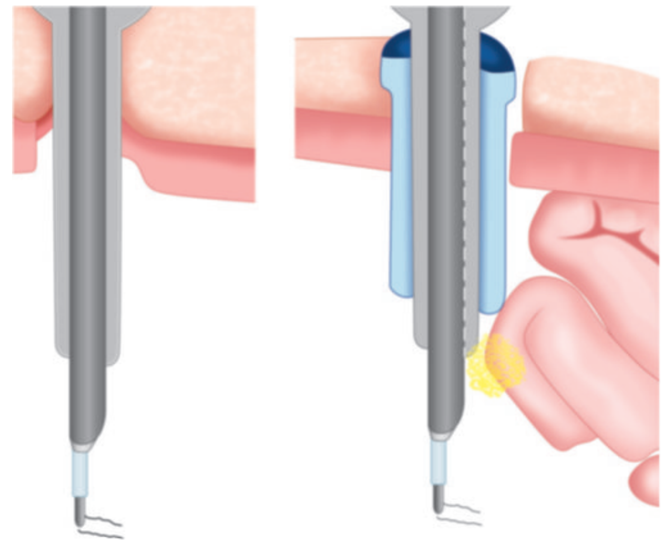


Fig. 24: Burn due to capacitive coupling.

Most common causes of overcooking or charring of tissue are:

- High power setting of electrosurgical generator
- Prolonged activation of foot paddle
- Keeping the jaw closed permanently in contact of tissue
- Poorly engineered electrosurgical generator.

Direct coupling: If the active electrode touches a noninsulated metal instrument within the abdomen, it will convey energy to the second instrument, which may in turn, if the current density is high enough, transfer it to surrounding tissues and cause a thermal burn. For example, the active electrode could come in contact or in close proximity (<2 mm) to a laparoscope, creating an arc of current between the two. The laparoscope could then brush against surrounding tissue, causing a severe burn to the bowel and other structures. The burns may not be in the visual field of the surgeon and therefore will not be recognized and dealt with in a timely fashion.

To prevent direct coupling, the active electrode should not be in close proximity to or touching another metal instrument before the generator is activated. Bowel is particularly susceptible to this kind of collateral damage from sparks and stray currents. Recognition of this complication may be delayed until the postoperative period with serious consequences. Check that the electrode is touching the target tissue, and only that tissue, before you activate the generator. Note that when target tissue is coagulated (desiccated), the impedance increases and the current may arc to adjacent tissue, following the path of least resistance.

We should be careful that all metal instruments such as laparoscopes pass through conductive metal trocars. This way, if the active electrode touches the instrument, the current will simply flow from the instrument to the metal trocar. As long as the trocar is in contact with a relatively large portion of the abdominal wall, the current will not concentrate. Instead, it will dissipate harmlessly from the trocar through the abdomen and back through adjacent tissue to the return electrode. If the trocar is completely or partially constructed of plastic, however, the energy may not be able to dissipate back through the body. The metal within the trocar will build up a charge, which could eventually arc to adjacent tissue and back to the return electrode, but at a harmful level of current. In doing so, it may travel through the bowel, skin, or even the operator's hands, causing burns **(Fig. 23)**.

To avoid direct coupling, surgeon should not activate the generator while the active electrode is touching or in close proximity to another metal object.

Capacitive coupling: This now never arise but occurred in the early days of laparoscopic surgery with the use of plastic fixation screws to fix metal ports to the abdominal wall, so as to prevent them from being accidentally pulled out or pushed when instruments were withdrawn during the course of an operation.

The physics underlying this injury is fairly straightforward. Whenever current is applied through an insulated instrument inserted through a metal trocar (port), some radiofrequency electric charge is transferred to the metal cannula by every activation (even if the insulation of the instrument is perfect). This effect is known as capacitance coupling.

There is absolutely no problem if the metal cannula is in contact with the full thickness of the abdominal wall, as the charge accumulated by the cannula is immediately discharged over a wide contact area (low power density like the neutral return electrode plate) and hence no damage is done.

However, if the cannula is isolated from the abdominal wall, by a plastic screw (acting as an insulator), the cannula cannot discharge and thus accumulates a substantial charge with repeated activation of the electrosurgical instrument. Thus, in essence, it becomes an electric accumulator. Should at any stage, the tip of the cannula inside the abdomen touches tissue or bowel, the accumulated charge will discharge immediately through a single point of contact, i.e., with a high power density sufficient to cause an electrical burn. Since this occurs away from the site of action of the operation, it is usually overlooked. Capacitive coupling is not a problem if plastic fixation screws are not used.

