



Non-CME Webinar Series
designed with the trainee in mind

first Tuesday of the month



Radiofrequency Interventions for the Facet Joints: Background, Improving Outcomes, and Guidelines

Tuesday, November 7, 2023

7-8:30 pm ET



Non-CME Webinar Series
designed with the trainee in mind

first Tuesday of the month



Applied Science of Radiofrequency Ablations

Maxim S. Eckmann

Interim Chair, UT Health San Antonio Anesthesiology

Ramamurthy Professor of Anesthesiology and Pain Medicine

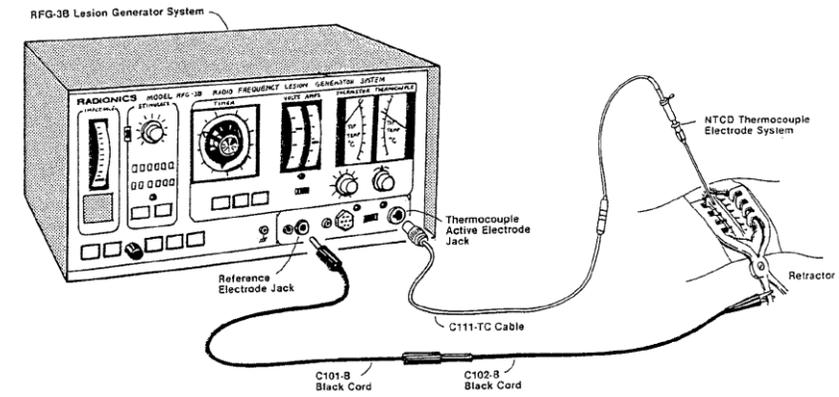
Co-Chair, ASRA CME Committee

Past President and Director Emeritus, Texas Pain Society

Examiner, American Board of Anesthesiology

Objectives

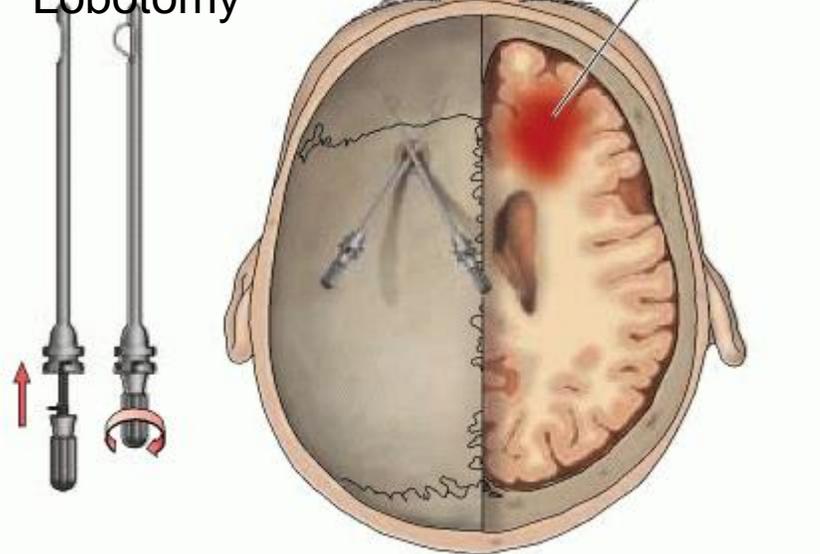
- Elucidate scientific principles governing Radiofrequency Ablation (RFA).
- Evaluate methods RFA for lesion manipulation.
- Apply current technological concepts to understand relevant advantages, limitations, and complications.



Modes of Lesion Making in the Nervous System

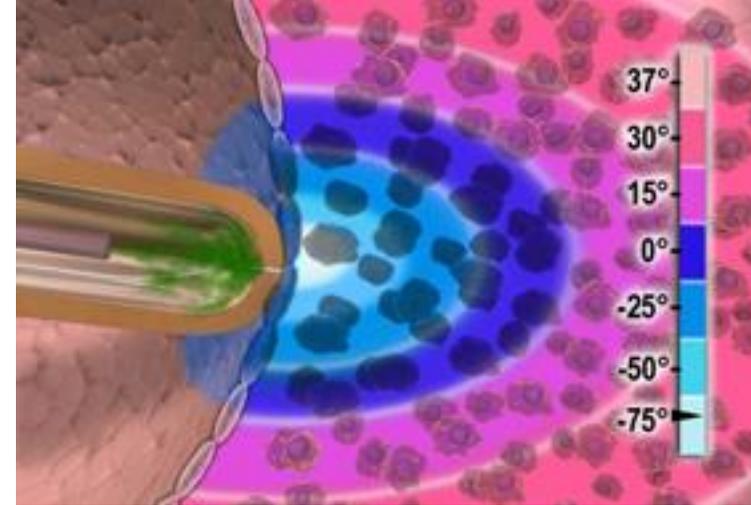
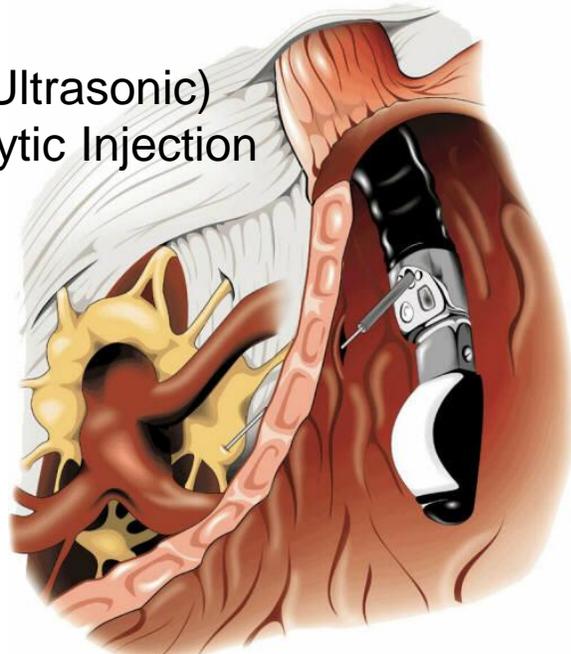
- Direct current (DC) heating
- Cryogenics (freezing)
- Focused ultrasound
- Chemical Injection (e.g. phenol)
- Ionizing Radiation
- Mechanical (Leukotome)
- Induction heating
- Focused Electromagnetic Waves
- Light Amplification by Stimulated Emission of Radiation (LASER)

Leukotome for Lobotomy



<http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=neurosci.box.1811>

Endoscopic (Ultrasonic) Celiac Neurolytic Injection



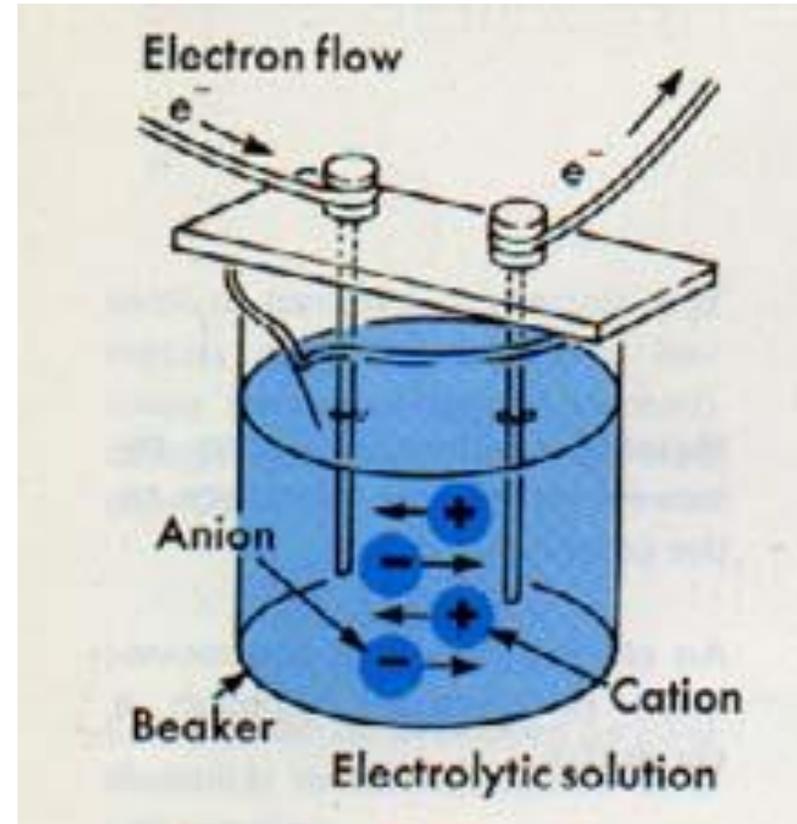
Cryoablation using a catheter-based approach in cardiology. Temperature profile. CryoCath Technologies Inc. 2006



Arcidiacono PG. *J Pancreas (Online)* 2004; 5(4):315-321

Physics of RF: Conductivity

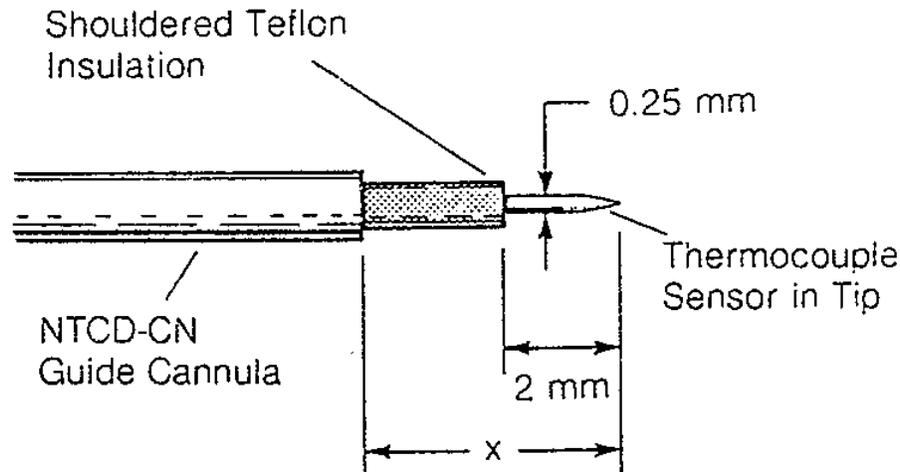
- Metals:
 - electrons in the outer shells of metal atoms are easily displaced
- Ionic solutions:
 - Ions (charged) move to and fro in the electric field
 - Contact of ions with the anode or cathode results in electron transfer (not desired *in vivo*)



Why is this important for RF?

