

ELECTROSURGICAL BURN INJURIES IN MINIMALLY INVASIVE SURGERY

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INTRODUCTION

This paper will discuss the possible mechanisms of electrosurgical burn injuries in minimally invasive surgery, illustrated by three case studies that the author has investigated.

THREE CASE STUDIES

The following three case studies illustrate some of the different mechanisms that lead to burns in the use of electrosurgery in minimally invasive surgery. In two of the cases, the burns occurred during the use of bipolar electrosurgery, which is considered to be inherently safer than monopolar electrosurgery.

Case Study 1. Tonsillectomy

After a routine tonsillectomy procedure, a patient was observed to have a serious burn to one side of her mouth that required plastic surgery. It is helpful to review some of the aspects of a tonsillectomy procedure to understand what could have caused this burn.

- The procedure is performed under general anaesthetic.
- Excision of tonsils is performed with a scalpel.
- Coagulation of bleeders is performed with bipolar electrosurgery.
- In this case, uninsulated bipolar forceps were used.
- The sides of the mouth were packed with cotton, which had become dislodged during the case.

Although the surgeon stated that he thought there had been an “equipment failure” the burn was in my opinion caused by an error in technique.

Errors That May Have Caused the Burn

The following are some of the errors that in combination could have led to the burn:

- Use of uninsulated forceps;
- Activating ESU before grasping tissue;
- Applying excessive heat;

- Creation of an alternate current path through unintended contact with adjacent tissue.

The following illustration shows what I believe was the most likely scenario that led to the burn.

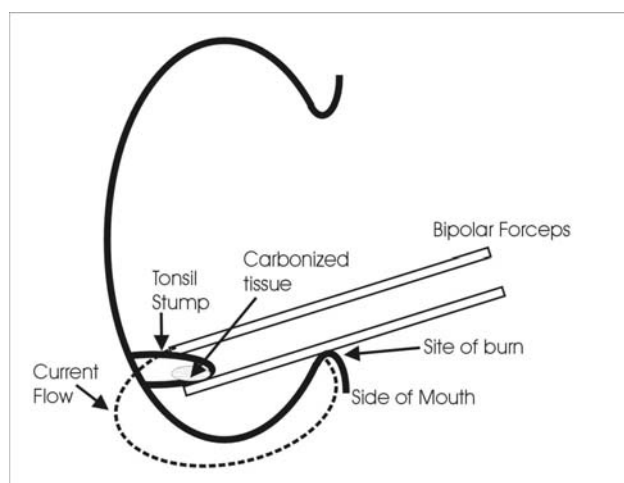


Figure 1.

One arm of the bipolar forceps touched the side of the mouth and the electrosurgical unit was activated long enough to cause a rise in tissue impedance at the points of contact of the tips of the forceps. Because of asymmetries in the points of contact, the tissue impedances at the two tips were unequal, creating a preferential path for current to flow from the lower impedance contact point to the contact point at the side of the mouth. Excess heat was applied by activating the ESU for long periods of time, causing a burn at the point of contact at the side of the mouth.

The burn could also have occurred if the surgeon had activated the ESU before he had grasped the tissue between the forceps. If one tip of the forceps touched tissue, and the opposite arm touched the side of the mouth, a similar return path through the side of the mouth would be created, causing a burn. In summary, the only way a burn could occur is through a combination of errors in technique.

Case Study 2. Laparoscopic Oophorectomy

An oophorectomy is a procedure to remove the ovaries using bipolar electro-surgery. One week after her surgery, the patient in this case returned to hospital with symptoms of peritonitis. A bowel perforation caused by an electro-surgical burn was discovered. The bowel was repaired and patient was given temporary colostomy bag. Bipolar electro-surgery is considered to be inherently 'safer' than monopolar electro-surgery, because of the lower voltages and power levels that are used. This case illustrates that burns are still possible in laparoscopic surgery when bipolar electro-surgery is used.

Errors in Technique that May have Caused Bowel Perforation

The following are some of the errors that in combination could have led to the burn:

- Application of excess electro-surgical current causing current redirection;
- Application of excessive electro-surgical current causing heating of adjacent tissues by heat conduction;
- Direct coupling to conductive instruments creating alternate current paths;
- Unintended contact with adjacent tissue.

The surgeon stated that he thought the burn was caused by an errant spark outside the field of view that had jumped to adjacent tissue resulting in a bowel perforation. The low voltages used in electro-surgery make this scenario highly unlikely. In my opinion, the most likely cause of this burn was direct coupling to a conductive instrument.

