Radiofrequency Ablation

Paul F. Laeseke

University of Wisconsin
Departments of Biomedical Engineering and Radiology

Disclosures

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Educational Objectives

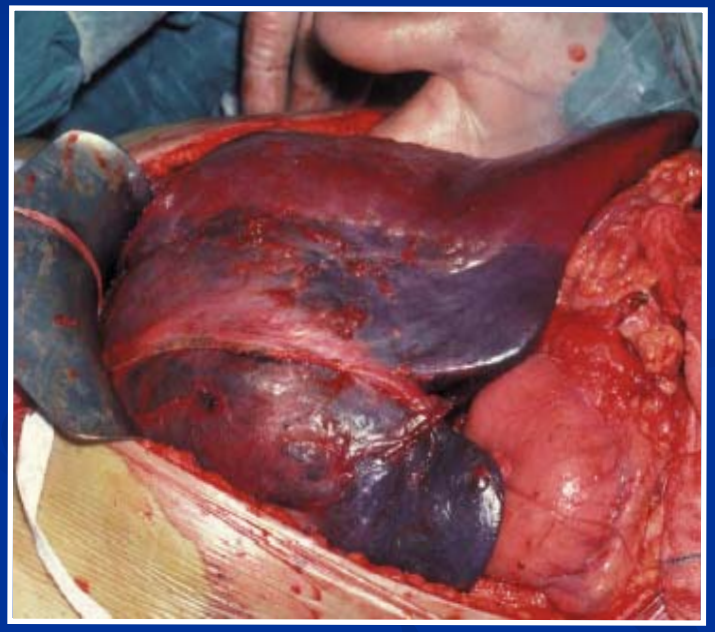
I. Introduction
II. Principles
III. Equipment
IV. Applications
V. Future directions
VI. Conclusions

RF ablation

- *In situ* destruction of tumors/tissue by heating with radiofrequency energy

Why radiofrequency (RF) ablation?

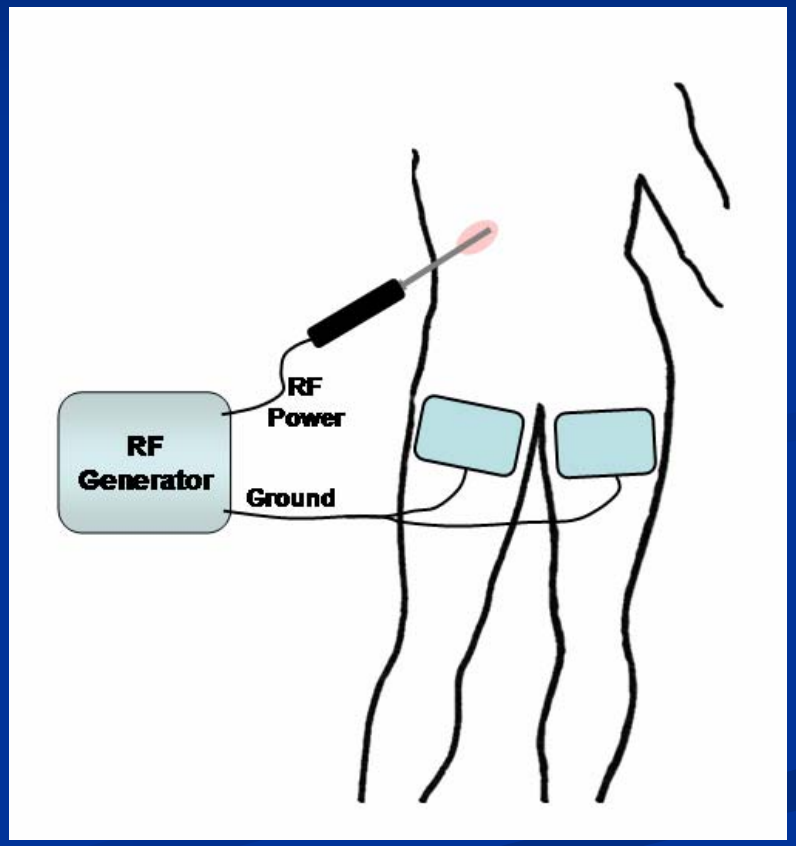
- ~250,000 deaths in 2005 from colon, kidney, liver, & lung cancer
- Most not surgical candidates
  - Size, #, location of tumors
  - Co-morbidities
- Resection (Fong Y. Ann Surg;236:2003)
  - 600 ml blood loss
  - 49% require transfusions
  - Morbidity 45%
  - Mortality 3.1%



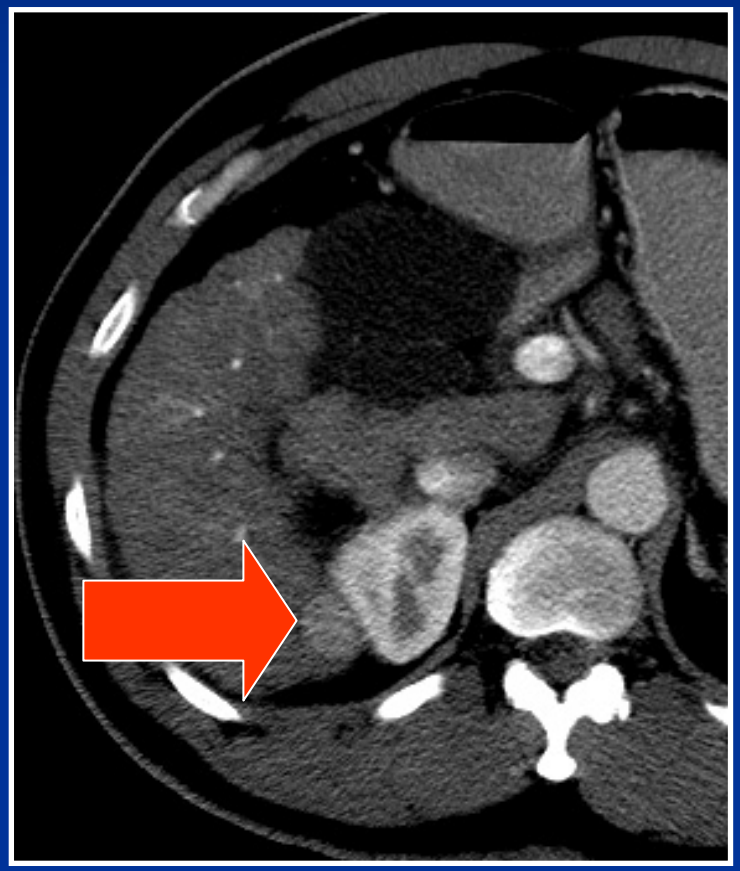
- Minimally-invasive alternative for NON-SURGICAL candidates

