Endoscopy Conference
Electrosurgery in Endoscopy
Department of Gastroenterology
Lahey Clinic Medical Center
Pavlos Kaimakliotis

Outline
- Definitions and Physics of Electrosurgery
- Thermal Effects in Biologic Tissues
- Equipment
- Principles of Electrosurgery
- Waveforms
- Polypectomy
- Implanted Devices

History
- The first commercial electrosurgical device is credited to William T. Bovie
- The first use of an electrosurgical generator in an OR occurred on October 1, 1926 at Peter Bent Brigham Hospital
  - Harvey Cushing removed a brain tumor
Slide 4

**Definition of Electrosurgery**

- **Electrosurgery** – Application of a high-frequency AC electric current to biological tissue
  - Cut, coagulate, desiccate, or fulgurate tissue
- **Electrocautery** – Application of heat conduction from a probe heated by DC
- The use of electrosurgery for hemostasis is termed – **Electrocoagulation**

---

Slide 5

**Importance of Electrosurgery**

- Hemostasis and ablation of pathologic tissue are important techniques in GI
- It is very important to know the principles of electrosurgery and how heat affects tissue
- Particularly true in the colon – thickness of the mucosa, submucosa and MP in the colon ranges from 1.5mm – 3mm

---

Slide 6

---
Electrosurgery

- After insufflation the wall can be even thinner
- Thermal injury should not extend beyond the submucosa
  - Damage to the MP may result in perforation
- The endoscopist is essentially limited to working on only half of the 1.5mm-3mm thick colon wall

The Physics ....

Electrosurgery

- High frequency electric current is used for electrosurgery
  - No "shock" at these high frequencies
  - No time for muscle/nerve depolarization
  - No danger to cardiac muscle
Slide 10

**Tissue heating by Electric Current**

- When *voltage* (V) is applied across a material, an **electric field** is produced.
- The electric field exerts a **force on charged particles**.
- The flow of electrons (in metal) or ions (in biologic tissue) is called **Current** (I).
- \( I = \frac{V}{R} \)

Slide 11

**Principles of Electrosurgery**

- Heat is produced when high-frequency alternating current passes through tissue as the current flows along a circuit.
- Current is produced by an electrosurgery generator unit (ESU).
- Current flowing through a **resistor** (tissue) causes the generation of heat (Joules).
- \( R = \frac{V}{I} \)

Slide 12

**Principles of Electrosurgery**

- The resistance of the tissue converts the electric energy of the voltage source into heat (thermal energy).
- This causes the tissue temperature to rise.
- The deposited electric power can be calculated.
- \( P \) (watts) = \( V \times I = I^2 \times R = \frac{V^2}{R} \)
Thermal Devitalization

- Defined as **irreversible cell death**
  - Occurs when tissue reaches 41.5°C or 106.7°F
- **Not a visible phenomenon**, therefore difficult to control
- Some degree of devitalization does inevitably occur outside the border of the coagulation zone
Slide 16

**Thermal Coagulation**

- Conversion of colloidal systems from sol to gel state (e.g., boiling an egg)
  - ~ 60°C or 140°F
- The structure of cells changes
  - Change in tissue color – visual control
  - Formation and contraction of collagen
- Contraction of collagen can result in some narrowing of the lumen of blood vessels

Slide 17

**Thermal Desiccation**

- Heat induced dehydration of tissue
  - 100°C or 212°F
  - Adhesive effect – desiccation of collagen derivatives
  - Hemostasis – shrinkage and contraction of vessels/adjacent tissue
- Results in a dry layer that acts to insulate tissue electrically
  - No cutting effect and the snare can get stuck within the desiccated tissue

Slide 18

**Thermal Carbonization**

- Partial oxidation of tissue
  - T > 200°C or 390°F in the presence of oxygen
  - Occurs after tissue is desiccated
- If tissue is bathed in a noble gas (argon) carbonization does not occur
- Carbonization can cause smoke which can interfere with visibility during endoscopy
Thermal Vaporization

- Combustion of desiccated or carbonized tissue
  - $T > 500 \text{ C}^\circ$ in the presence of oxygen
- Vaporization does not occur in the presence of inert gas
- Thermal vaporization can be used directly for the ablation of pathologic tissues as well as indirectly for tissue cutting (Nd:YAG laser)

Monopolar Accessories

- Electrosurgical Unit: generator, foot pedal, cords
- Circuit is completed via a remote return electrode (grounding pad)
- Energy leaving the remote return electrode (snare) travels in the path of least resistance through the patient’s body
- The energy is collected over the grounding pad and return to the generator to complete the circuit
Slide 22