- The RF generator delivers an alternating (AC) electric field to the tissue.
- This field causes movement of ions and charged proteins in the tissue, extracellular fluid, and intracellular fluid.
- Ionic movement causes frictional heating, resulting in a lesion.
- Tissue has both a **Resistance** and an **Impedance**, and both must be in appropriate range for safety and efficacy.

Temperature Feedback Control



1980s Radionics Probe w/Thermistor;

Development of probe thermistors and practically sized probes/cannulae in the 1980's lead to the expanding popularity of percutaneous RF Lesioning.

- Temperature control allows for lesion size control/consistency
- Time limits lesion size somewhat
- Power added until goal Temp reached
- Negative feedback, Voltage modulation limits power at goal Temp

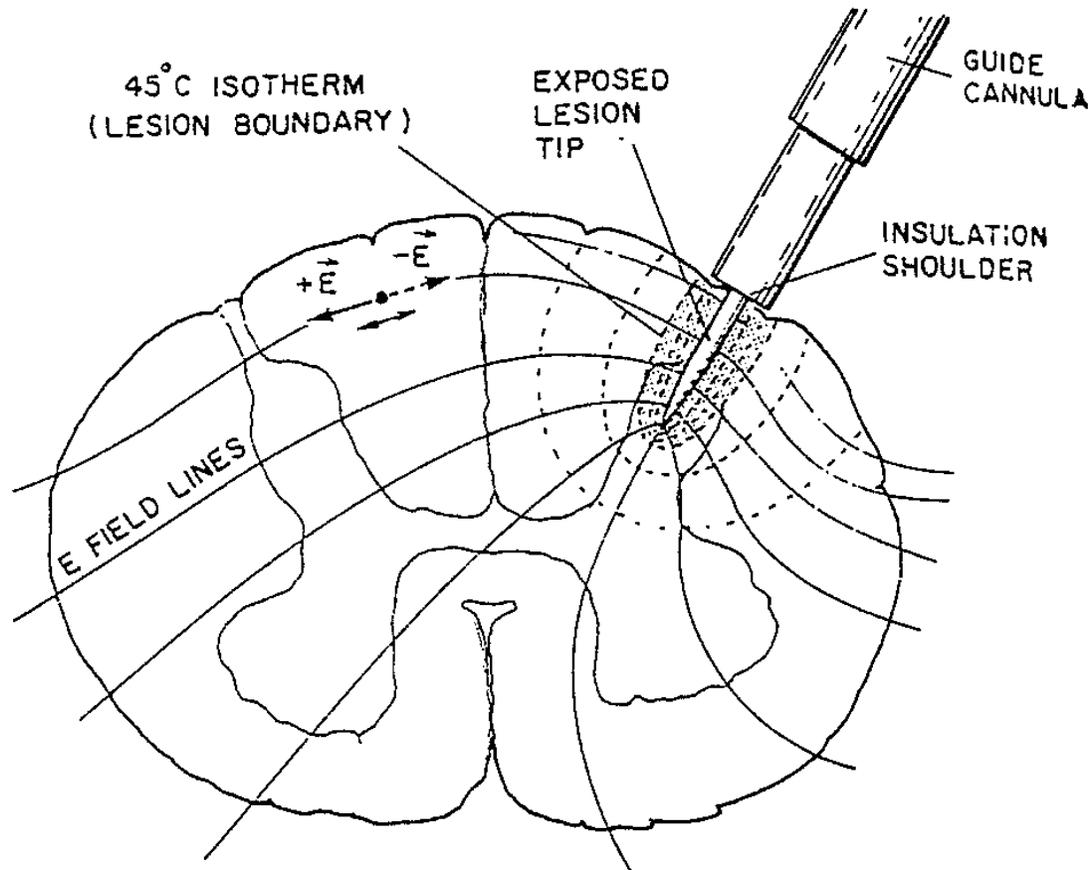
Optimal Time/Temperature/Impedance

- Rate of temperature increase: **1°/sec**
- No benefit of durations beyond 60-90 seconds
 - Equilibrium of heat generation and dissipation
 - Rise in impedance and drop in current
- Impedance should be 400 Ω or less. >600 Ω mandates repositioning

Duration at 80°C	0 sec	30 sec	60 sec
Maximum Lesion size	60%	85%	94%

Flow of Electrical Current

RF ELECTROLYTIC DISSIPATION TO
CREATE A LESION IN THE DREZ REGION



- Current density near tip generates heat.
- Dispersion of electrical field limits lesion size.

Creating Lesions in Tissue

$$\frac{dQ}{dt} = \kappa \nabla^2 T + \frac{1}{\sigma} j^2 - \frac{dQ_c}{dt}$$

Heat change Per volume Per time

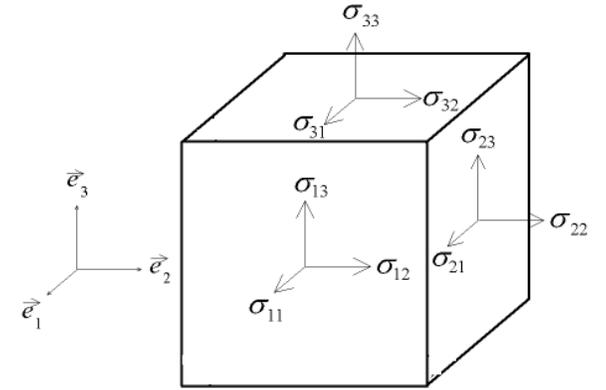
Thermal Conductivity

Tissue Temp

Electrical Conductivity

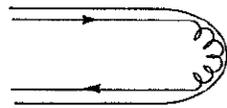
Current Density²

Heat loss To circulation

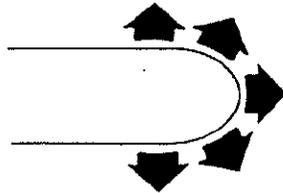


(Direct Heating)

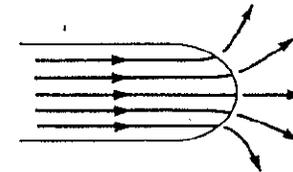
Current through heater element in probe



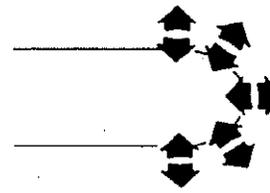
Heat flow from probe to tissue



Current flows into tissue

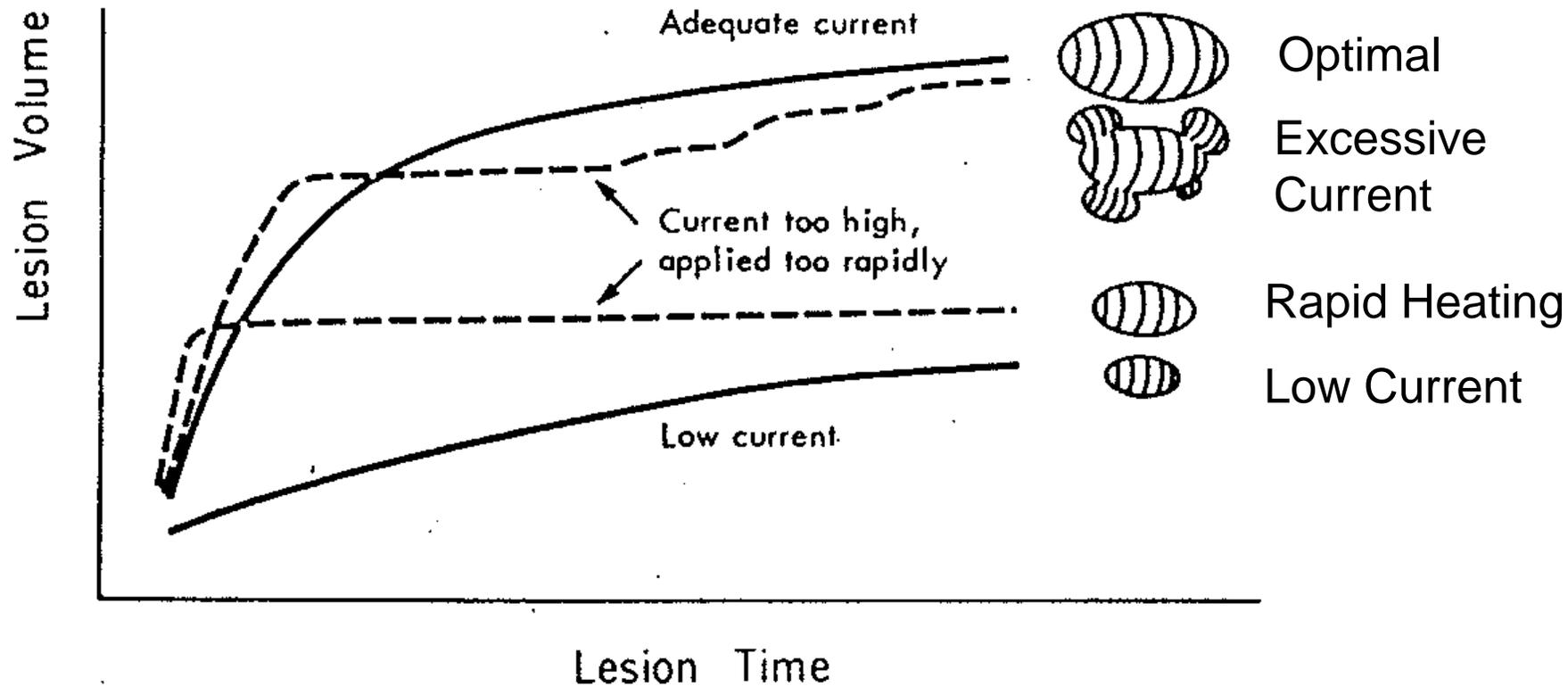


Heat flow from tissue to probe



RF Heating (indirect)