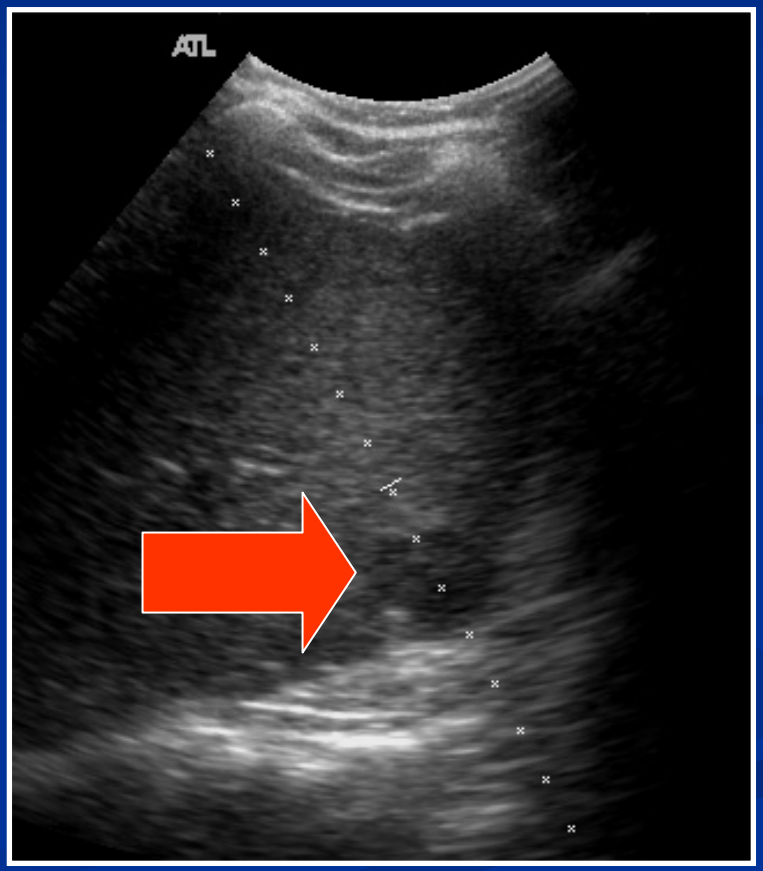
The Procedure

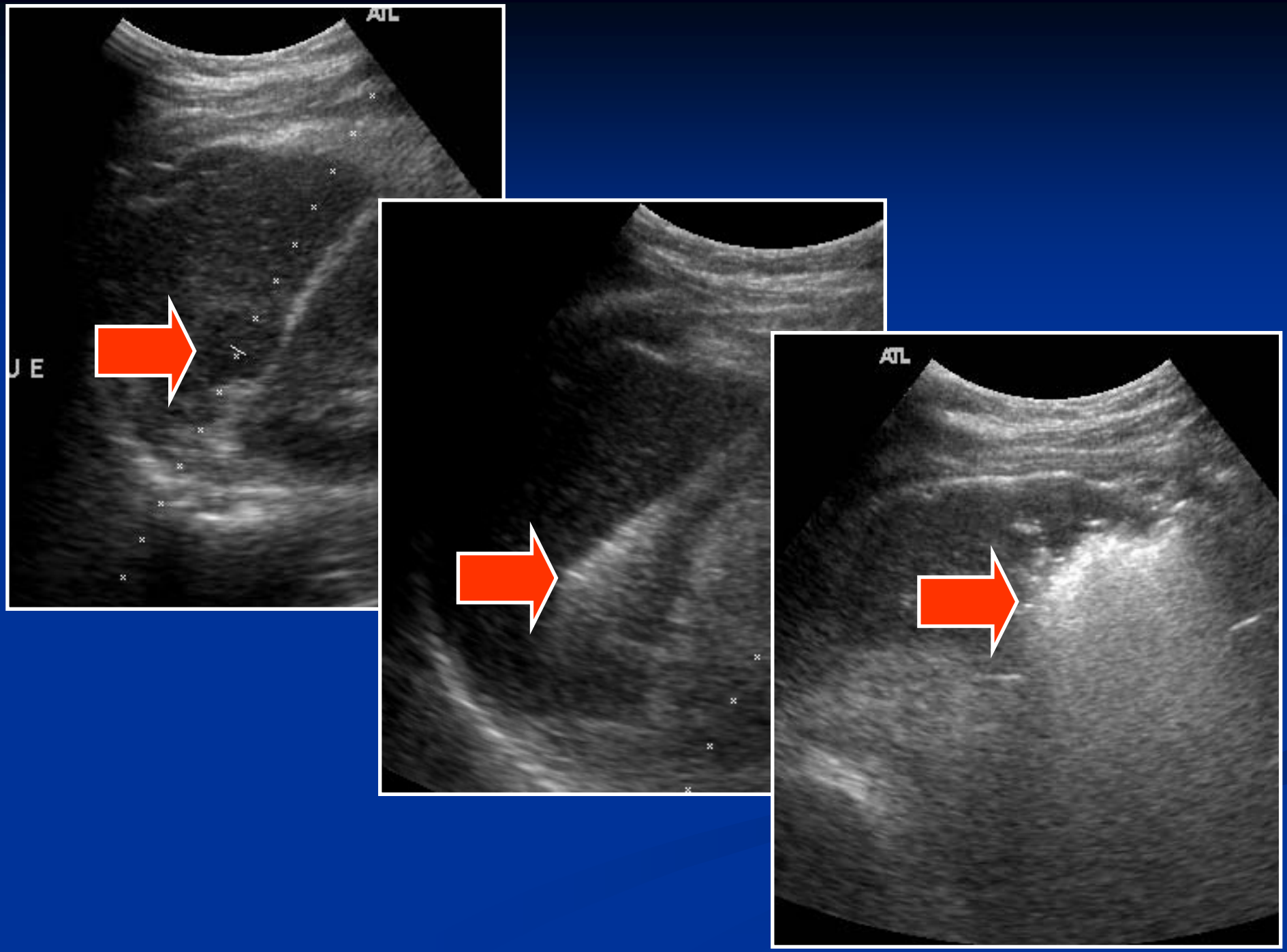
- Open, laparoscopic, or percutaneous
  - CT, MRI, or US
- Electrode placed in tumor
- Ground pads equidistance from electrode (thighs)
- Power applied
- Imaging
  - Pre
  - Post – immediate; 1, 3, & 6 mo; and every 6 mo to 2 yr



RF ablation of liver tumor (HCC)



