Cardiac Arrhythmia Mapping
Challenges and Opportunities

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OUTLINE

• Historical perspective

• Current mapping techniques
  – Optical mapping
  – Electrical mapping (Purkinje example)

• Future directions and opportunities
Noninvasive Electrical Mapping

• Surface ECG was developed by William Einthoven in the early 1900s
• Lead I, II, III
Noninvasive Electrical Mapping

If 3 leads were good, then 12 leads must be better…

And dozens to hundreds of body surface potentials even more useful…
Epicardial Mapping

- Initially performed with a limited number of channels on the epicardial surface.
- Advances in computing power and storage have allowed for thousands of channels of data to be collected simultaneously.
Electrical Epicardial Mapping

- Direct contact with plaques and socks
Epicardial & transmural arrays

Epicardial array

Plunge electrodes
Electrical Endocardial Mapping

- Endocardial baskets
- Open heart models
- Plunge needles
- Endocardial catheter mapping
Clinical Endocardial Mapping

• Endovascular catheter mapping reduces invasiveness of mapping techniques

• Many clinically available mapping systems with mapping catheters
  – Carto (Biosense-Webster)
  – EnSite NavX (St. Jude Medical)
  – Others
Invasive Electrical Mapping
Historical Optical Mapping

• Carl Wiggers performed high speed cinematography of VF in the 1930s and 40s
• He visualized motion and defined 4 distinct periods of activity during VF
Current Optical Mapping

• Voltage sensitive dye binds to cell membrane and fluoresces at a different wavelength when the transmembrane potential ($V_m$) changes

• Other dyes may be used to display intracellular calcium ($Ca_{i}^{++}$) levels
Optical Mapping

• Advantages
  – Simultaneous $V_m$ and $Ca_{i^{++}}$ possible
  – Large numbers of pixels and high resolution

• Disadvantages
  – Motion artifact problematic
  – Direct line of site required
Panoramic Optical Mapping of Vm
Optrode Recordings

- Fiberoptic bundles arranged in an optical plunge needle configuration
Simultaneous $V_m$ and $Ca_{i^{++}}$ measurements
Example of Multiple Mapping Techniques in Research

Role of Purkinje Fibers in Long Duration Ventricular Fibrillation
Purkinje Fibers in Sinus Rhythm
Traditional Mechanisms of VF Maintenance

- Wandering Wavelets
- Mother Rotor Reentry
Development of Activation Rate

• Several groups have observed an activation rate gradient in LDVF
• Present in dogs but not pigs
Purkinje Fiber Distribution

In humans, dogs, primates, and rabbits:

In pigs, sheep, cows, ungulates, whales:

Epicardium

Endocardium
Purkinje Potential During VF
V to PF Activation
PF to V Pattern
Focal PF Activation Pattern
Lugol’s Ablation

Caused VF to terminate after 4.9 min in treated hearts vs 9.2 min in control hearts
Eliminated the activation rate gradient
3-D Plunge Needle Mapping
Intact Endocardial Mapping
At VF Onset
5 Minutes of VF
Purkinje in Defibrillation

- Sinus
- SDVF Success
- LDVF Success
- SDVF Failure
- LDVF Failure

Unipolar:

Bipolar:

100 ms

10 ms
Purkinje System in LDVF:

1. Is a source of rapid activation in VF lasting more than 2-3 minutes
2. Is the source of first postshock activation following long but not short duration VF
What next?

- Optical mapping of the Purkinje system and endocardium during LDVF
- Mapping with pharmacological interventions
- Pacing of Purkinje system
- Mapping of human hearts
- Improved modeling
Future of Cardiac Mapping

- Electrophysiological mapping combined with anatomical (CT, MRI) or functional imaging (DTI, SPECT or PET)
- Electrical and optical mapping of arrhythmogenic models (AF, HF, ischemia/reperfusion, pathologic ion channel conditions, genetic conditions, etc.)