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Complications in Surgical Diathermy: Causes and Prevention

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ABSTRACT

Surgical Diathermy is process that involves transmitting high-frequency alternating current through the body to achieve a specific surgical outcome. It is a great tool in surgical practice for dissection and heamostasis, making the dissection precise and minimizes blood loss. It has been used in various surgical specialties, but it has its inherent complications. It can produce a spectrum of complications from minor surgical burns, tissue injuries, nerve palsies, and even major fire incidents in the operation theatre. This review article examines the causes of the complications during the surgery and possible preventive measures. We have searched articles published about the diathermy during the period 1975 to 2025 for analyzing the causes, design modifications in the diathermy, and management of risk. We have also tried to make a protocol for the safety of diathermy usage in the operating theatre. From analysis of previous articles it was found that the complication can be reduced by regular inspections and maintenance, use of safety features, proper patient preparation, effective smoke evacuation, mandatory training, and implementing institutional safety protocols.

Introduction

Dr William Bovie introduced surgical diathermy, but it was more popularized by the great neurosurgeon Sir Harvey Cushing in 1920 [1,4]. Surgical diathermy uses high-frequency electric current for tissue dissection and coagulation. It has been extensively used in all specialties, involving the dissection of soft tissues and for dissection of soft tissues from bone.

Though the surgical diathermy has helped surgeons in safe dissection and easy coagulation of bleeding vessels, it has many risks. The major reason for the complications is due to improper earthing (grounding), failure of insulation, capacitive coupling, or due to exposure of the skin to conducting instruments [5-7]. There are many case reports in the literature about the incidence of burns to the patient, cardiac complications in those who had pacemaker implants, and also about fires in the operation theatre [8,9].

As the complications are reported, there is more understanding about the process. This led to the development of the bipolar system, which involves less risk, active monitoring of the electrodes, and safety alarms in the diathermy. This review article aims to explore the reasons for diathermy injuries, their contributing factors. We also explore the recommended preventive measures based on clinical evidence. Implementing the proper safety protocols, updating the equipment, and training surgeons about the equipment, the possibility of complications, and prevention are the most important things in improving patient outcomes [3, 10].

Evolution of Diathermy

In 1926, William T Bovie developed an instrument for coagulation and precision cutting of tissues by thermal energy. This was by a high-frequency electrothermal generator. Bovie's invention was first used by Harvey Cushing in neurosurgery, where intra operative bleeding was a big challenge. Intra operative bleeding was significantly reduced by the use of electrocautery [3, 4].

Mechanical methods such as clamping and ligating the bleeding vessels were used before the advent of electrocautery. These methods were time-consuming and were often not adequate to achieve good heamostasis [11]. Electrosurgery allowed easier heamostasis, better visualization of the operative field, which helped in reducing the operation duration.

The initial model was “Spark-gap Generator,” which was reined to “Safe waveform-controlled Generator”. Now the modern diathermy units are using microprocessor-based control systems. They can deliver consistent energy to the cutting and coagulation by precisely regulating the power output [9, 12]. There are many additional safety features included, such as Return Electrode Monitoring (REM), Active Electrode Monitoring, and impedance monitoring. They have contributed greatly to patient safety [13,14].

Earlier diathermy was with the use of a single active electrode, which is called the Monopolar system, where a single active electrode is used to complete of circuit with return from a pad electrode at a different part of the body. In the middle of the 20th century, the bipolar system was developed, where the current flow between the two tips of the same instrument will reduce the risk of damage to distant tissue [15]. The invention of bipolar diathermy has extended its use in microsurgery, laparoscopy, and robotic surgeries involving complex procedures.

Many recent innovations utilize other energy modalities with electro-surgical principles, namely argon-enhanced coagulation, ultrasonic dissectors, and vessel sealing systems. With these innovations, more precision is achieved, and thermal spread is reduced [16,17].

