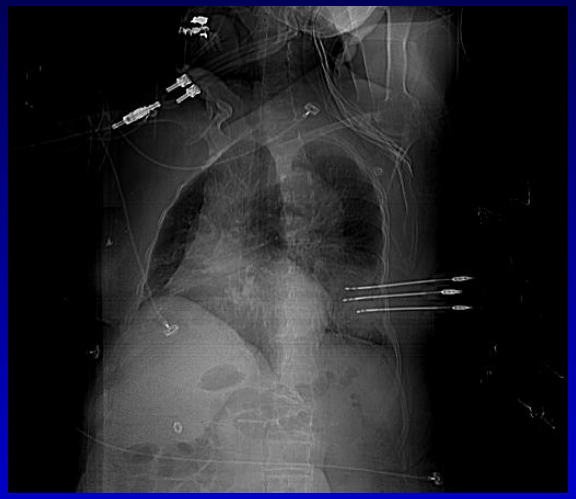
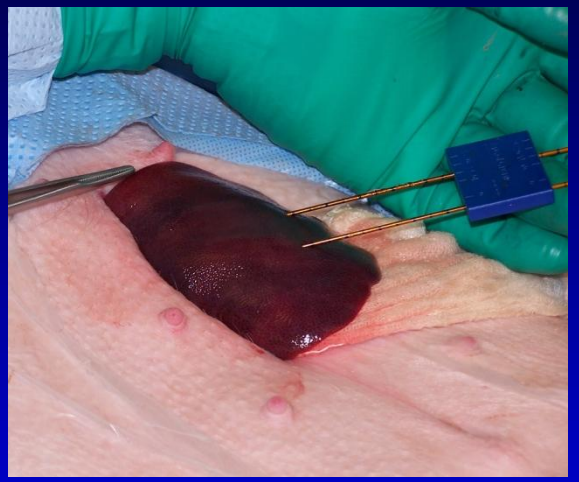
Microwave Ablation and IRE





Damian E. Dupuy, M.D., FACR
Professor Diagnostic Imaging
Brown Medical School
Director of Tumor Ablation
Rhode Island Hospital

BROWN
Alpert Medical School

Disclosures

Consultant

- Veran Medical Technologies, Inc
- Ethicon Endosurgery
- BSD Medical
- Covidien

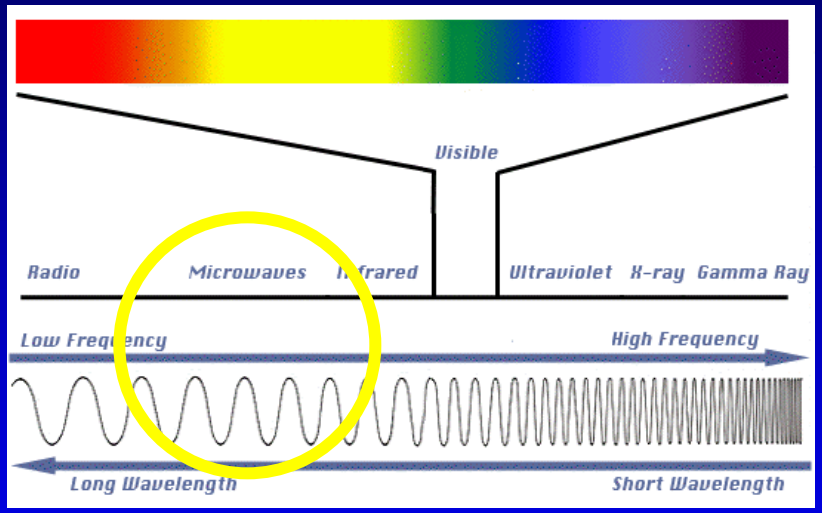
Grant Support

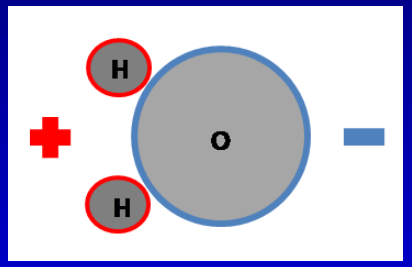
- ACRIN
- ACOSOG
- Veran Medical Technologies, Inc
- Mayo Clinic/Endocare
- AngioDynamics
- MedWaves
- Biotex

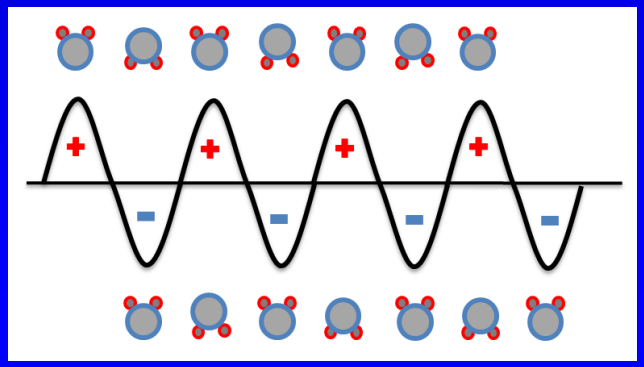
Learning Objectives

- Explain current MWA technology and potential advantages
- Discuss principles of IRE
- Show early data, clinical and preclinical examples.

Background



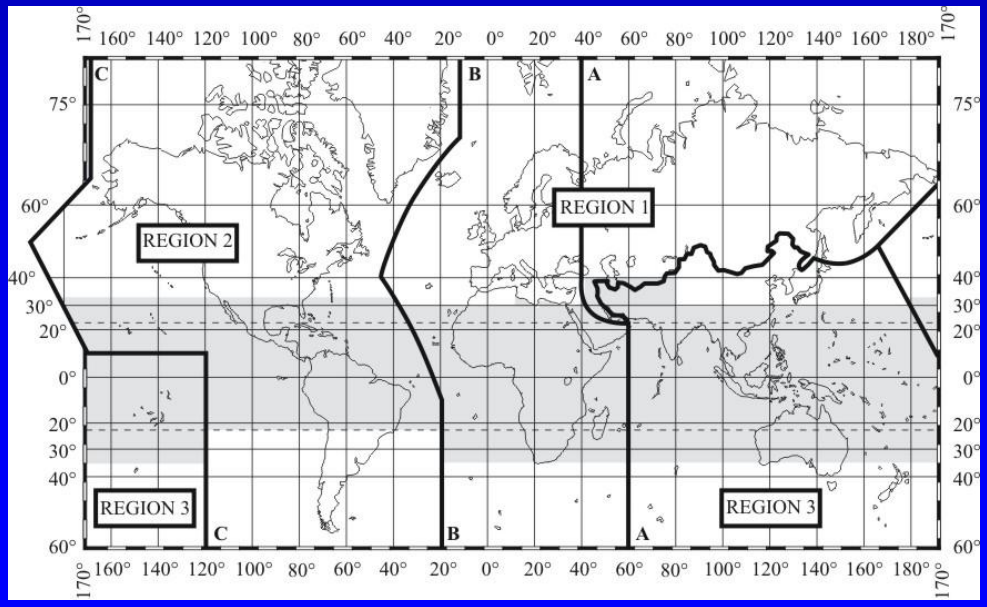




→ ↑ Kinetic Energy → **Heat**

Non-telecommunication MW Systems

- Only allowed certain frequencies depending on International Telecommunication Union (ITU)



Industrial, Scientific, Medical (ISM) Bands

- 915 and 2450mHz available in North America, Asia, Europe

Advantages of MWA Compared with RFA

- Shorter ablation times
- Larger ablation volumes
- Less nerve stimulation

MWA vs.. RFA

	Microwave ($n = 40$)	Radiofrequency ablation ($n = 40$)
No. tumors	1–2	1–2
Ablation success	98%	92%
Ablation recurrence	2%	17%
Ablation time (min)	13	40 (20–65)
OR time	56.9 (23.8–1256)	125.8 (21.2–243.6)
OR charges		
Median (range)	$13,389 ($8059–18,136)	$25,687 ($19,410–40,235)
OR variable direct charges	$909 ($562–1420)	$2903 ($2052–4503)
OR fixed direct charges	$514 ($337–628)	$787 ($565–1305)

Martin et al Ann Surg Oncol August 2009

Martin et al MWA vs.. RFA Time=$Money$

- Mean MWA ablation time 13 min vs. 40 for RFA
- OR time 50% less with MWA
- Median MWA OR charges ½ of RFA
- MWA recurrences 2% vs. 17% with RFA

Microwave Ablation Factors

- Microwave antenna transforms electrical current to broadcast electromagnetic field about itself which interacts with its environment
- Therefore antenna design needs to consider following factors:
  - operating frequency and
  - permittivity of its environment
- Tissue is a lossy environment where permittivity changes during ablation
- Changes in permittivity can affect forward power transformation efficiency and impede power broadcast to surrounding tissue
- This can result in antenna and transmission line heating that
  - chars tissue adjacent to the antenna and
  - elongation or movement of field that can produce unwanted regions of thermocoagulation.

MW Systems
Percutaneous Applicators

- 2450mHz
  - -Neuwave
  - -Acculis
  - -HS (Forea) ⟵ FDA Approved
- 915mHz
  - -Covidien
  - -MedWaves ⟶ FDA Approved
  - -BSD Medical

Evident MW System

- 14 gauge
- 12, 17, 22cm lengths
- Cooled needle and Cable
- 915mHz, 45W at generator
- ~5.5cm in 10min-3 applicators 2.0cm spacing
- Commercially available

Acculis 2450mHz System

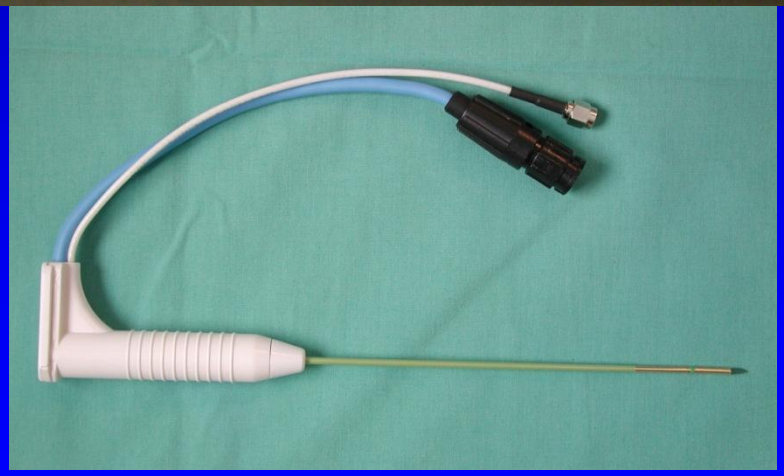
- 1.8mm Diameter
- 14cm and 29cm lengths
- Cooled needle and Cable
- 2.45 GHz, 180W at generator
- 5.5cm in 6minutes
- Q2 2010 Commercial Release