**Bipolar Accessories**

- The active and return electrodes are closely spaced into the working tip of the probe
  - Energy travels from the active to the return electrode through a very small portion of tissue in contact with the probe’s tip

---

Slide 23

**Electrosurgical Cutting ...**

---

Slide 24

**Options ....**

- **Mechanical cold cut** – produces no coagulation – “Pure Cut”
- **Electrocautery** (uses a DC to heat an electrode) produces coagulation without cutting
- **Electrosurgery** – provides both cutting and coagulation at the same time
  - The ideal technology for producing therapeutic coagulation, resection and tissue ablation in the GI tract
Principles of Electrosurgical Cutting

- **Voltage** determines the depth of thermal coagulation along the cut edges.

- **Current density** determines how fast cellular water heats.
  - Cellular water heats rapidly, resulting in boiling and bursting of cell membranes.
  - Tissue is immediately evaporated or burned away.

- When these bursting cells are aligned along a blade or wire the result is **electrosurgical cutting**.

---

Current Density

- If current is allowed to spread out and flow through a large area of tissue:
  - Overall resistance and heating effect falls.

- To be effective the flow of current must be restricted through the smallest possible area of tissue.

---

Current Density

This is the principle of current density and explains why intense heat occurs at the small area of a closing loop and no injury occurs at the broad area of the “return pad.”
Tissue Effect Variables

- Ultimately, the end result at the target site is determined by **current density**
- Current density is influenced by several variables:
  - Tissue impedance
  - Chosen power output
  - Waveform
  - Time

Tissue Impedance

- Tissue heats because of high electrical resistance:
  - Resistance varies according to type of tissue and water content
- Tissue with high resistance to current flow:
  - Fat
  - Scar tissue
  - Desiccated tissue
  - Water loss during desiccation increases resistance

Chosen Power Output

- Energy = Power (watts) x time (seconds)
- Coagulation increases directly proportional to increase in power setting
Slide 31

**Chosen Power Output**

- Most modern ESUs have a microprocessor that compares the selected power with a measure of the tissue resistance in contact with the electrode.
- Resistance rises as tissue becomes coagulated.
- This affects power – as impedance rises the current flow decreases.

---

Slide 32

**Chosen Power Output**

- ESUs have a selection that attempts to hold power constant as closely as possible to the selected watts over a broad range of impedance.
- Constant power output is especially important during polypectomy.
- This helps reduce the possibility of snare entrapment by providing adequate power during the entire resection.

---

Slide 33

**Time**

- Significant variable controlled by the operator.
- Energy = Power (watts) x time (seconds).

---
Waveform

- Every ESU is designed to offer several different waveforms
- Cut, Forced Coag, Dessicate, Blend, etc (this nomenclature is not standardized)
- ESU produce outputs that range from low voltage, continuous sine waves to interrupted (modulated) with high voltages

---

Waveform – Cutting Current

- A cold cut is the only 'pure' cut
- Electrosurgical cutting is possible at 200Vp
- Uninterrupted (high power) waveform of relatively low voltage spikes

---
Slide 37

**Waveform – Cutting Current**

- A continuous waveform with >200Vp will produce current densities high enough to produce many rapidly heated, exploding cells along a wire
- Pure cut setting will result in some coagulation at the margins of the cut
- Due to the relatively low voltage, cut current is less able to pass desiccated tissue and to heat deeply

---

Slide 38

**Waveform – Coagulating Current**

- Intermittent higher voltage spikes with intervening “off periods”
- “Off periods” last ~80% of the time
- Higher voltage allows deeper spread of current across desiccated tissue

---

Slide 39

**Waveform – Coagulating Current**

- By intermittently stopping the current flow, tissue has a chance to cool down
- The portion of cells that desiccates without exploding increases
- By balancing how frequently current flows (duty cycle) with the voltage peak, allows prediction of effect on tissue
Slide 40

**Waveform – Blended Current**

- Combines Cutting and Coagulating Currents
- May provide more effective hemostasis

Slide 41

**Waveform – Summary**

- A generator will have a defined time on/off cycle
  - A continuous wave has a 100% duty cycle and is named ‘Cut’
  - One that is supplying current half the time and off the remainder has a 50% duty cycle
- Duty cycles of 20–80% often have names such as: Swift coag, blend, blend cut
- ‘Coag’ often have duty cycles of 6–12%
  - During the time there is current flowing, the voltage spikes far over 200Vp and cutting occurs

Slide 42

**Applications – Polypectomy**

- It is important that the temperature required for an intended thermal effect is delivered only into the target tissue
- Although it is not possible to avoid heat transfer, it may be possible to keep thermal damage of adjacent tissues to a minimum
- Some coagulation and/or desiccation effect to adjacent tissue may be desired in some cases
Polypectomy

- The tightness of the snare is critical – the area through which the current is concentrated decreases as the square of snare closure ($r^2$).