Optimal Lesions



- Excessive Current: Steam formation, unpredictable
- Rapid Heating: Char formation, rise in impedance
- Low Current: Small lesion, heat generation insufficient

Advantages of Modern RFA

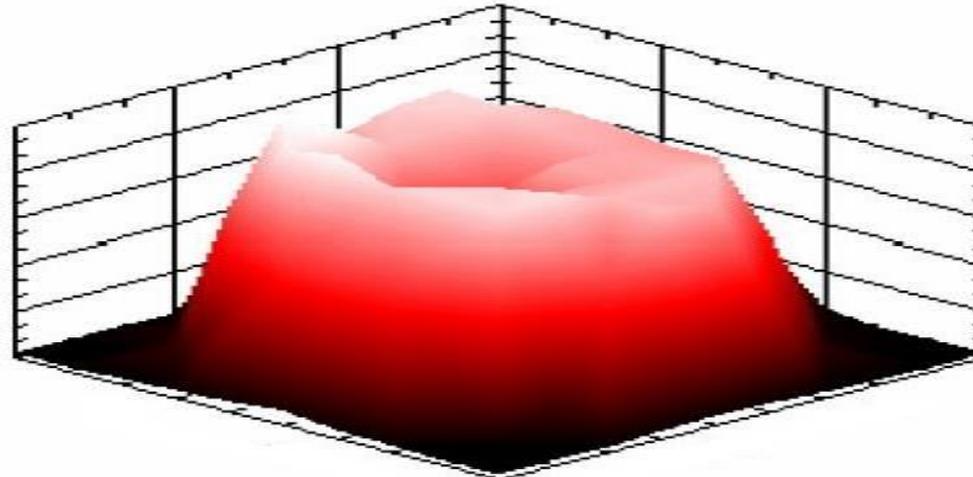
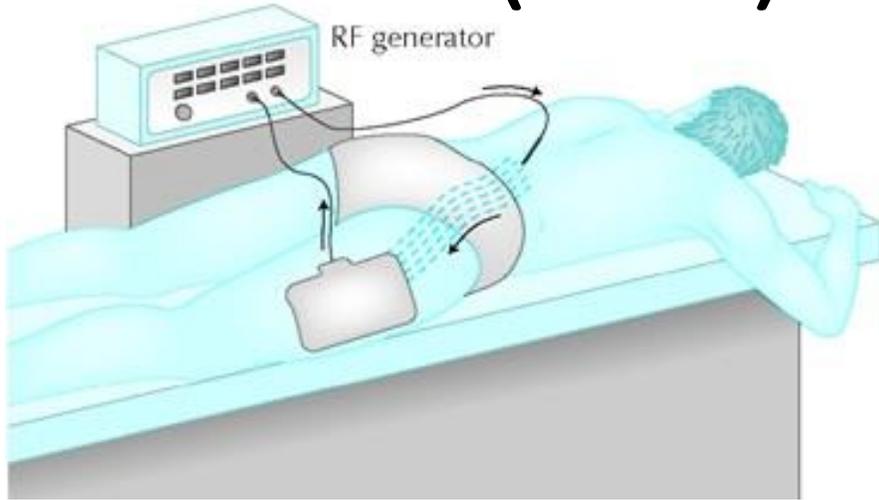
Technical Advancements

- Control of tip temperature
- Impedance testing
- Increases in lesion size
- Multiple outputs
- Materials

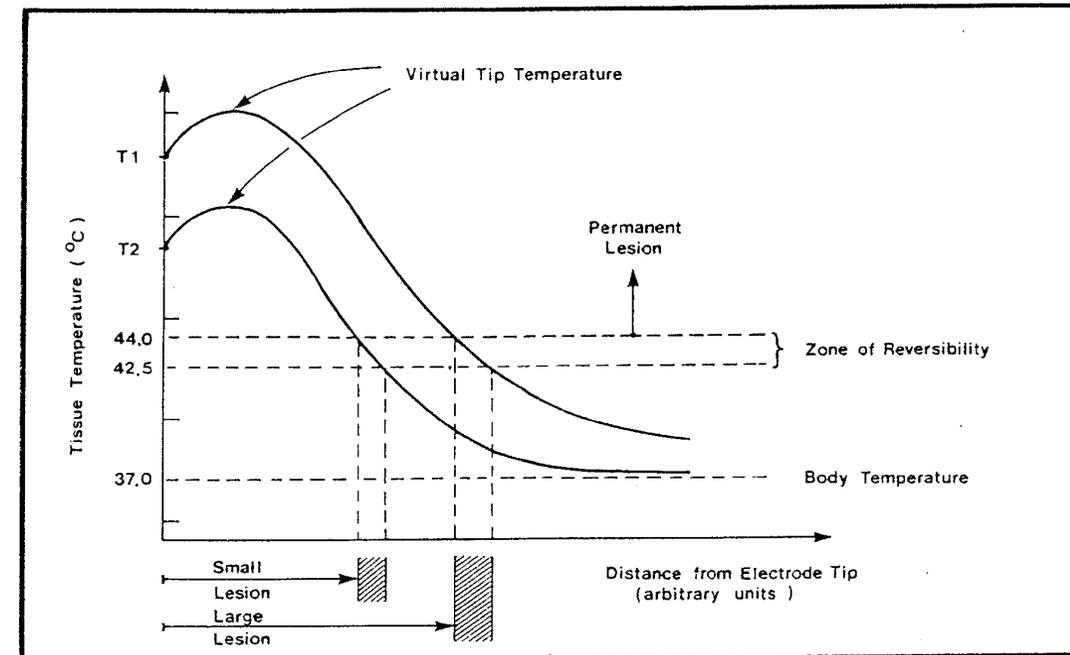
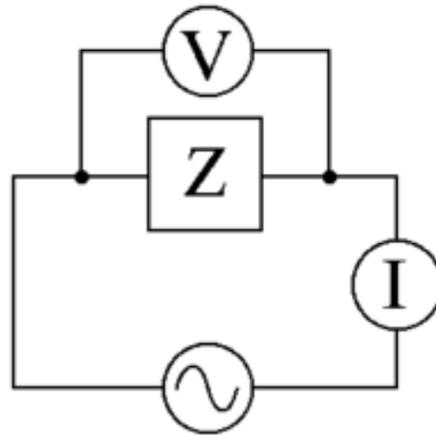
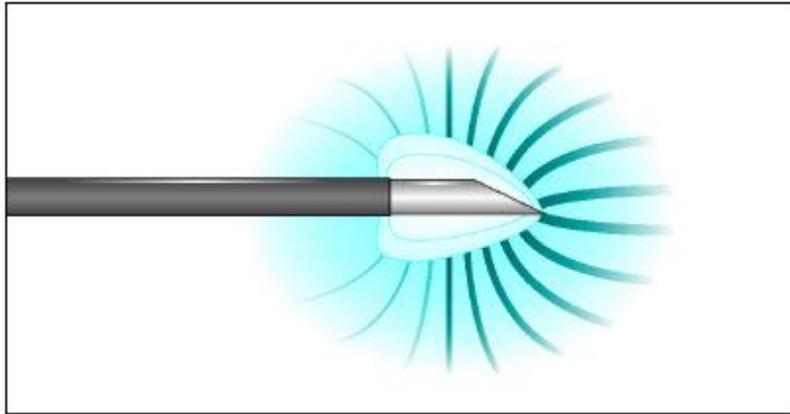
Advantages

- Smooth boundary
- Low complication rate
- Confirmation
- Flexible / Percutaneous
- ~Durable

Conventional "Standard" Radiofrequency Ablation (SRFA)



TISSUE TEMPERATURE VS. DISTANCE FROM ELECTRODE



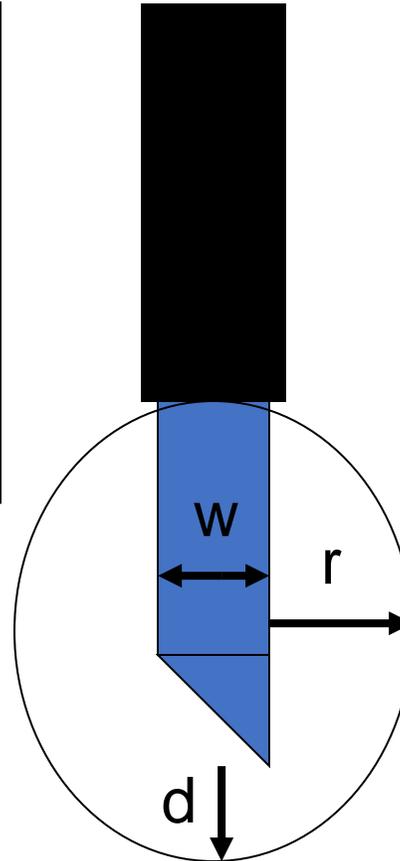
Cosman ER. *Neurosurgery* 1984;15(6): 945-950

Ahadian FM. *Current Pain and Headache Reports* 2004;8:34-40

Lesion Size Estimation (SRFA)