Classification and Mechanism of Diathermy

Surgical diathermy is classified as Monopolar and Bipolar based on the current delivery mode and effect on the tissue. Each has a different mechanism of action and clinical uses[13]. In monopolar diathermy, the flow of the current is from the electrode of the surgical site to the body of the patient. From the body, it goes to the grounding pad attached to another part of the body. Monopolar diathermy allows both cutting and coagulation, hence it is used in open as well as minimally invasive procedures. The longer current path is a disadvantage, as it increases the possibility of tissue injury if the grounding pad is not connected properly or there is a metallic implant in the body, which may act as a grounding pad [12,15].

Bipolar diathermy is a forceps, where the current flows between the tips of the forceps.
There is no grounding pad. Here, the flow of current is localised, so there is no risk of distant electric burns. It is also very safe in very delicate tissues like near the vessels and nerves, where the flow of the current should be very precise [18].

Electrosurgical waveform can be (a) cut, (b) coagulation, or (c) blend. The cut wave forms are continuous, and they produce a focused heat effect. The coagulation wave forms are intermittent; it produces slower heat and helps in coagulation. The blended form is a combination of the above [7, 17]. The newer developments in diathermy are pulsed bipolar and ultrasonic diathermy. The lateral thermal spread is less, there is less smoke production, and increased tissue selectivity [15, 16]. There is also real-time feedback on tissue impedance, which helps the system to adjust the power settings, leading to a safer dose of electricity delivery [19, 20].

Understanding the mechanism of the electrosurgical unit is important for safe usage of these instruments. Considering the type of tissue, patient factors like pacemakers or metallic prosthesis will be considered in selecting the proper mode and energy level for safer surgical outcomes.

Common Complication in Diathermy

Diathermy has a risk of complications when it is not properly used. There can be (a) Thermal injuries, (b) interference with implanted devices, and (c) surgical smoke.

Thermal injuries are the most common of the complications. At the site of surgery, prolonged application and excessive power settings can cause direct burns. Insulation failure and capacitive coupling can produce indirect burns, which may result in delayed wound healing, deep tissue necrosis, or formation of fistula [7, 14]. Capacitative coupling means the transfer of electricity through insulations, injuring the tissues, especially in laparoscopic surgery [17,21]. Away from the site of surgery, in monopoly, diathermy burns can occur due to poor contact of the pad or issues with grounding pads. These burns may cause significant morbidity [13]. Another cause of burns outside the surgical field is due to insulation failure, which can cause severe burns [22].

Interference with a pacemaker and a defibrillator can cause it to malfunction or completely stop functioning. It can also cause inappropriate shock [23, 24].

Smoke generated during surgical electrocautery contains many toxic chemicals, bioaerosols, and viable viruses. Prolonged exposure to smoke can lead to respiratory irritations, DNA damage, and transmission of HPV (Human Papilloma Virus) [25,26].

Operating theaters also pose a fire hazard due to their oxygen-rich environment, with surgical drapes commonly being the reason for the fire.

Causes of Complications in Surgical Diathermy

Different factors like technical errors, inexperience in using the diathermy, equipment-related issues, and patient-specific factors are responsible for the complications. A clear understanding of the factors is important for the safe use of electrosurgical instruments.

1. TECHNICAL FACTORS

The commonest error is in the power setting, especially in monopoly diathermy. It can cause deep tissue burns [27]. But decreased power will cause repeated use and increased operating time.

Improper placement of the return pad in the monopoly system can produce burns. This return electrode burn occurs when there is insufficient contact between the pad and skin, usually due to hair or bony prominence, as the concentration of current occurs at the point of least resistance [9].

2. INSTRUMENT DESIGN

Insulation failure is a major cause of thermal injury in laparoscopic surgeries. Microscopic cracks in the insulation cause the current flow to adjacent tissues [22]. These injuries may not get noticed during the surgical procedures.

Current transfer between the electrode and the conductive material adjacent to it is called Capacitive coupling. It can occur with metallic tracers and cannulas during laparoscopic surgery. Long insulated instruments can accumulate current and may discharge to the tissues, causing thermal necrosis [17].