The phenomenon of "capacitance" is the ability of two conductors to transmit electrical flow even if they are separated by an intact layer of insulation. Capacitive coupling can occur even in the best-case scenario, i.e., when the insulation around the active electrode is intact and the tip of the electrode is not touching anything metal. If the active, insulated electrode is wrapped around a towel clamp, or placed inside a metal trocar sleeve, or comes in close contact with any conductive substance for an extended period of time, the current in the active electrode may induce a current in the second conductor.

As long as the induced current can dissipate easily, through a large surface of tissue, it would not present a problem. The danger occurs if the second conductor contains some insulating material, as in the case of a metal cannula held in place by a plastic anchor. The plastic anchor will prevent the energy from dissipating and increase the likelihood of a thermal burn. Burns from capacitance current may occur when the surface area is <3 cm^2 or the current density is approximately 7 W/cm^2.

As with direct coupling, the best way to prevent this phenomenon is to use the active electrode monitoring system that prevents current from capacitive coupling from building to dangerous levels. Also, you should avoid all plastic-metal hybrid instruments, including cannulas, trocars, and clamps, when doing electrosurgery.

Insulation failure: During a laparoendoscopic procedure, only about 10% of an insulated instrument is visible on the video monitor at any one time, which means about 90% of that electrode remains outside the surgeon's field of view, where it can cause the most damage. Whenever a defective instrument is introduced into the patient, electric current can escape to contiguous tissue or organs, but the surgeon is not aware that a thermal burn at a peripheral site has occurred. It is estimated that 67% of such injuries are not recognized at the time of surgery. Sadly, manifestations of these unsuspected injuries do not appear until several days after the actual surgery and so, when the impaired patient presents, his or her clinical symptoms are already severe. Diagnosis is difficult and often delayed and the damage can be irreversible. Complications include perforated bowel diaphragm, urinary bladder, permanent disfigurement, fecal peritonitis cases, etc. **(Fig. 25)**.

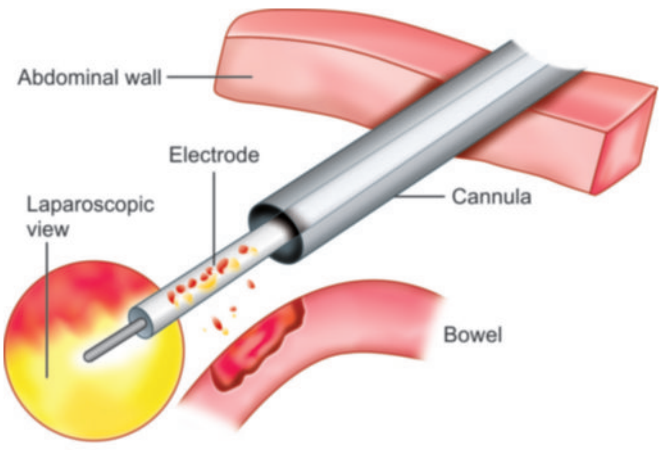


Fig. 25: Insulation failure.

Continued regular use of cleaning and sterilization can cause the layer of insulation covering the shaft of the active electrode to break down. Tiny, visually undetectable tears are actually more dangerous than large cracks, since the current escaping from these miniscule breaks is more concentrated and therefore capable of causing sparks (averaging 700°C). These sparks can cause severe burns and even ignite fires, especially in oxygen-rich environments. In fact, all insulated electrodes should be considered suspicious, unless adequate safety measures are introduced.

Unfortunately, many surgeons unknowingly contribute to the problem. Routine use of the high-voltage "coagulation" current may actually compromise insulation integrity. The higher the voltage, the greater the risk that the current will break through weak insulation.

Surgeon should always use the lowest voltage. All electrosurgery systems will allow to use a "coagulation" or "cutting" waveform of current.

In most cases, we should try to use the cutting current for both cutting and coagulation. The coagulation mode is necessary only when you need to fulgurate or stop diffuse bleeding on highly vascularized tissue. Using the lowest voltage, it may reduce the wear on the insulation and minimize the chance that the current can escape through hairline cracks.

The surgeon should test for insulation defects in the operating room, after the set has been opened. This step can significantly reduce the number of accidental electrosurgical burns because it will prevent a surgeon from inserting a potentially lethal instrument into the patient's abdomen. Insulation that degraded during that final sterilization cycle cannot be detected until this point in time, so it is critical that inspection in the operating room itself be made an integral part of hospital protocol. It is advisable to keep a supply of single-use electrodes available to replace any found to be faulty during the preoperative scan. One can also devise a vigorous and ongoing inspection plan with a qualified technician to ensure that all reusable electrosurgical tools are scanned and reinsulated as needed.

If the instruments are rescanned in the operating room following surgery, the surgeon can be secure in the knowledge that no stray electrical current escaped into adjacent, but unseen sites and so if any postoperative clinical complications were to arise, he or she could more easily isolate the cause. Conversely, if the postoperative scan revealed that insulation was damaged during the procedure, he or she may elect to take aggressive steps to investigate further. For documentation purposes, the results of both scans can be recorded in the patient record.