Neuwave Certus 140 MWA System

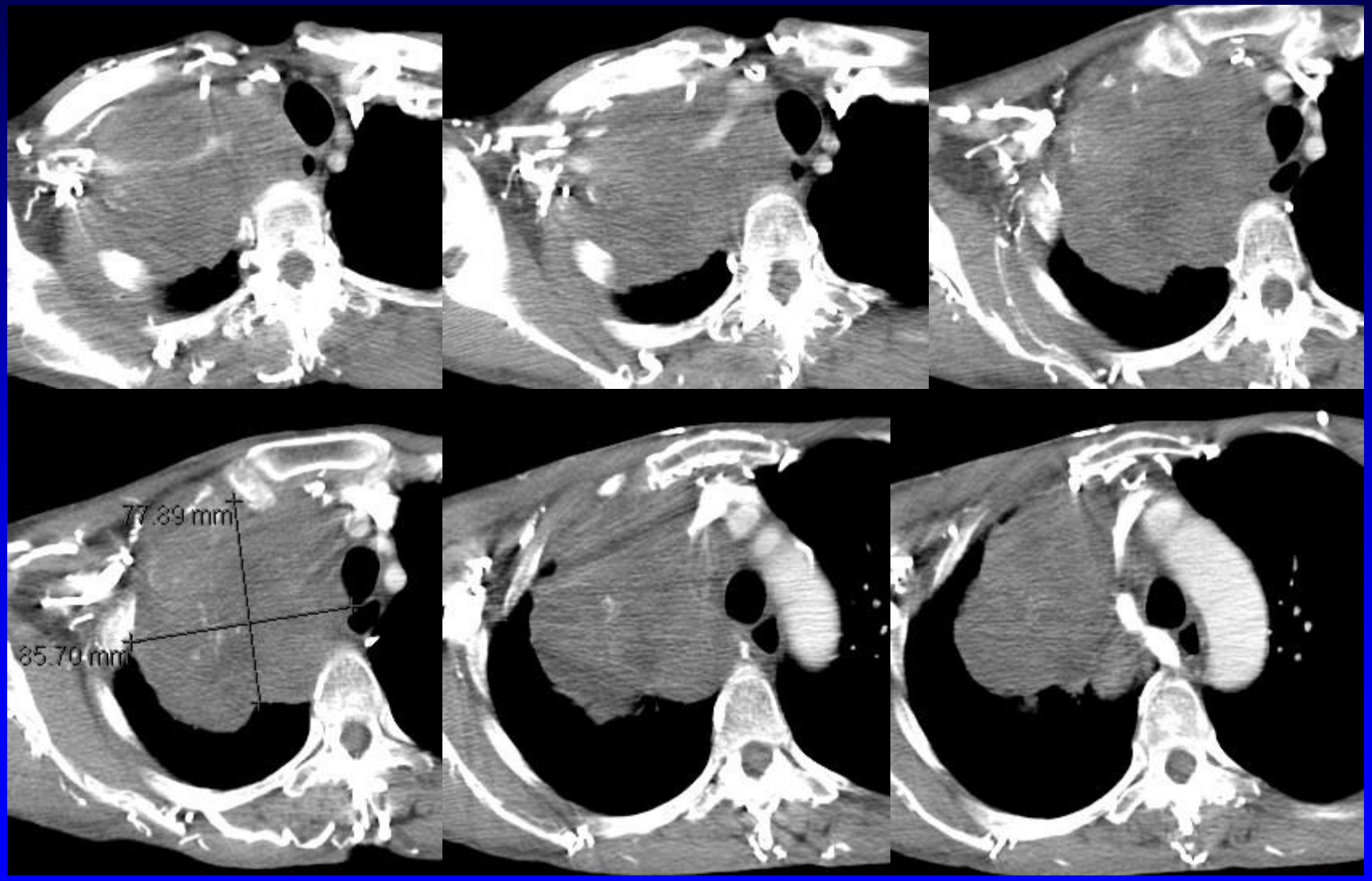
- CO_2 cooled needle and Cable
- 2.45 GHz, 140W 3 generators
- Measures temp
- ~3 x 4cm ablation in 5 min
- Commercial Release 2010?

MedWaves
915mHz MW System

- 14 gauge
- 15, 20cm lengths
- No cooling needed
- 915mHz, 32Watt generator
- Measures reflectivity and temperature
- 5 x 4cm in 10min-1 applicator
- FDA approved and available at select centers