Direct coupling occurs when the user activates the generator while the active electrode is touching another metal instrument. The secondary instrument will become energized. This energy will seek a pathway to complete the circuit to the return electrode. There is potential for significant patient injury. Direct coupling is more likely to occur in monopolar electro-surgery, but is still possible in bipolar electro-surgery. Figure 2 illustrates this.

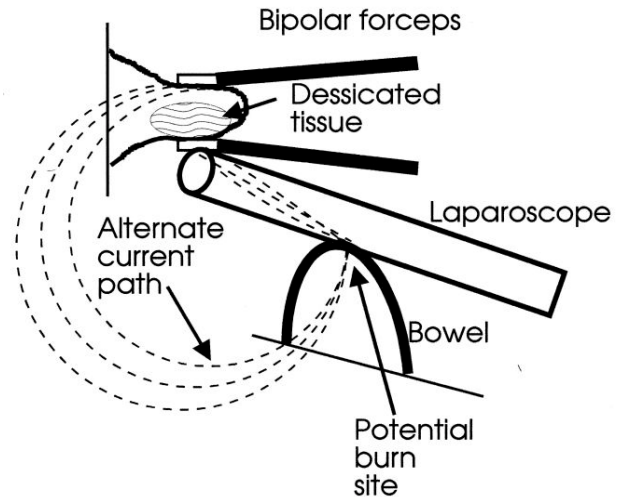


Figure 2.

If the tissue between the bipolar forceps has become desiccated, and is a poor conductor of current, and a metal instrument such as the laparoscope touches the tip of one blade of the forceps, and is in contact with bowel tissue somewhere along the shaft of the laparoscope, an alternate path is set up for current to flow. Before a burn could occur, current would be required to flow through this path for an extended period of time. It is a common recommendation that the surgeon not activate the electro-surgical unit when the forceps are in close proximity or direct contact with another instrument.

Case Study 3. Laparoscopically Assisted Vaginal Hysterectomy

In this procedure, the uterus is removed using a partial laparoscopic technique. Both monopolar and bipolar electro-surgery are used during the case. One week after her surgery, the patient in this case returned to hospital with symptoms of peritonitis. It was discovered that a bowel perforation had occurred caused by an electro-surgical burn. The surgeons agreed that the burn had occurred during the use of monopolar electro-surgery, but suggested that capacitive coupling had led to a spark that caused the bowel perforation.

Errors in Technique that May have Caused Bowel Perforation

All these possible errors relate to the use of monopolar electro-surgery:

- Application of the active electrode tip to non-target tissue;
- Electrode insulation failure;
- Capacitive coupling to adjacent tissues;
- Heat conduction;

- Direct coupling to other conductive Instruments. Each of these errors will be discussed briefly.

Application of the Active Electrode Tip to Nontarget Tissue

Because of limited visibility in laparoscopic surgery, if the electrosurgical unit (ESU) is activated while the active tip is out of sight of the surgeon, it may pass the current into unintended tissue, causing a burn

This type of occurrence can be avoided with careful technique. The surgeon must be the one to operate the footswitch of the ESU, rather than delegating it to an assistant. In addition, the surgeon must not activate the ESU until the active tip of the electrode is in contact with the target tissue.

Electrode Insulation Failure

In laparoscopy, the ESU electrode consists of a rigid metal conductor surrounded by an insulating material, with an exposed metal tip that the surgeon places in contact with the target tissue. These electrodes are typically reused many times, being cleaned and sterilized between each use. This repeated cleaning causes gradual degradation of the insulation, and eventually small cracks or pinholes may develop, allowing electrosurgical current to leak out to unintended pathways. More recently, disposable electrodes have come into common use, but insulation failure can still occur with these electrodes.

Current leaking through a break in the insulation can cause injury to any adjacent tissue that it may come in contact with. Such injuries will have a small area corresponding to the point where the current enters the tissue. It is at this point that the highest current density occurs, and hence the greatest heating effect. Precautions necessary to avoid such injuries are that the surgeon should carefully inspect all instruments before use, to verify that they are in good condition. In addition, the surgeon must be careful not to allow the insulated shaft of an electrode to touch adjacent organs, as ESU current can leak into any tissue either through insulation breaks, or through capacitance effects.

Capacitive coupling to adjacent tissues

The normal laws of electrical circuits say that electrical current will only flow through conductors, and will not flow through insulators. At high frequencies, however, this rule starts to break down. Electrosurgical generators use high frequency current, typically 500,000 Hz or higher, to minimize muscle stimulation. At these frequencies, capacitive coupling can become a problem.