We should always keep in mind that using the cutting current minimizes, but does not eliminate the risk of insulation failure. To really be sure that the insulation is not compromised, it is recommended to use an electrosurgical unit that employs active electrode monitoring (AEM) technology. This technology is called "ElectroShield" (Electroscope, Inc., Boulder, Colorado) and it virtually eliminates these types of electrical burns.

The traditional system for inspection in the sterile processing department is hardly foolproof and its weaknesses must be addressed. Because the margin for error is so great, risk managers and physicians alike are insisting on alternatives that will ensure patient safety and reduce liability exposure. AEM protects against thermal burns in two ways. First, it encases the insulated electrode in a protective metal shield that is connected to the generator; the entire probe is also covered with an extra layer of insulation. The extra conductive and insulating layers ensure that stray current is contained and flows right back to the generator. Second, the system monitors the electrical circuit so if stray energy reaches dangerous levels, the unit shuts off automatically and sounds an alarm before a burn can occur. Electroscope's AEM system operates on a principle similar to ground fault interrupter (GFI) outlets in our home. It protects against insulation breaks by grounding electricity in unpredictable elements, eliminating stray burns to the patient. This is presently considered the standard of care in endoscopic electrosurgery.

Surgical Smoke

Dissection with electrocautery produces a great deal of smoke. Carbon monoxide at levels as high as 1,900 ppm, many times higher than the Environmental Protection Agency Standard of 35 ppm for a 1-hour exposure, are produced by electrocautery in the hypoxic environment of the carbon dioxide-filled abdomen. Fortunately, carbon monoxide is a very insoluble molecule and does not cross the peritoneum. Carbon monoxide absorption is therefore not a problem for patients undergoing laparoscopy. However, contamination by carbon monoxide and other toxic or infectious byproducts of electrocautery may affect the operating room personnel if the smoke is vented into the room.

When an electrosurgical probe heats tissue and vaporizes cellular fluid, one byproduct is surgical smoke. We know that these fumes, which can contain viral deoxyribonucleic acid (DNA), bacteria, carcinogens, and irritants, are malodorous and can cause upper respiratory irritation. We do not yet know whether they are capable of causing cancer or spreading infectious disease. Surgical smoke can also obscure the operative site and causes the surgeon to inadvertently touch the electrode to nontargeted tissue.

Surgical masks do not adequately filter surgical smoke, the particles are too small. A much better solution is a smoke evacuation system, a high-flow suction, and filtering device that remove the particles from the air. Two kinds are available commercially. One uses a handheld nozzle, which is intended to be positioned at the surgical site.

To avoid complication of laparoscopic electrosurgery, following important points are:

- Inspect insulation carefully
- Use lowest possible power setting
- Use a low voltage waveform (cut)
- Use brief intermittent activation versus prolonged activation
- Do not activate in open circuit
- Do not activate in close proximity or direct contact with another instrument
- Use bipolar electrosurgery when appropriate
- Select an all metal cannula system as the safest choice. Do not use hybrid cannula systems that mix metal with plastic
- Utilize available technology, such as a tissue response generator to reduce capacitive coupling or an active electrode monitoring system, to eliminate concerns about insulation failure and capacitive coupling.

Argon Beamer Coagulator

The argon beamer is used in conjunction with monopolar electrosurgery to produce fulguration or superficial coagulation **(Fig. 26)**. Less smoke is produced because there is lesser depth of tissue damage. The system emits a high-energy jet of argon plasma possessing thermal and kinetic energy that can be used to coagulate a tissue surface including small vessels and lymphatics. Since its introduction, plasma jet has been used safely in both open and endoscopic cases in orthopedics, oncology, gastroenterology, liver surgery, plastic surgery of the abdomen and face, and in thoracic surgery.

Neutral argon plasma can be utilized as a multi-functional device that has vaporization, coagulation, and superficial cutting capacities with minimal thermal spread and acceptable outcomes. The use of neutral argon plasma appears to be efficacious and safe for laparoscopic surgery such as endometriosis, presacral neurectomy, liver resection, myoma bed bleeding control, etc.

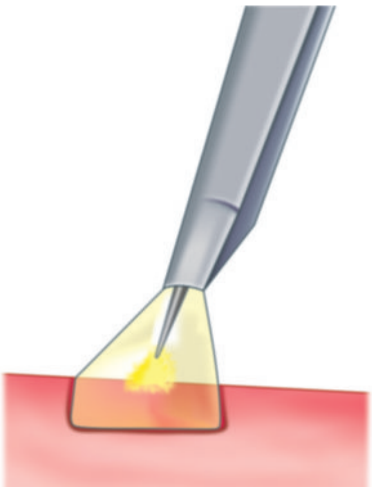


Fig. 26: Argon electrosurgery.