	SMK	RRE
w	0.7mm	1.6 mm
r	2.3 w +/- 0.4	1.6 w +/- 0.3
d	1.4 w	0.4 w

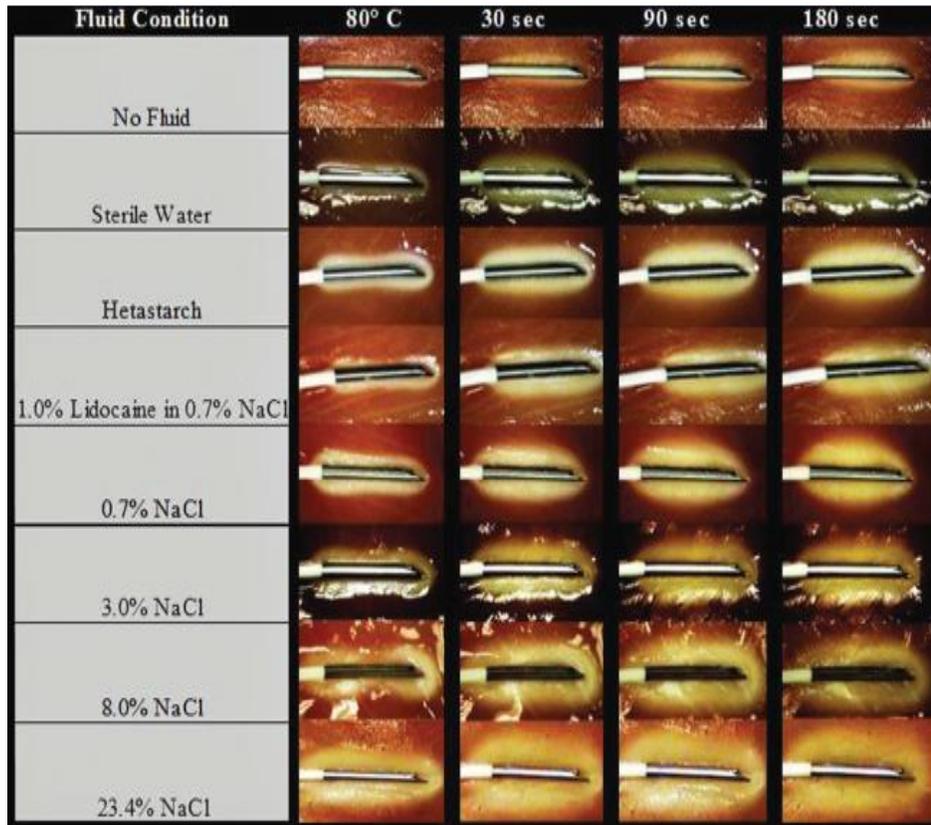
97.5% confident of coagulating tissues within 1.0-1.7 electrode widths radially from probe.



Needle Gauge	Lesion Diameter (mm)
18	3.8-5.6
20	2.7-4.0
21	2.5-3.6

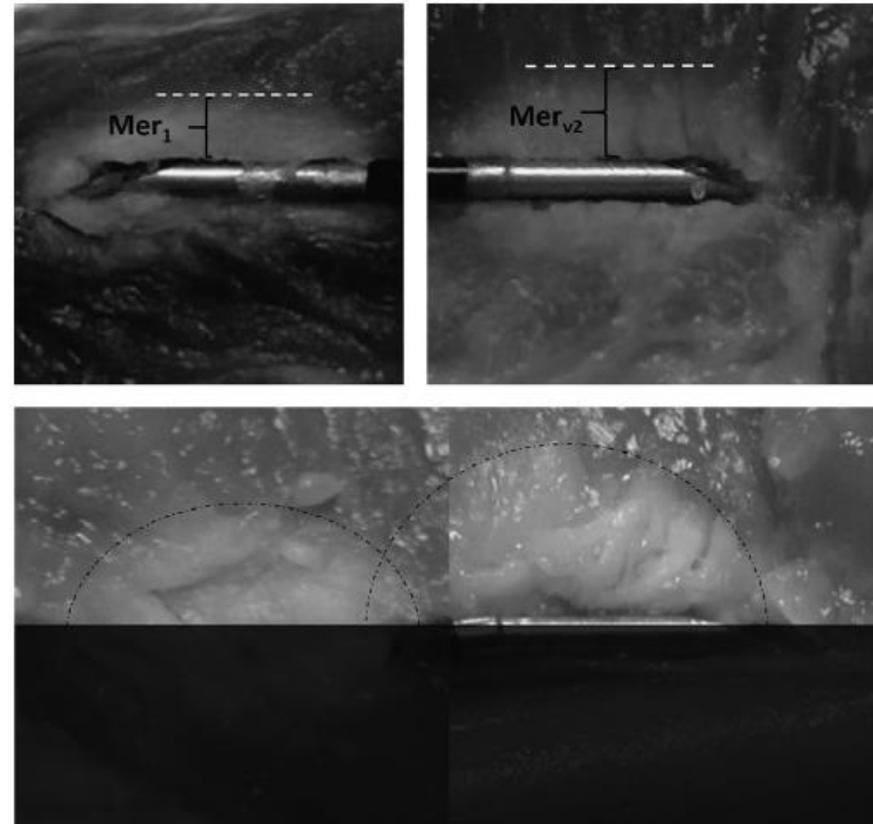
Tissue Factors Affecting Lesions

- Fluid Pre-injection and time to 180 sec



Provenzano DA, et. al. Reg Anesth Pain Med. 2015 Mar-Apr;40(2):112-24.

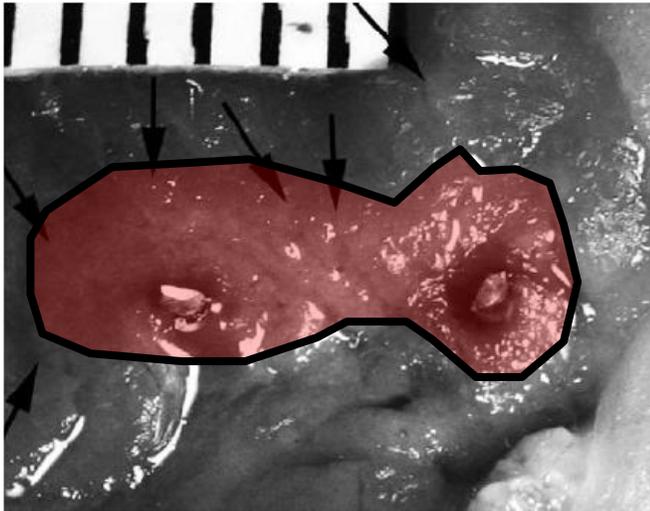
- Bone Proximity



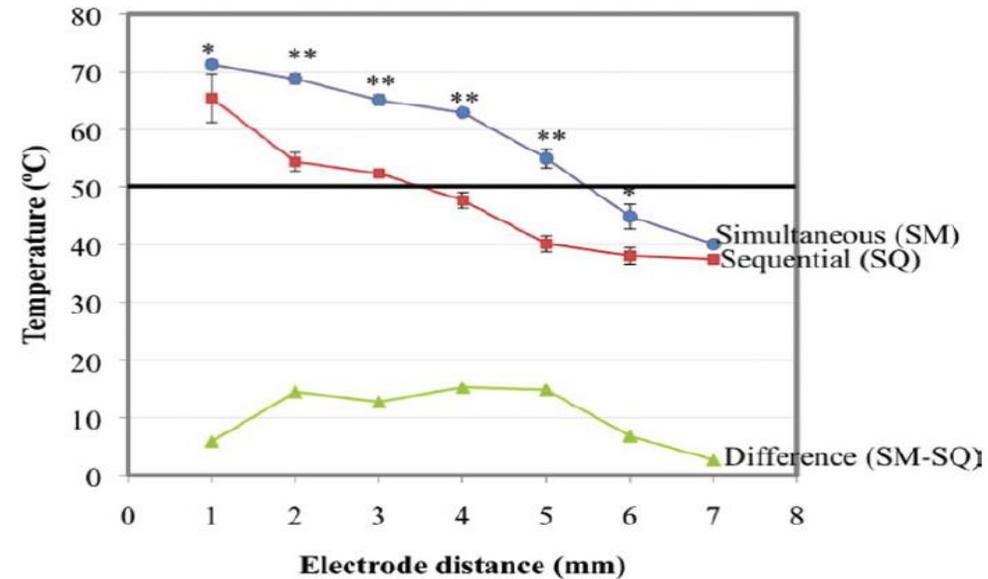
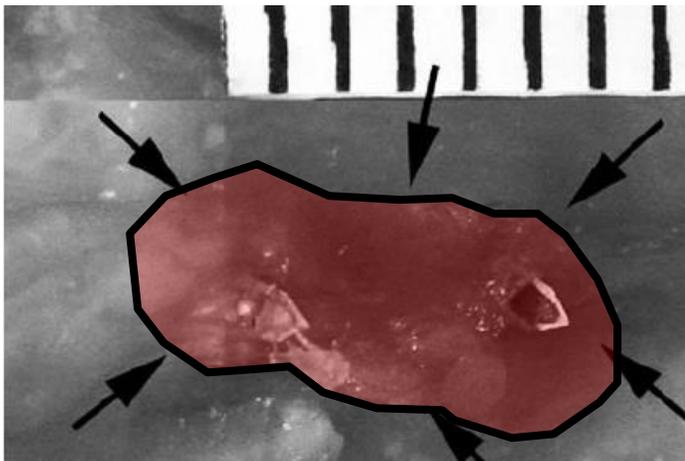
Eckmann MS, et. al. Reg Anesth Pain Med. 2015 May-Jun;40(3):270-5.

