

SURGICAL DIATHERMY: MECHANISMS, USES, RISKS AND RISK REDUCTION

Bashir Musa **Umar**¹, Samuel **Ndewaneku**², Michael Shalzim **Felix**², Ibrahim E, **Suleiman**³, Isa Hassan **Muhammad**⁴

¹Department of Surgery, Gombe State University/State Specialists Hospital, Gombe State, Nigeria

²Department of Surgery, Federal Teaching Hospital, Gombe State, Nigeria

³Department of Surgery, Bayero University Kano/Aminu Kano Teaching Hospital, Kano State, Nigeria

⁴Department of Radiology, Yobe State University/Yobe State University Teaching Hospital Damaturu, Yobe State, Nigeria

Corresponding Author: *Bashir Musa Umar, E-mail:* mmbashiru@gmail.com

Received: 17-Mar-2026

Accepted: 21-Apr-2026

Published: 30-Apr-2026

Abstract

Surgical diathermy is an electrosurgical device that enables precise dissection with minimal bleeding. It uses high-frequency alternating electrical current to cut, coagulate, and vaporize tissue. It reduces surgery time and reduces possibility of blood transfusion. Risks involved in the use of surgical diathermy include burns, nerve injury, infection, post-operative pain and inhalation of hazardous surgical smoke containing cells, viruses and potentially carcinogenic chemicals. Surgical diathermy also causes electromagnetic interference with implantable cardiac devices such as with pacemakers and defibrillators. It is important to take all measures to minimize risks to the patient, the surgical team and other theatre staff. This review discusses the basic mechanisms of diathermy function, its uses, risks and basic measures to minimize complications.

Keywords: Diathermy, electrosurgery, uses, mechanisms, risks

Cite this article: Umar BM, Ndewaneku S, Felix MS, Suleiman IE, Muhammad IH. Surgical diathermy: mechanisms, uses, risks and risk prevention. Yob Med J.2026;2(1):1-8

Introduction

Electrosurgical devices have revolutionized surgery in recent times. Surgical diathermy enables precise tissue dissection with minimal bleeding. It reduces surgery time, blood loss and the consequences, and reduces possibility of blood transfusion. It uses high-frequency alternating electrical current to cut, coagulate, and vaporize tissue, enabling precise dissection with minimal bleeding by generating localized heat that destroys cells.¹ Current passes through the body, often via an active electrode, creating high current density at the diathermy tip to heat the tissue. Cutting occurs by vaporization at $\sim 100^{\circ}\text{C}$ and coagulation by dehydration at $60\text{-}99^{\circ}\text{C}$.² The passage of current through the body is via electrolytic solutions in the tissues and bloodstream. The source voltage is created by the diathermy generator which converts mains 50 Hz current into a high-frequency current of 0.2–3 MHz. At these radiofrequencies there is minimal risk of muscle or nerve stimulation. Instead, electrical energy is converted to heat as the electrons overcome the impedance of the body.^{2,3} Risks involved in the use of surgical diathermy include burns, tissue damage, infection, post-operative pain and inhalation of hazardous surgical smoke (fume). Diathermy fume is a recognized occupational hazard, exposing surgery staff to smoke equivalent to about 27 to 30 cigarettes per day.



Consequences of inhaling this smoke include acute and chronic inflammatory lung conditions, exposure to pathogens such as Viruses and bacteria.^{4,5,6}

Types of Diathermy

i) Monopolar: In this mode, current flows from the diathermy device through the active electrode called the diathermy pencil tip (which has the highest current density and is where heating occurs), through the body (serving as the electrolyte), and back to the diathermy device via a dispersive electrode (the return pad). Monopolar diathermy is used more frequently due to its greater versatility. The *cutting effect* in diathermy uses a pure continuous sine wave of low-voltage, high-frequency alternating current to create high temperatures ($>100^{\circ}\text{C}$) at the electrode tip causing rapid intracellular fluid vaporization and clean cutting. *Coagulation mode* uses high-voltage, low-frequency pulsed waveforms (wave with a short 'on' time and a longer 'off' time) to achieve haemostasis by desiccating or charring tissue, rather than cutting it. It causes protein denaturation at $60\text{-}100^{\circ}\text{C}$ via contact (desiccation) or non-contact (fulguration) methods, providing deep, controlled coagulation of bleeding vessels.³