Despite these advantages, the argon beamer suffers from a very significant drawback in laparoscopic surgery, namely increased intra-abdominal pressure to potentially dangerous levels due to high-flow infusion of argon gas.

Ultrasonic Dissection

Ultrasonic dissectors are of two types: (1) low-power systems which cleave water containing tissues by cavitations leaving organized structures with low water content intact, e.g., blood vessels, bile ducts, etc., and (2) high-power systems which cleave loose areolar tissues by frictional heating and thus cut and coagulate the edges at the same time. Thus, low-power systems are used for liver surgery (CUSA, Selector) and do not coagulate vessels. High-power systems (Autosonix, Ultracision) are used extensively especially in fundoplication and laparoscopic colon surgery. It is important to remember that high-power ultrasonic dissection systems may cause collateral damage by excessive heating and this is well-documented in clinical practice.

Ultrasonic surgical dissection allows coagulation and cutting with less instrument traffic (reduction in operating time), less smoke, and no electrical current.

- Mechanical energy at 55,500 vibrations/s
- Disrupts hydrogen bonds and forms a coagulum
- Temperature by harmonic scalpel (80–100°C)
- Temperature through electrocoagulation (200–300°C)
- Less collateral damage, less tissue necrosis.

The ultrasonic shears (harmonic scalpel) is ideal for dividing and simultaneously sealing small and medium vessels by tamponade and heat. However, larger vessels, >2 mm in diameter, need additional measures (clips, tie, or staple) to control bleeding. Other disadvantages of the harmonic scalpel include lack of tissue selectivity and relatively expensive. Ultrasonic dissecting applicators are also designed in hook, spatula, or ball coagulator shapes **(Figs. 27A and B)**.

The cavitational ultrasonic aspirator has the advantage of removing debris and is tissue selective, e.g., divides liver but spares bile ducts and vessels. It affords safe rapid dissection with reduction in tissue damage and blood loss compared to the harmonic scalpel. The problems associated with its use are evacuation of the pneumoperitoneum together with vibration and irrigation which cloud the telescope lens necessitating frequent cleaning **(Fig. 28A)**.

It is not correct that ultrasonic generators are without any risk. If bowel or blood vessels touch directly to the vibrating jaw, it can be punctured.

High-velocity Water-jet Dissection

High-velocity high-pressure water-jet dissection involves the use of relatively simple devices to produce clean cutting of

Figs. 27A and B: Ultrasonic generator.

reproducible depth. Other advantages are the cleansing of the operating field by the turbulent flow zone and the small amount of water required to complete dissection.

Specific problems were identified with the use of this modality. The "hailstorm" effect results in excessive misting which obscures vision. This has been solved to some extent by incorporating a hood over the nozzle. The nonhemostatic nature of this modality, difficulty in gauging distance, and poor control of the depth of the cut are additional drawbacks. The spraying of tissue fragments renders it also oncologically unsound. The present use of water-jet dissection is limited to dissection of solid organs.

Hydrodissection

Hydrodissection uses the force of pulsatile irrigation with crystalloid solutions to separate tissue planes **(Fig. 28B)**. The operating field at the same time is kept clear. Like water-jet dissection, no hemostasis is achievable. The use of this dissecting modality is restricted to pelvic lymphadenectomy and pleurectomy in thoracoscopic surgery. Today, the hydrodissection technique is frequently used with success in cataract, urologic, and plastic surgery. Hydrodissection is also used in laparoscopic surgery as an adjunct to electrocauterization to facilitate the dissection of fascial planes. The mechanical benefits of hydrodissection infiltrates the serosal layers with saline, it both creates and reveals the correct plane between adherent tissues and subsequently makes separation easier.

Hydrodissection is a safe technique that can be applied as an adjunct to electrocauterization, which facilitates dissection in the correct plane during many laparoscopic surgeries such as cholecystectomy, hernia, colectomy, and endometriosis surgery. Although hydrodissection does not have additional benefits in terms of dissection time, postoperative outcome, or overall survival, it can be useful for inexperienced surgeons, especially for those in the learning phase. Hydro-Surg□ Plus Irrigator is designed to provide controlled powered irrigation to, and aspiration of fluids/smoke from, the operative site during laparoscopic surgical procedures (e.g., laparoscopic cholecystectomy and laparoscopic gynecological procedures). It may also be used for resection of filmy adhesions by hydrodissection and peritoneal lavage. Appropriate fluids include those which have a specific gravity of approximately 1 (e.g., saline). Additional specialty probe tips are available from Davol including insulated and nonconductive tips for use with electrosurgery. Suction/irrigation probe tips, when included, have a nonreflective surface to help avoid laser beam reflection. With proper adapter, a laser fiber and laser fiber sheath can be passed through the probe handle and tip.

