Radiofrequency (RF) Needle Ablation Techniques: Wet / Dry

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14 August 2002
• Thermal therapy irreversibly destroys tissue
• Heat more predictable/controllable than cold
Thermal therapy

• Temperature governs tissue destruction

• Coagulation necrosis = (energy deposited x local tissue interactions) – heat lost

• What is the optimal temperature?
Thermal therapy results are temperature dependent

- Hyperthermia - up to 45 °C - not predictable
- 46 °C - up to one hour to achieve cell death
- 50-52 °C - may be as short as 5 minutes
- 55 °C -(at least 15 seconds) - reliable cell kill
- 60-100 °C - near instantaneous cell death
What is radiofrequency (RF) ablation?
Radiofrequency (RF)

- High frequency alternating current, similar to diathermy
- Ionic agitation: heating due to friction
- No heat flows directly from the device: tissue near electrode is source of heat
Tissue death in RF depends on

1. Distance from the electrode
2. RF current intensity
3. Duration of application of RF current
1. Distance from the Electrode

- Tissue heating decreases rapidly with distance: $\propto \frac{1}{r^4}$
2. Power, impedance and current

- Power and impedance determine current

  Ohm’s law
  \[ P = I^2R \quad (I^2 = P/R) \]

  - **I**: current
  - **P**: power
  - **R**: impedance

- Adequate current = maximum lesion volume
  (ie if current insufficient, lesion too small)
2. RF and current intensity

If current too high and applied too rapidly:

1. Charring, limiting current flow and heating
   - Increased electrical resistance (impedance) of tissue
   - Lesion volume smaller than desired

2. Scattered areas of water vaporization
   - Irregular-shaped lesions
   - Sometimes larger than desired volume
IMPEDANCE RISING

Electrons

STOP
3. Duration

Goal:

- adequate heating
  - without overheating / charring
- adequate time
  - for conduction of heat to surrounding tissue
Summary:
RF lesion size and shape depend upon

1. Heat Generated
   - $1/(\text{distance})^4$
   - $(\text{current})^2$
   - duration

2. Heat Lost
   - conduction (heat diffusion)
   - convection (vascul arity)

3. Electrode Size
   - larger electrodes produce larger lesions.

4. Electrode Configuration
   - determines shape of the lesion
Stages of RF Ablation

Heating due to friction

Conductive Heating

Conduction Over Time . . .
‘Dry’ RF electrodes

• Thin (usually 14-21 gauge), needle-like electrodes inserted directly into the target
• Insulated metal shaft except for exposed tip
  • may have multi-array prongs
• connected to monopolar RF generator
• electric current flows between probe and ground pad
RF probe and generator
Animal (porcine) studies - ‘Dry’ RF

Gill et al., Urology Aug 2000
- laparoscopic and percutaneous application
- RFA results in necrosis

Crowley et al., Urology May 2001
- multi array probes
- lesions up to 5 cm
- treatment times avg. 12 minutes
Clinical results:
AUA 2001 - ‘Dry’ RF

Pavlovich et al

- 17 patients, 19 tumours (17 Clear RCC)
- RITA (Radiofrequency Interstitial Tumour Ablation)
- Tumours < 3 cm
- Rx 2 cycles for 10 minutes
- Results: Majority non-enhancing or smaller by 6 months (no follow-up biopsy)

Conclusion: longer follow-up needed
Clinical results:
AUA 2001 - ‘Dry’ RF
Rendon et al; Sweet et al

- 6 patients
- 4 had intra-operative RFA with immediate nephrectomy; 2 had RFA 7 days pre-op.
- 5/6: ‘viable’ tumour

Conclusion:
- Further research needed
Clinical results: AUA 2002
Percutaneous CT guided ‘Dry’ RFA

Ogan et al
• 6 patients, 5 GA
• 4 patients had no recurrence at 3 month CT

Su et al, J Urol 2002
• 17 patients, 22 procedures, all LA
• poor surgical risk candidates
• 21 procedures: no evidence of enhancement at mean radiographic follow up of 3.2 months (range 3-9 months)
Clinical results: AUA 2002
Percutaneous CT guided ‘Dry’ RFA

Conclusion:

- Percutaneous CT-guided RFA viable nonsurgical treatment option for the management of small posterior or lateral renal tumors
Clinical results: AUA 2002
Percutaneous CT guided ‘Dry’ RFA

Pautler et al

- 19 patients 22 procedures: 1 year follow up
- Median lesion diameter decreased from pretreatment size of 2.5 cm to 1.8 cm
- 5 (23%) had persistently enhancing tumours (DHU >20) on CT.