ii) Bipolar: Current flows between two closely placed active and return electrodes. A bipolar handle has a pair of forceps where one blade acts as the active electrode and the other as the return, obviating the need for a distally placed return electrode/pad. It causes less tissue destruction. Conventional bipolar diathermy only coagulates but when combined with ultrasonic energy devices it can also achieve tissue cutting.

Key Surgical Uses

i) Cutting/Dissection: Creating precise cuts in a tissue with minimal bleeding.

ii) Coagulation: Achieving haemostasis by coagulating blood vessels. Conventional diathermy is generally effective for sealing vessel smaller vessels, typically up to 2–3

mm in diameter while advanced vessel sealing systems of combined bipolar diathermy and ultrasonic devices can seal vessels up to 7 mm in diameter.

iii) Fulguration/Desiccation: Shrinking or destroying tissue achieved by keeping the probe in contact with the tissue while applying heat insufficient for cutting. This dries out the tissue and a coagulum is formed.^{2,3}

Useful definition of terms

Lateral thermal spread: It is the unintended heat transfer to tissues adjacent to the target site; the risks increase with higher power usage, longer application time, and depends on instrument type. In electrosurgery, Monopolar diathermy causes the highest heat spread (>20mm), compared to bipolar diathermy, Harmonic scalpel (approx. 2.9mm) and LigaSure (<1mm).^{7,8}

Capacitive coupling: Accumulation of current (heat) on a metallic instrument high enough to cause burn at the site of patient contact. The metal causing the burn injury is not the primary source of heat. The heat at this secondary conductor accumulates due to current flowing through electrostatic field created between the two conductors (the diathermy tip i.e. the active electrode and a nearby conductor such as a trochar in laparoscopic surgery). Capacitive coupling can occur despite intact insulation of secondary conductor when the insulating capacity is exceeded.

Conductive coupling (Direct Coupling): Accumulation of current (heat) when an energized electrode directly (often accidentally) touches another metal instrument, transferring high-frequency current and causing unintended, often unseen, thermal injuries to tissues. It is a major risk in monopolar electrosurgery, preventable by visualizing the tip and avoiding contact with other metal objects. In addition, when an active electrode is too close to (but not touching) another metal object in direct contact with the patient,

current may jump from the diathermized tissue into the metal conductor, resulting in high heat in an unintended tissue or organs in contact with the secondary instrument. Proper spacing and insulation of instruments prevents this complication.

Active Electrode Monitoring (AEM) is a safety technology in monopolar laparoscopic diathermy that prevents stray energy injuries caused by insulation failure and capacitive coupling. It uses a shielded instrument to detect breaches and automatically shuts down the generator, enhancing patient safety during minimally invasive surgery.^{9,10,11}

Risks Considerations in Surgical Diathermy use

1) Risks to patients

Thermal injury: Risks of surgical diathermy in patients undergoing surgical procedures include *burns* due to unintended contact of the activated diathermy pencil tip to skin. Full thickness injury to the skin called *button hole skin injury* occurs when dissection is carried too close to, and perforating the skin. Thermal injury to nerves may occur when an activated pencil tip nears a normal or an anomalous nerve. Pedal-controlled diathermy machines are prone to inadvertent device activation and thermal injuries. Thermal injuries may also result from direct (conductive) coupling, capacitive coupling or lateral thermal spread (see section above).