3. OPERATOR-DEPENDENT FACTORS

Inadequate experience of the surgeon with wrong mode selection, like cutting in the place of coagulation, wrong power settings, and poor hand techniques, can lead to an increased incidence of tissue burns [28]. Proper inspection of cables and insulations, proper placement of return electrode pad, and using correct settings in the instruments are important factors in preventing thermal injuries to the patient [13].

4. PATIENT-RELATED RISK FACTORS

Large subcutaneous fat in obesity increases the possibility of return burns at the pad site. Hairy skin, dry skin, and scars also increase the possibility of burns at the pad site (29). Patients with implanted cardiac devices are at risk of interference during the monopolar diathermy use if the device is in the path of electric flow [30].

Patients with poor vascular supply as diabetics, smokers, are susceptible to tissue burns with standard diathermy usage.

Preventive Measures and Safety Protocols

1. EQUIPMENT CHECKS AND MAINTENANCE

Diathermy Cables, handpicks, and insulations should be inspected periodically. Special attention should be given to detecting small insulation defects. Insulation testing devices can be used for this, especially before doing minimally invasive surgeries [22].

Newer diathermy units have Return Electrode Monitoring (REM) for real-time assessment of the quality of contact between the return pad and the patient (9). There should be caution with the use of return pads. Only approved, pre-gelled, single-use pads should be used to prevent thermal injuries [13].

2. SAFE OPERATING TECHNIQUES

The lowest effective power setting should be used. Surgeons should use short activation times. The tip of the electrode should be activated only when it is in contact with the tissues [28]. In laparoscopic surgeries, the metal tracers with plastic or other insulation shielded instrument should be used. Use of Active Electrode Monitoring (AEM) will help to detect stray currents and trigger auto shut-off [17].

3. PATIENT PREPARATION

The return pad should be judiciously applied. It should not be applied over hair, scars, or bony prominences. It should be applied to a flat, muscular area [29]. Larger electrodes or dual-dispersive return pads may be used in obese persons. A cardiologist should be consulted while using diathermy in patients with implanted cardiac devices. Bipolar diathermy should be used where possible. If using monopolar, the current pathway near the implant should be avoided [24].

4. SMOKE EVACUATION

As smoke contains viruses and toxic gases, it can be eliminated with smoke evacuators, HEPA filters, and local exhaust ventilation, especially in prolonged procedures [25, 32]. Personal protective equipment like face shields should be worn during procedures that are likely to be contaminated with viruses like Human Papilloma Virus [26].

5. TRAINING AND EDUCATION

Studies have shown that up to 80% of surgeons did not have any training on the principles of electrosurgery. Formal training in "Fundamental Use of Surgical Energy

(FUSE), has proven to decrease the misuse of the device [28]. There should be ongoing education and mandatory competency assessment for surgeons, operation room nurses, and Technicians [33].

6. INSTITUTIONAL PROTOCOLS
Verification of diathermy settings, electrode insulation integrity, and smoke evacuation may be incorporated into timeout procedures. Diathermy-related injuries and near-miss events should be audited and investigated [13].

Advances in Technology and Future Directions

Innovations in the electrosurgical technology have improved the efficacy and safety of diathermy. They have helped to decrease the complication rate and improve the efficiency. The development of minimally invasive instruments and smart systems has increased the standards of diathermy for a better postoperative outcome.

1. SMART ELECTROSURGICAL UNITS
Real-time monitoring of the tissue impedance and automatic correction of power output can be achieved in modern diathermy machines by incorporating "microprocessor-based intelligence". Only the required amount of energy is delivered to the site, preventing tissue damage (20). Many systems can use "feedback-controlled algorithms" which adjust the power based on tissue conductivities of fat, muscle, and fibrous tissue [34].

2. BIPOLAR AND ADVANCED BIPOLAR SYSTEMS
Advanced Bipolar instruments can seal larger diameter of vessels permanently without adjacent tissue injury. "Ligasure", "EnSeal", "Thunderbeat", etc, are the advanced bipolar systems which has superior vessel sealing capabilities [35]. As the bipolar system does not require return electrodes, there are no pad-related complications. There are more precise and very useful in laparoscopic and robotic surgeries [36].