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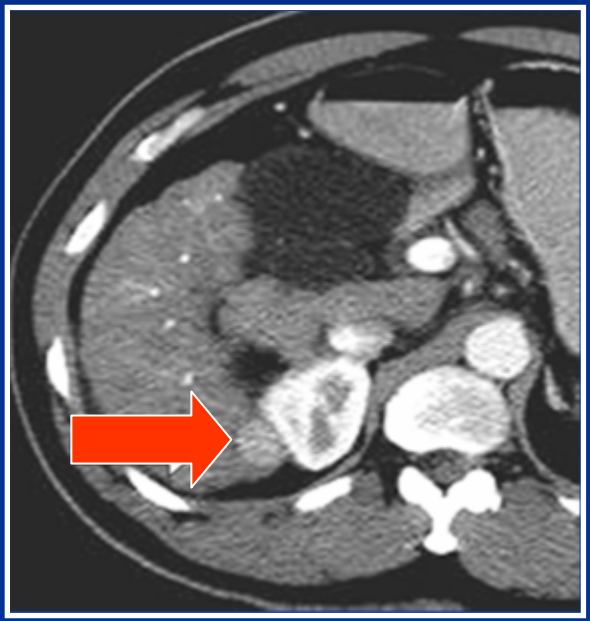
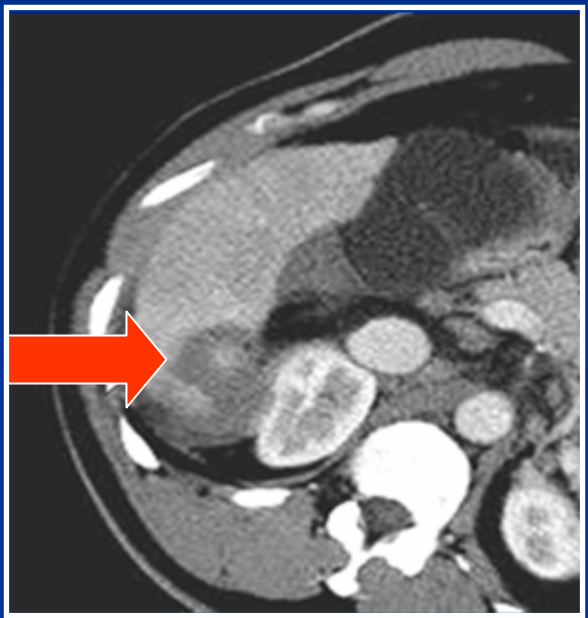
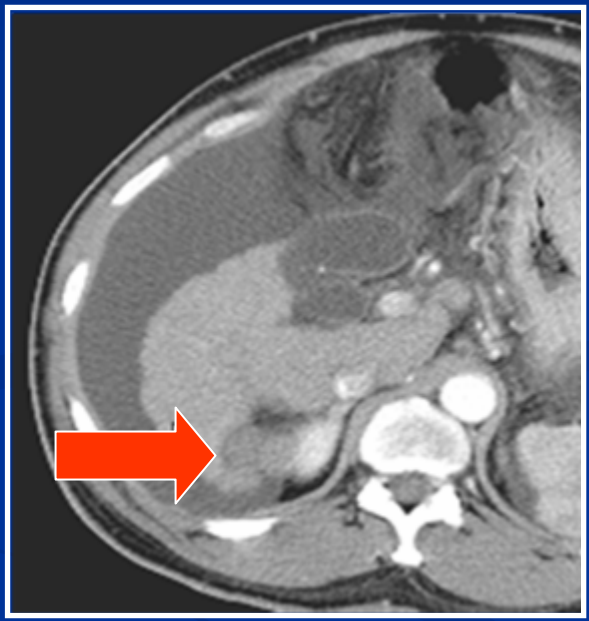
Successful ablation



Pre-ablation



Post-ablation



2 year follow-up

Principles of RF ablation

- Joule heating – rapidly alternating current (~460 - 480 kHz) passing through a resistive medium is converted to thermal energy
- RF ablation: electrode → tissue → ground pads
- AC current → ionic agitation → friction causes tissue heating

Transient heat transfer equation

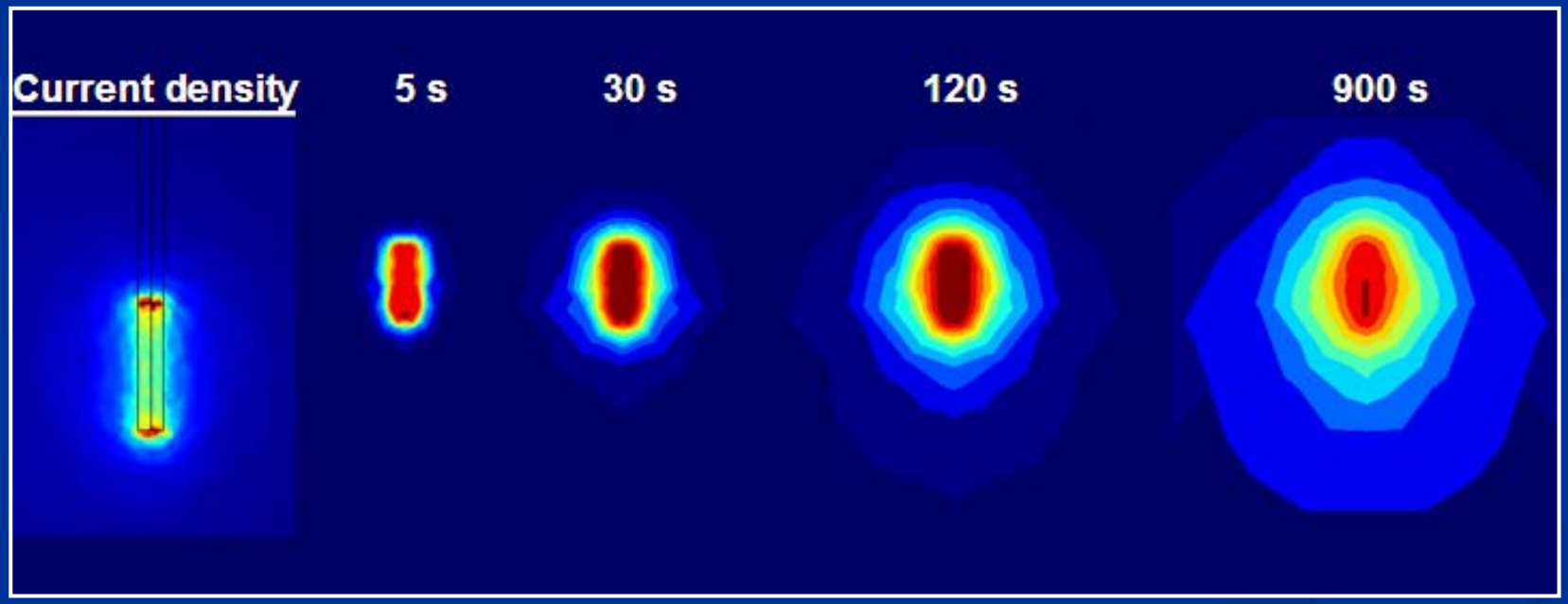
Thermal conduct
most of the heating
density and power
and $1/r^4$, res

Cooling due to **"heat sink"** effect of local blood flow

$$\rho C \frac{\partial T}{\partial t} = \nabla \cdot k \nabla T + \mathbf{J} \cdot \mathbf{E} - Q_p ,$$

Active heating causes large temp gradient near electrode radially outward (a few mm).