Thermal injury due to ignited local fires may occur when dissecting tissues with flammable agents such as mannitol (as used for pre-operative bowel preparation). Diathermy use on body areas still wet with alcohol-based skin preparations such as methylated spirit (ethanol) carries high risk of burns, fires, and operating room mishaps. Alcohol-based antiseptics are highly flammable, and when combined with the heat produced by electrocautery, can easily ignite, leading to severe, often full-thickness burns.¹² In laparoscopic surgery,

intraoperative diathermy smoke may reduce visibility and increase operating time.

Return electrode burn (also called grounding pad burn) occurs when there is ineffective contact between the return diathermy pad and the skin. Bony prominences and excessively hairy or scarred skin increase the possibility of burns at the conductive pad site as the concentration of current occurs at a point of least resistance. Lack of good contact creates a high-impedance, low-resistance, or unevenly distributed contact area, causing the electric current to concentrate on a small area of skin, resulting in heat buildup and subsequent thermal injury. Patients with poor vascular supply as diabetics, smokers and those with peripheral vascular disease are susceptible to tissue burns even with standard pad placement, primarily due to impaired tissue perfusion, which reduces the body's ability to dissipate heat, leading to tissue damage.^{3, 13, 14}

Another complication of diathermy use include post-operative *wound infection* due to melting of diathermized fat tissue (a good medium for bacterial proliferation).

Wrong connections and insulation breaches may cause electrocution to patients and staff.

Diathermy can interfere with both electrocardiography (ECG) and electroencephalography (EEG) monitoring probes placed during surgery through *Electromagnetic interference (EMI)*. Of greater consequence is the interference with cardiac pacemakers and implantable defibrillators. Interference is more likely if a monopolar diathermy tip is used in the path of electric flow of such devices. The effects are unpredictable and include inappropriate pacing, damage to the device, inappropriate defibrillation, and myocardial heat damage. Bipolar diathermy is safer than monopolar in this regard, but can still cause electromagnetic interference. Modern pacemakers have a titanium shell and interference monitor to protect them.^{3, 13}

2) Risk to operating team

Surgical diathermy poses significant risks to the surgeon, his assistants, the peri-operative nursing staff/surgical technician, anesthesia staff and other theater team members in the form of *electric shocks, burn and fires*.¹⁴ Diathermy *fume* or *surgical smoke* may contain hazardous, toxic, and, infectious agents and in some cases, mutagenic or carcinogenic compounds in the form of cells, viruses, and chemicals.¹⁵ Diathermy smoke consists of approximately 95% water vapor (steam) and 5% cellular debris/solid particles. This *5% solid portion* contains over 150 known chemical and biological compounds. Chemical compounds in diathermy smoke include acetaldehyde, acrylonitrile, acrolein, benzene, cyclohexanone, furfural, formaldehyde, polyaromatic hydrocarbons, styrene, toluene and xylene which have been classified as carcinogens by the International Agency for Research on Cancer (IARC).^{16, 17} The biological components of surgical diathermy smoke are cellular debris including cancer cells and infectious viable materials such Human Papillomavirus (HPV) and Human Coronavirus (SARS-CoV-2). In addition, fragments of human immunodeficiency virus (HIV) and hepatitis B virus (HBV) were isolated in the inner lumen of smoke evacuation tubing following diathermy use. Bacteria isolated from surgical smoke include *Serratiamarcescens, Escherichia coli*, and others.^{18, 19, 20, 21}

3) Risks to other theatre staff

In addition to inhalation of diathermy smoke other operating room (OR) staff may be exposed to *electrocution* and *operating room fires* resulting from inadequate fuse fixation, improper earthing (grounding) and failure of insulation.^{2, 21}

Preventive Measures and Risk reduction strategies

(I) Diathermy Set up, Patient connection and settings

Proper connection to electrical source and avoidance of exposed wires (insulation defects) prevents electrocution and fires from sparking exposed wires. Energy settings on the machine should be at the minimum effective level. Risk of burn injury at the site of return pad is minimized by ensuring proper skin contact. The pad should be applied to a flat, muscular area.^{2, 20} The site, often behind the gluteal area, thigh or the calf, should not be excessively hairy, harboring large scars, bony prominences or be excessively wet. In men (especially the elderly), it should be ensured that the scrotum is not resting on a return pad to avoid burn injury.