Laser Dissection

The laser devices release photons which induce molecular vibration and create heat when they interact with the tissue and create heat. LASER is an acronym for "light amplification by stimulated emission of radiation" **(Fig. 28C)**. Each lasing substance has a unique atomic and molecular structure and so the waveform and frequency. Laser light is monochromatic and cannot be separated into colors when passed through prism. The amount of power delivered by laser is measured in Watts. The basic components in a laser unit are a pumping system, lasing medium, optical cavity, and operating system. The operating system controls delivery of laser into tissue when activated by surgeon. The surgeon controls power control knob. There are many modes of power delivery such as continuous, pulse, superpulse, and ultrapulse modes.

The primary difference from other source of energy is that generally tissue is not directly touched by surgical instrument. Thus, the depth of incision is not controlled by pressure exerted on the tissue but by the power density delivered by surgeon. The unique property of laser is determined by its wavelength and tissue absorption. By changing the power setting, desired tissue effect such as ablation, fulguration, coagulation, or vaporization can be achieved. These days laser is not used frequently in general laparoscopic surgery as they offer no advantages over more user friendly and safer forms of energized dissection and coagulation systems.

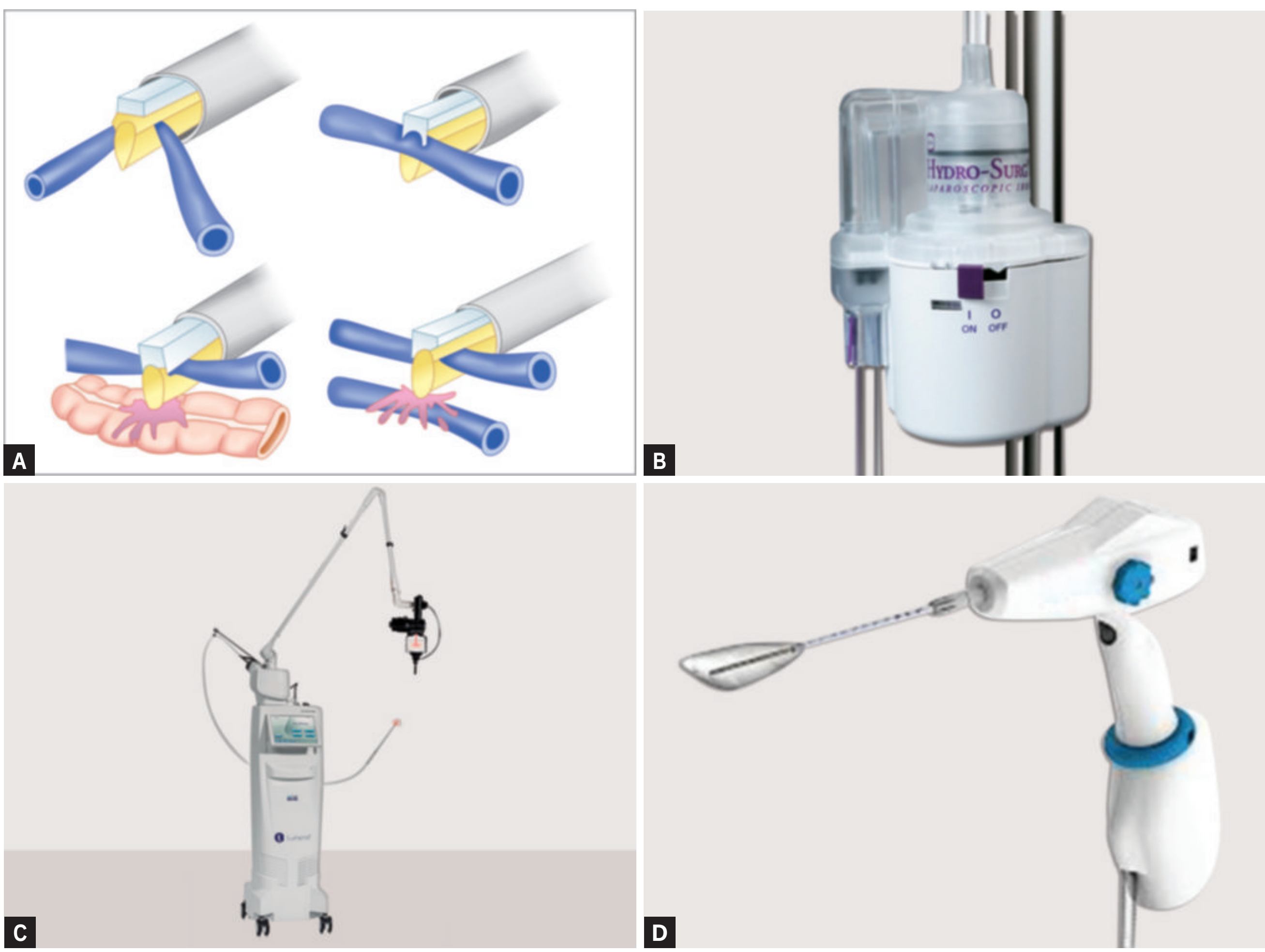
The previous generation of lasers (with gas vapor chambers) was large, very expensive, and required special power supply (three-phase electricity) and maintenance. In addition, they lacked portability. The current generation of solid-state lasers diode array has overcome all these disadvantages and may well be used for certain applications of laparoscopic general surgery in the future. Currently, laser ablation is used largely in gynecological laparoscopic surgery, e.g., ablation of endometriosis and much less commonly for the photoablation of secondary tumors of the liver. The most effective use of carbon dioxide (CO_2) laser beam is laser knife that gives high precision for dissection over sensitive areas such as bladder, ureter, and major blood vessels.