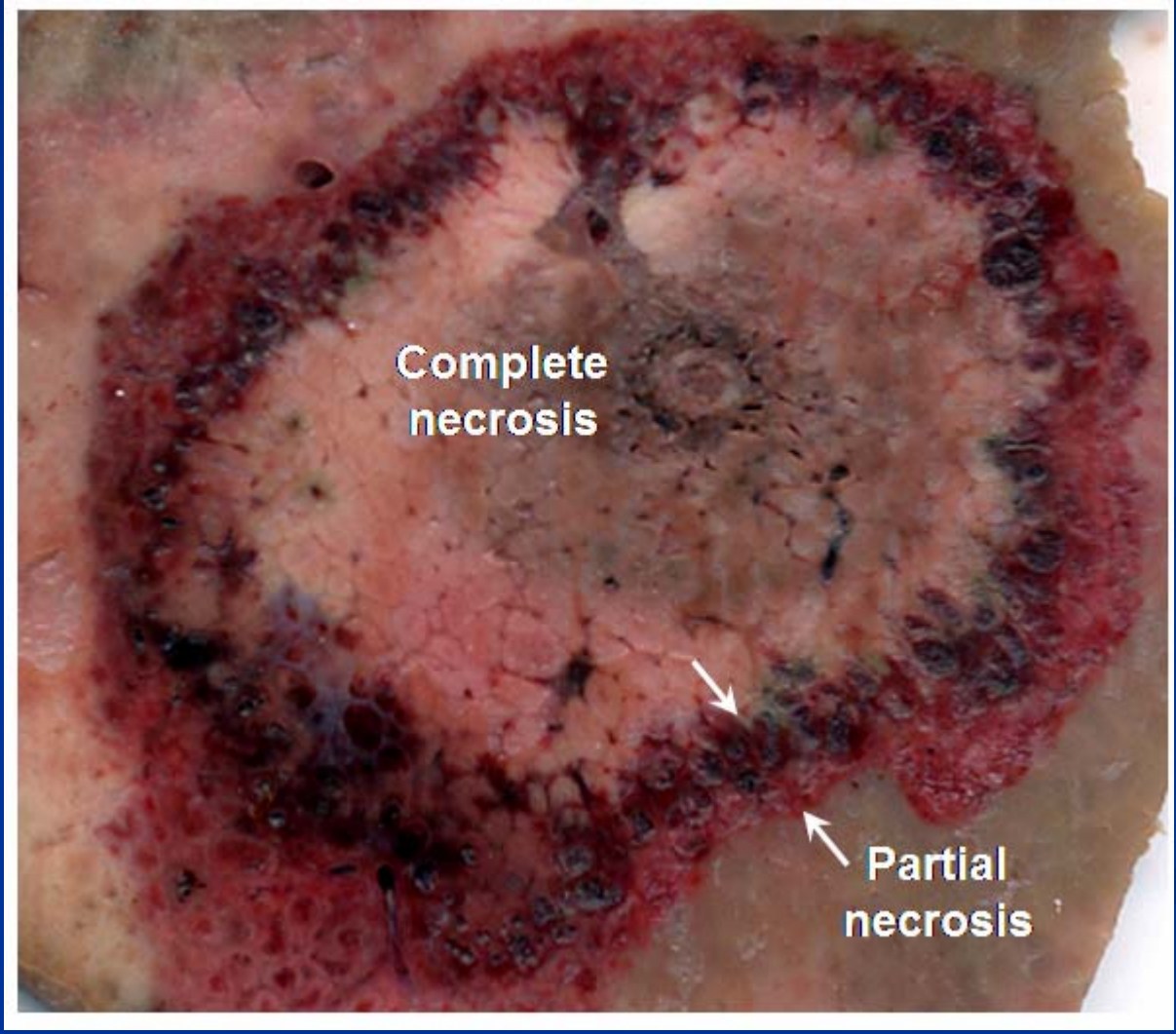
Current density & time progression of ablation



Mechanism of tissue injury

- Tissue heating → protein denaturation
- Tissue boiling → release of water vapor → mechanical tissue disruption
- Breakdown of cell membranes
- Vascular thrombosis, red cell fragmentation
- Irreversible cell death by thermal damage
  - >50 °C – 4 - 6 min
  - >60 °C - instantaneous

Ablation zone

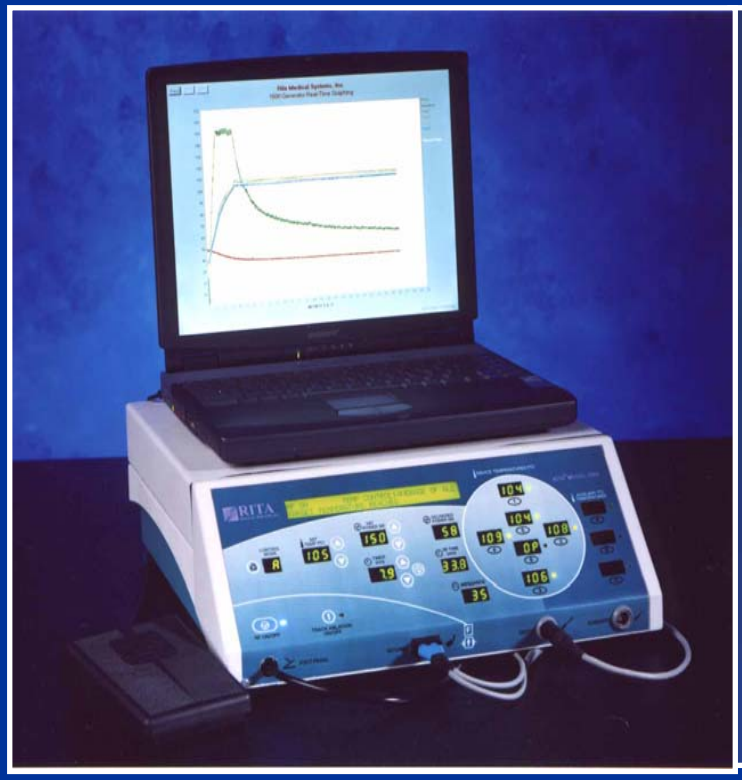


Limitations to RF tissue heating

- Charring/dessication increases impedance → temps limited to < 100 °C
- Basic single needle electrode: zone of necrosis too small (~1.6 cm)

RITA Starburst™

- 250 W generator
- Dry or wet multi-prong electrodes
- Maintain target temp for specified time period