Pad-related complication in obese patients is minimized by using larger pads or dual-dispersive return pads. Newer diathermy units have Return Electrode Monitoring (REM) for real-time assessment of the quality of contact between the return pad and the patient. Consultation with a cardiologist should be made before using diathermy on patients with implanted cardiac devices and where possible, bipolar diathermy should be used. If a monopolar diathermy is to be used, current flow near or across the cardiac implant should be avoided.²

(II) Operative use and techniques

Accidental skin burns including ‘button hole’ injury is prevented by minimizing energy delivery and careful dissection. Activation of the tip of the electrode should be done only when it is in contact with the intended tissues. Accidental activation in cases of foot-activated pedals should be avoided. In laparoscopic diathermy use, trochars with plastic insulation prevent thermal injury to the abdominal wall.

Where available, an Active Electrode Monitoring (AEM) device should be connected to a diathermy machine. As a safety measure, when an AEM device

detects stray currents it activates an auto shut-off action on the diathermy machine. Diathermy use should be avoided in body areas that are wet with alcohol-based preps. Intestinal luminal entry with diathermy should be avoided where mannitol is used for pre-operative bowel preparation to avoid sparks and thermal injuries.^{2, 12}

(III) General safety protocols

General measures: Crucial steps in improving patient outcomes include implementation of proper safety protocols, updating the equipment, and training surgeons and other OR staff about the equipment, the nature and possibility of complications, and prevention. Diathermy cables, handpicks and insulations should be inspected periodically. Diathermy-related injuries and near-miss events should be investigated and documented.²

Smoke barriers and protective equipment.

It is important to note that face shields and basic surgical masks provide only limited protection through avoidance of direct smoke inhalation. It is advisable to wear N95 masks or masks with layers of activated carbon particularly during lengthy procedures involving diathermy use.^{22, 23}

Smoke extractors: These are designed to remove diathermy smoke during electrosurgery. They are essential but often underutilized. They include the usual separate suction tube or the specialized diathermy pencil-attached suction system (also called suction-integrated pencils, Figure 1). Examples include SuperVac and PlumeSafe® - X5™.^{4, 22}

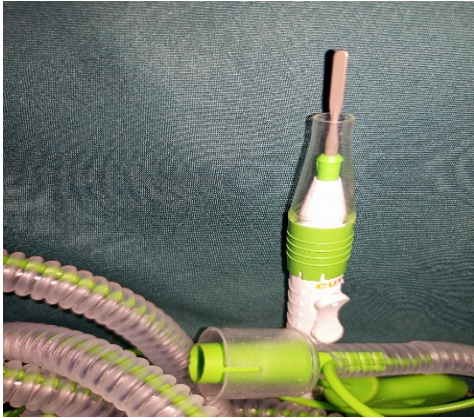


Figure 1. Diathermy pencil-attached suction system.

Smoke Evacuation: These are the wall-mounted filtration units and local exhaust ventilation (LEV) systems which reduce toxic exposure to personnel (Figure 2).



Figure 2. Wall-mounted ventilation system.

Advances in the electrosurgery equipment such as adaptive tissue feedback systems, advanced bipolar devices, Return Electrode Monitoring (REM), Active Electrode Monitoring (AEM), and impedance monitoring have provided additional safety features, contributing to patient safety. Integration of these systems into laparoscopic and robotic gadgets has improved safety and precision of surgery.²⁵

Many recent innovations utilize other energy modalities with electro-surgical principles. These include ultrasonic scalpel/dissectors (e.g., Harmonic scalpel, THUNDERBEAT® and SonoSurg), advanced bipolar electrosurgery systems (e.g., LigaSure™ and EnSeal™), laser energy systems (e.g., argon

laser and CO₂ laser), Radio-frequency energy systems (e.g., StarBurst® and Cardioblate®) and argon-enhanced coagulation and vessel sealing systems.²⁶ With these innovations, more precision is achieved and thermal spread is reduced.