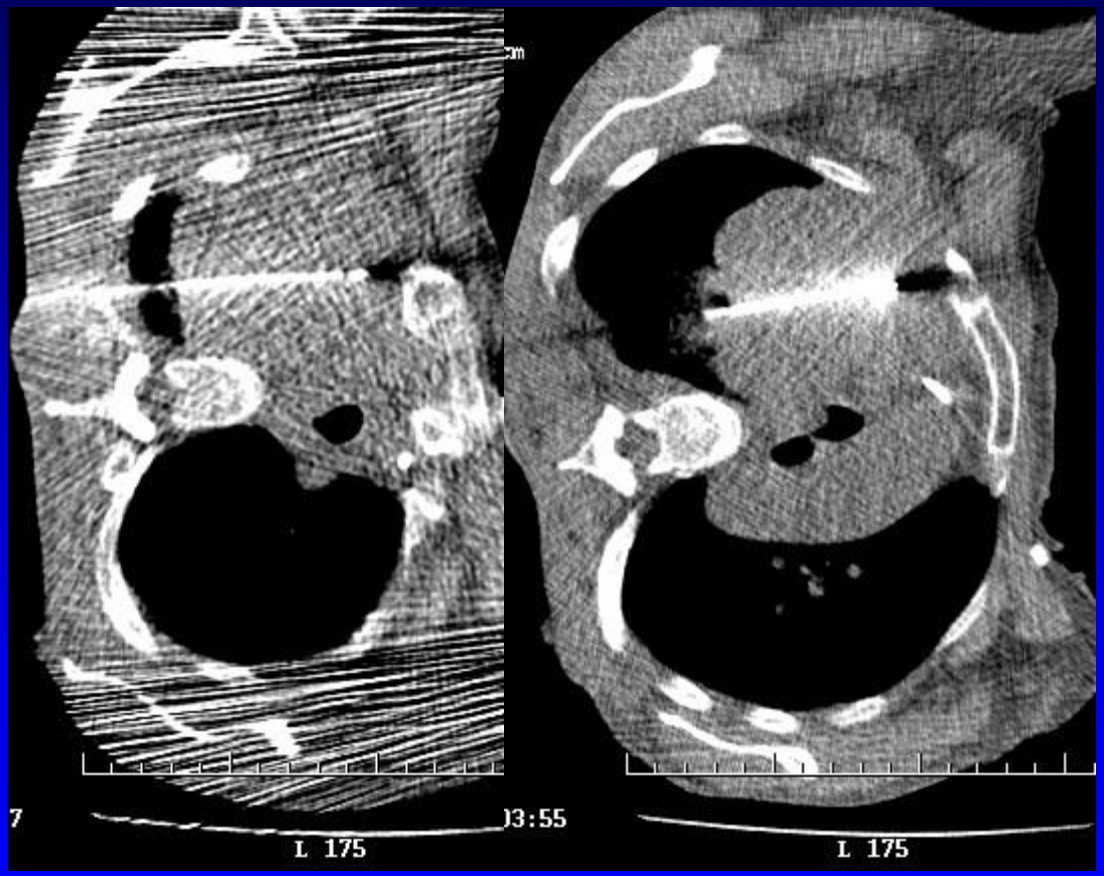


68 yo Woman with Pancoast Tumor



68 yo Woman with Pancoast Tumor

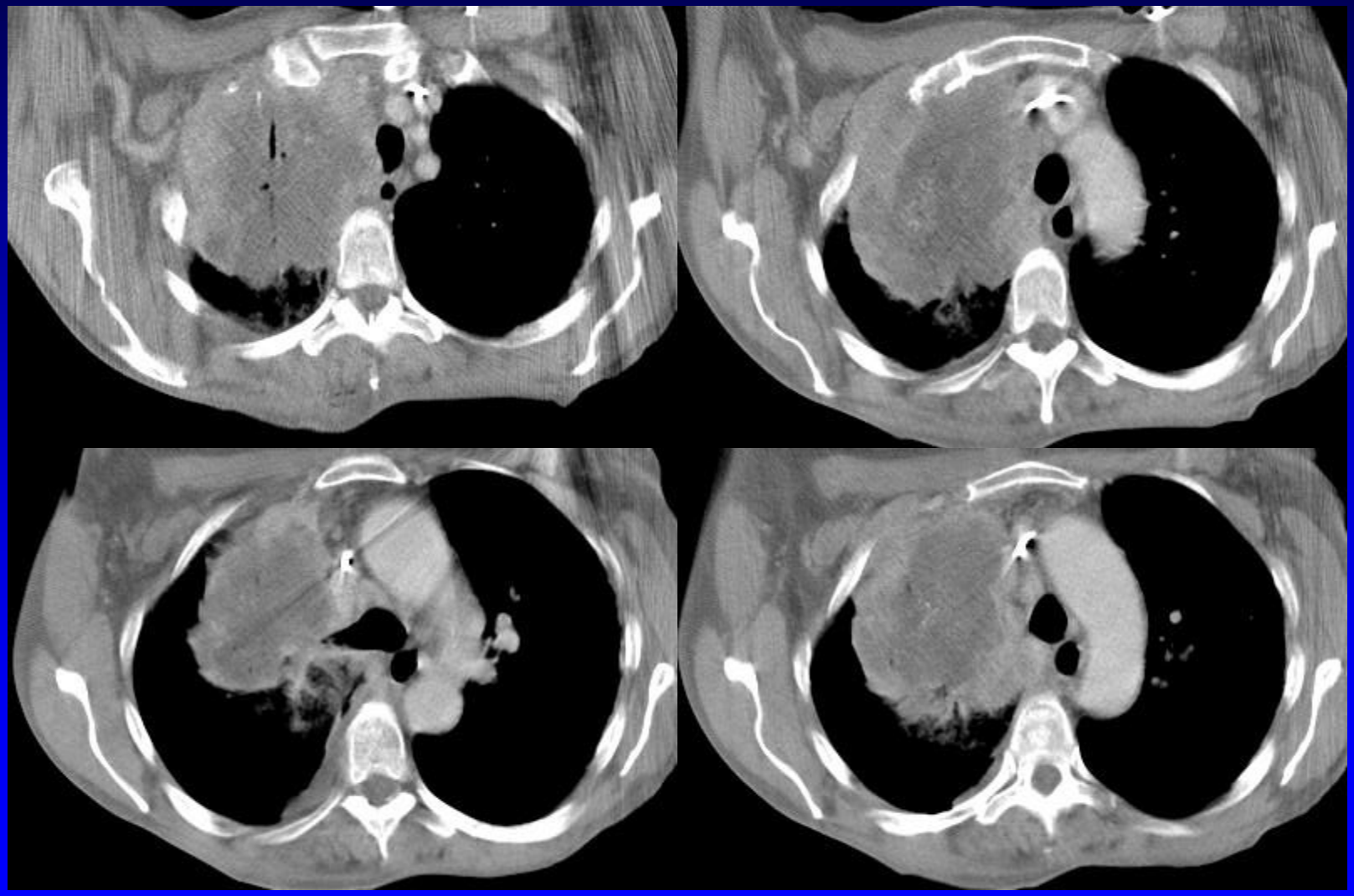
68 yo Woman with Pancoast Tumor



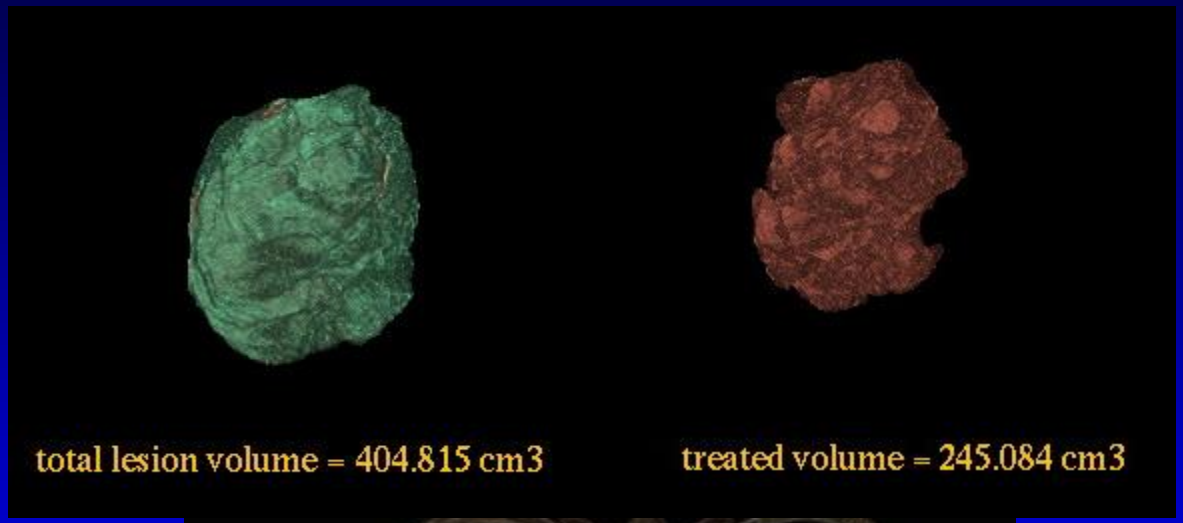
3 MedWaves Antennae

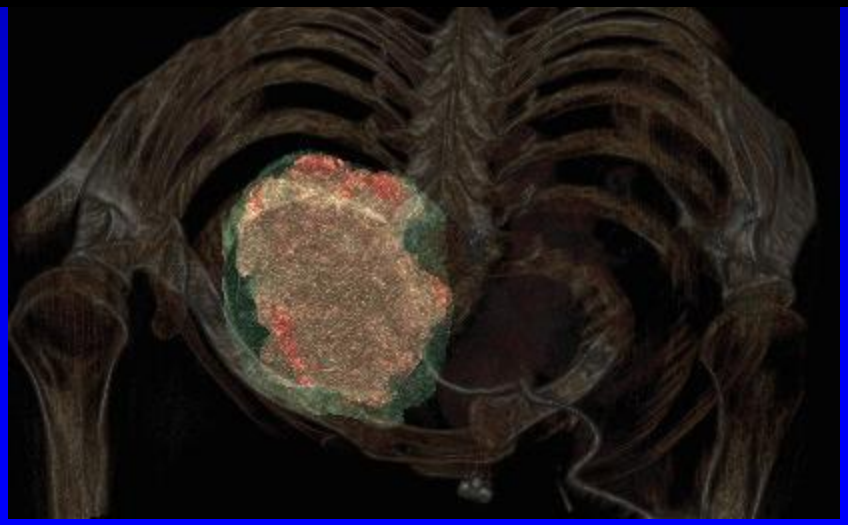
10 min treatment time 12-32 Watts

68 yo Woman with Pancoast Tumor



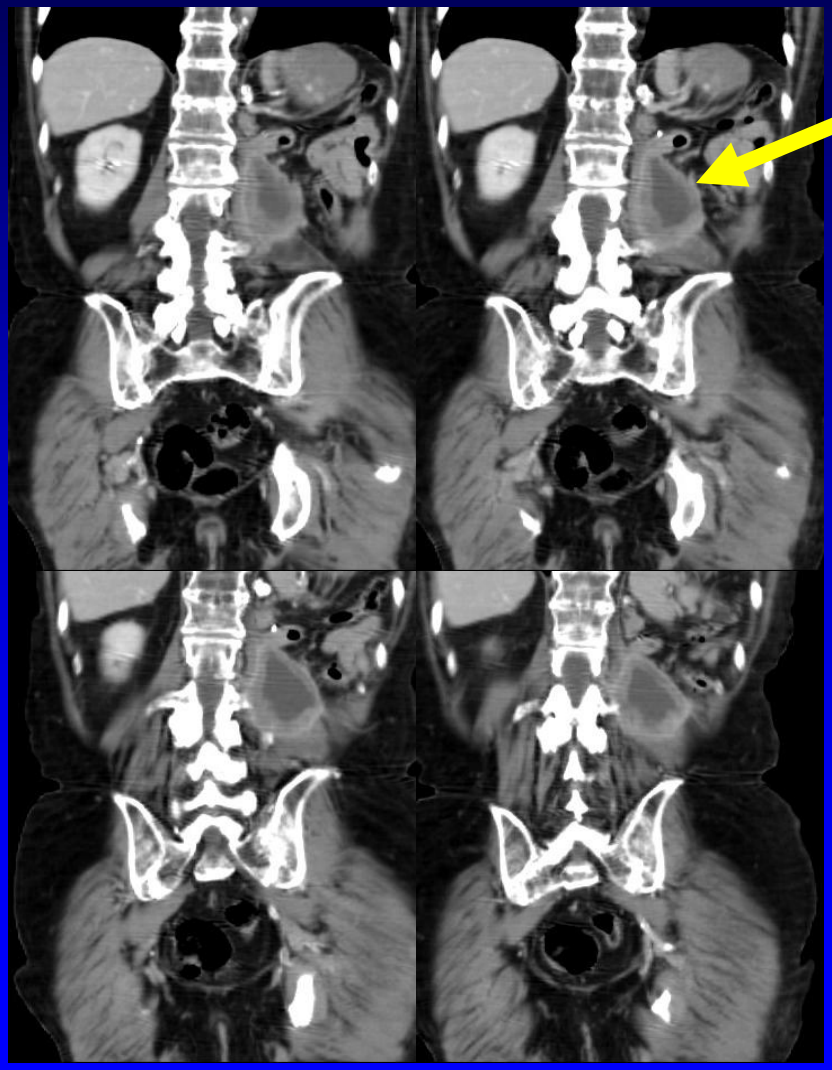
68 yo Woman with Pancoast Tumor





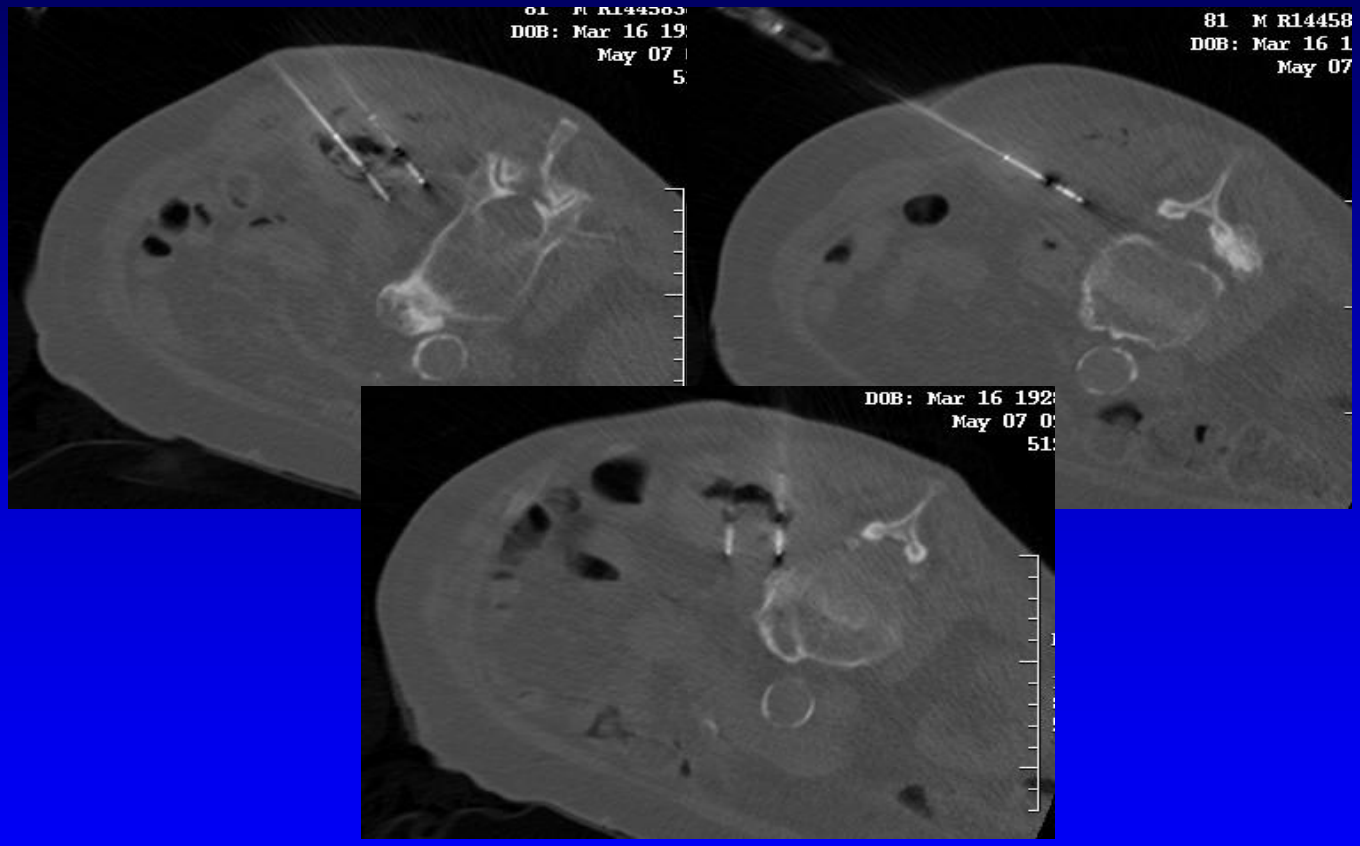
Fusion Image

9cm Recurrent Squamous Cell CA



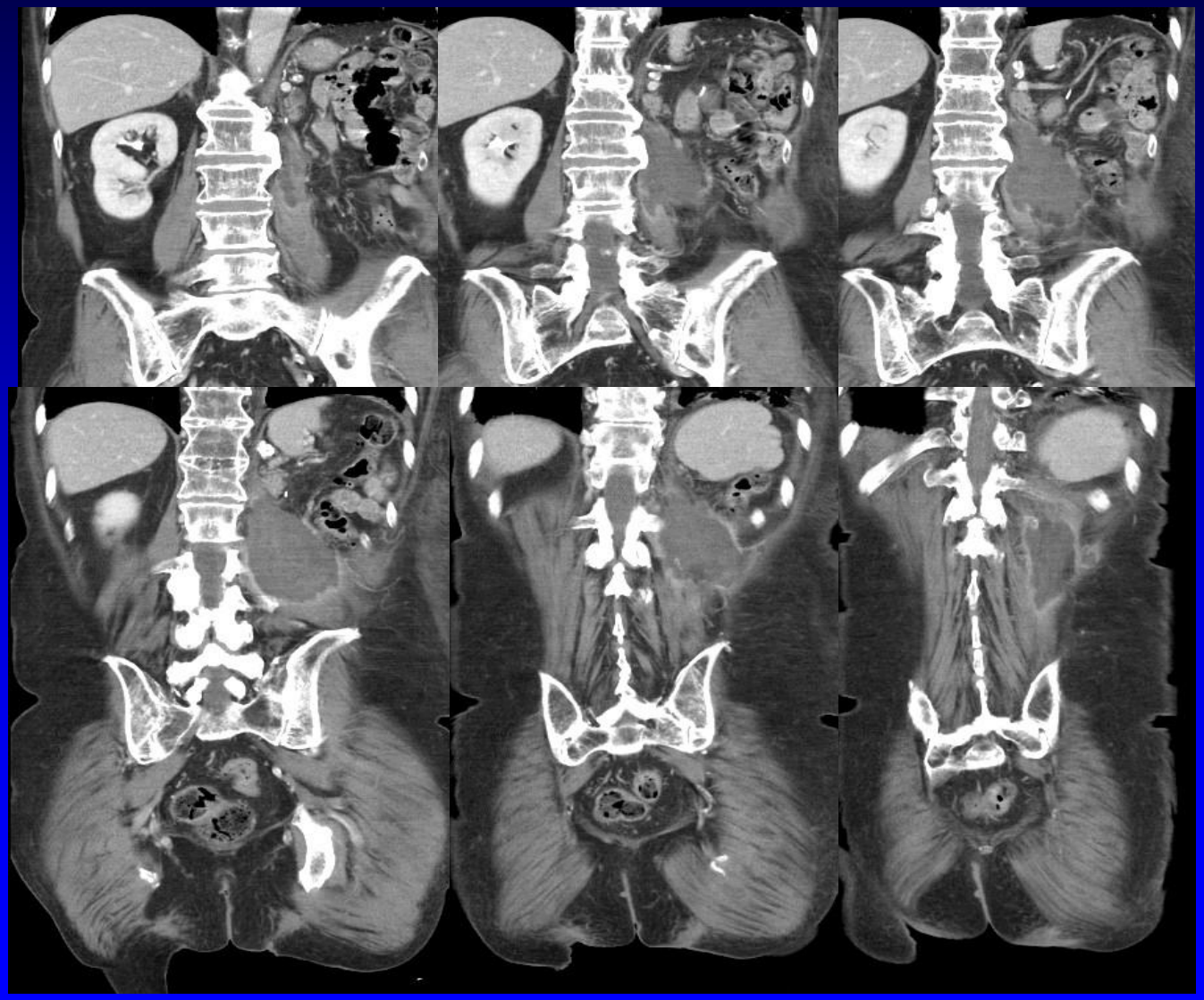
Necrotic center

9cm SQCCA

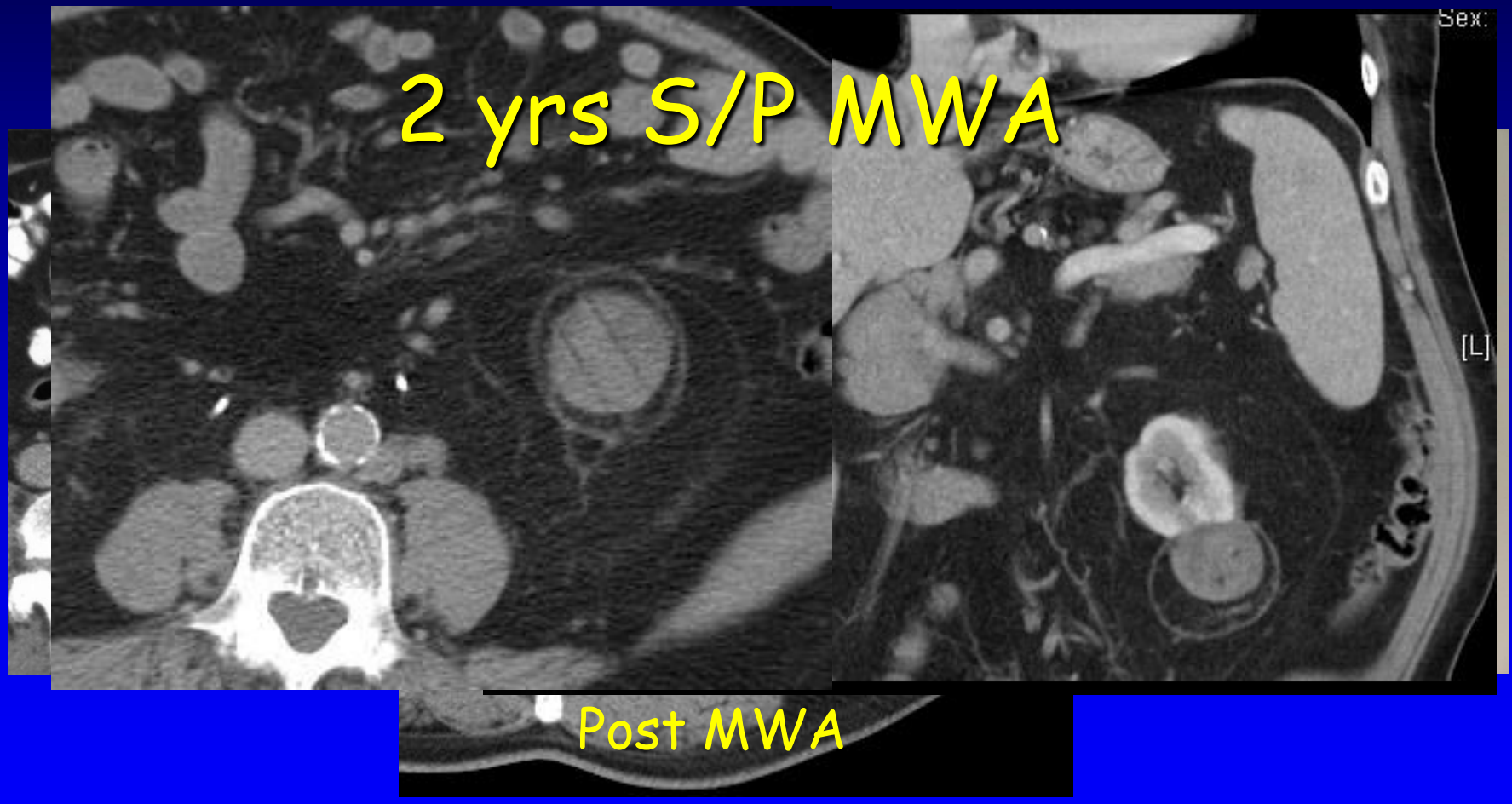


CT-guided MWA 3 Evident antennae
10 min x 2

