The Art and Science of Electrosurgery and Argon Plasma Coagulation in Endoscopy

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Electrosurgical Procedures
An Art and Science...
My Mother...My Mentor...My Teacher
Disclosure/other pertinent facts

Employed full-time with ERBE-USA as a Clinical Education Manager

Program has been approved as a GI-Specific contact hour program for 1.0 hours by the American Board for Certification of Gastroenterology Nurses (ABCGN)

Separate sign-in, evaluation, and certificate
Objectives

1. Discuss the basics of electricity and how it’s adapted for use in the human body.

2. Describe how Electrosurgery is used therapeutically and the variables that affect it.

3. Discuss how to provide safe electrosurgical care to patients.

4. Describe the basic principles and components of Argon Plasma Coagulation (APC) and how it’s applied safely in clinical applications.
How cauterization all started...

Various tools were heated with fire -17th century.
History - Hemostasis by cauterization

1848
Galvanocautery

Christian Heinrich Erbe

von Bruns, MD

These devices were comprised of a metal wire, heated by means of an electrical galvanic (direct) current - used for coagulation and separation of biological tissue and was referred to as **galvanocautery**.
In 1978, Dr. Glover published an article on the use of thermal knives in comparison to other modalities and stated, "There is no group of instruments in the surgical armamentarium that is used as frequently and understood as poorly as Electrosurgery units...."
We are educated...but...

- None: 50%
- 1/2 to 1 Day: 19%
- < 1 Hour: 10%
- 1+ Day: 21%
Electrocautery vs. Electrosurgery...

...there is a difference

Electrocautery:
- Uses direct current.
- Often used inaccurately to describe “Electrosurgery”.
- Current does not enter the patient’s body – only the heated wire tip comes in contact with tissue.

Electrosurgery:
- Uses High-Frequency Alternating Current (AC).
- The AC Circuit must be completed: includes the electrosurgical generator, active electrode, the patient and return electrode.
Using High-Frequency Alternating Current

- **60 Hz**
  - Household

- **100,000 Hz**
  - Neuromuscular stimulation

- **350,000 Hz**
  - ESU’s
    - Therapeutic Effect

- **54-880 MHz**
  - TV

- **550-1550 kHz**
  - AM Radio
Fundamental Properties of Electricity

The Clinical Circuit is complete when current flows from the ESU to the active electrode, to the patient, to the pad, and back to the ESU.

Three variables are always present during electrosurgery:

• **Current** – flow of electrons moving through the electrical circuit, *measured in amps (I)*.

• **Voltage** – electrical force pushing current around the circuit, through varying degrees of tissue resistance, *measured in volts (V)*.

• **Resistance** (Impedance) – opposition to current flow - literally the tissue being treated, which has varying characteristics, *measured in ohms (R)*.
Volunteers ???
Ohm’s Law is a set of mathematical formulas used in electronics to calculate an unknown amount of current, voltage or resistance.

- Ohm’s Law helps to predict how ESUs will interact with tissue.
- The mathematical formula looks like this:

\[(I) \text{ Current} = \frac{(V) \text{ Voltage}}{(R) \text{ Resistance}}\]

or

\[V = I \times R\]
Adding Power (W) to the Equation:

*Power is the amount of energy produced over time and is a result of Voltage x Current.*

\[ W \text{ (Power)} = (V) \text{ Voltage} \times (I) \text{ Current} \]
Types of Electrosurgical Generators

**Constant Voltage**
- The voltage remains constant, to maintain consistent tissue effect, regardless of changes in tissue resistance (muscle, fatty tissue).
- The power (watts) automatically adjusts in response to the tissue impedance/circuit variables.

**Constant Power**
- Watts (power) setting is chosen.
- The Watts remain constant.
- Voltage varies to maintain Watts.
- All tissue is treated with same Wattage.
Example of CP vs CV

Example:

**Constant Power Generator:**

\[ R \text{ (variable tissue resistance)} \times \text{Power} = V^2 \text{ (voltage or thermal damage)} \]

<table>
<thead>
<tr>
<th>R</th>
<th>x</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>100</td>
<td>5000</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>10000</td>
</tr>
<tr>
<td>200</td>
<td>100</td>
<td>20000</td>
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</tbody>
</table>

**Constant Voltage Generator:**

\[ R \text{ (variable tissue resistance)} \times \text{Power} = V^2 \text{ (voltage or thermal damage)} \]

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<td>100</td>
<td>10</td>
<td>1000</td>
</tr>
<tr>
<td>200</td>
<td>5</td>
<td>1000</td>
</tr>
</tbody>
</table>
Monopolar Circuit
Bipolar Circuit
Basic Principles of Electricity