Conclusion:
- RFA successful in majority
- Surgery or retreatment indicated for failures
Clinical results:
AUA 2002 - ‘Dry’ RF

Michaels et al

- 13 patients, 20 tumours
- Open RFA prior to partial nephrectomy
- 90m-110 deg for 6 – 16 minutes
- US monitoring
- HPE: all specimens showed evidence of incompletely eradicated tumour

Conclusion:
- RFA should be considered investigational
Modification of ‘Dry’ RF: ‘Cool-tip™’

• Circulation of chilled water into hollow channel of needle prevents it from overheating
• Local tissue impedance does not rise as fast
• more energy can be put in
• bigger lesions result
Clinical results:- ‘cooled’ RF

McGovern et al; J Urol 161:599; 1998
- 1st case report - 3 cm tumour; no follow-up reported

Gervais et al; Radiology 217(3):665, 2000
- 8 patients, 9 tumours, 24 percutaneous Rx
- 3 were < 3 cm = single probe (Group A)
- 6 were > 3 cm = multiple probes (Group B)
- limited follow-up
- free of “enhancement”: ‘success’ 4/6 (Group B)
Clinical results: AUA 2001
‘cooled’ RF

McGovern et al

- expanded series to 17 patients (19 tumours)
- IV sedation, outpatient procedures
- CT/MRI: complete response 15/18 tumors
- 3 ‘partial’ responses - in large (>4 cm) tumours or those with central location

Conclusion: viable nonsurgical treatment option for the management of small tumours
RFA: How do we bypass its limitations?

• keep impedance steady
• control temperature
• increase energy deposition to treat larger area
• shorten treatment time
Infusion of electrolyte coupler

- spreads current density away from tissue
- couples electrode to tissue
- prevents impedance rise
- results in LARGE lesion development
- can be viewed radiographically
- temperature range better controlled
Liquid electrode conductivity

Cardiac tissue → Blood → Normal saline (0.9%) → Iodinated contrast → Saturated saline → Conductivity
Saline shifts the curve to the right
Impedance Measurements of "Wet" vs. "Dry" Ablation in Canine Kidney

- 10 Watt "Dry" Ablation
- 50 Watts "Wet" Ablation
Animal Studies: ‘Wet’ RF

  in vivo model (canine and porcine)
- Polascik et al., Urol 53:465, 1999
  acute rabbit model with VX-2 tumor
- Patel et al., J Endourol 14:155, 2000
  acute & chronic rabbit model - 54 days
Edge of Ablation (Rabbit) - 3 days
Patel et al., 2000

- 1: normal
- 2: basophilia and necrosis
- 3: haemorrhagic necrosis
Ablation size depends on tissue characteristics

Canine liver

Average Lesion Size, 50W, 75 second

<table>
<thead>
<tr>
<th>Organ</th>
<th>Volume (cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liver</td>
<td>5</td>
</tr>
<tr>
<td>Spleen</td>
<td>3</td>
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<tr>
<td>Kidney</td>
<td>2</td>
</tr>
<tr>
<td>Prostate</td>
<td>1</td>
</tr>
<tr>
<td>Heart</td>
<td>4</td>
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Summary: ‘Wet’ RF

- more controlled lesions
- reproducible
- lesions can be visualized fluoroscopically
- impedance NOT limiting factor
- excellent animal data with no long term problems (e.g. fistula, loss of function, visceral injury, etc)
- human trials underway
Thermal probes being inserted into tumour adjacent to template

18 guage ‘Wet’ RF needle placement
CONTROL LESION
NORMAL KIDNEY

TUMOUR ABLATION

Approximately 2.5 cm

Both ablations done for 180 seconds @ 120W
RCC- Clear cell
Fuhrman Grade 3

Untreated control

Treated: ‘pseudosarcomatoid’ appearance
Results: ‘Wet’ RF; AUA 2001

Leveillee et al

• 15 patients, (12 RCC, 2 oncocytoma, 1 AML)
• 14.6% saline at 2 cc/min
• RF applied 60-180 seconds
• Lesions 1.5-3.0 cm
• Gross appearance of control – obvious change
• Histology altered
Summary ‘Wet’ RF: Human Kidney

- Renal cell cancers are sensitive to thermal injury
- Homogeneous tissues (NO tumour) demonstrate more uniform response to thermal injury than heterogeneous tissue (tumour)
- ‘Normal’ tissues demonstrate grossly visible lesions with distinct measurable borders
- Large lesions can be created in human kidney via single puncture and short time (less than 3 minutes)
Summary ‘Wet’ RF: Human Kidney

- Pre-ablation biopsies necessary
- Pathologic interpretation can be altered by heat treatments: misinterpretation can occur if untreated tumour not available for comparison
RFA: summary and take home messages

- Both ‘dry’ and ‘wet’ RF destroys cells
- Impedance / rapid temperature increases limit applications of thermal therapies
- Preliminary studies look promising
- However, much work needs to be done to determine optimal treatment times and temperatures
- Optimal treatments likely to be tissue / tumour specific
Rendon et al; J Urol 167:1587-92; 2002
‘Uncertainty of RFA: findings at immediate and delayed nephrectomy’

- RFA is potentially curative
- Complete tumour cell death difficult to achieve with current treatment protocols
- More research necessary to ensure reproducibility
Acknowledgements

- Ray Leveillee, MD
- University of Miami
- Michael Hoey, MD
- University of Minnesota

Thank you