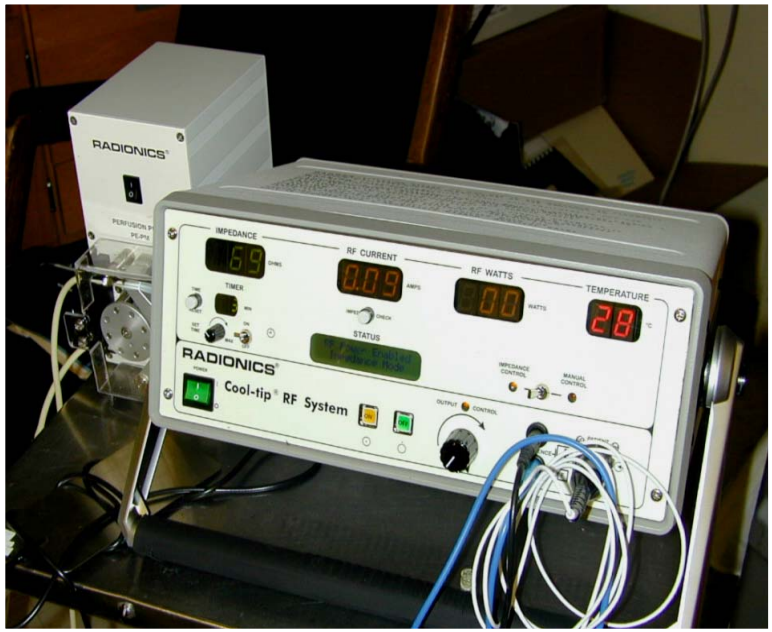


Boston Scientific LeVeen®

- 200 W generator
- Multi-prong expandable ("umbrella") electrode
- Roll-off

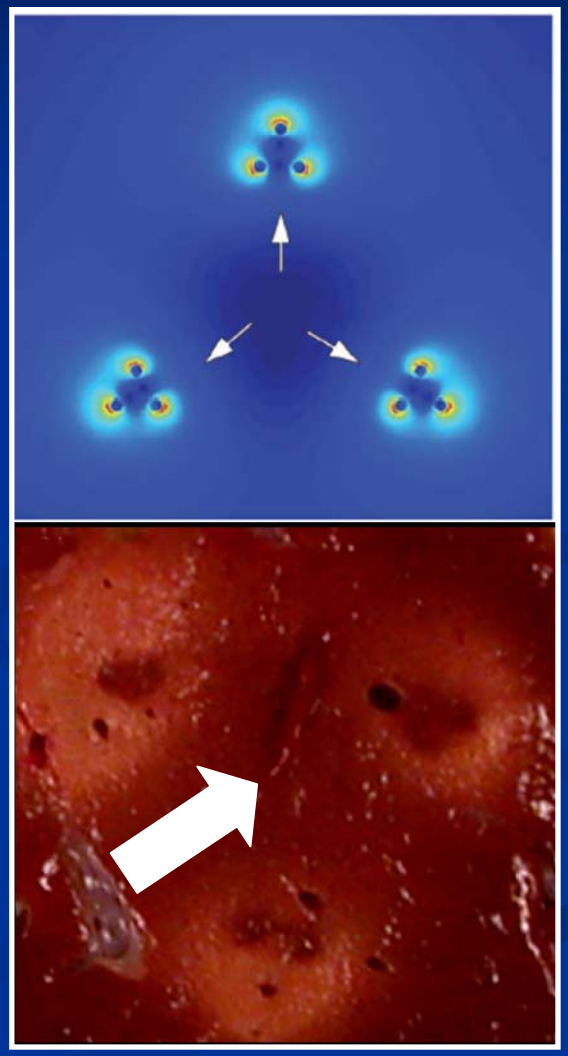
Valleylab Cool-tip™

- 200 W generator, impedance-controlled pulsing algorithm
- Cooled single or cluster electrodes
- 12 min

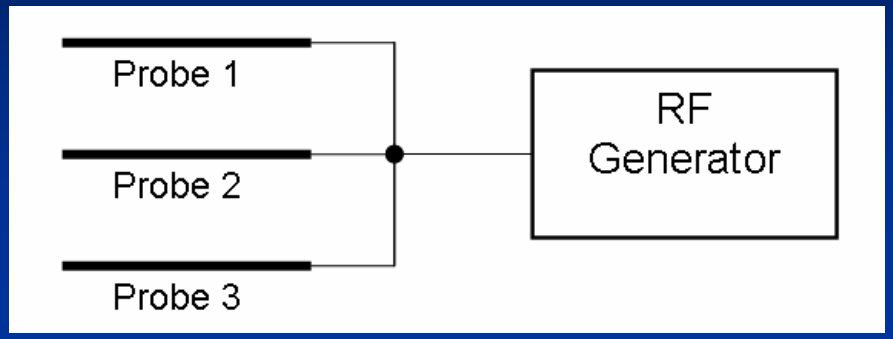


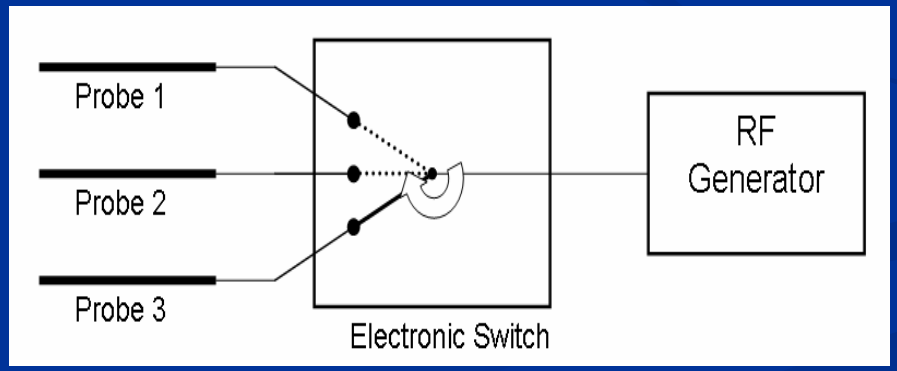
Why not just use multiple electrodes?

