MR Guided Electrophysiology Ablations

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Why Atrial EP Ablation?

- Atrial fibrillation common, with 500,000 admits/yr, 80,000 deaths/yr in US
- Ablation 95% effective if done open heart
- Only 70% effective with catheter/x-ray
- Anatomically driven procedure
- Large patient benefit
Atrial Arrhythmia Ablation

(a)

- Catheter
- Atrio-Ventricular (AV) Node
- Pulmonary Veins

- Left upper PV
- Left lower PV
- PV strands
- RF lesion
- Circular mapping catheter
- Ablation catheter

Braunwald's Heart Disease, Ch 30
Atrial EP Ablations: Challenges

- Visualization of devices and anatomy
- Control
- Device Safety
- Lesion visualization
X-Ray Visualization

Flat Panel X-Ray on Signa SP

Braunwald’s Heart Disease, Ch 30

Fahrig, Pelc Stanford
MR Visualization

(a) 2D Real-Time

(b) 3D Breath Hold
Real-Time Interaction

1 mm resolution
20 cm FOV
75 ms total time
Variable-density spiral

3D space mouse
Real-time control
Remote Manipulation

- Vascular procedures “one dimensional”
- Intracardiac procedures are “three dimensional,” much harder
Remote Manipulation

- Anchor device in atrial septum
- Device bends to access entire atrium
Remote Manipulation

- Shaped metal nitinol bending elements
- “Elephant trunk”

Fritz Prince, Gunter Niemeyer, ME
Device Tracking

- Control requires knowing device location
- Passive visualization
- Active tracking
Device Visualization & Tracking

Passive
- Nickel Marker
- Through-plane dephasing gradient

Active Receiver
- Sharp near-wire signal

Transmit/Receive
- Op-amp-based RF transmitter
Active Catheter

Catheter Coil Image

Overlay

Aorta
Stent

Catheter Tracking and Imaging

Ch 1
Ch 2
32 Coil Tracking Catheter

non-approved investigational device that is currently not for sale

8 French catheter with a working lumen

Charles Dumoulin, GE CR&D
32 channel tracking

Charles Dumoulin, GE CR&D
Safety

• EP procedures require many devices (wires)
• RF transmitter can put out 20 kW
• If any of this power couples to devices, accidental burns!
• Can this be safe?
Device Heating

High Power, Body Coil

High Power, Surface Coil
Deep Brain Stimulators

Henderson, Neurosurgery, 57:1063–1066, 2005
RF Current Detection

- RF currents produce image artifacts
- Detectable well before heating
- Patients could be prescanned for problematic devices

Experiment Simulation
Birdcage Body Coil

Catheter Heating Experiment

Body Coil Test Setup

w/ Faraday Shield
Parallel Transmit

- Control over RF field
- Reduced interaction with devices
- “Device Safe” MRI

Coil Sensitivities
Parallel Transmit MR

- **RF Modules**
  - Direct RF sampling/synthesis
  - Tx and Rx at 0 – 1.5T (64MHz)
  - Up to 3.2MHz RF BW
- **Digital Gradient Module(s)**
  - High-speed differential serial
  - 950 k s/sec per ch max
  - 16/32 bit transfers
- **Controller Module**
  - Data management
  - Local Control & Sync
  - USB High-Speed to Host
Distributed Transmit Systems

Replace Monolithic RF Amp with Low Cost RF Modules
Modular RF Amplifier

- Single RF Module ~$1000 per channel.
- Medusa controls & monitors linearity & power
- Avoid expensive monolithic feedforward linearized body RF amplifiers.
Lesion Visualization

- MR views anatomy well
- Need to know where lesions are immediately to guide procedure
- Many options
- Many problems
Delayed Enhancement

• Patient with atrial EP ablations
• Contrast (Gd) enhancement 30 days later
• Useful for followup, not for interactive guidance

Lesion Visualization: $T_1$

- $T_1$ longer during heating
- Reduced signal
- Returns to normal on cooling
RF Current Density Imaging

- MRI can measure the distribution of applied RF current
- Ablation patterns can be predicted
- Electrode can be repositioned as local impedance rises

Leveen Electrode
Cryoablation

- 10% of all cardiac ablations
- Safer than RF
- Easily visualized
- Returns to normal on heating
• Frequency shifts with temperature (0.01 ppm/°C)
• Challenging, but possible, in the heart
Lesion Visualization

- Methods for after the procedure (DCE) and during each ablation (T1, RF current, cryo, temperature)
- Want acute image of all ablations
- Many possibilities (diffusion, conductivity, perfusion) but no clear answers
Conclusions

- MR guided EP procedures offer
  - Improved visualization and control
  - Potential for acute lesion visualization
- Many remaining issues
  - Guidance/control, safety, lesion visualization
  - Devices
  - System integration
Cardiology

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