Artificial intelligence (AI) is revolutionizing electrosurgery by enabling real-time, adaptive energy delivery that improves precision, safety, and efficiency during surgical procedures. AI-powered, voice-controlled, robotic-integrated technologies are becoming commonplace in contemporary operating rooms. Smart Electrosurgical Units (ESUs) uses machine learning (ML) to measure tissue impedance thereby minimizing heat damage and optimizing coagulation.²⁷

Conclusion

Surgical diathermy has changed surgical practice by enabling effective hemostasis and precise tissue dissection, resulting in shorter operating times and less bleeding. However, it also has its inherent risks and complications to patients and OR staff. Surgeons and operation room staff should be aware of the functioning of the device and strictly follow the safety guidelines to reduce its complications and ensure patient and theatre staff safety.

Conflict of interests: None

Financial Sponsorship: None

References

1. Vedbhushan ST, Mulla MA, Haroon R, Chandrashekhar DM. Surgical incision by high frequency cautery. *Indian J Surg.* 2013 Dec;75(6):440-443. doi: 10.1007/s12262-012-0520-x.
2. Hamid, AM., Karuppall, R., et al., 2025. Complications in Surgical Diathermy: Causes and Prevention. *Medical*

- Research Archives, 13(6). [Internet] doi: [10.18103/mra.v13i6.6625](https://doi.org/10.18103/mra.v13i6.6625)
3. Boyd DE, James H, Palmer M. Surgical diathermy, Anaesthesia & Intensive Care Medicine, 2013;10(14):431-433. doi:10.1016/j.mpaic.2013.07.003
 4. Brown OD, Aroori S. A surgeon-modified device for the evacuation of diathermy smoke. *Ann R Coll Surg Engl.* 2026; 108(1):68-69. doi: 10.1308/rcsann.2024.0061.
 5. Hill DS, O'Neill JK, Powell RJ, Oliver DW. Surgical smoke - a health hazard in the operating theatre: a study to quantify exposure and a survey of the use of smoke extractor systems in UK plastic surgery units. *J Plast Reconstr Aesthet Surg.* 2012; 65(7):911-6. doi: 10.1016/j.bjps.2012.02.012.
 6. Alp E, Bijl D, Bleichrodt RP, Hansson B, Voss A. Surgical smoke and infection control. *J Hosp Infect.* 2006; 62(1):1-5. doi: 10.1016/j.jhin.2005.01.014.
 7. Sutton PA, Awad S, Perkins AC, Lobo DN. Comparison of lateral thermal spread using monopolar and bipolar diathermy, the Harmonic Scalpel and the Ligasure. *Br J Surg.* 2010;97(3):428-33. doi: 10.1002/bjs.6901.
 8. JM Admin. How to prevent Electrosurgical Fires and injuries. Jackson Medical. Updated December 15, 2021. <https://jackson-medical.com/prevent-electrosurgical-fires/>
 9. L. Barrett, S. M. Garber. Surgical smoke—a review of the literature. Is this just a lot of hot air? *W Surg Endosc* 2003; 17: 979–987. doi: 10.1007/s00464-002-8584-5
 10. Siddaiah-Subramanya M, Tiang KW, Nyandowe M. Complications, Implications, and Prevention of Electrosurgical Injuries: Corner Stone of Diathermy Use for Junior Surgical Trainees. *Surg J (N Y).* 2017; 14;3(4):e148-e153. doi: 10.1055/s-0037-1606547.
 11. Vancaillie TG. Active electrode monitoring. How to prevent unintentional thermal injury associated with monopolar electrosurgery at laparoscopy. *Surg Endosc.* 1998; 12(8):1009-1012. doi: 10.1007/s004649900769.
 12. Batra S, Gupta R. Alcohol based surgical prep solution and the risk of fire in the operating room: a case report. *Patient Saf Surg.* 2008; 26(2):10. doi: 10.1186/1754-9493-2-10.
 13. Wee J, Tan XR, Gunther SH, Ihsan M, LeowMKS, Tan D S-Y, Eriksson YG, Lee JKW. Effects of Medications on Heat Loss Capacity in Chronic Disease Patients: Health Implications Amidst Global Warming. *Pharmacological Reviews* 2023; 75(6): 1140-1166
 14. Bae HS, Lee MY, Park JU. Intraoperative burn from a grounding pad of electrosurgical device during breast surgery: A CARE-compliant case report. *Medicine (Baltimore).* 2018; 97(1):e8370. doi: 10.1097/MD.00000000000008370.
 15. Schultz L. Can Efficient Smoke Evacuation Limit Aerosolization of Bacteria? *Aorn J.* 2015 ;102:7 -14. doi: 10.1016/j.aorn.2015.04.023.
 16. Liu Y, Song Y, Hu X, Yan L, Zhu X. Awareness of surgical smoke hazards and enhancement of surgical smoke prevention among the gynecologists. *J Cancer.* 2019; 10(12):2788-2799. doi: 10.7150/jca.31464.
 17. Wild CP. International Agency for Research on Cancer in Encyclopedia of Toxicology (3rd Ed) Academic Press: Oxford; 2014. pp. 1067-1069
 18. Loveridge R. The Hazards of Surgical Smoke or Plume. *Journal of Military and Veterans' Health.*