Faraday Cage

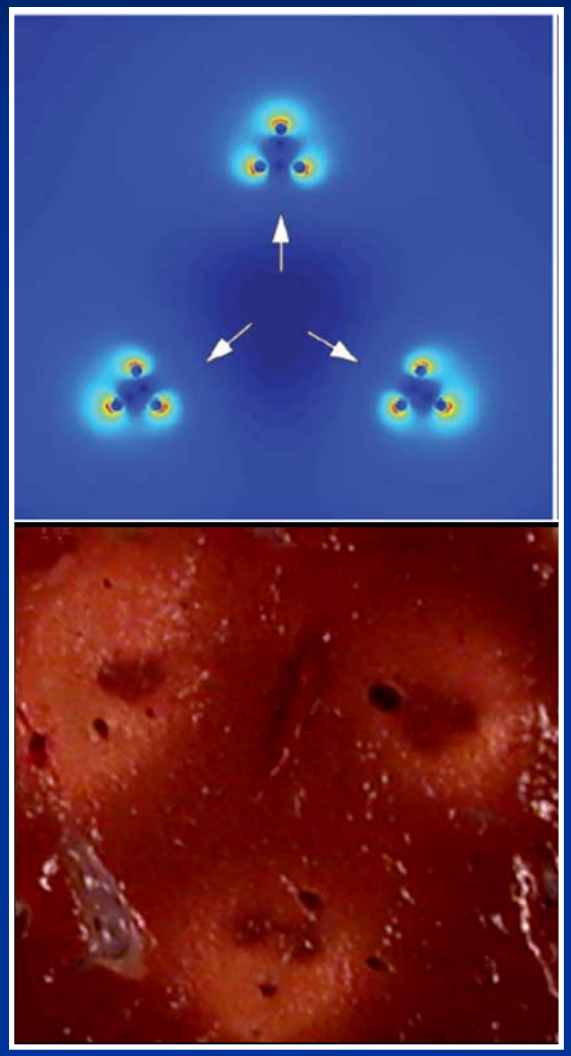


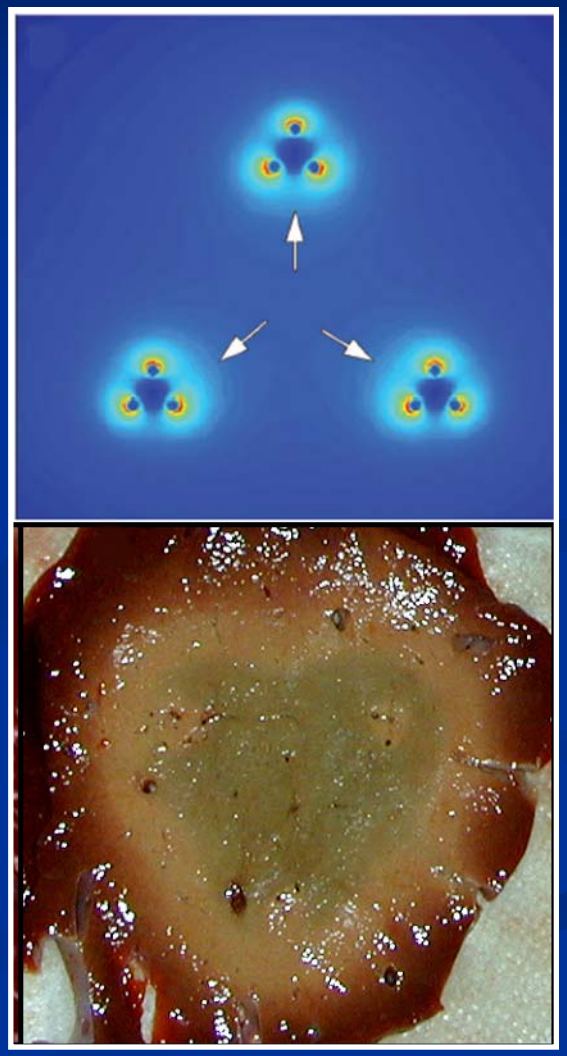
Multiple-electrode RF ablation



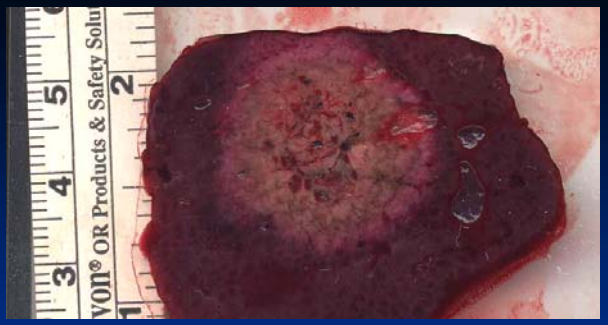


Multiple-electrode RF ablation

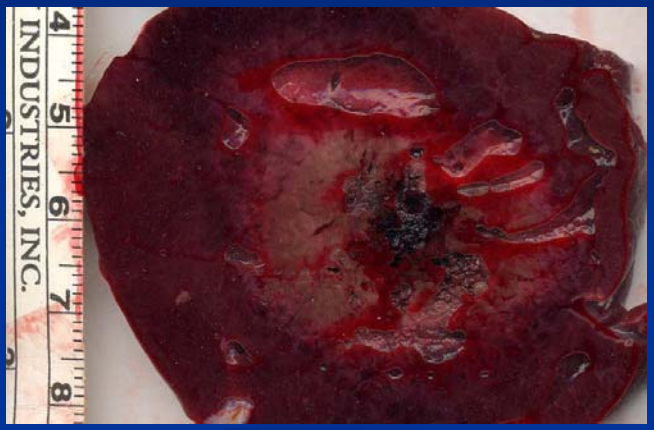




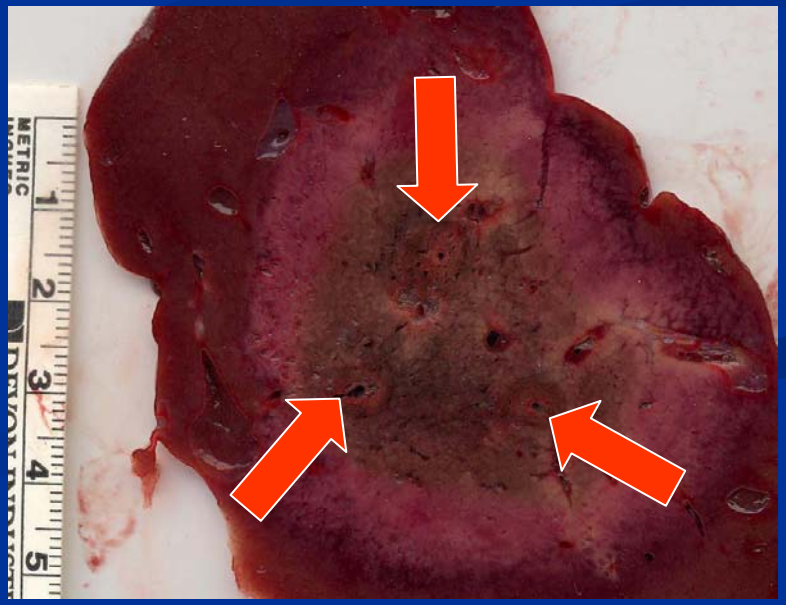
Single electrode (2.0/2.1 cm)
(min/max diameter)



Cluster electrode (2.8/3.6 cm)

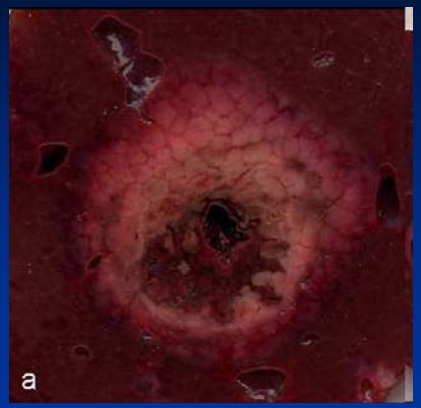


3 switched electrodes:
(4.1/6.0 cm)