Double Unipolar Lesions

Sequential, 4mm separation

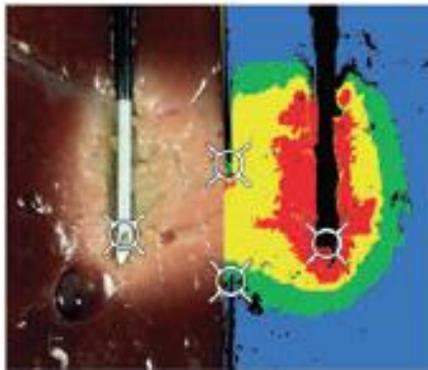
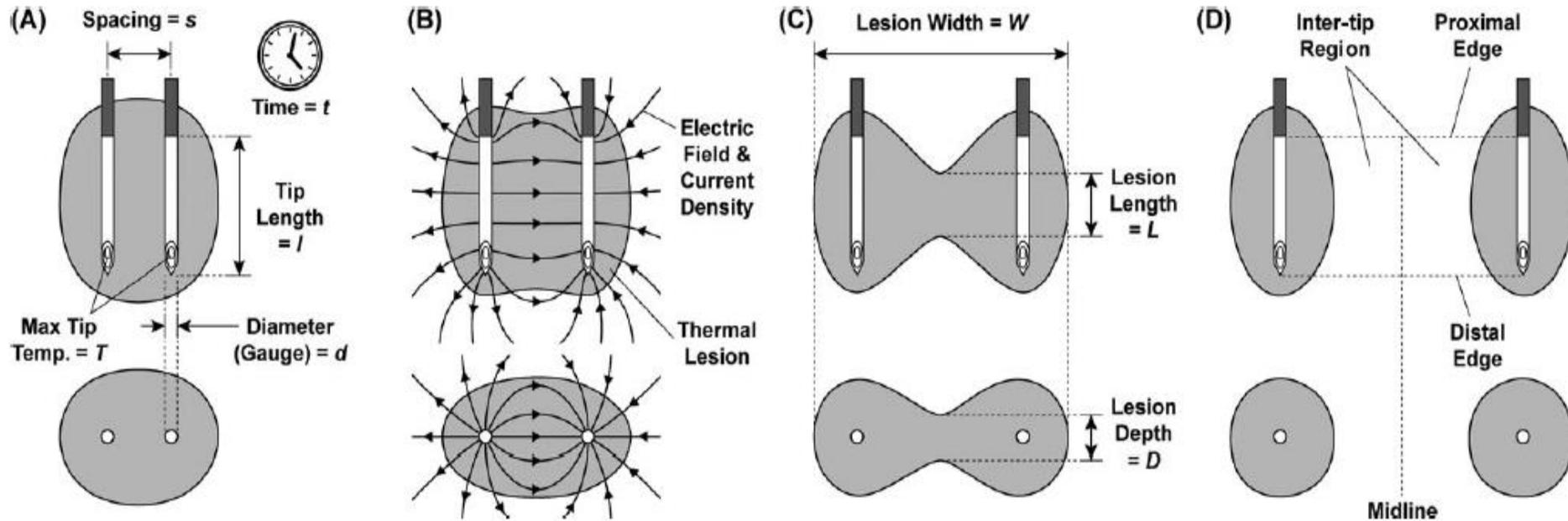


Simultaneous, 4mm separation

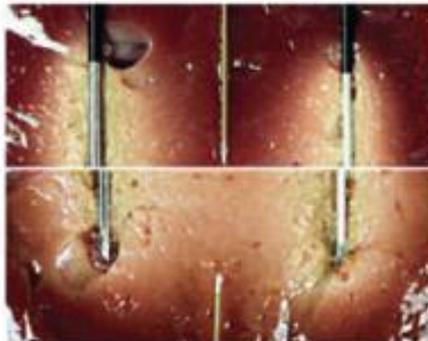


- Simultaneous heating increases lesion size vs. sequential

Bipolar Lesions

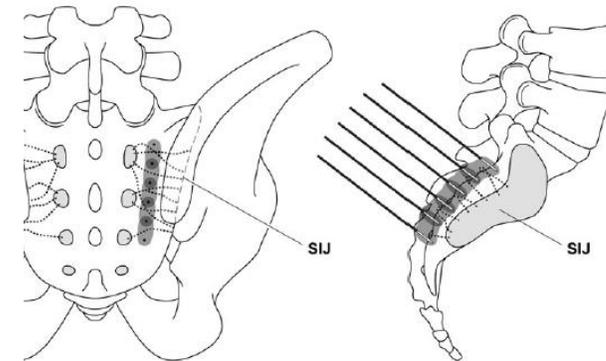


Spacing = 20 mm



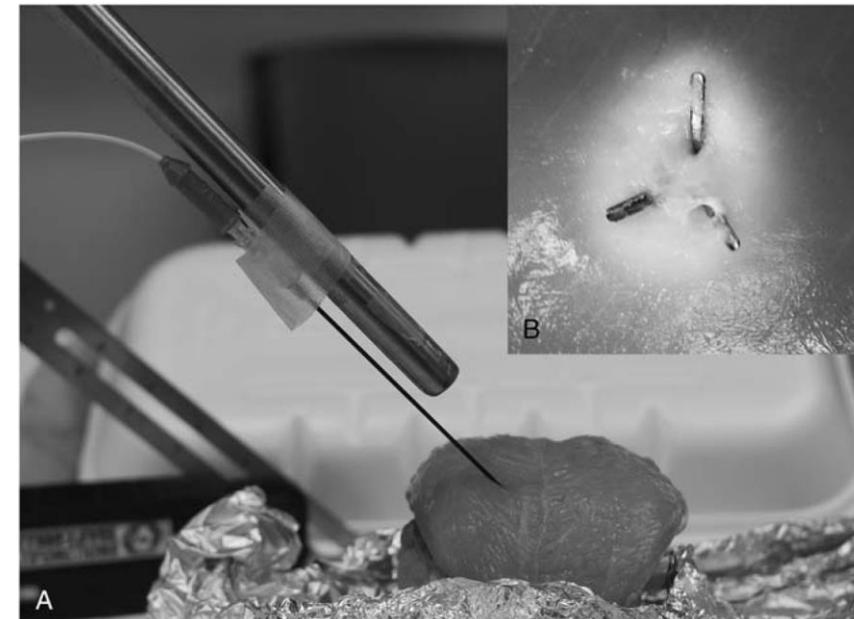
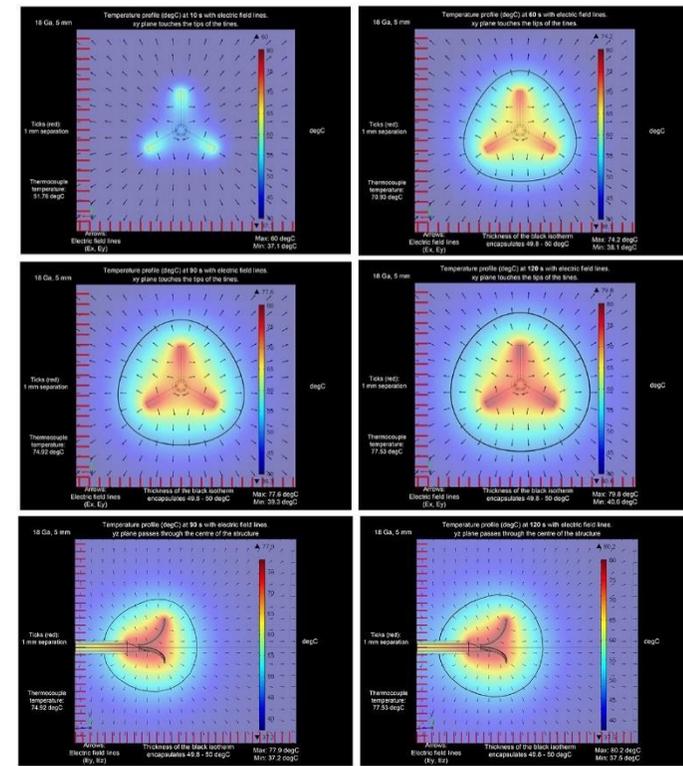
3:00 min