The degree and extent of thermal damage produced by laser depends on the structure, water content, pigmentation, optical and thermal properties, and perfusion of the tissue. The properties of a particular laser beam are also other determinants of heat damage. Therefore, each of the various types of laser available have a specific clinical application.

In gynecology, the argon laser coagulator is the ideal method of treating small red endometriotic deposits. Tissue absorption of light is low and hemoglobin absorption is high at its operating wavelengths of 488 nm and 514 nm, i.e., selective absorption.

The CO_2 laser is best suited for extremely superficial ablation. It is relatively inexpensive (compared to other lasers) and has the ability to vaporize a very thin surface of tissue. On the other hand, photocoagulation of vascular lesions is ineffective using CO_2 laser. This type of laser also has the potential for injuring structures in the abdomen distant from the site under laparoscopic view.

The contact neodymium-doped yttrium aluminum garnet (Nd:YAG) laser virtually eliminates the free beam effect and is therefore suitable for laparoscopic application. The thermal injury from contact laser is superficial. No additional protection is needed for the endocamera since they are already fitted with infrared filters. However, Nd:YAG laser dissection was found to be significantly slower and produced more blood loss than monopolar electrosurgery in laparoscopic cholecystectomy.



Figs. 28A to D: (A) Harmonic scalpel; (B) Hydro-Surg® Plus Irrigator; (C) Laser generator; (D) Cryotherapy device.

All lasers including potassium-titanyl-phosphate (KTP) and the more recently developed solid state have several major drawbacks in common. They are expensive, inefficient, produce toxic smoke, nontunable, require specialized theater, and achieve variable penetration. Safety issues such as heat cumulative effect, burns due to accidental exposure, and retinal damage also contribute toward preventing widespread use of laser.

It is now obvious that from the range of available dissecting modalities in laparoscopic surgery, none has proven to be ideal. Utility of a particular modality is dictated by how close it meets the requirements to achieve safe, effective, and hemostatic tissue division under the specific circumstances. The surgeon must be able to use the appropriate combination of modalities in order to exploit the benefit each has to offer during dissection.

When properly used, laser, microelectrode, ultrasonic dissector, tissue response generator, and mechanical instruments are equally effective in any surgery. The choice of instrument should be on the instrument with surgeon that is more comfortable and he has the skill and experience for that particular instrument.

Cryotherapy and Radiofrequency Ablation

Both are used in the laparoscopic ablation of secondary tumor deposits in the liver, usually when the lesions are inoperable for whatever reason, laparoscopic cryotherapy with implantable probe destroys tumors by rapid freezing to –40°C or lower.

The lesion revascularizes for a short period (12–14 hours) on thawing but because the vasculature and the tumor parenchyma are damaged beyond repair, hemorrhagic infraction ensues. With radiofrequency thermal ablation, a radiofrequency current is transmitted through the probe implanted in the tumor. The radiofrequency current causes molecular and ionic agitation which heats the tissues (much like the microwave) and hence the tumor is heated to destruction. Both modalities are operated with laparoscopic contact ultrasonographic scanning.