3. ULTRASONIC ENERGY DEVICES
They use high-frequency mechanical vibrations (55.5 Hz) for dissection and coagulation. They do not use electrical current [37]. They produce less heat and do more precise dissection. These Harmonic Scalpels produce a lesser amount of smoke. It has been found that the use of ultrasonic scalpels causes fewer adhesions in gastrointestinal and endocrine surgeries [38].

4. HYBRID TECHNOLOGY
There are instruments like "Thunderbeat" that combine ultrasonic and bipolar energy to produce a multipurpose tool, which can do dissection, heamostasis, and vessel sealing. This reduces the need for instrument change during complex procedures like colorectal surgeries and hepatic surgeries [39].

5. ROBOTIC AND ELECTROSURGERY
Electrosurgical instruments are incorporated into robotic platforms. This allows remote-controlled bipolar and monopolar cautery. This allows for reaching deep pelvic or thoracic spaces with much precision. As robotic surgery gives more precision by 3D visualization, haptic feedback, surgery is more precise and has fewer chances of damage to the surrounding tissues [40].

6. ENERGY DELIVERY SAFETY ENHANCEMENT
New insulation materials have been developed to reduce thermal conductivity. Technologies like "Active Electrode Monitoring (AEM)" continuously check for stray current and automatically shut down the power if there is an insulation failure [41]. Development of color-coded hand pieces reduces operator errors [13].

7. FUTURE DIRECTIONS
Nanotechnology, plasma energy, and low-temperature radio frequency ablations do targeted tissue destruction with the least injury to the adjacent tissues. There is a possibility of AI-integrated machines, which will allow prediction of energy modulation based on intra operative imaging and machine learning algorithms [42]. Augmented Reality (AR) combined with real-time thermal imaging may help to visualize the thermal energy in the operating field to prevent injuries to adjacent tissues [43].

Table 1: Complications of Surgical Diathermy and Preventive Measures

Complication	**Mechanism**	**Preventive Measures**
Accidental skin burns	Poor return electrode contact, insulation failure	Proper placement and inspection of return pads; avoid bony prominences
Direct thermal injury	Contact with active electrode	Surgeon vigilance, use of insulated tools
Lateral thermal spread	Excessive energy delivery	Use of advanced bipolar or ultrasonic tools; power modulation
Capacitive coupling	Energy transfer through intact insulation	Avoid metal trocars in laparoscopy; use active electrode monitoring
Conductive coupling	Contact with secondary conductive material	Proper spacing and insulation of instruments
Operating room fires	Ignition of flammable agents near sparks	Avoid alcohol-based preps; minimize oxygen near cautery sites
Interference with pacemakers/ICDs	Electromagnetic interference	Preoperative cardiology consultation; use bipolar devices when possible
Nerve injury	Excessive heat near neural structures	Use the lowest effective settings; anatomical awareness
Delayed wound healing	Excessive coagulation leads to devitalized tissue	Use pulsed current settings or harmonic tools

Complication	Mechanism	Preventive Measures
Surgical smoke hazards	Inhalation of toxic or carcinogenic particles	Use smoke evacuators, N95 masks, or equivalent PPE
Return electrode burns	Current concentration at the pad site	Use split-pad monitors; verify correct pad placement
Insulation failure	Worn or cracked instrument insulation	Routine inspection and maintenance of instruments

Conclusion

Surgical Diathermy has changed surgical practice by enabling effective heamostasis and precise tissue dissection, resulting in shorter operative times. However, it also has its inherent risks, ranging from minor burns, vital tissue injuries, life-threatening complications, and fire. The cause of these complications is often due to improper use, poor maintenance of the equipment, and inadequate training for the surgeons and operation room staff.