- Always seeks ground.
- Always seeks the path of least resistance.
Tissue Impedance

Tissue Impedance Varies with Water Content

Least to Most Resistance

- Muscle, Kidney, Eye
- Liver, Oral Cavity
- Gallbladder
- Bowel, Fat
- Mesentary, Brain
- Scar Tissue, Lung, Adhesions
GI Endoscopy Pad Placement

Pad Placement

• Well vascularized area
• Shortest circuit possible
• Optimum – on flank
• Alternatives – Thigh or Arm
• Avoid Buttock placement
• Remove pads carefully to prevent shearing of skin
Did You Know...

If the hair on the hand looks like this, imagine the hair at the pad placement site...

The Dispersive Electrode Should NOT Be Placed Over:

- Boney prominences
- Scar tissue – including Tattoos
- Skin/Scars over an implanted metal prosthesis
- Hairy surfaces – clip if necessary
- Lotions or oils on skin
Diagonal alignment of the dispersive electrode may result in higher current densities at the corner.
Using the Dispersive Electrode Correctly

The long side of the dispersive electrode must face the operating field.
What is Current Density?

- Current Density is one of the most important elements of electrosurgery.
- Basically, current density is the amount of current concentration (intensity of heat generation) at a given area.
- Thermal effect is created at the active electrode.
Current Density
Which one offers more *Electrical Impedence*?

A Small Polyp?  ...or a Larger One?
...all shapes and sizes...many variables
Endoscopy Polypectomy Techniques

Quality indicators for colonoscopy

Douglas K. Rex, MD, John L. Petrini, MD, Todd H. Baron, MD, Amitabh Chak, MD, Jonathan Cohen, MD, Stephen E. Deal, MD, Brenda Hoffman, MD, Brian C. Jacobson, MD, MPH, Klaus Mergener, MD, PhD, Bret T. Petersen, MD, Michael A. Safdi, MD, Douglas O. Faigel, MD, ASGE Co-Chair, Irving M. Pike, MD, ACG Co-Chair

ASGE/ACG Taskforce on Quality in Endoscopy
Variables Impacting Tissue Effect

- Type of Generator: Constant voltage vs. constant power
- Waveform: Cut vs. Coag
- Type (size) of Electrode
- Physician technique
- Pad placement
- Patient variables: age, body type, hydration, tissue, IED's, etc.
- Length of activation
- Anatomical location
- Physician technique
- Pad placement
- Patient variables: age, body type, hydration, tissue, IED's, etc.
- Length of activation
- Anatomical location
# Electrosurgical Thermal Effects on Cells

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Tissue Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>104°F:</td>
<td>Reversible cellular trauma</td>
</tr>
<tr>
<td>120°F:</td>
<td>Irreversible cellular trauma</td>
</tr>
<tr>
<td>158°F:</td>
<td>Coagulation (Desiccation)</td>
</tr>
<tr>
<td>212°F:</td>
<td>Cutting</td>
</tr>
<tr>
<td>392°F:</td>
<td>Carbonization</td>
</tr>
</tbody>
</table>
Cutting

- Voltage quickly raises cell water temperature to the boiling point.
- Cell water turns to steam.
- Cell explodes, separating from adjoining cells.
- Cleavage plane is created = clinical “CUT”.

Note: For cutting to occur a minimum of 200 Vp is required to get a spark.
• ENDO CUT is a specialized waveform which involves a fractionated cutting mode with patented spark recognition technology, characterized by alternating cutting and coagulation cycles.

• Constant Voltage/Power Dosing Technology.

• Yellow Pedal.


Spark Recognition (arc regulation) technology

• Patented algorithm capable of recognizing microelectric arc production.

• Limits the “spark on” time to a few milliseconds, depending upon the duration chosen (the higher the duration, the longer the spark on up to 12 ms).

• Rapid spark production with limited ‘on’ time decreases thermal spread.
Coagulation

Hemostasis due to shrinking tissue

• Waveform with spikes of high voltage, followed by rest periods.
• This allows the cellular proteins to slowly denature (dehydrate).
• Coagulation occurs.
Yellow + Blue **IS NOT** Green in electrosurgery...

- COAGULATION (Blue) is completely independent of CUT (Yellow).
- BLEND-CUT or ENDO CUT is a CUT feature (Always Yellow).
- Settings on one side do not effect the other.

Like a set of rail tracks running into infinity... they never meet.
Argon Plasma Coagulation (APC)

APC is a non-contact monopolar application for hemostasis and thermal destruction
What is Argon Plasma?