9cm SQCCA Post MWA

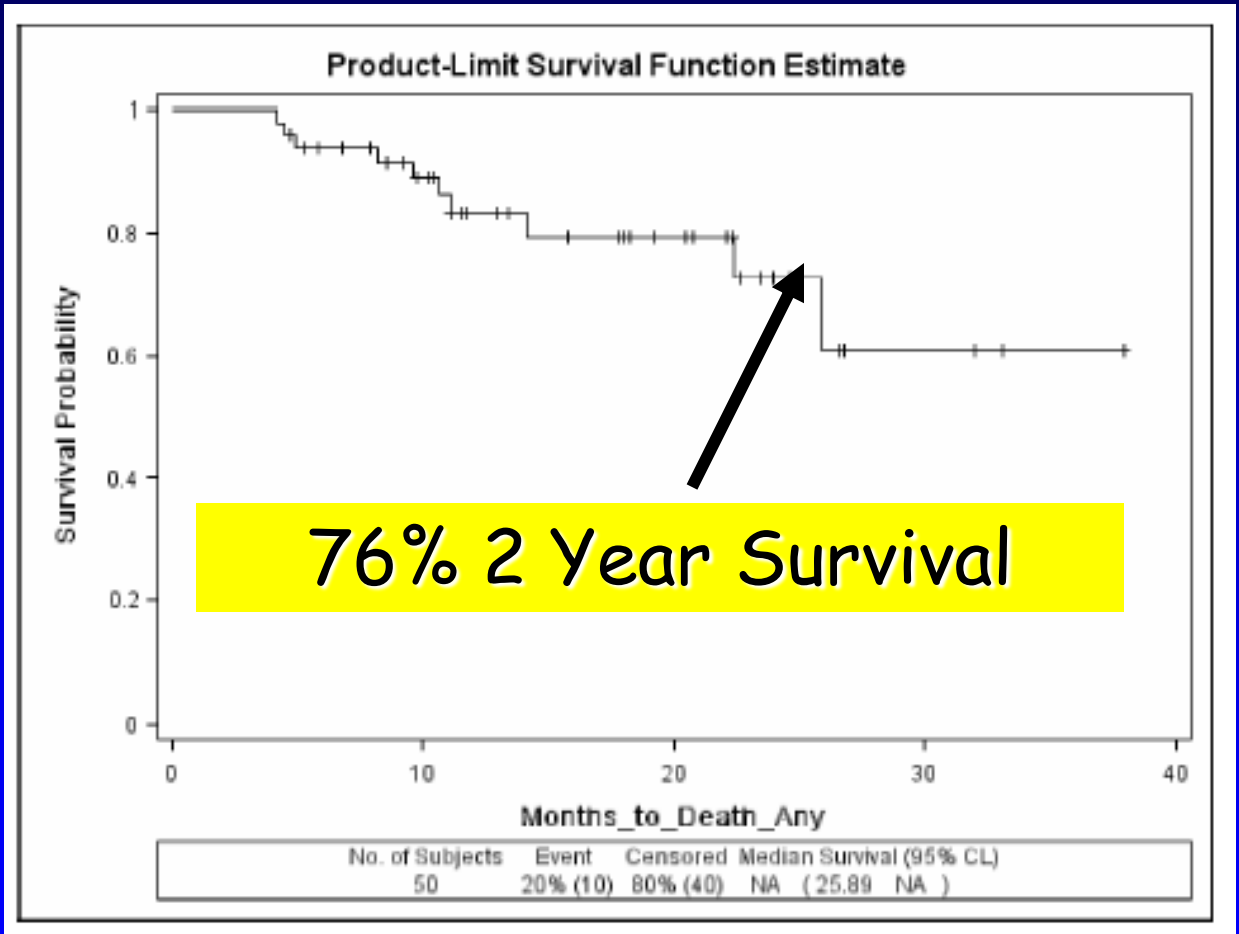


Large Renal Cell carcinoma



CT-guided MWA 3 Evident antennae 10 min

MWA of Lung Neoplasms Cancer Specific Survival

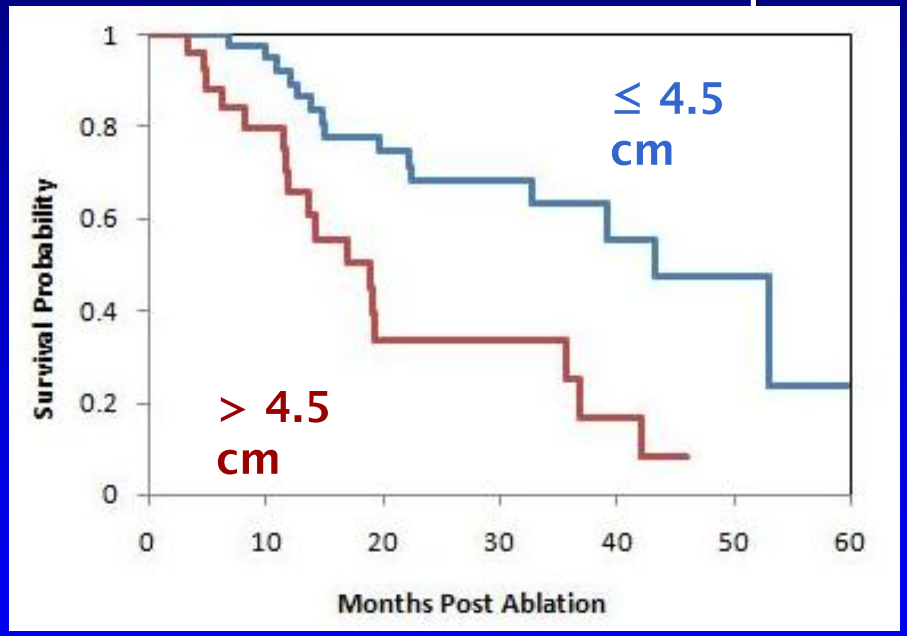


Wolf et al Radiology 2008

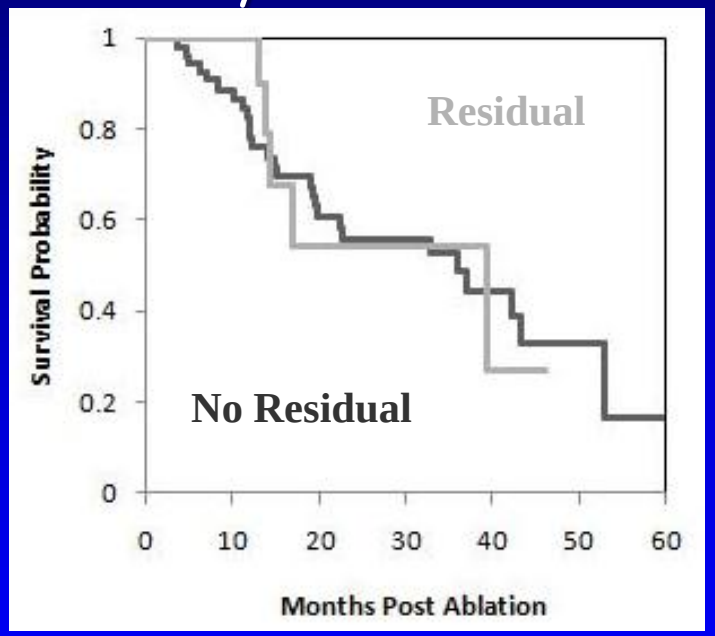
Results

Survival

Cancer-Specific Mortality



P= .001



P= .71

Wolf et al RSNA 2009

MWA Advantages

- Multiple applicators increase flexibility of treatment
- Large volumes in shorter time periods
- Heat sink effect may not be as apparent as RFA
- ? Improved penetration in lung tissue, Potentially
- Direct comparison with RFA unknown at present
- Appears to be less painful c/w RFA