This review has outlined the spectrum of complications with the use of monopolar and bipolar diathermy, including direct and indirect thermal injuries, capacitive and conductive coupling, interference with implanted devices, and risks of smoke evolution during the surgery. It is important to understand the diathermy physics, to use appropriate settings in the equipment, to train the surgeon, and to implement preventive protocols for minimizing the complications associated with Diathermy.

Advances in the Electrosurgery equipment, such as adaptive tissue feedback systems, advanced bipolar devices, ultrasonic scalpels, and integration of these systems with robotics, have improved the safety and precision of the surgery. AI-driven electrosurgery and thermal imaging may be the future advancement in achieving much more precision and decreasing complications associated with the electrosurgery. The surgeons and operation room staff should be aware of the functioning of the device and strictly follow the safety guidelines to reduce the electrosurgical complications and ensure patient safety.

References

1. Geddes LA, Baker LE. The specific resistance of biological material: a compendium of data for the biomedical engineer and physiologist. Med Biol Eng. 1967;5(3):271-293.
2. Meeks GR, Rose GS, Brancazio LR, Austin JM. Fatal gas embolism during operative hysteroscopy. J Gynecol Surg. 1994;10(3):141-146.
3. Cushing H. Electro-surgery as an aid to the removal of intracranial tumors. Surg Gynecol Obstet. 1928;47:751-784.
4. Bovie WT. The use of high frequency currents in surgery. Boston Med Surg J. 1928;199:130-136.
5. McFalls M, Lewis BL. Diathermy burn injury during laparoscopic surgery. J Minim Invasive Gynecol. 2007;14(5):650-652.
6. Goudie EB, Miskovic D, El Boghdady M. Electrosurgery and thermal injury: a clear and present danger. Int J Surg. 2020;79:35-41.
7. Brill AI, Nezhat CH. Complications of electrosurgery. Clin Obstet Gynecol. 2009;52(3):540-548.
8. Robinson TN, Stiegmann GV. Minimally invasive surgery and electrical injuries. Surg Endosc. 2007;21(8):1216-1219.
9. Fitzgerald JE, Malik M, Ahmed I. Electrosurgery: history, principles and current and future uses. J Surg. 2012;10(2):66-70.
10. Kopelman D, Orenstein A, Mizrahi S. Diathermy-induced burns: hazards and preventive measures. Burns. 2010;36(3):359-362.
11. Dobbie JW. The surgical ligature: a historical review. J R Coll Surg Edinb. 1996;41(6):416-422.
12. Reilly JP. Applied Bioelectricity: From Electrical Stimulation to Electropathology. Springer; 1998.
13. Vilos GA, Rajakumar C, Montgomery B. Electrosurgical generators and monopolar and bipolar electrosurgery. J Minim Invasive Gynecol. 2015;22(4):559-570.
14. Tucker RD. Laparoscopic electrosurgical injuries: survey results and their implications. Surg Laparosc Endosc. 1995;5(4):311-317.
15. Moossa AR, Easter DW, Van Sonnenberg E. Complications of monopolar electrosurgery: the potential for patient injury. Am J Surg. 1984;147(6):766-768.
16. Ghosh S, Saleh GM. Energy devices in ophthalmic surgery. Eye (Lond). 2007;21(9):1146-1151.
17. Sankaranarayanan G, Resapu RR, Jones DB, Schwaitzberg SD, De S. Common uses and complications of energy in surgery. Surg Endosc. 2013;27(9):3056-3072.
18. Milsom JW, Bohm B, Hammerhofer KA, Fazio VW. Prospective randomized trial comparing ultrasonic and electrosurgical dissection in laparoscopic colorectal surgery. Dis Colon Rectum. 2001;44(6):846-852.
19. Ito M, Sugito M, Kobayashi A, Nishizawa Y. Use of ultrasonic dissection in laparoscopic colorectal cancer surgery. Surg Endosc. 2004;18(5):808-812.