10:00 min



Example: Multi-tined Probes

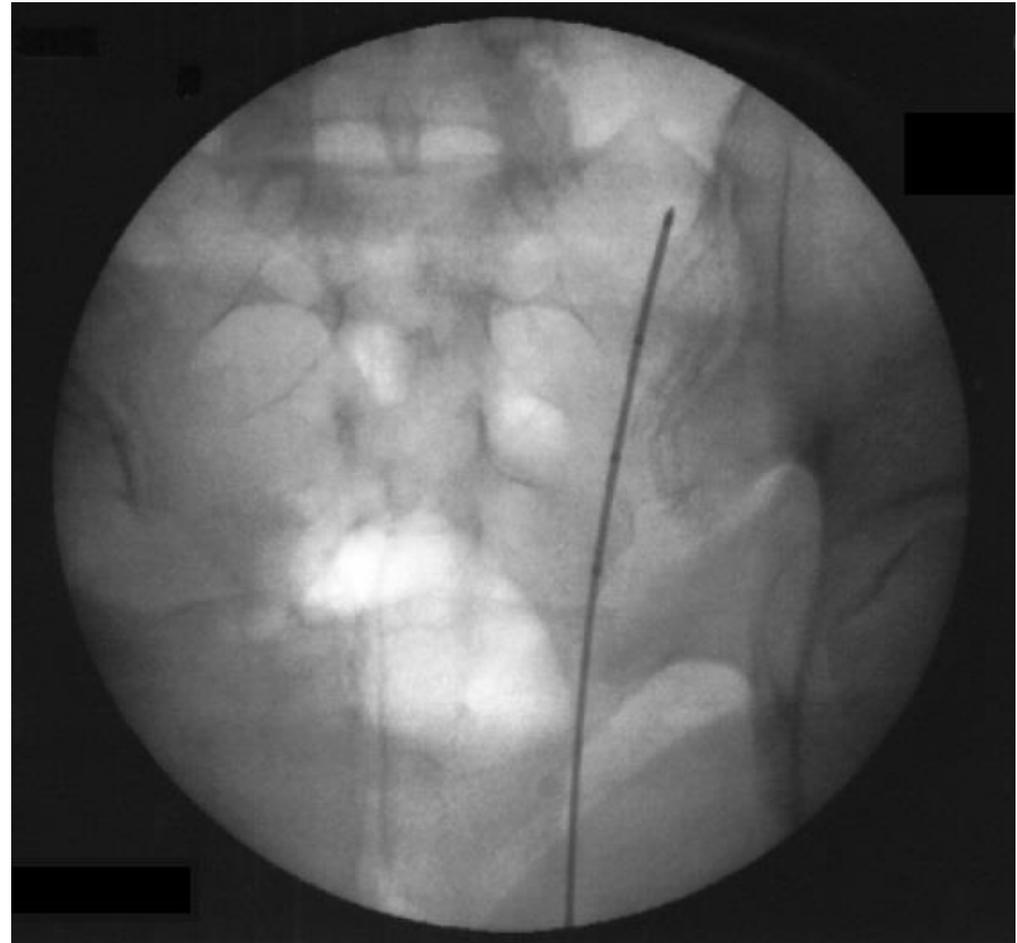
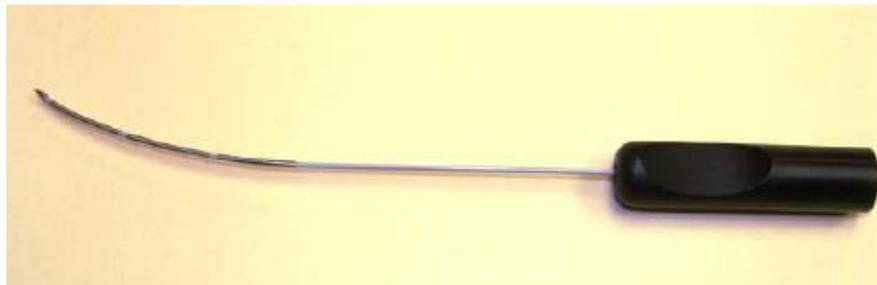
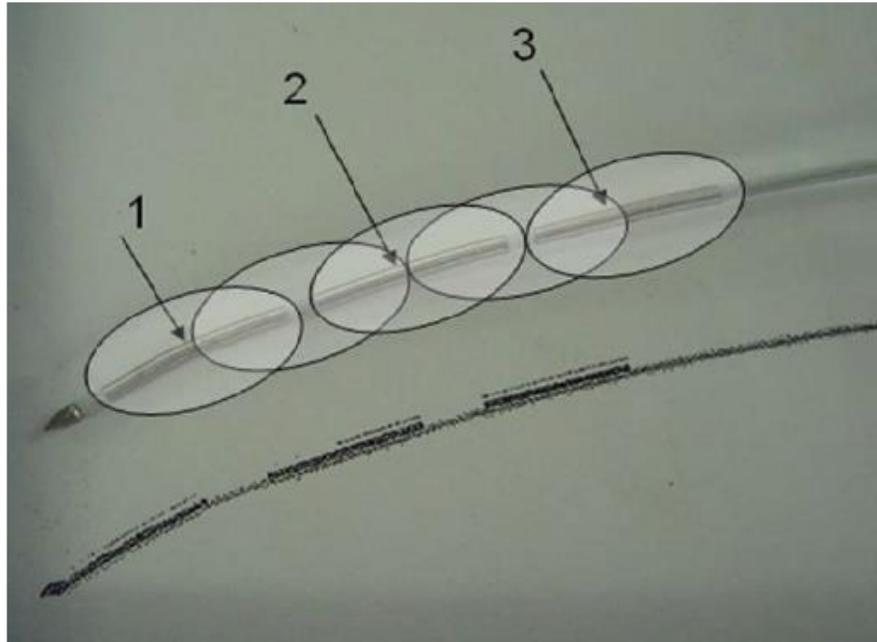
- Monopolar Conventional RFA
- Functionally Larger Active Tip



Example: Multi-tined Probes



Multipolar Probes



Multi-channel



Multiplexed

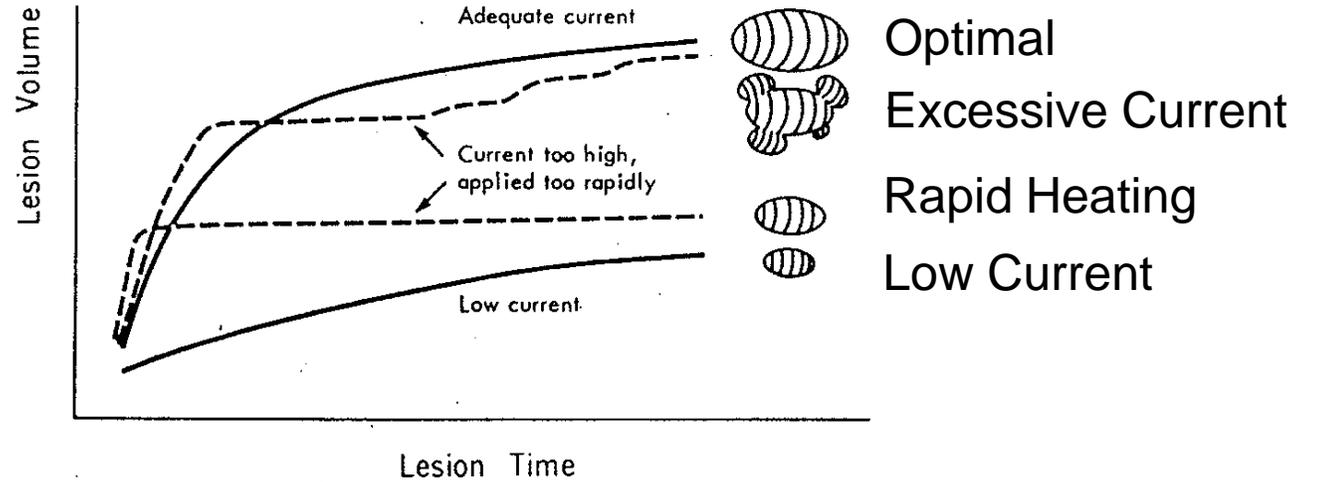
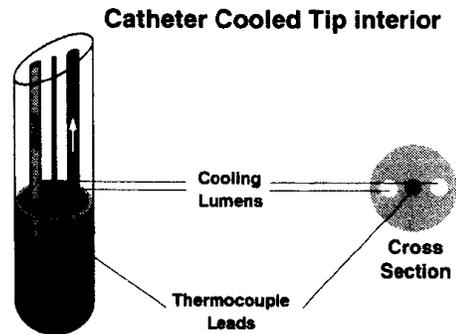
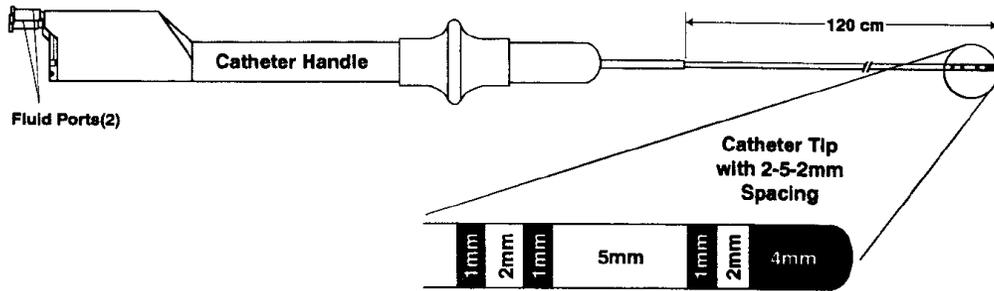


Cooled-Tip Ablation Results in Increased Radiofrequency Power Delivery and Lesion Size in the Canine Heart: Importance of Catheter-Tip Temperature Monitoring for Prevention of Popping and Impedance Rise

Ichiro Watanabe, Riko Masaki, Nuo Min, Naohiro Oshikawa, Kimie Okubo, Hidezou Sugimura, Toshiaki Kojima, Satoshi Saito, Yukio Ozawa, and Katsuo Kanmatsuse

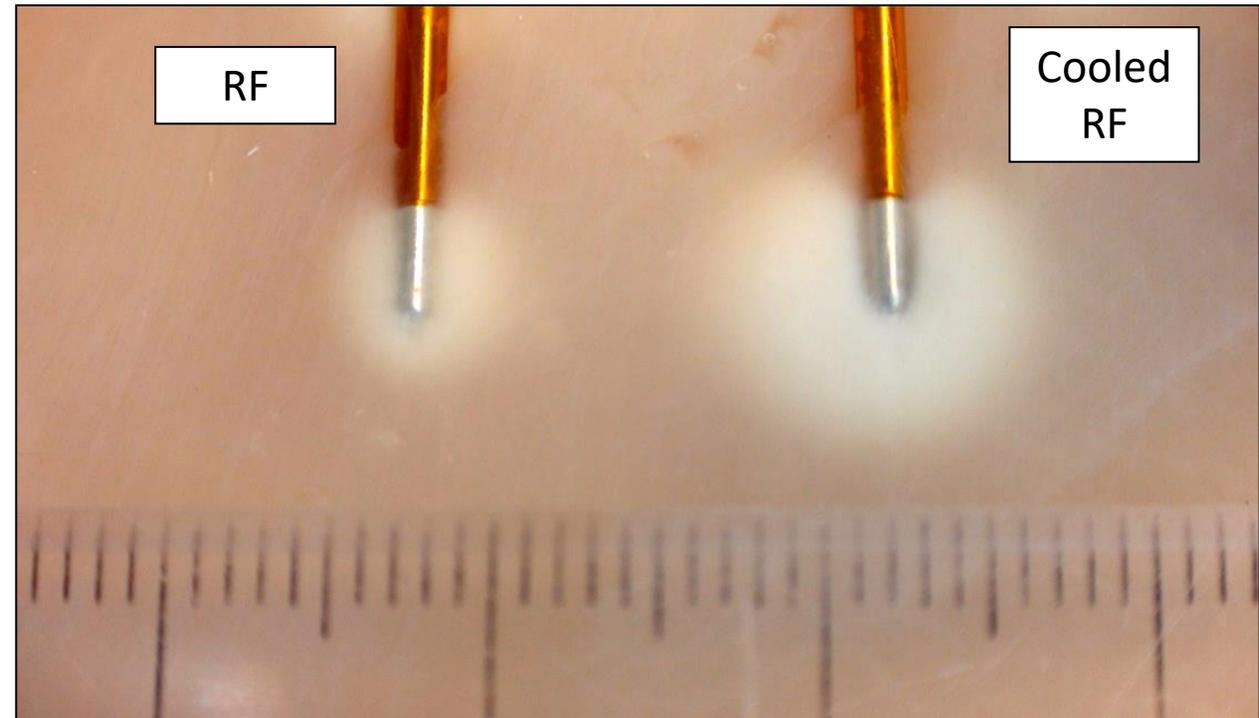
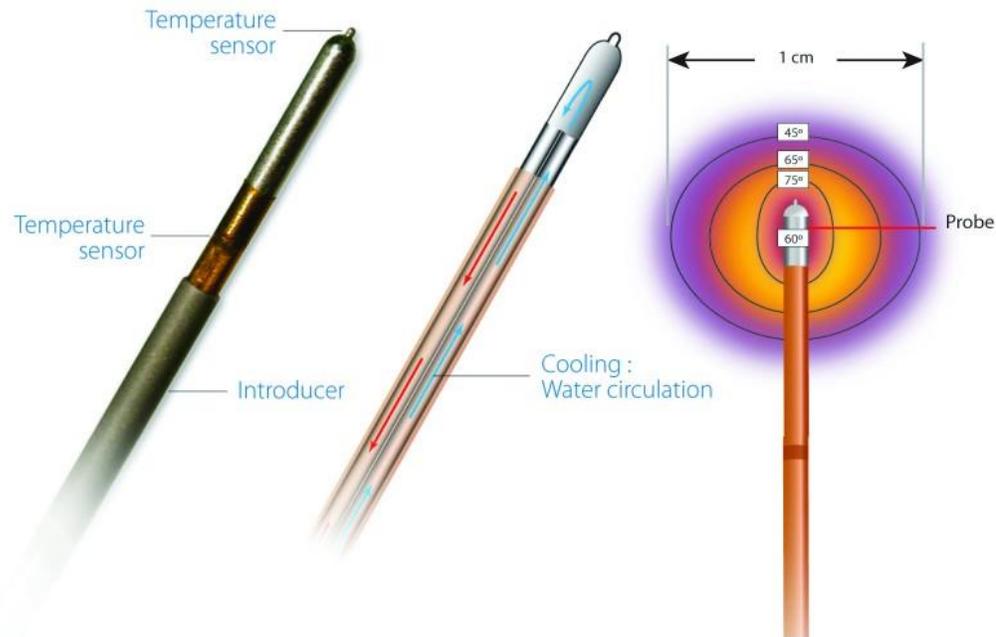