Argon

- Nobel gas
- Present in air (≈ 1%)
- Non-flammable
- Non-toxic
- Ionizes easily
- Heavier than air

Plasma

- Ionized, electrically conductive gas
- Ionization by way of high voltages
Argon—one of the Nobel gases
IF A QUEEN PASSES GAS, IS IT CONSIDERED A NOBEL GAS???
The voltage required for ionization of gas is ≈ 4000 volts.

APC is a monopolar application in which HF electrical energy is transferred to the target tissue using ionized (conductive) argon gas (plasma), without the electrode coming in contact with the target tissue.
Argon Plasma Coagulation offers particular advantages for endoscopic applications as it can be applied en face or tangentially, enabling less accessible areas to be easily treated.
Argon Plasma Coagulation

APC Advantages:

- Non-contact application.
- Smoke is reduced.
- Thinner, more flexible eschar.
- Widespread areas can be treated.
- Applications can be –
  - Axial
  - Radial
  - Retroflexed
  - Circumferential
Argon Plasma Coagulation

Using APC:

• Purge probe at least twice before placing in the scope channel.

• Advance the tip of the probe until the first black line is visible on the monitor; at this point, you can slightly pull the probe back to facilitate scope articulation, depth perception, and treatment as needed.

• APC probe tip must always remain in the clinicians field of vision.

• Activate only when the tissue being treated is within the field of view.

• Leave the probe stationary – move the SCOPE.

• Proximity to tissue: 1 - 5 mm.
# Argon Plasma Coagulation

**Application techniques:**

<table>
<thead>
<tr>
<th>Static:</th>
<th>Dynamic:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Probe is focused in one single area.</td>
<td>• Probe is moved with paintbrush-like strokes over the target area while observing the target tissue effect.</td>
</tr>
<tr>
<td>• Thermal penetration will increase over time.</td>
<td></td>
</tr>
<tr>
<td>• Carbonization and vaporization can occur with long activations in one area.</td>
<td></td>
</tr>
<tr>
<td>• For superficial treatment, short activation times of 1-2 seconds are used.</td>
<td></td>
</tr>
</tbody>
</table>
Proper Technique

Clinical Video
ERBE.VIO.TOMMYGUN.GAVE.mpg
Argon Plasma Coagulation

APC thermal tissue effect depends on several factors

<table>
<thead>
<tr>
<th>Factors Influencing the Tissue Effect</th>
<th>Very Important</th>
<th>Less Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Duration of Activation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Power Setting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Probe Distance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Duration of Activation

- When the application time over the same area is increased, the depth of the tissue being affected will increase.

- The physician should treat with an activation time to correspond with the desired thermal effect and anatomical location.

Fig. 12: Depth effect depending on the duration of activation with the APC modes in a bovine liver. Testing was performed with an ESU (VIO® 300 D Model)/APC (APC™ 2 Model) System along with an A-type (Straight Fire) APC probe, O.D. 2.3 mm. Also, the application was vertical and the probe distance was 5 mm.
Power Setting or Effect Setting

In general:

- **Lower output settings** – are used for treatment of very small superficial areas, or in applications with very thin-walled tissue structures.

- **Higher output settings** – are used for treatment when devitalization is required, or for the reduction of tissue.
Probe distance can influence thermal tissue effect based on the mode chosen:

- **FORCED APC**
- **PULSED APC**
  - Effect 1
  - Effect 2
- **PRECISE APC**
Another important factor involving thermal effect is the mode chosen...

<table>
<thead>
<tr>
<th>FORCED</th>
<th>PULSED EFFECT 1</th>
<th>PULSED EFFECT 2</th>
<th>PRECISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Constant beam</td>
<td>• Higher energy output one pulse/second.</td>
<td>• 16 pulses/second with a lower energy output per pulse.</td>
<td>• Superficial coagulation effect using a low-energy output.</td>
</tr>
<tr>
<td>• <em>Areas of Application:</em></td>
<td>• “Static” applications used for more focused treatment of smaller, superficial areas in need of hemostasis.</td>
<td>• “Dynamic” applications used for the treatment of diffuse, superficial hemostasis.</td>
<td>• <em>Areas of Application:</em></td>
</tr>
<tr>
<td>• Rapid devitalization of target tissue</td>
<td></td>
<td></td>
<td>• Superficial hemostasis in thermosensitive areas and/or within thin-walled structures.</td>
</tr>
<tr>
<td>• Hemostasis of acute bleeding</td>
<td></td>
<td></td>
<td>• Devitalization and reduction of lesions or tissue remnants that are superficial in nature.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• When maintaining the probe distance from the tissue is difficult, e.g., enteroscopic intervention due to plasma regulation.</td>
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Areas of Application:

- Superficial hemostasis.
- Thermosensitive areas and/or within thin-walled structures.
- Devitalization and reduction of lesions or tissue remnants that are superficial in nature.
- In situations where maintaining the probe distance from the tissue is difficult, e.g., enteroscopic intervention.