Irreversible Electroporation Overview

- Small (16-18G) needle electrodes placed with CT/US guidance
- Very short high DC current(2500-3000 volt) pulses create holes in cell membranes that lead to apoptosis in 2 hrs.
- Rapid non-thermal treatment delivery

Irreversible Electroporation

Technique that increases the permeability of cell membranes by changing the transmembrane potential resulting in disruption of the cell membrane

Application of short pulse high-voltage DC current

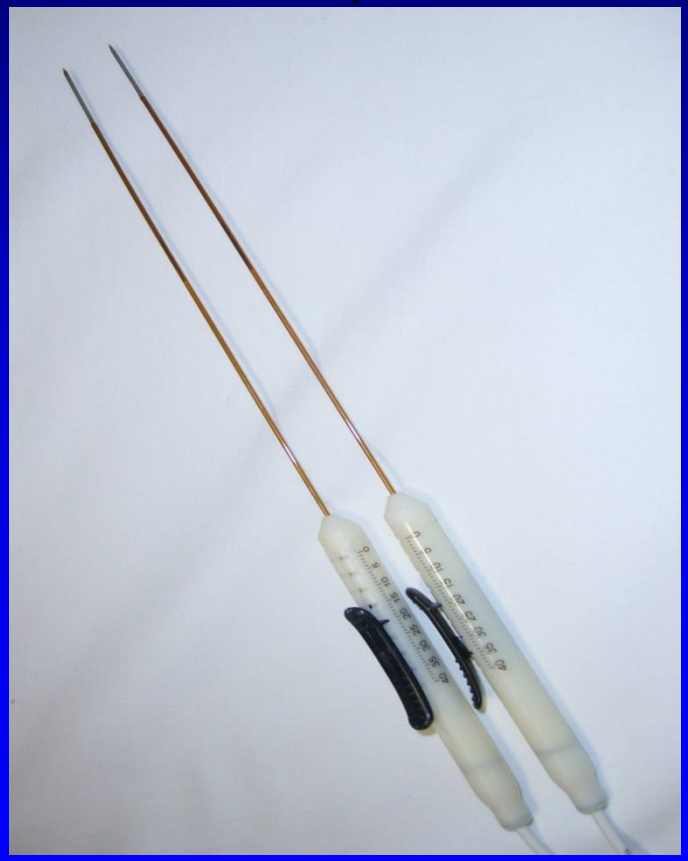
*NanoKnife IRE Generator

- Portable light weight similar to US unit
- Upgradeable Windows OS
- USB data export
- Fail safe electric shut-off system
- EKG cardiac synchronization
- 6 electrode ports