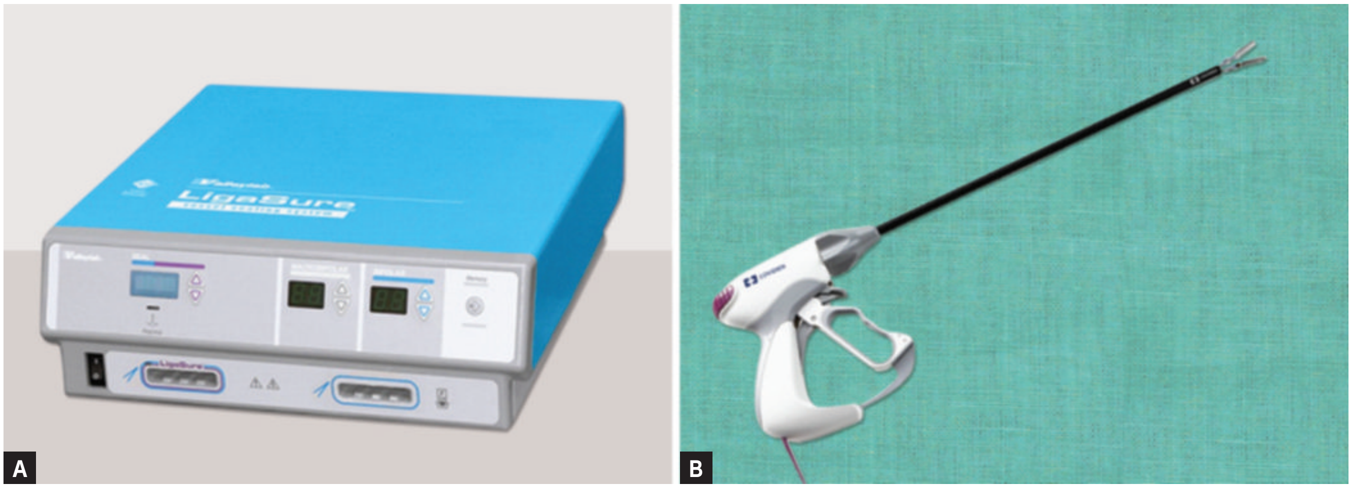
Cryotherapy device is also used to ablate the endometrial lining of a woman's uterus and reduce heavy menstrual bleeding **(Fig. 28D)**. The cryotherapy device has a slim probe that inserts through the cervix and then into the uterus. Once inserted, a freezing agent is released and the endometrial lining of the uterus is destroyed. The device is intended to be used in premenopausal women with heavy menstrual bleeding due to benign (noncancerous) causes who do not want to become pregnant in the future. Use of cryotherapy destroys the endometrial lining of the uterus to reduce menstrual bleeding. In the pivotal clinical study, 76% of women observed a reduction in menstrual blood loss from an excessive level to normal or less than normal levels.

Tissue Response Electrosurgical Generator

The tissue response generator has unique vessel sealing ability. These vessel sealing produces significantly reduced thermal spread compared to existing bipolar instruments. These generators precisely confine its effects to the target tissue or vessel with virtually no charring and with minimal thermal spread to adjacent tissue **(Figs. 29 and 30)**. These generator uses seal mechanism by sensing body's collagen to actually change the nature of the vessel walls by obliterating the lumen. The collagen and elastin within the tissue melt and reform to create the seal zone. These electrosurgical generator works by fusing the collagen in vessel walls to create a permanent seal. The jaw of electrosurgical forceps using this technology leaves no foreign material behind to potentially interfere with future diagnosis. The system uses the body's own collagen to reform the tissue, creating a permanent seal which resists dislodgment.

Tissue response generator has following advantages:

- It can be used with confidence on vessels up to 7 mm
- It seals all the tissue bundles without dissection and isolation



Figs. 29A and B: Tissue response generator (LigaSure□).

- It causes minimal thermal spread
- It has good effect to the target tissue
- The unique energy output results in virtually no sticking