Capacitive coupling is defined as the phenomenon that occurs when electrical current is transferred from one conductor (the active electrode), through intact insulation, into adjacent conductive materials (tissue, trocars, etc.). The amount of current that flows through a capacitor depends on a number of factors, including the distance separating the two conductors, and their surface area.

The phenomenon of capacitive coupling in electrosurgery has been known for many years. Tucker et. al. (1992) studied this phenomenon in laparoscopic and endoscopic instruments. They concluded that it is possible to obtain over 15 watts of power from capacitive coupling to instruments during laparoscopic procedures. This power level is capable of causing bowel perforations. Tucker et. Al. (1992) recommend that open-circuit activation of the ESU, high power settings, prolonged activation, hybrid cannulas, and inadequately insulated guide wires be avoided to minimize the possibility of capacitive coupling. Preventive measures to avoid this problem include the use of bipolar electrosurgery, and active electrode monitoring.

Heat conduction

Another source of tissue damage is simple conduction of excess heat from the point of application of the electrosurgical current to adjacent tissues. At elevated temperatures, the bloodstream acts to cool the heated tissues, which makes the blood the most important heat removal mechanism. If blood flow is restricted greater heating of adjacent tissues will occur. In addition, if the electrosurgical current is applied for a prolonged period of time, the heat flowing into the tissue will exceed the ability of the blood circulation to remove heat, and damage to unintended areas will occur. To avoid burns by heat conduction, it is generally recommended that electrosurgical current be applied in short bursts, with pauses between application, to allow the dissipation of heat from adjacent tissues.

Direct coupling to other Conductive Instruments

Direct coupling occurs when the user activates the generator while the active electrode is near another metal instrument such as the laparoscope. The secondary instrument will become energized. This energy will seek a pathway to complete the circuit to the return electrode. In this mechanism, all the output power that the machine is delivering can flow through an alternate current path, and there is potential for significant patient injury. This mechanism is illustrated in Figure 3.

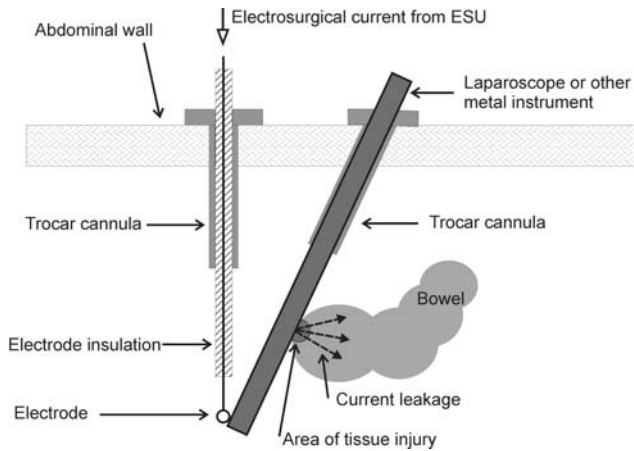


Figure 3.

The potential for injury is reduced if the conductive instrument passes through a conductive (e.g. stainless steel) cannula. In this case, the current leakage will also dissipate into the abdominal wall, reducing its effect on internal structures. It has been recommended that an important protective measure in laparoscopic surgery is the use of conductive cannulas for all instruments. (ECRI 1995, p.10)

Case Study 3. Most likely cause

In this case, I concluded that direct coupling to other instruments was the most likely cause of the burn. The surgeon stated that insulated cannulas were used during the case, increasing the potential for burns in this scenario. While capacitive coupling was also possible, the amount of power available in capacitive coupling is limited, while in direct coupling is limited, while in direct coupling to another instrument, all the output power that the machine is delivering can flow through the alternate current path. It is never possible to know with complete certainty what has caused a burn in this type of case. It is only possible to assign approximate relative probabilities to various scenarios.

SUMMARY AND CONCLUSIONS

The majority of electrocauterization burns reported in the literature are caused by errors in technique. Clinical engineers can take initiatives to reduce the probability of electrocauterization burns such as those described above. Some of these initiatives are the following:

- Understand the instruments that your surgeons are using – are they using insulated or uninsulated trocars?
- Ensure that the insulation on laparoscopic instruments is tested regularly;
- Get involved in educating surgeons about the physics of electrocauterization.

REFERENCES

ECRI, "The Risks of Laparoscopic Electrocauterization", *Health Devices*, 24(1): 4-27, January, 1995.

Tucker, R.D., Voyles, C.R., and Silvis, S.E., "Capacitive Coupled Stray Currents During Laparoscopic and Endoscopic Electrocauterization Procedures", *Biomedical Instrumentation & Technology*, 26(4):303 – 311, August 1992.