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Endoscopy Conference

Electrosurgery in Endoscopy

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Outline

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

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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

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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**

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Importane 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

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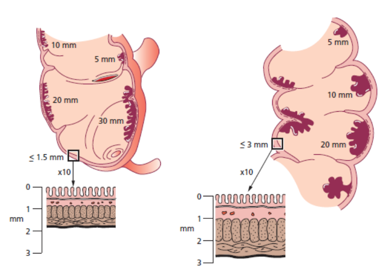

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Electrosurgery

- 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

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The Physics ....

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Electrosurgery

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

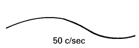

Fig. 7.7 A household current alternates 50–60 times per second, producing heat and shock.

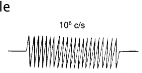

Fig. 7.6 An electrosurgical current alternates 1 000 000 times per second, producing heat but no shock.

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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** = V/R

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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 = V/I

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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
  - $P \text{ (watts)} = V \times I = I^2 \times R = V^2/R$

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Thermal Effects in Biologic Tissues …

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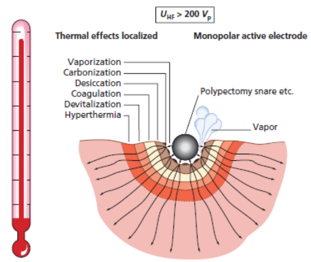

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Thermal Devitalization

- 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

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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

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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

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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

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Thermal Vaporization

- **Combustion of desiccated or carbonized tissue**
  - T > 500 C° 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)

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Equipment …

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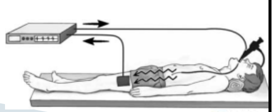
Monopolar Accessories

- 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



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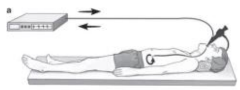
Bipolar Accessories

- 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



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Electrosurgical Cutting …

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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

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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**

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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**

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Current Density

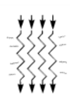
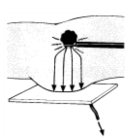


Fig. 7.11 Current flows more easily through larger areas of tissue resistance and so produces little heat.

Fig. 7.12 Current density results from constricting tissue and greatly increases heating.



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"

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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**

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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

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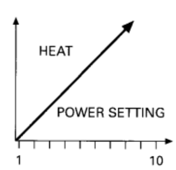
Chosen Power Output

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



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Chosen Power Output

- Most moderns 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

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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

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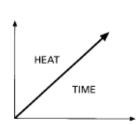
Time

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



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Waveform

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

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Table 1. Monopolar output mode characteristics for selected electrosurgical generators*

Duty cycle	Crest factor	Conmed 5000	Conmed 7500	EndoStat	EndoStat III	Erbe ICC200	Erbe VIO300	Medtron 3000B/pentax	Valleylab SurgiStat II	Valleylab force EZ-C	Valleylab force 2	Valleylab force FX
100%	1.4	Pure cut Pulse cut	Pure cut Pulse cut	Cut	Cut and control cut	Soft Coag (190) Autocut and EndoCut	Soft Coag (190) Autocut, EndoCut I, Q	Cut			Cut	
	1.5									Pure cut (2000), desiccate low 2 (660) low 3 (1100)		Low cut (1350) Pure cut (2300)
92%			Blend 1									
84%			Blend 2									
76%			Blend 3									
70%	1.7	Blend 1			Blend							
68%			Blend 4									
60%			Blend 5									
52%			Blend 6									
50%				Blend				Blend 1			Blend 1	
50%	2.5											Blend
44%			Blend 7									
37%											Blend 2	
38%			Blend 8									
	2.1	Blend 2								Blend		
30%	2.7	Blend 3	Blend 9		Coag							
	2.9								Cut			
	3.0						Dry cut Effect 1–4					
	3.2						Dry cut Effect 5–6					
	3.3								Blend			
	3.8	Pinpoint Coag					Dry cut Effect 7–8					
25%								Blend 2			Blend 3	
12%			Pinpoint Coag	Coag				Blend 3				
8%	5.0									Desiccate low 1 (3900)		Desiccate
	5.0									Fulgurate high 1 (6200)		
	5.4						Swift Coag					

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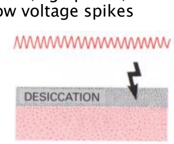
Waveform – Cutting Current

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



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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

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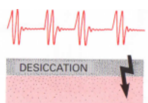
Waveform – Coagulating Current

- 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



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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

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Waveform – Blended Current

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

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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

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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

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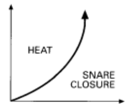
Polypectomy

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



- The heat produced increases as the square of the current density
- **Heating increases as the cube of snare closure**

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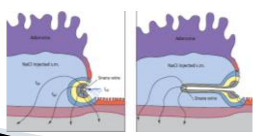
Polypectomy

- 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**"



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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

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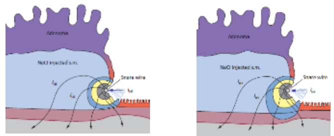
Cut Delay – Risk of Perforation



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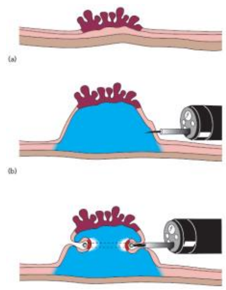

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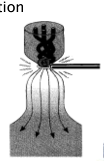
Polypectomy – Pedunculated Polyps

- 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



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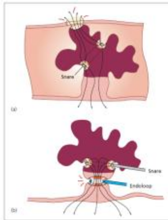
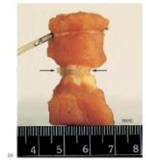
Unintended Thermal Effects





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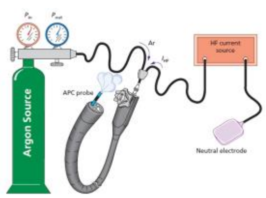
Argon Plasma Coagulation



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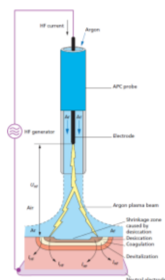
Argon Plasma Coagulation

- Argon – inert gas prevents carbonization
- Relatively inexpensive
- Electrically active beam seeks conducting tissue



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APC – Safety Issues

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

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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

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Electromagnetic Interference (EMI)

- The effect of a 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

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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

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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

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Pacemakers and Magnets

- Patients who are PM dependent (complete AV block)
  - Require temporary reprogramming of the PM to an asynchronous mode (VOO or DOO)
  - 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

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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

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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

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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

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Summary

- Definitions
  - Electrosurgery vs Electrocautery
- Thermal Effects in Biologic Tissues
  - Devitalization, Coagulation, Dessication, Carbonization and Vaporization
- Physics of Electrosurgery
  - From electricity to heat

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Summary

- Equipment
  - Monopolar vs Bipolar
- Principles of Electrosurgery
  - Current density, Electrosurgical cutting, Tissue effect variables, waveforms
- Polypectomy
- Implanted Devices