* AngioDynamics, Queensbury, NY

IRE Electrodes

Monopolar

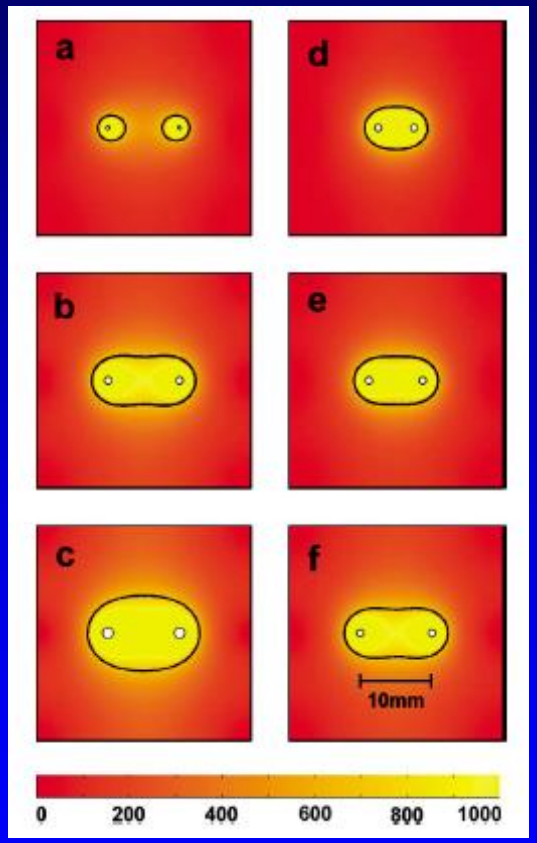


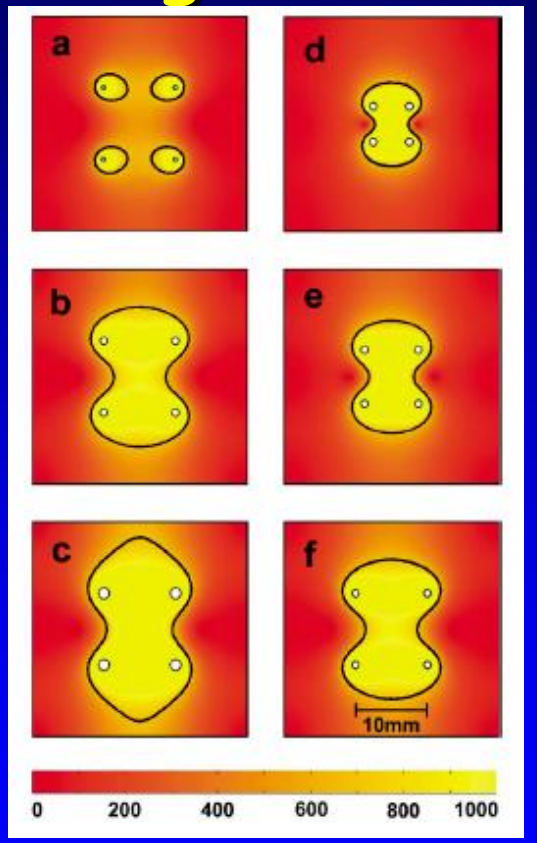
Bipolar

Tissue Ablation with Irreversible Electroporation

R. V. DAVALOS,[1] L. M. MIR,[2] and B. RUBINSKY[3]

IRE Electric Field Changes for 2 and 4 Monopolar Configurations



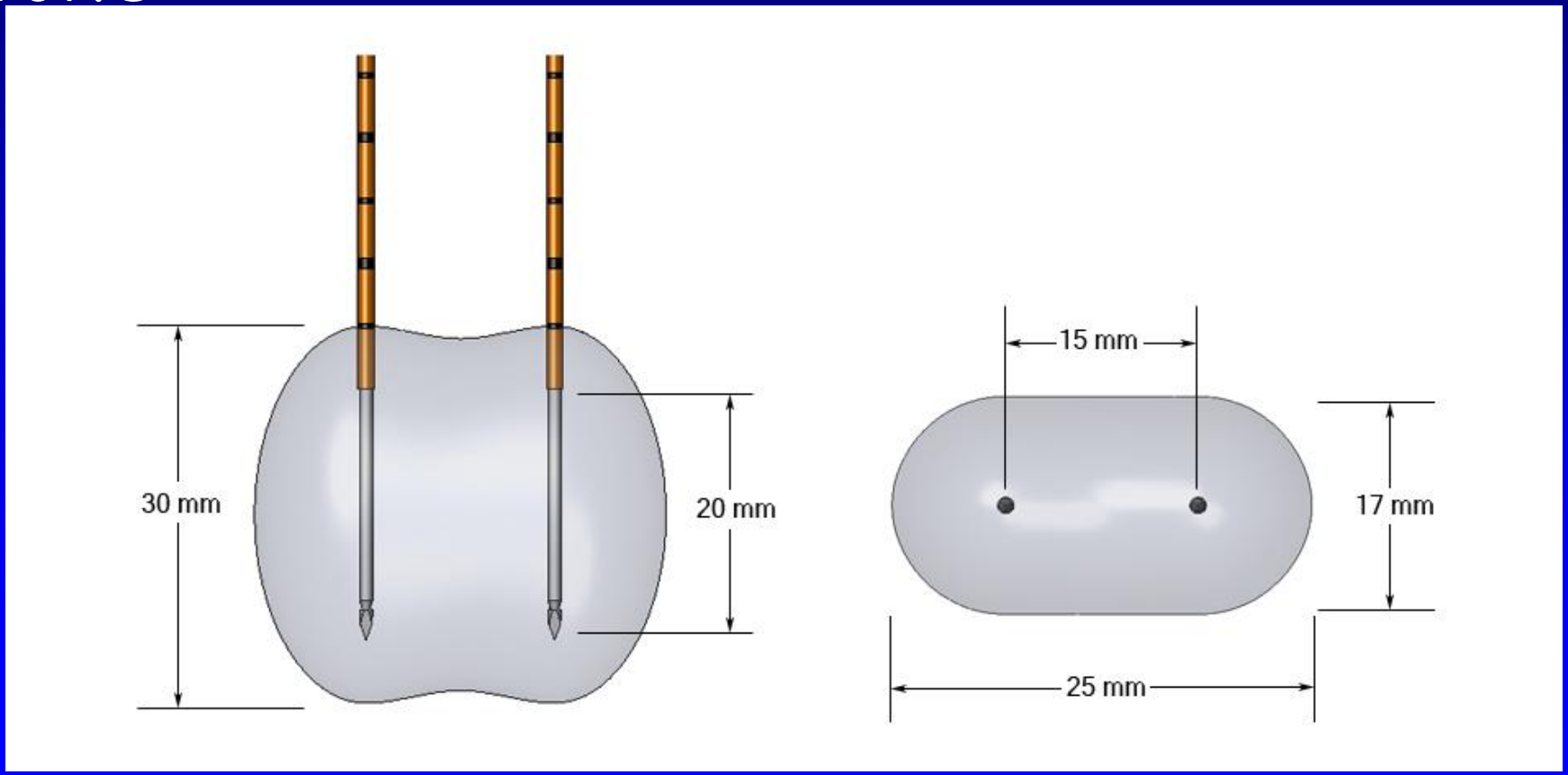


680v/cm=cell death=solid line

Annals of Biomedical Engineering 2005;33:223-231

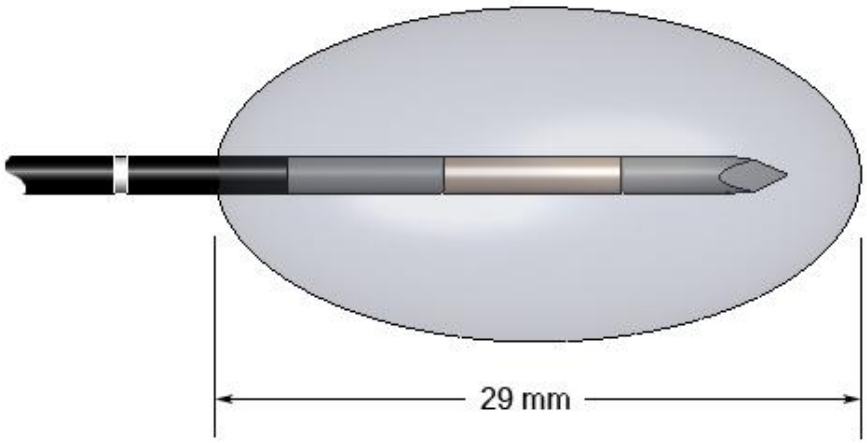
Two Monopolar Electrodes

- 2 cm exposure & 1.5 cm spacing @ 2,500 volts

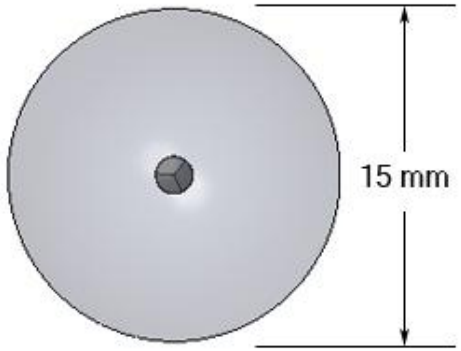


Bipolar Electrode

- 15mm x 29mm Treatment Zone @ 2,700 volts with 70 usec pulse width



SIDE VIEW



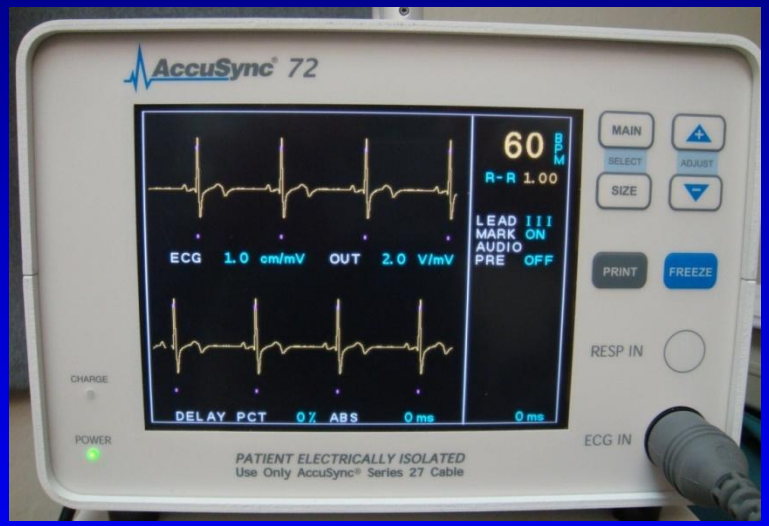
FRONT VIEW

Irreversible Electroporation Overview

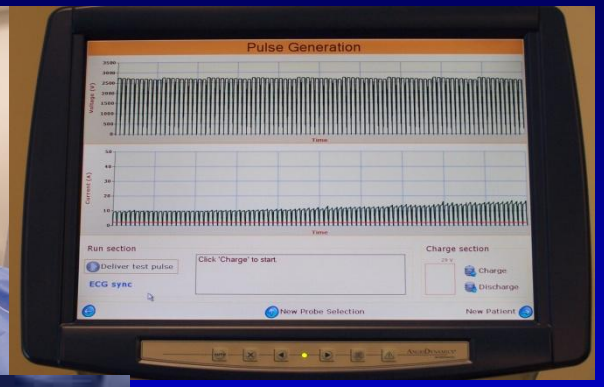
- Collagenous architecture spared
- Dead cells resorbed by body with no foreign body reaction like RFA/MWA/Laser
- Minimal tissue distortion
- Post-procedural pain minimal since non-thermal
- Need to perform under GA with neuromuscular blockade

Cardiac Synchronization

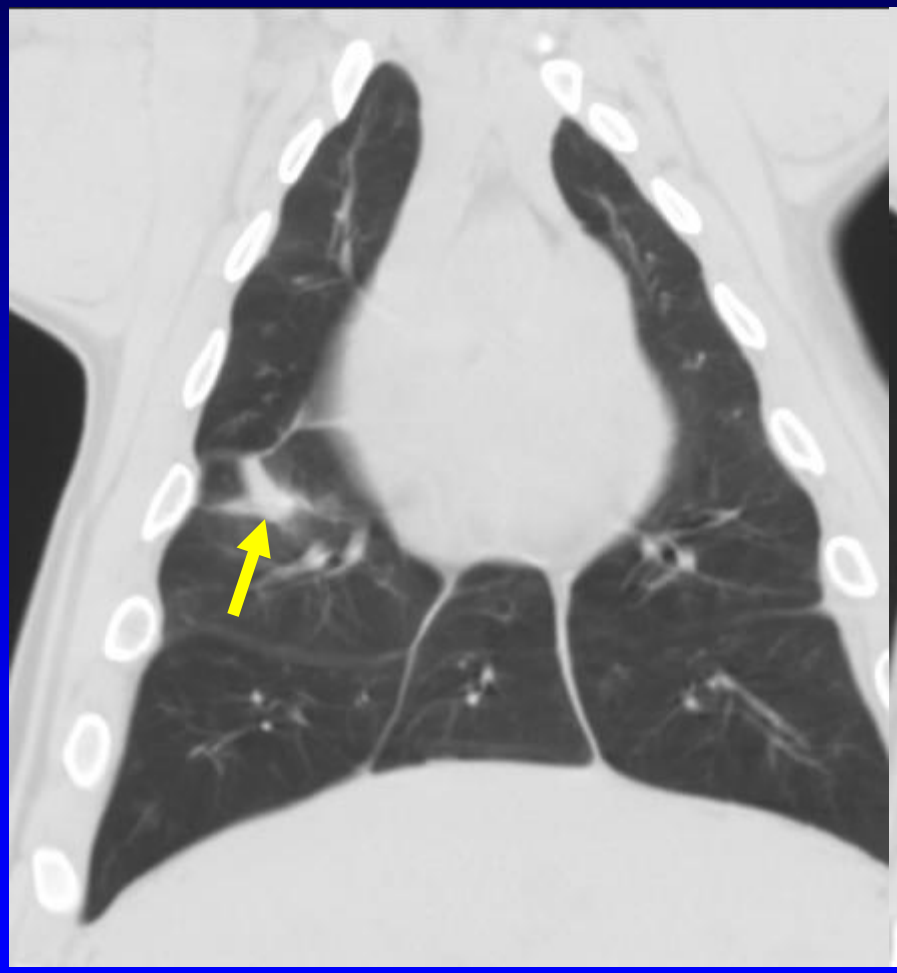
- High current pulses may stimulate cardiac conduction system
- Tachyarrythmias reported in IRE procedures near heart
- Cardiac synchronization delivers IRE current during refractory period



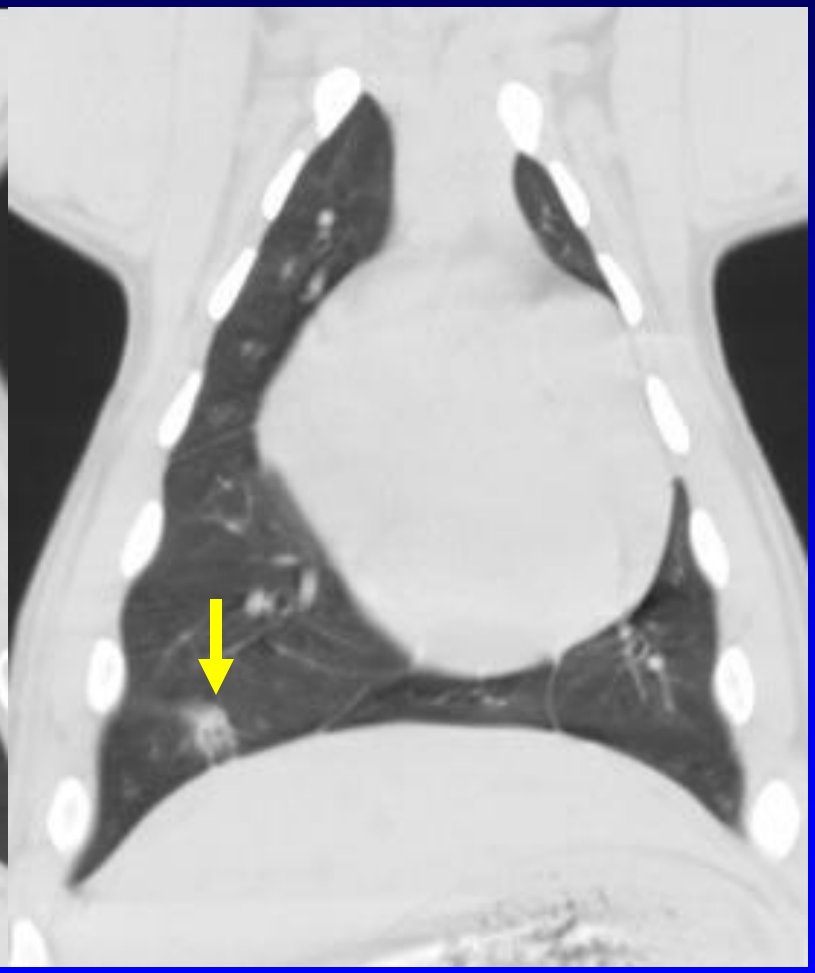
Irreversible Electroporation in Swine Lung