Clinical Video
Angiodysplasia
PRECISE APC Effect 5
There are differences:

• Diameter
• Length
• Shape of the probe’s outlet:
  • Axial direction
  • Side fire
  • Circumferential

Black rings:
• 1cm apart (10mm)
Clinical Applications - APC

Gastroenterology Uses reported in Clinical Literature

- Radiation Induced Proctopathy
- Watermelon Stomach (GAVE)
- Treatment of Residual Adenomatous Tissue
- Stent Shortening (e.g. migrated stents)
- Strictures
- Exophytic Benign or Malignant Tumors
- Oozing from Vascular Lesions (e.g. Angiodysplasias, Arteriovenous Malformations (AVMs), Telangiectasias)
Clinical Applications

Residual Tumor Ablation

1. Adenoma of Cecum
2. Adenoma Injected
3. Adenoma Snared (piecemeal)
4. Ablation of Bed with APC

Long term clinical study results show 50% reduction in re-growth of adenomatous polyps after tissue treatment with APC.


References:

Clinical Applications - APC

**Gastroenterology Uses found in Clinical Literature**

References:

Clinical Applications

Pulmonary Uses reported in Clinical Literature

- Granulation Tissue
- Bleeding/Hemoptysis
- Exophytic Tumors
- Stent Over-growth/In-growth
Clinical Applications - APC

Pulmonary Uses found in Clinical Literature

References:

Clinical Safety Considerations...

...let’s discuss further.
Clinical Safety

Important Considerations for Endoscopy

- Use the lowest possible output settings, as well as the shortest activation times.
- Confirm gas flow (with APC use) and settings prior to activation.
- Continuously monitor for signs of over-distention.
  - Brief and repeated aspirations should be routinely performed throughout the procedure.
Clinical Safety

Important Considerations for Endoscopy

APC is a non-contact modality

If an ‘Axial’ Probe probe is too close to the tissue, an undesirable thermal effect or submucosal emphysema may occur.
Avoid APC activation in close proximity of metal objects

- The APC probe should not be activated if the tip is in close proximity to metal objects.
- Unintended thermal injury of the surrounding tissue may occur.
- Metal objects may receive unintentional damage.
- Exceptions - “trimming” of migrated metal stents.
The Importance of Bowel Preps...

- Incomplete Preps or enema-only preps for Flexible Sigmoidoscopy increases the risk for bowel explosions.

- Bowel explosions can occur with **ANY** monopolar electrosurgery (e.g. snare, APC, hot biopsy) when combined with hydrogen and methane gases in a dirty colon.

- Patients should be fully prepped.
Quiz: Who’s has the most gas? Hint: Not the female

12/24/08-07/31/16
“Yes! That was very loud Mr. Trainer, but I said I wanted to hear your **HEART!**”

“I'll release you when you're able to pass gas. I'll be in tomorrow to pull your finger.”
Clinical Safety - Oxygen Management

Preventative Measures to Avoid Combustion

Maintain oxygen concentration at safe levels:

- **Conscious Sedation Patient**
  Supplemental nasal cannula
  \( O_2 \) at 3 L/M or LOWER.
  *Mask delivery is considered high risk.*

- **Intubated Vent Patient**
  \( \text{FiO}_2 \) Concentration should
  be reduced to 40% or less.

- **Activation**
  Activate APC during the patient’s exhalation phase, or during apnea.

*Combustion requires a heat source, fuel, and oxygen, all components of the fire triangle.*
Patient Return Electrode Monitoring

- Introduced in the 1980’s:
  - Return Electrode Monitoring (REM)
  - Aspen Return Monitoring (ARM)

- Introduced in the early 1990’s:
  - Neutral Electrode Safety System (NESSY)

- Introduced in 2012:
  - Neonatal Monitoring

According to AORN guidelines, return-electrode contact quality monitoring (RECQM) should be furnished on general purpose electrosurgical units.

2013 Perioperative Standards and Recommended Practices, AORN.
Dispersive Electrodes

• According to AORN:
  • Dispersive electrode site burns are the most reported electrosurgical injury.
  • With improved technology and the use of safety features, pad-site burns have decreased from 50 to 100 in the late 1970’s to one to two per month in 2007.
  • Return electrode quality monitoring must be furnished.
  • Dual pads should be used.