- The heat produced increases as the square of the current density.

- Heating increases as the cube of snare closure.

Polypectomy

- Resection of a polyp consists of two phases:
  - Precut phase
  - Effective cut phase

- Precut Phase – time between activation of the generator and start of the effective cut, the so-called 'cut delay'.

Polypectomy – Cut Delay

- The tissue adjacent to the snare becomes heated until the water in this tissue reaches boiling temperature.

- The steam from this thermal effect insulates the snare from tissue.

- The heat produced during this cut delay causes thermal damage of the colon and could result in perforation.
**Cut Delay – Risk of Perforation**

- [Diagram](#)

---

**Polypectomy – Pedunculated Polyps**

- It is essential to coagulate the core of the polyp stalk or base.
- When removing a thick stalked polyp there should be visible whitening at the stalk to coagulate the plexus of vessels prior to transection.
- Closing the snare loop:
  - Stops the blood flow.
  - Concentrates the current to flow through the polyp stalk.

---
Slide 52

APC – Safety Issues

- Monopolar device – pad placement
- Argon gas insufflates the GI lumen
- The end of the probe must not touch the mucosa
- Perforation

Slide 53

Implanted Electronic Devices

- Endoscopy is commonly performed in patients with implanted electronic devices
  - Pacemakers (PM)
  - Implantable cardioverter-defibrillator (ICD)
- Familiarity with the potential for patient injury
- Risk and management strategies for endoscopy and the use of electrosurgery in patients with implanted electronic devices

Slide 54

Electromagnetic Interference (EMI)

- The effect of an electromagnetic field (EMF) on any electronic device
- Variables that determine the likelihood of EMI
  - Intensity of EMF
  - Frequency and waveforms of the signal
  - Distance between the electrocautery application and the leads of the implanted device
  - The orientation of the leads with respect to the EMF
Effect of EMI on Implanted Devices

- The signal can be interpreted as:
  - Physiologic – sensed as intrinsic cardiac electrical activity and inhibit PM output
  - Pathologic – sensed as VF resulting in discharge of an ICD
- Electrical impulses may conduct down leads and cause inappropriate stimulation (AF, VF)
- High levels of current may pass through the implanted leads and damage tissue or the device battery

Management of Patients with Cardiac Devices

- Peri-procedural planning:
  - Obtain information regarding the device
  - Indication for the device
  - Degree of dependence and the patient’s underlying rhythm
- Consult with the patient’s Cardiologist:
  - How will the device respond to a magnet
  - Should the device be reprogrammed during or after the procedure

Pacemakers and Magnets

- Patients who are PM dependent (complete AV block):
  - Require temporary reprogramming of the PM to an asynchronous mode (VDD or DDD)
  - Achieved temporarily by placement of a magnet taped over the PM
  - This converts the PM to a constant rate prespecified by the manufacturer
  - The magnet response varies among manufacturers and device models
Slide 58

ICDs and Electrocautery

- Potential for triggering inappropriate ICD therapy
- ATP during sinus rhythm can trigger VT or VF
- A properly placed magnet over an ICD will suspend tachycardia detection and/or ICD therapies
- Certain ICD models (Guidant) may be programmed to permanently disable ICD therapy after prolonged application of a magnet

Slide 59

General Safety Issues

- Poor prep - risk of explosion
- Separate circuits for ESU and other equipment
- Position cords to prevent accidents
- Investigate requests for more power
  - Check the pad
  - Check all connections
  - Consider trying different pad, snare, ESU
- Familiarize yourself with the manufacturers recommendations for power settings
- Confirm power settings with the endoscopist prior to use

Slide 60

Safety – Dispersive Electrode (Pad)

- Avoid patient to metal contact
- Place pad prior to covering patient and document location
- When placing the pad avoid
  - Bony prominences
  - Hairy surface
  - Scars, pre-existing skin lesions, tattoos
  - Implants
- Check for skin damage under the pad at the end of the case
Definitions
- Electrosurgery vs Electrocautery

Thermal Effects in Biologic Tissues
- Devitalization, Coagulation, Dessication, Carbonization and Vaporization

Physics of Electrosurgery
- From electricity to heat

Summary

Equipment
- Monopolar vs Bipolar

Principles of Electrosurgery
- Current density, Electrosurgical cutting, Tissue effect variables, waveforms

Polypectomy

Implanted Devices