Cooled Ablation Catheter



Cooled RF

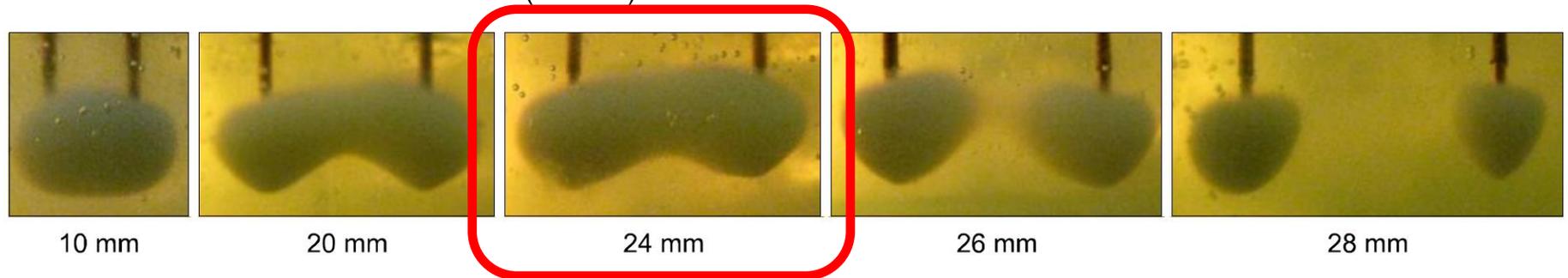
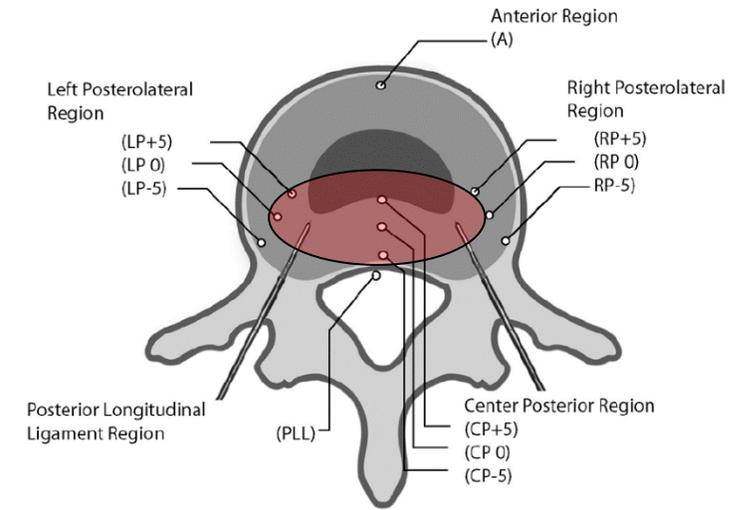
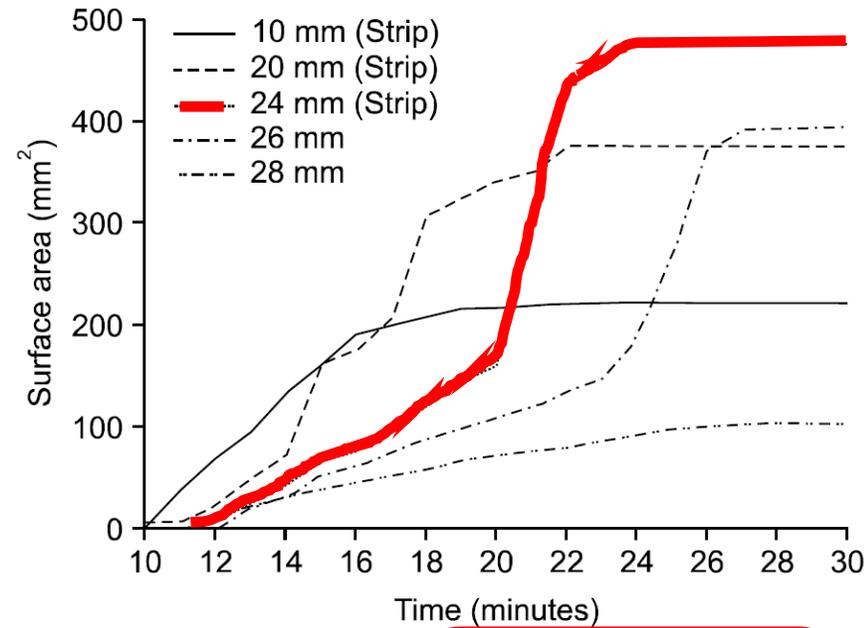
- Cooled RF now applied to spine ablation
 - Has been used elsewhere for increasing size of solid organ lesions to 30-50mm.
- Applied to joint denervation for pain management.
- Fluid Pre-injection may not affect lesion size¹



1. Wang H, et. al. Spine (Phila Pa 1976). 2016 Jun 15.

Bipolar Cooled RFA

- Large Strip Lesions
- Diminishing returns >24 mm



Is More Better? Complications summary, published and verbal reports

- Thoracic CRFA
 - Skin Burn

Walega D, Roussis C. Pain Pract. 2014 Jul;14(6):e154-8.

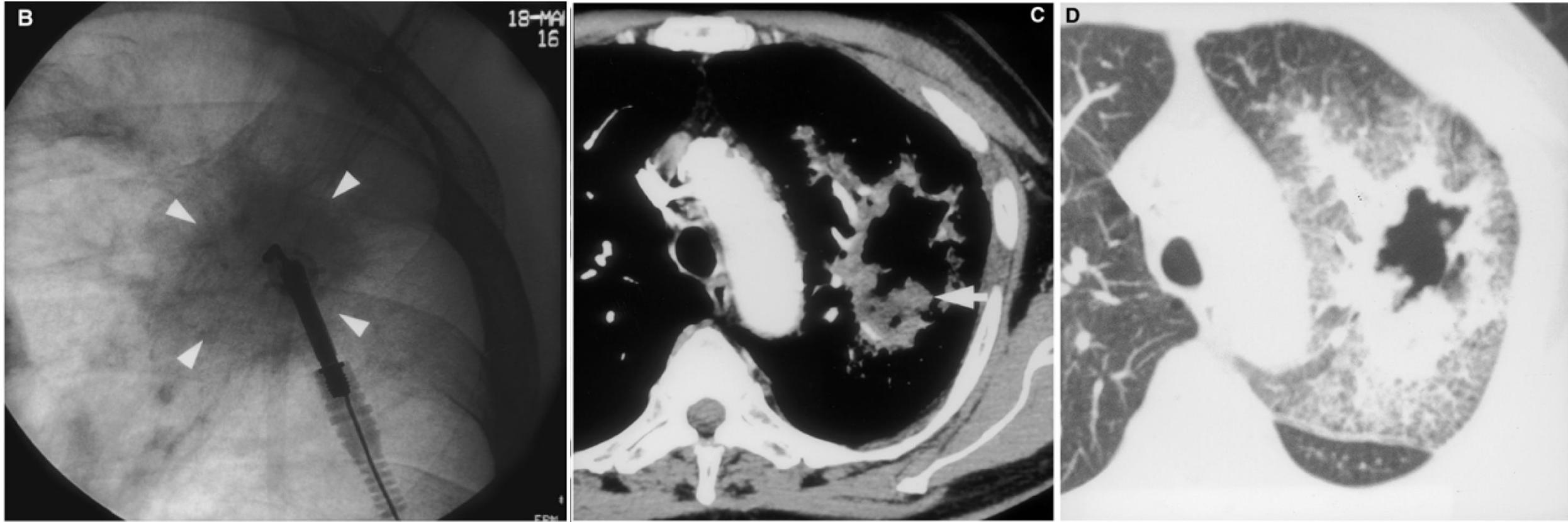
- Genicular CRFA
 - Hematoma
 - Skin Burn

- Hip Articular CRFA
 - Femoral Artery Cannulation / Hematoma
 - Femoral Nerve Injury

Gooding I, et al. Pain Pract. 2016;16(S1):147.