2013 Perioperative Standards and Recommended Practices, AORN.
Dispersive Electrodes

- **MONO Foil or Single pad:**
  - Performs only completion of the electrical circuit.
  - The current density of the pad edges is not measured.
  - The correct orientation of the pad is not measured.

- **DUAL Foil or Split Pad:**
  - Completes the electrical circuit.
  - Disperses the current density.
  - Engages the safety system of the unit to monitor for high current density (and correct orientation with NESSY ®).

*Mono Pads bypass the pad safety system of generators...*

*Always recommended*
Dispersive Electrode Reminders

- Open the pad only when ready to use.
- Pads cannot be repositioned; always replace the pad.
- Remove pad SLOWLY to prevent skin shearing.
- Always check the pad placement before activation of the ESU.
- Do not “test” instruments on the pad, e.g. snares, hot forceps.
Clinical Safety

Jewelry Removal:

- ESU Manufacturers and Clinical Guidelines recommend removal of ALL pierced and non-pierced jewelry, due to the risk of burn if within the electrical circuit.

- Removal helps to:
  - Avoid Burns
  - Avoid accidental injury
  - Lower staff liability
Challenge?
Clinical Safety – Additional Challenges

Body modifications require special attention for maintenance of the patients skin integrity...

Trans-dermal and micro-dermal implants – thin metal posts protruding through skin

Sub-dermal implants

Additional risks are posed due to:
- Patient positioning
- Patient transfers
- Electrosurgery use and pad placement
Implanted Electronic Devices

Implanted Electronic Devices (IEDs) are battery operated devices placed within a patient’s body to treat a physiological defect or to replace a sensory function.

- **Cardiac**
  - Pacemakers
  - Internal Cardiac Defibrillators (ICDs)
  - Ventricular Assistive Devices (VADs)

- **Neurostimulators**
  - Deep brain stimulators
  - Spinal cord stimulators
  - Vagal nerve stimulators
  - Programmable ventricular shunts

- **Implantable Hearing Devices**
  - Cochlear Implants
  - Auditory Brainstem Implant (ABI)
  - Bone-conduction stimulators

- **Implanted Infusion Pumps**

- **Osteogenic (Bone-growth) Stimulators**

- **Gastric Electronic Pumps**
Safety Considerations – IED’s

Pre-planning is crucial...

• Pre-procedure knowledge of IED patients allows time for adequate planning:
  • Determine the type and location of the device.
  • Contact the implanting physician to determine -
    • Last device evaluation.
    • Any specific pre-op/post-op orders for the device.

• Consider having a policy in place specific to IED patients:
  • Utilize anesthesia and manufacturer device-specific guidelines as warranted to assist with establishing facility protocols and guidelines for care of IED patients.
  • Contact appropriate device representatives and arrange presence during procedures, based on protocols.
  • Notify the physician, anesthesia and other team members in advance of an IED patient.
Implanted Electronic Devices

“AORN Guidance Statement: Care of the Perioperative Patient With an Implanted Electronic Device”

AORN offers guidelines for Implanted Electronic Devices
Safety Considerations – IED’s

Electrosurgical Safety for Patients with IED’s

• Use Bipolar when possible.
• Keep 15 cm between the active electrode and any EKG electrode.
• Have resuscitation equipment at the ready – DOCUMENT.
• Have the device clinical support line available.
• Contact the IED manufacturer for specific deactivation recommendations.
Safety Considerations – IED’s

Electrosurgical Safety for Patients with IED’s

*If the physician must use Monopolar current:*

- Apply the dispersive electrode close to the operative site, but as far away from the IED as possible (e.g., for patients with pacemakers/ICD’s, place on the opposite lower extremity to draw current away from the device).

- Use the lowest settings possible.

- Use the shortest possible activations.

- If the ICD is deactivated, re-establish integrity of the device post-procedure.
Summary

• The “art” of therapeutically utilizing high-frequency (HF) electricity/electrosurgery within the hollow lumen of the GI tract requires a fundamental working knowledge of the scientific principles involved in order to optimize clinical outcomes while minimizing risks.

• It is important for the clinician to understand the basic principles and properties of electrosurgery and APC and how it’s adapted for clinical use.

• In addition, staying well-informed on the current standards and recommended practices for clinical safety, e.g. SGNA and AORN, enhances our ability to make critical decisions and to promote optimal patient outcomes.
Gratitude to my family!

12/24/08=07/31/16