- 2002;(11)2 [https://doi-
ds.org/doi/10.1136/oemed-2016-103724](https://doi.org/doi/10.1136/oemed-2016-103724)
19. Kwak HD, Kim SH, Seo YS, Song KJ. Detecting hepatitis B virus in surgical smoke emitted during laparoscopic surgery. *Occup Environ Med.* 2016; 73(12):857-863. doi: 10.1136/oemed-2016-103724.
 20. Rimmer V. Diathermy Smoke Plume: Why do we put up with it? *Journal of Perioperative Practice.* 2016; 19(12)
 21. Bree K, Barnhill S, Rundell W. The Dangers of Electrosurgical Smoke to Operating Room Personnel: A Review. *Workplace Health Saf.* 2017; 65(11):517-526. doi: 10.1177/2165079917691063.
 22. Neill BC, Golda NJ. Smoke-evacuating cautery pencils for dermatologic surgery. *J Am Acad Dermatol.* 2017; 77:e137–e138. doi: 10.1016/j.jaad.2017.05.046.
 23. Hahn KY, Kang DW, Azman ZAM, Kim SY, Kim SH. Removal of Hazardous Surgical Smoke Using a Built-in-Filter Trocar: A Study in Laparoscopic Rectal Resection. *Surg Laparosc Endosc Percutan Tech.* 2017; 27:341–345. doi: 10.1097/SLE.0000000000000459.
 24. Katoch S, Mysore V. Surgical Smoke in Dermatology: Its Hazards and Management. *J Cutan Aesthet Surg.* 2019; 12(1):1-7. doi: 10.4103/JCAS.JCAS_177_18.
 25. Mishra RK. Active Electrode Monitoring System. World Laparoscopy Hospital. Updated 2026. [Internet] Accessed on March 5, 2026. <https://www.laparoscopyhospital.com/Active-Electrode-Monitoring-System.html#:~:text=During%20laparoscopic%20surgery%20unlike%20external, and it%20will%20light%20the%20indicators>.
 26. Dutta DK, Dutta I. The Harmonic Scalpel. *J Obstet Gynaecol India.* 2016; 66(3):209-210. doi: 10.1007/s13224-016-0850-x.
 27. Diamond Electronic Enterprises. Exploring the Future of Electrosurgery: Latest Innovations in Units and Tools. Updated 2024. Accessed on March 5, 2026. <https://diamondsurgical.com/exploring-the-future-of-electrosurgery-latest-innovations-in-units-and-tools/#:~:text=Smart%20Electrosurgical%20Generators,tissue%20response%20can%20vary%20significantly>.