Excessive Hyperthermic Necrosis of a Pulmonary Lobe after Hypertonic Saline-Enhanced Monopolar Radiofrequency Ablation

Tae Sung Kim,¹ Hyo K. Lim,¹ Hojoong Kim²



Livraghi T, et al. Radiology. 1997 Jan;202(1):205-10.

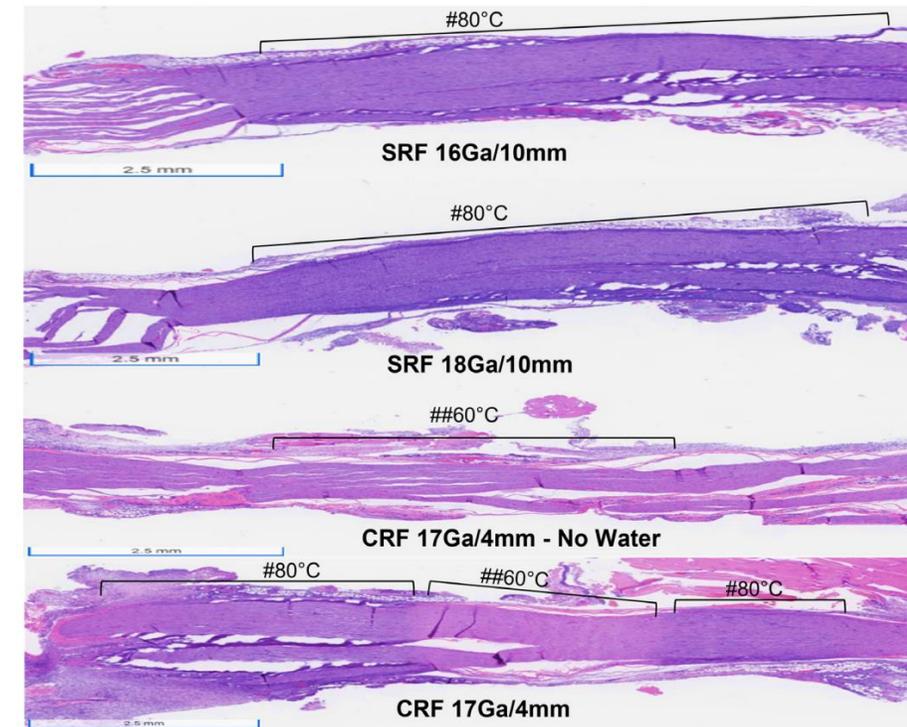
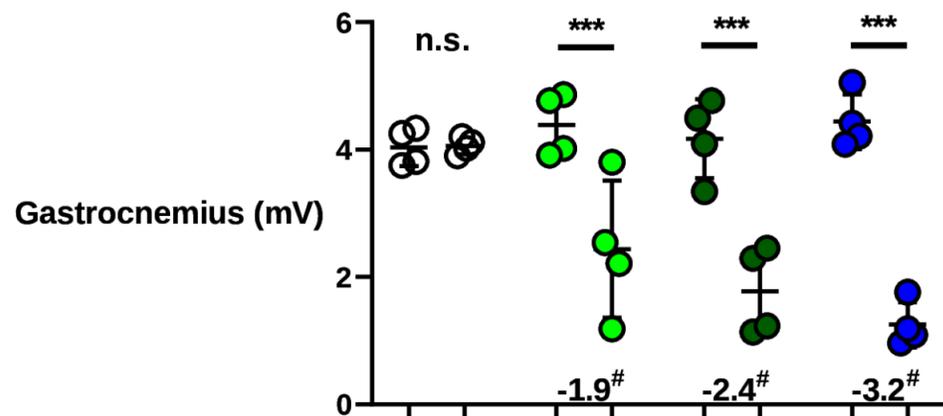
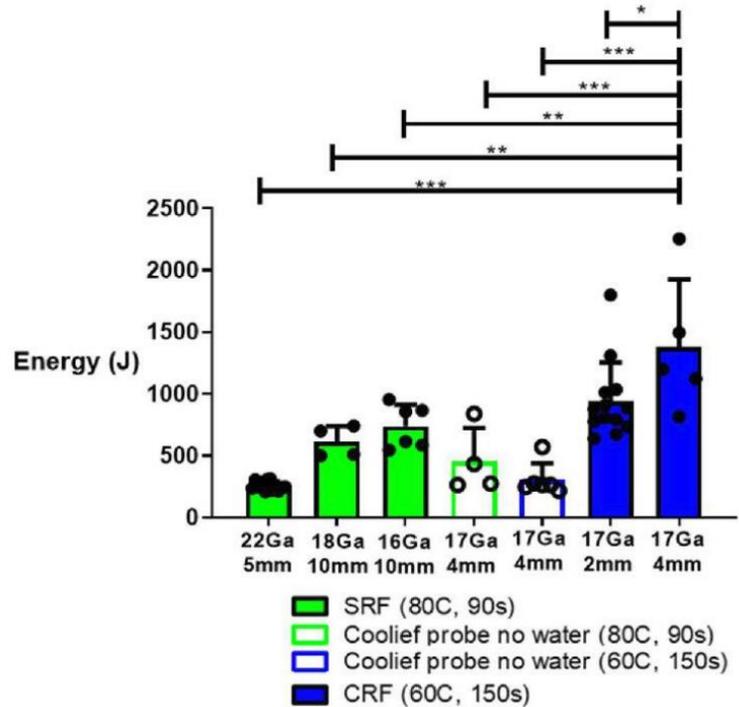
Provenzano DA, et. al. Reg Anesth Pain Med. 2015 Mar-Apr;40(2):112-24.

The Argument for Augmented Lesions:

Water-circulating probes significantly modify lesion length and axon damage in cooled radiofrequency ablations when compared with similar-sized standard radiofrequency probes in rats

Alyssa Cobbs ¹, Guillermo Alas ¹, Ruchi Yadav ¹, Jacques Mayeux ¹, Maxim S Eckmann ², David Anthony Provenzano ³, Arthur W English ⁴, Alencia Washington ¹, Ruoya Wang ¹

Reg Anesth Pain Med. 2023 Sep 24:rapm-2023-104554.

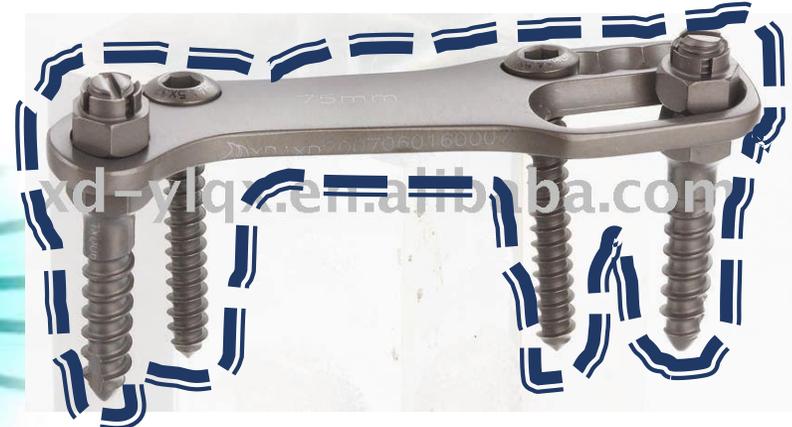
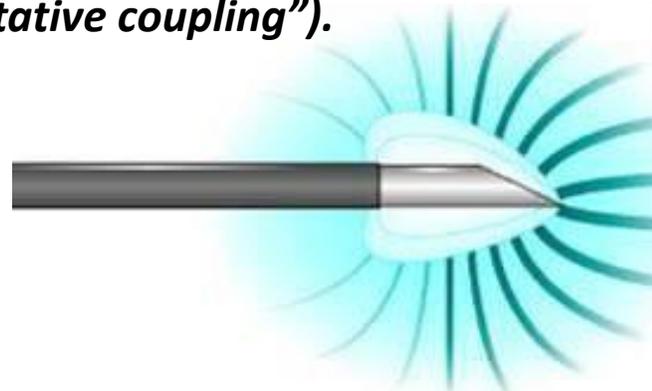


RF and Spine Hardware

- No articles/case reports found to date.
- Per d/w product engineers:
 - Contact NOT recommended
 - May act as a **heat sink** and artificially cool the probe, causing RF Machine to remain in state of maximum power output.
 - *Tissue temperature therefore not reliable*
 - May conduct/heat the hardware, potential for unwanted surrounding tissue damage.

Implant Hardware and Burns

- **Electrical conductivity:**
 - Stainless Steel : 3.5% that of copper
 - Titanium: 3.1%
- **4 Types of electrosurgical burns:**
 - direct contact burns
 - burns at the grounding electrode site
 - burns resulting from either the active or indifferent electrode heating pooled solutions,
 - ***aberrant intraoperative circuits (“alternate-site,” or “capacitive coupling”).***



RF and AICDs/Pacemakers

- Per device manufacturers:
 - Cardiac ablation performed successfully
 - No formal recommendation
- Follow same practices as for preparation for electrocautery in the operating room.
 - ? Risk with myopotentials from motor stim
 - Have crash cart available
 - Deactivate tachyarrhythmia therapies



Non-CME Webinar Series

designed with the trainee in mind

first Tuesday of the month



Thank you!

Maxim S. Eckmann

Interim Chair, UT Health San Antonio Anesthesiology

Ramamurthy Professor of Anesthesiology and Pain Medicine

Co-Chair, ASRA CME Committee

Past President and Director Emeritus, Texas Pain Society

Examiner, American Board of Anesthesiology