20. Sutton C. Energy sources for laparoscopic surgery. J Minim Invasive Gynecol. 2006;13(4):245-253.
21. Soper NJ, Barteau JA, Clayman RV. Laparoscopic cholecystectomy: the experience of the Washington University group. Surg Clin North Am. 1992;72(5):1037-1056.
22. Diamantis T, Kontos M, Arvelakis A. Insulation failure in laparoscopic instruments. Surg Laparosc Endosc Percutan Tech. 2009;19(3):191-194.
23. Fiek M, Dorwarth U, Dagres N, et al. Safety of monopolar electrosurgery in patients with implantable cardioverter defibrillators: a randomized study. Europace. 2009;11(8):1004-1009.
24. Crossley GH, Poole JE, Rozner MA, et al. The Heart Rhythm Society expert consensus statement on the perioperative management of patients with implantable defibrillators, pacemakers. Heart Rhythm. 2011;8(7):1114-1154.
25. Barrett WL, Garber SM. Surgical smoke—a review of the literature. Is this just a lot of hot air? Surg Endosc. 2003;17(6):979-987.
26. Ilce A, Yuzden GE, Yavuz van Giersbergen M. Exposure of operating room nurses to surgical smoke. J Clin Nurs. 2017;26(11-12):1552-1561.
27. Massarweh NN, Cosgriff N, Slakey DP. Electrosurgery: history, principles, and current and future uses. J Am Coll Surg. 2006;202(3):520-530.
28. Feldman LS, Fuchshuber PR, Jones DB. The SAGES Manual on the Fundamental Use of Surgical Energy (FUSE). Springer; 2012.
29. Nduka CC, Super PA, Monson JR, Darzi AW. Cause and prevention of electrosurgical injuries in laparoscopy. J Am Coll Surg. 1994;179(2):161-170.
30. Rozner MA. The patient with a cardiac pacemaker or implanted defibrillator and management during surgery. Curr Opin Anaesthesiol. 2007;20(3):261-268.
31. Mimica M, Vranesic Bender D, et al. Skin injuries from electrosurgery in at-risk patients: incidence and consequences. Acta Dermatovenerol Croat. 2017;25(1):40-46.
32. Ball K. Surgical smoke evacuation guidelines: compliance issues. AORN J. 2010;92(2):130-142.
33. Jayaraman S, Davies W, Schlachta CM. Training and skill assessment in electrosurgery: the FUSE curriculum. Can J Surg. 2014;57(2):E47-E50.
34. Bertin F, Chevallier JM. The VIO electrosurgical unit. J Vis Surg. 2008;145(5):205-209.
35. Kennedy JS, Stranahan PL, Taylor KD, Chandler JG. High-burst-strength, feedback-controlled bipolar vessel sealing. Surg Endosc. 1998;12(6):876-878.
36. Milone M, Musella M, Maietta P, et al. Safety and efficacy of LigaSure in laparoscopic colorectal surgery. Updates Surg. 2013;65(3):201-205.
37. Amaral JF. The experimental development of an ultrasonically activated scalpel for laparoscopic use. Surg Laparosc Endosc. 1994;4(2):92-99.
38. Kamenova P, Petkov T, Drangova M, Kirova G. Comparative analysis of the surgical outcomes using harmonic scalpel versus electrocautery. J IMAB. 2017;23(4):1774-1778.
39. Aiolfi A, Scolari F, Fumagalli C, et al. Safety and efficacy of Thunderbeat™ in abdominal surgery: systematic review and meta-analysis. Surg Technol Int. 2015;27:65-70.
40. Kaye K, Kwok AC, Brownlee SA, et al. Current applications and future trends in robotic surgery. Am J Surg. 2021;222(5):903-911.
41. Berguer R. Electrosurgical injuries: mechanisms and prevention. AORN J. 1997;66(6):1031-1042.

42. Chen PC, Sirjani D, MacDonald B, et al. Artificial intelligence in surgical energy application. Ann Surg. 2022;276(1):e19-e27.

43. Kuramoto Y, Sasaki Y, Ohta M, et al. Augmented reality surgical navigation with thermal visualization. Int J Comput Assist Radiol Surg. 2020;15(6):1025-1031.