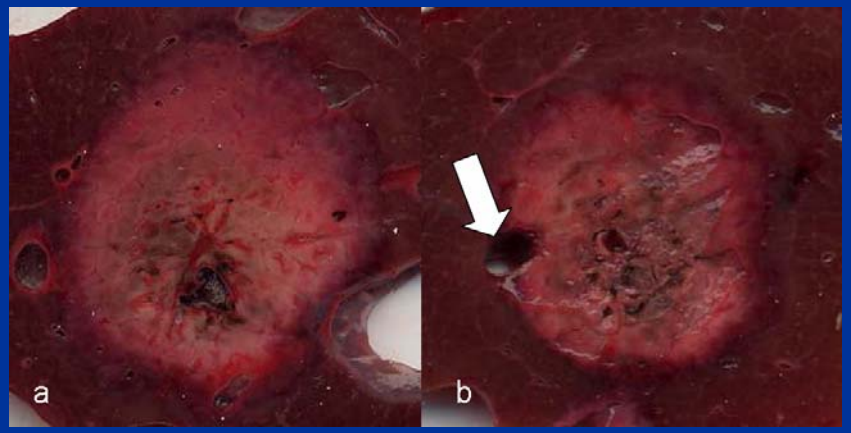


Simultaneous lesions created in separate lobes

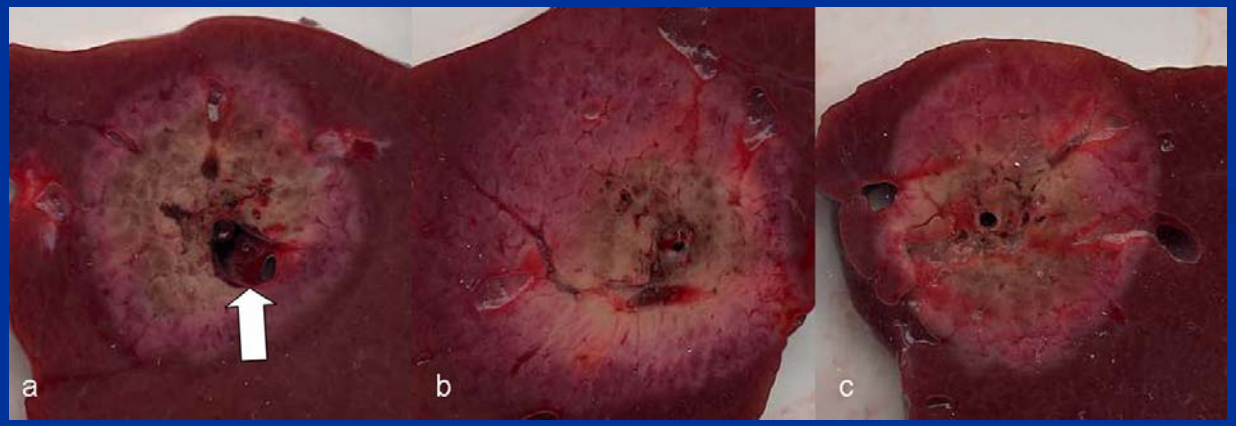
(Laeseke et al, accepted to JVIR)



Single control, 12 minutes total



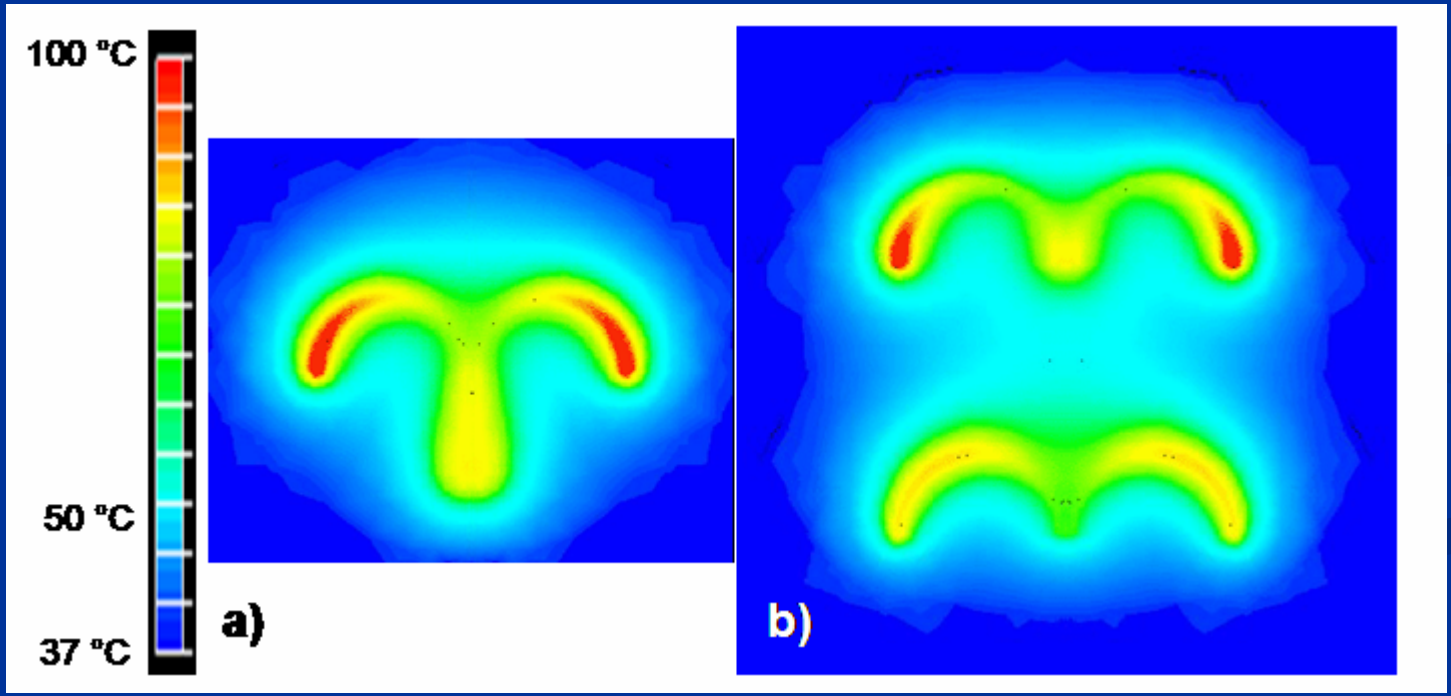
Simultaneous doubles,
13 minutes total



Simultaneous triples
13 minutes total

Bipolar

- High current density and temps at/between electrodes
- Eliminates ground pads
- Requires accurate electrode placement



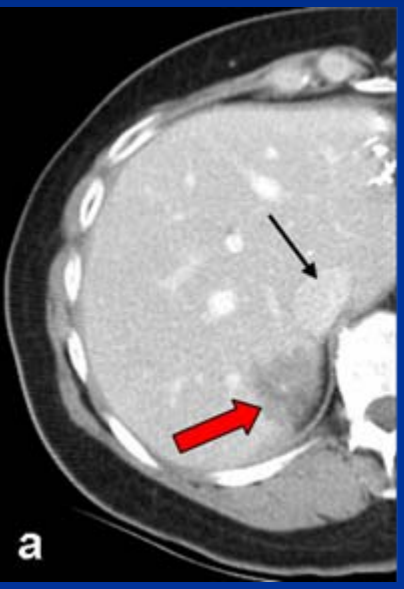
Application: liver

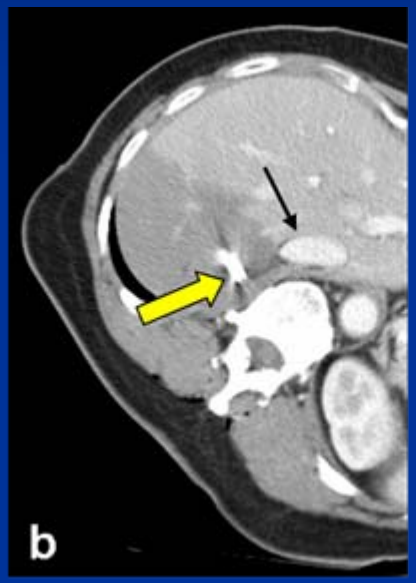
- Indications
  - HCC in cirrhotics
  - Hepatic CRC mets in non-op candidates
  - Debulking symptomatic tumors
- Contra-indications
  - Extra-hepatic mets
- Mortality rate – 0.3%
- Complications
  - Hemorrhage, abscess, neoplastic seeding, bile duct stricture, bowel perforation, pain
  - Major – 2%
  - Minor– 5%