IRE Lesions
Swine Lung – 4 weeks

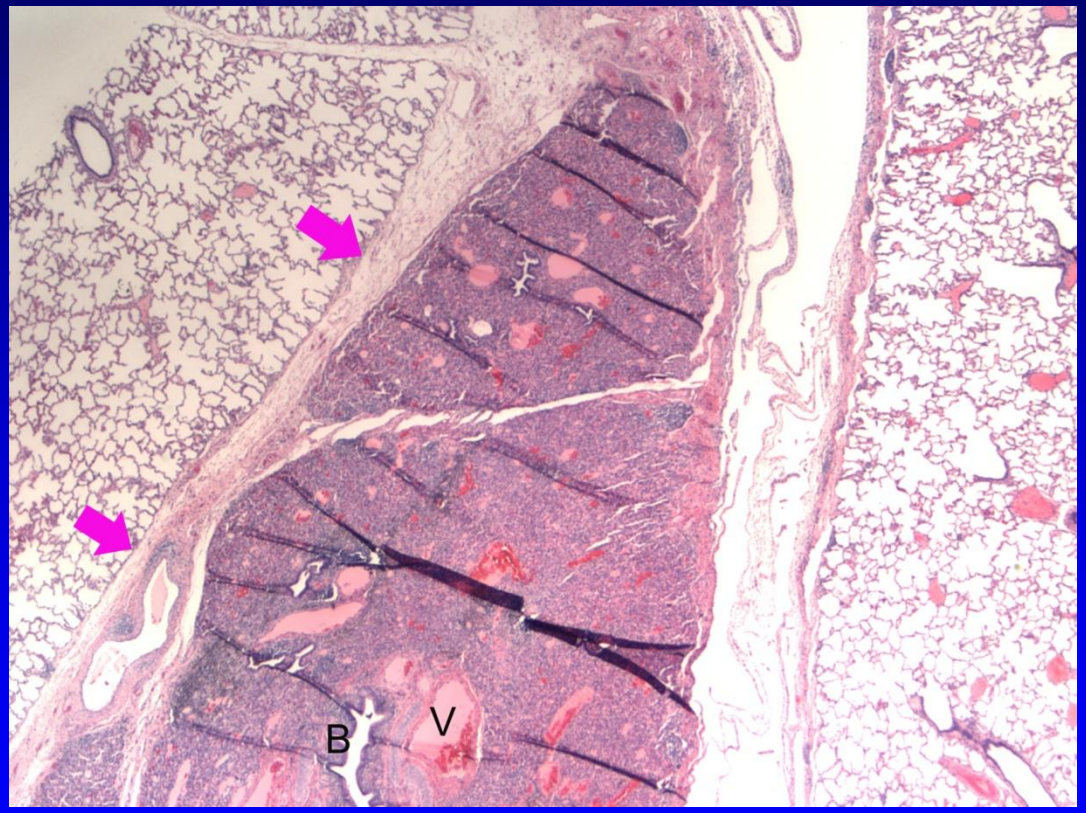


Bipolar Lesion

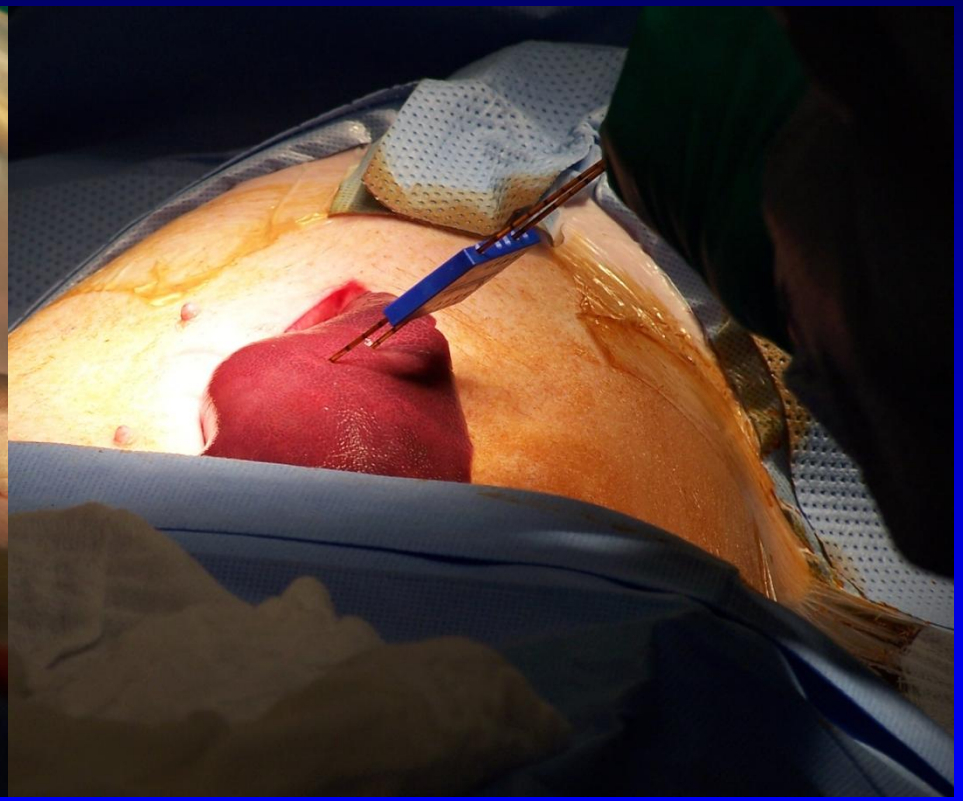


Monopolar Lesion

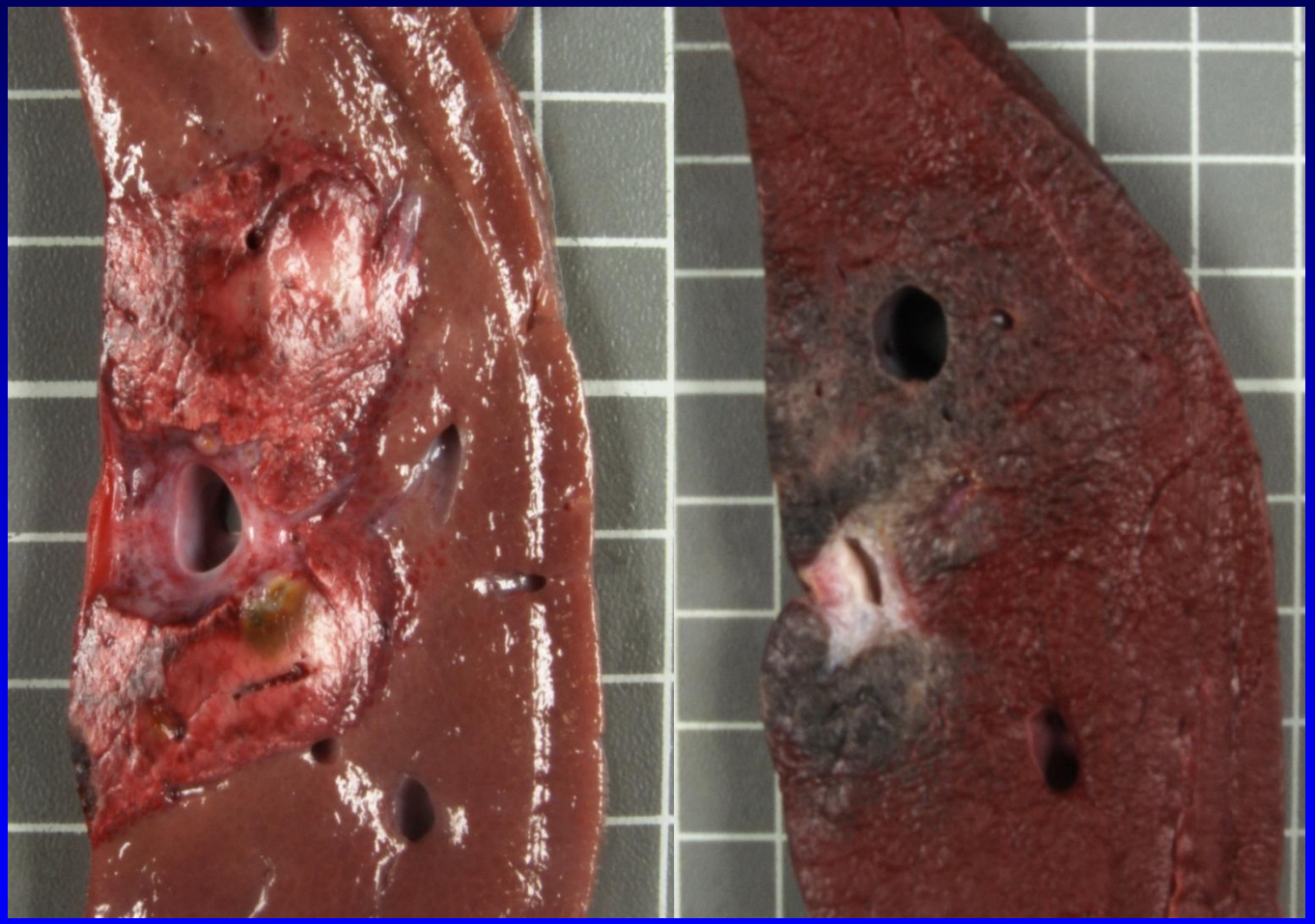
IRE lesion
Swine Lung



IRE Liver



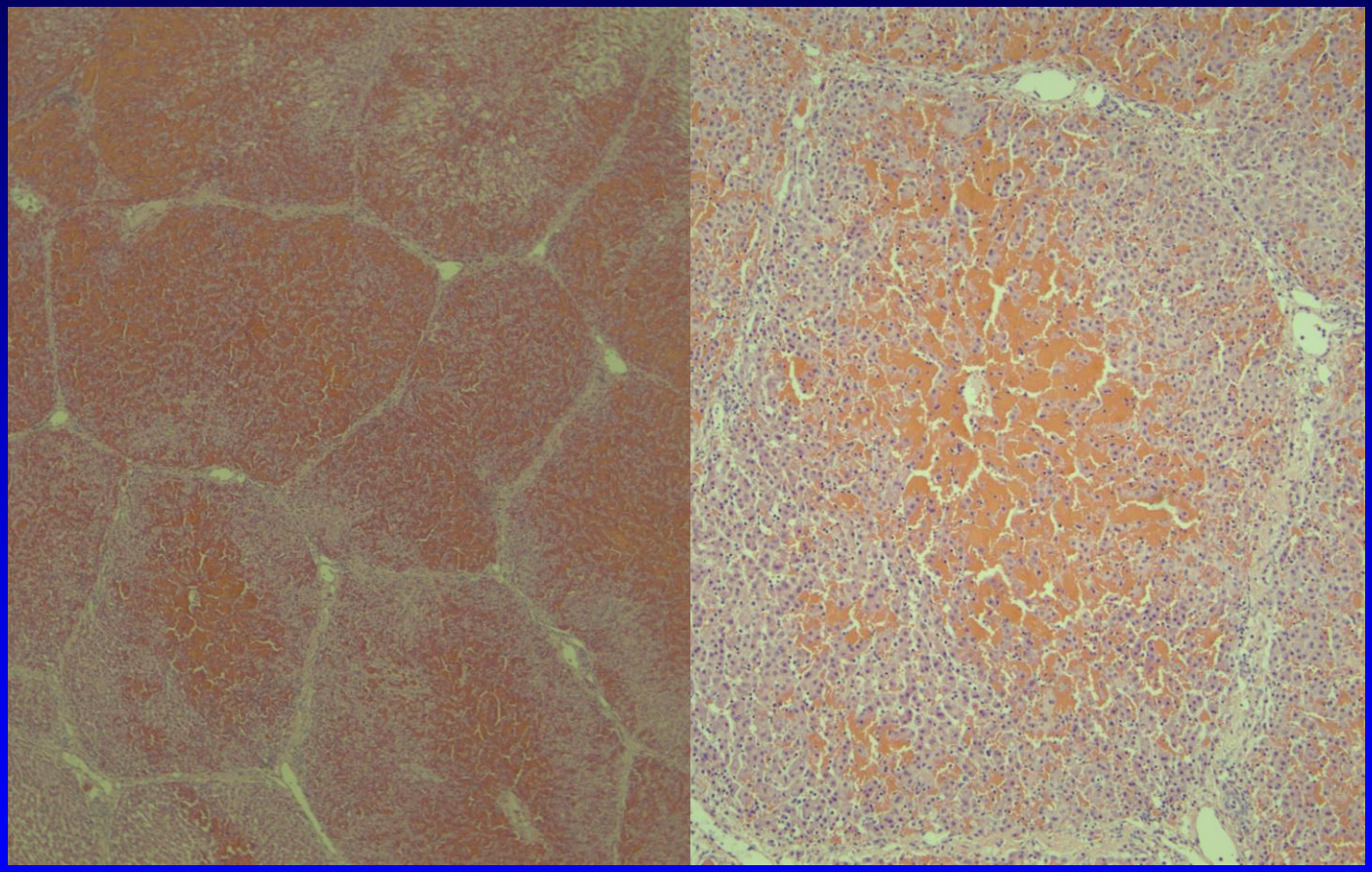
Liver IRE



TTC Fresh

TTC Fixed

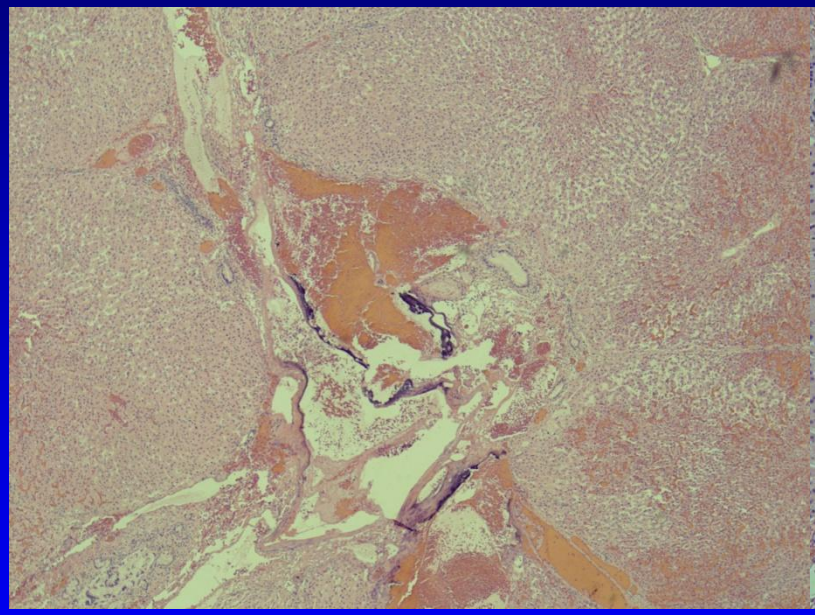
Liver IRE



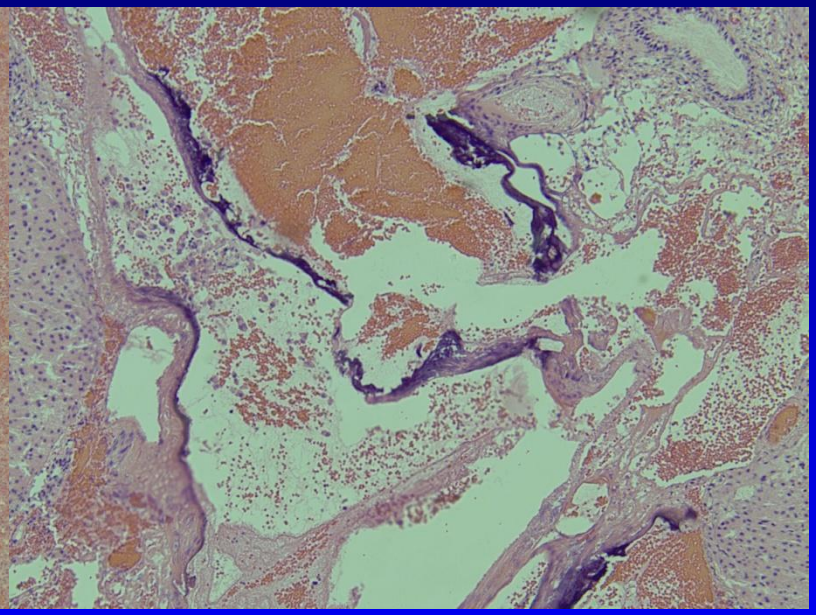
x 4

x 10

Liver IRE

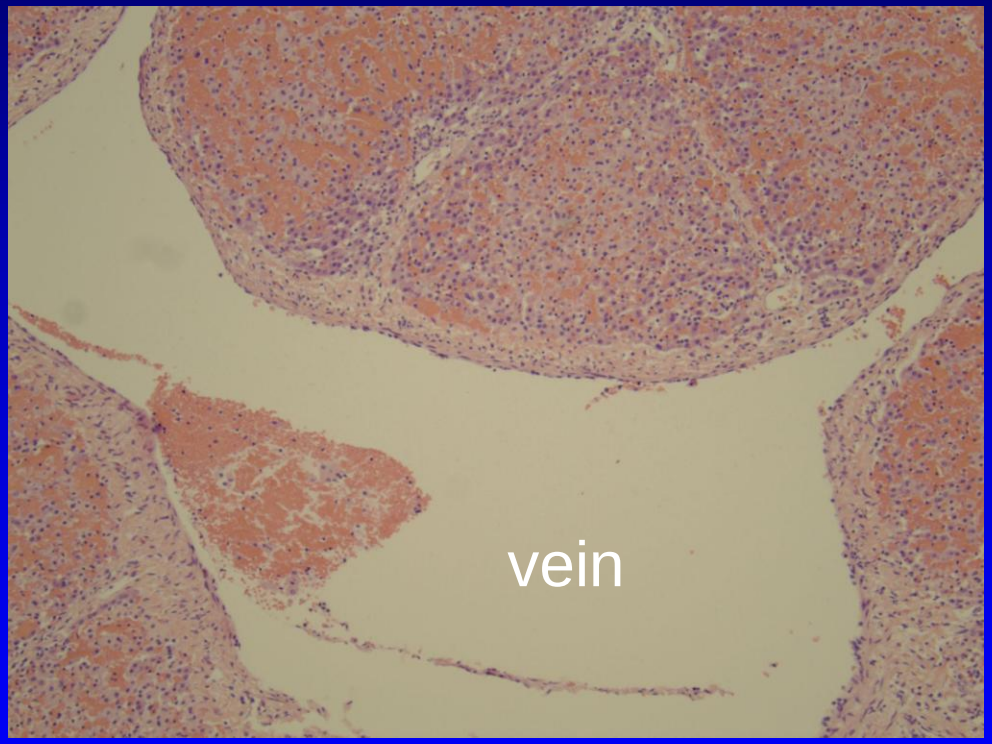


x 4



x 20

IRE Liver

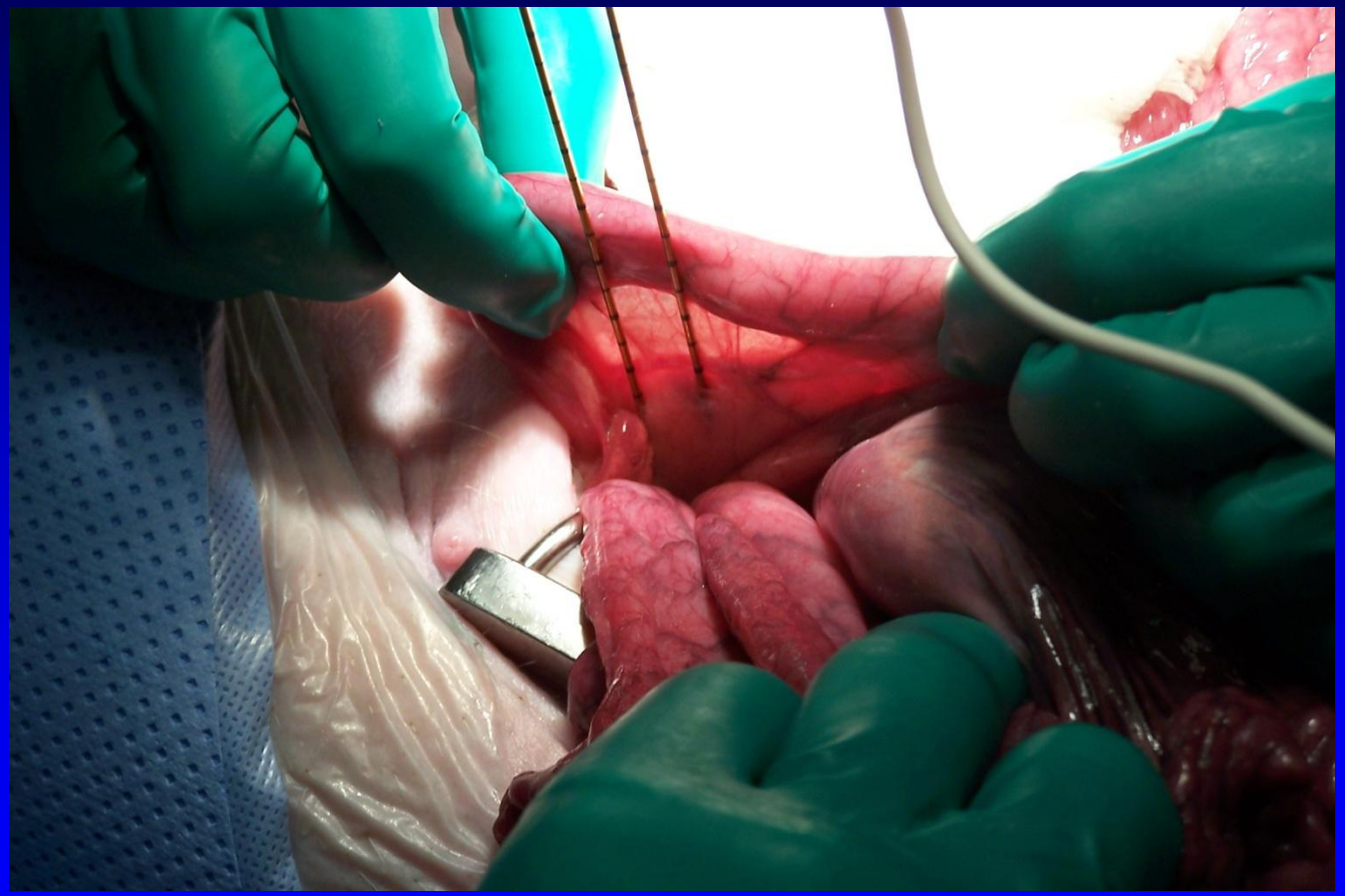


x 20

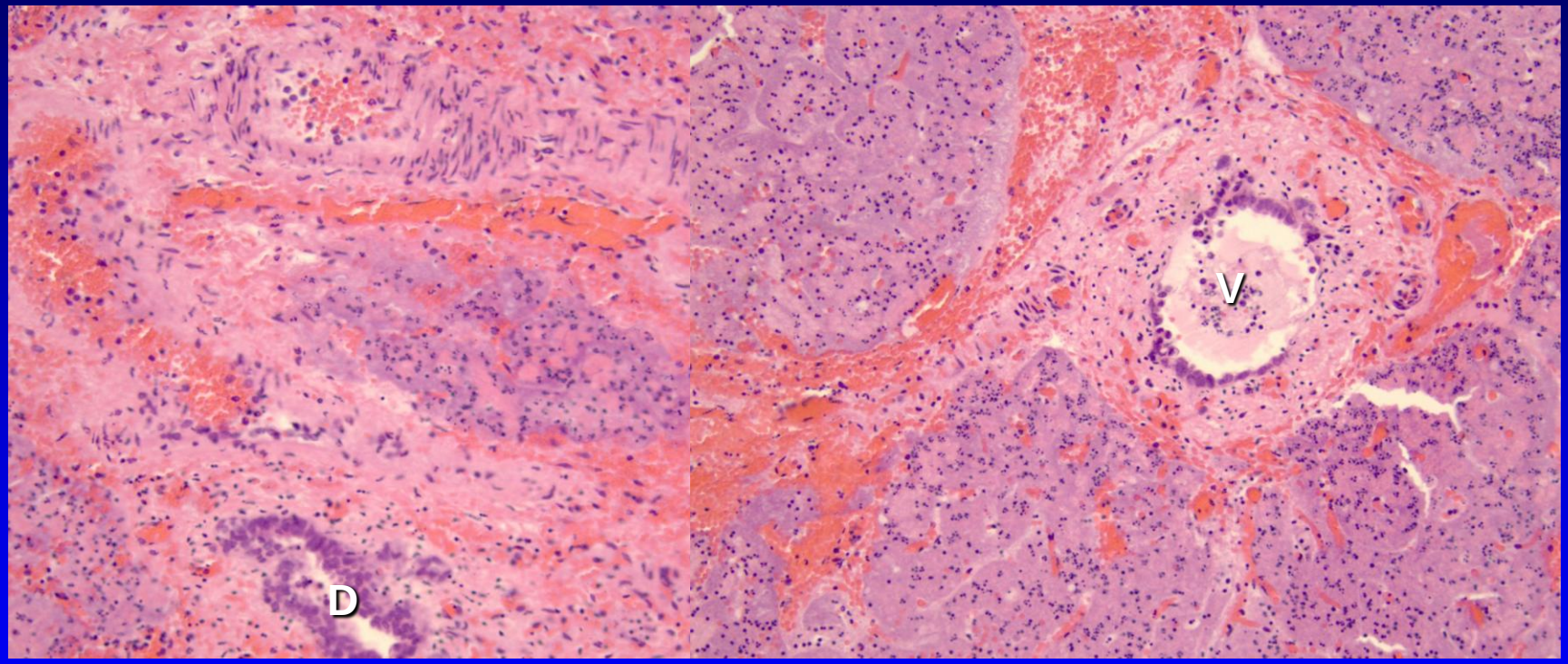
Liver IRE

Location	N	*Probe*	*Spacing*	*Exposure*	*Voltage*	*Reverse polarity*	*Ablation Zone (cm)*
Intra-hepatic	4	2 mono	2cm	2cm	3,ooo	yes	**3.25** +/- 0.35 x **1.45** +/- 0.21
Intra-hepatic	9	2 mono	2cm	2.5cm	2,500	yes	**2.95** +/- 0.31 x **1.5** +/- 0.44
Intra-hepatic	3	2 mono	2cm	2.5cm	3,000	No	**2.27** +/- 0.23 x **1.5** +/- 0.2
portal	4	2 mono	2cm	2cm	3,000	yes	**4.45** +/- 0.07 x **1.8** +/- 0

IRE Pancreas



IRE Pancreas



X20 duct and vessel

Conclusions

- IRE creates well defined areas of cell kill unaffected by heat sink effects
- Airways, bile ducts, vessels remain patent
- Potential applications in high heat sink areas and near critical structures
- Need to use GA with neuromuscular blockade and cardiac synchronization
- No human data currently just anecdotal cases
- Human trials in and outside US beginning