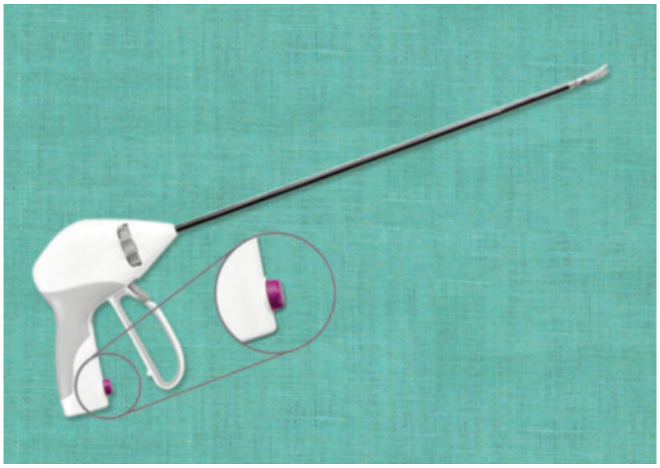
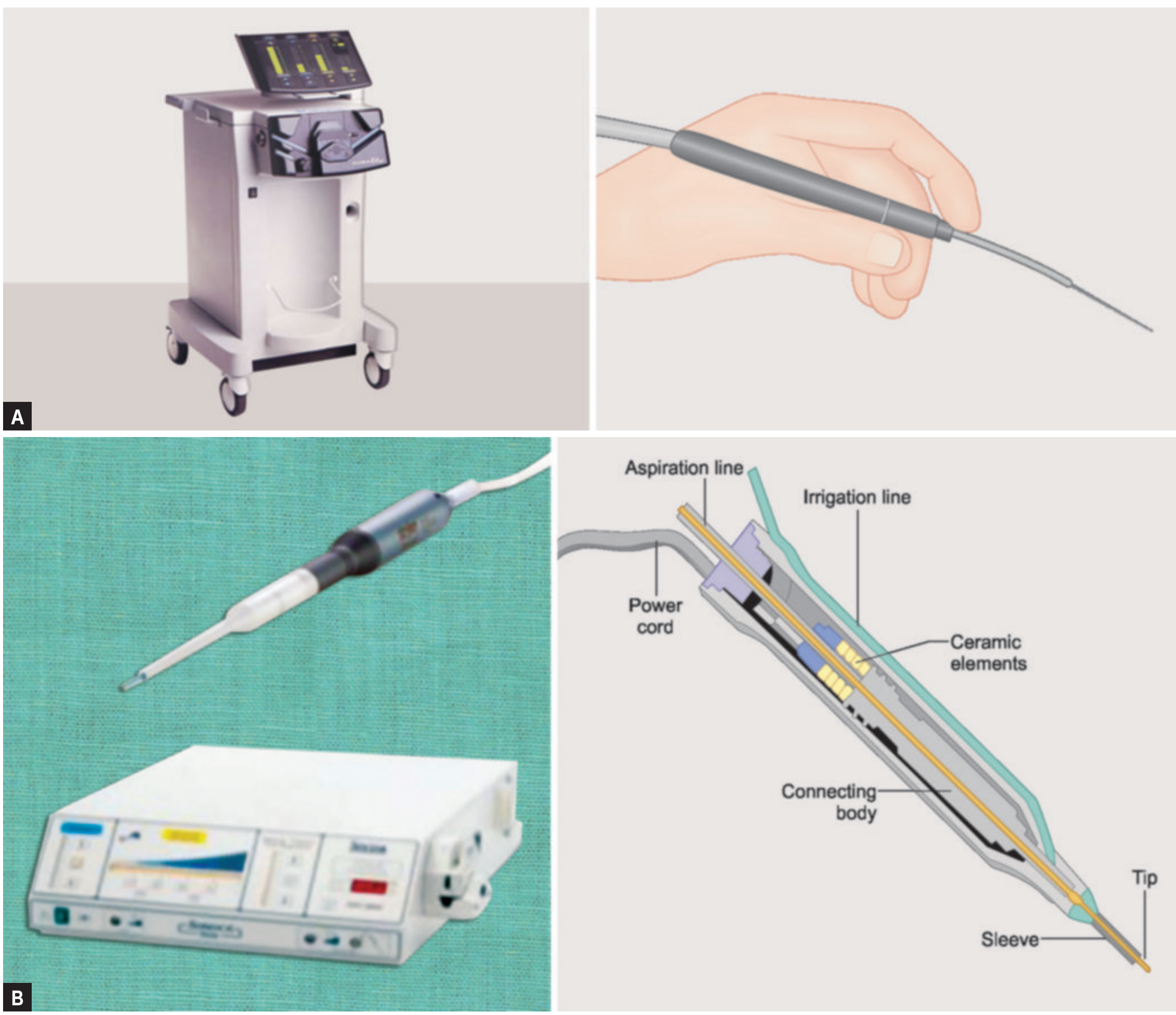


Fig. 30: LigaSure□ .

- Reduced sticking and charring
- Minimized need for multiple applications
- No dislodged clips
- No foreign material is left behind.

In 1916, the physicist Lord Rayleigh discovered the effect of cavitation while investigating damage to a ship's propeller. He concluded that the collapse of the bubbles created a small jet stream of water, which was responsible for the structural damage. Using a similar principle, high speed mechanical waves can be used in nonelastic media, such as water, to create a cavitation effect. If this phenomenon is applied to water-rich tissues, such as liver, the final effect is the destruction of all the cells, preserving structures rich in collagen (low in water), such as blood vessels, nerves. The Cavitron Ultrasonic Surgical Aspirator (CUSA) device generates ultrasonic waves in the range of 23 kHz to produce tissue cavitation **(Figs. 31A and B)**. This mechanical energy is delivered through a hollow 3 mm tip that vibrates



Figs. 31A and B: Cavitron Ultrasonic Surgical Aspirator (CUSA).

at 23,000 cycles per second. The entire device is embedded with an irrigator and aspirator in order to dispose off the tissue debris.

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