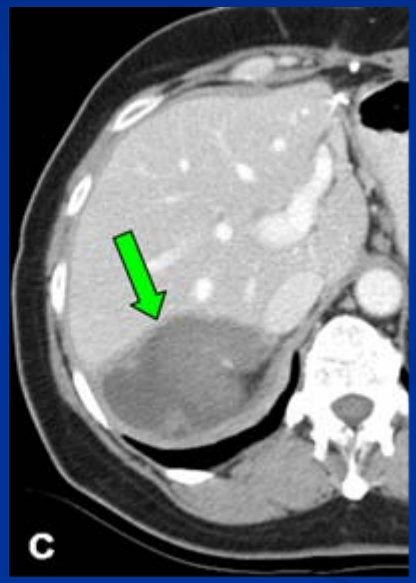
Liver results

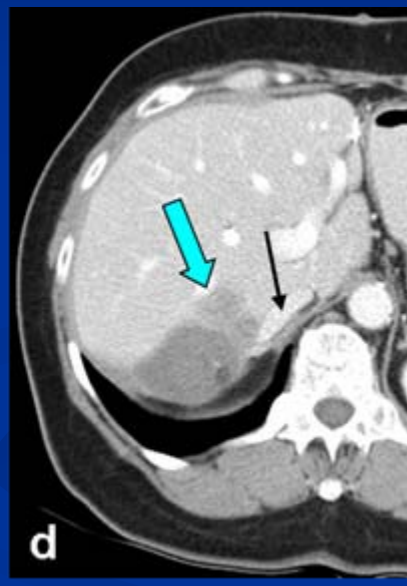
- Recurrences
  - Rate as high as 34% - higher for tumors > 4 cm
  - Local blood flow ("heat sink") is major contributing factor
- Long-term survival results
  - CRC mets
    - 96.2%, 64.2%, 45.7%, and 22.1% at 1, 2, 3, and 5 years
  - Early-stage HCC
    - 97% at 1 year, 67% at 3 years, and 41% at 5 years

Treatment failure from "heat sink"







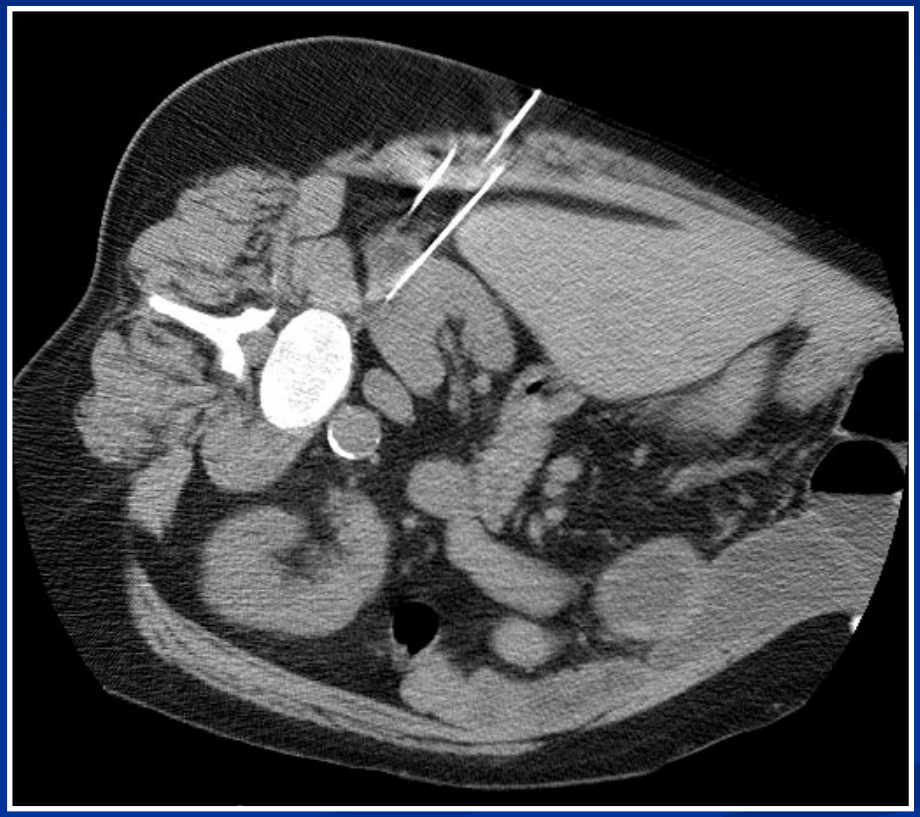


Application: lung

- Aerated Environment is mixed blessing
  - Oven effect
  - High impedance
  - No ultrasound
- Primary (e.g. NSCLC) and mets
- >500 cases
- Minor complications < 30%
  - Small pneumothorax
  - pleural effusion
  - hemorrhage
- Major complications - rare
  - massive pulmonary hemorrhage
  - several deaths

Application: kidney

- Indications
  - prior nephrectomy
  - renal insufficiency
  - co-morbidities ↑ surgical risk
  - Syndromes w/ multiple tumors (e.g., von Hippel-Lindau)
- ↓ post-procedure renal failure
- Hemorrhage minor & self limited (retroperitoneal)
- Small or exophytic tumors easier to treat



Other applications

- Bone
  - Osteoid osteomas and painful metastases
  - Symptoms often resolve immediately post-ablation
  - Cement can be added to increase stability
- Breast
- Prostate
- Adrenal
- Head and neck tumors
- Cardiac arrhythmias
- Parkinson disease

Future directions

- Electrode tracking systems
  - GPS/lasers to maintain insertion angle and depth
- Higher power generators
- Ground pad design
- Monitoring
  - Contrast-enhanced US
  - Virtual sonography (CT/US fusion)
  - US elastography
  - MR thermometry
- Adjuvant therapies

Conclusions: RF ablation

- Relatively new, but effective
- Advances in imaging and ablation technology will improve outcomes.
- Role in other organ systems expanding
- Adjuvant therapies will ↑ effectiveness and indications
- Role in reducing burden cancer places on both patients and society

Thank you

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