

Cardiac Arrhythmia Mapping

Challenges and Opportunities

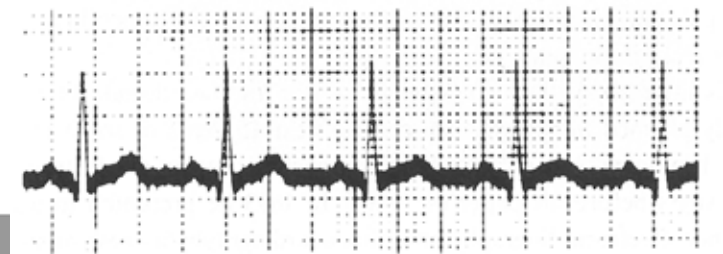
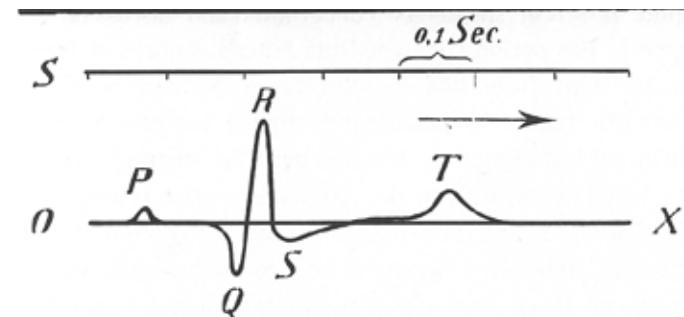
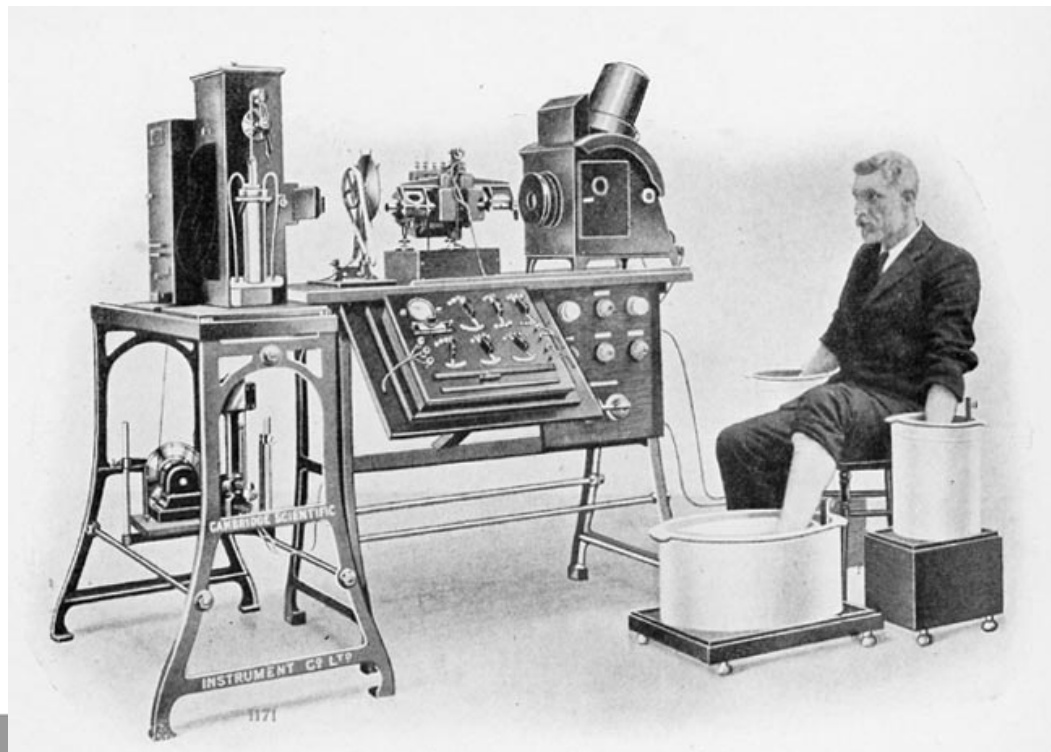
Derek J. Dossall, Ph.D.
22 October, 2010

OUTLINE

- Historical perspective
- Current mapping techniques
 - Optical mapping
 - Electrical mapping (Purkinje example)
- Future directions and opportunities

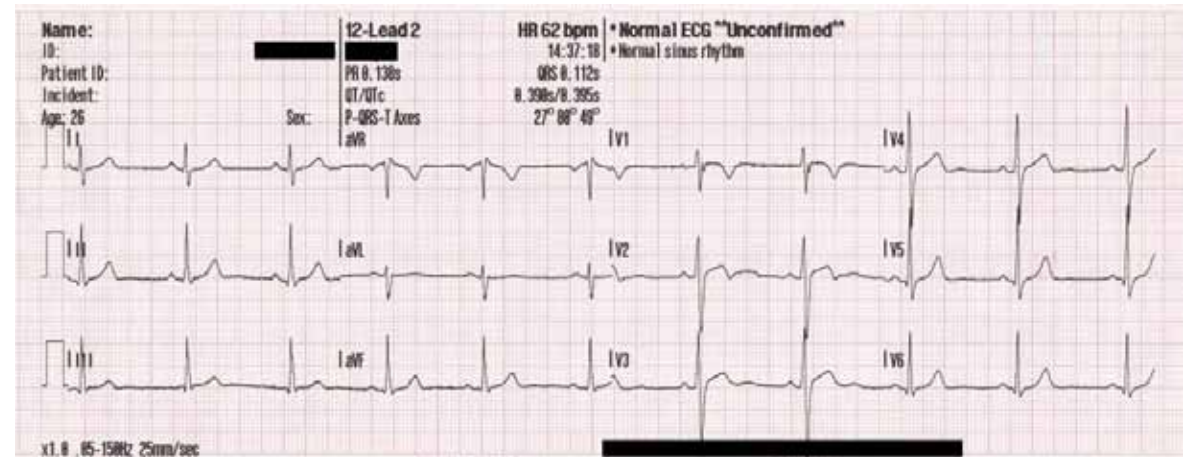
Noninvasive Electrical Mapping

- Surface ECG was developed by William Einthoven in the early 1900s
- Lead I, II, III

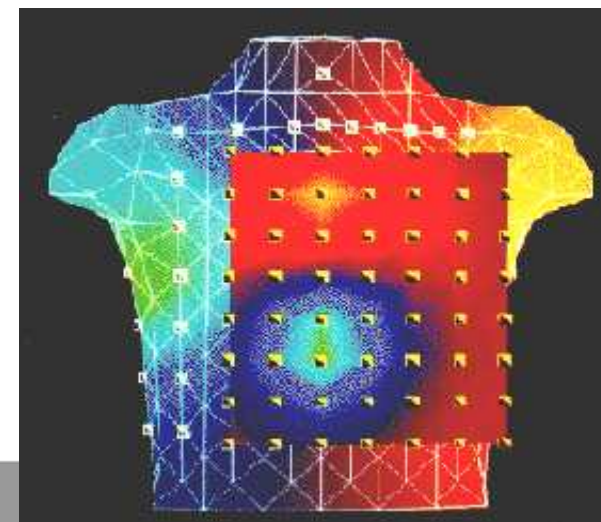


Noninvasive Electrical Mapping

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



And dozens to hundreds of body
surface potentials even more useful...

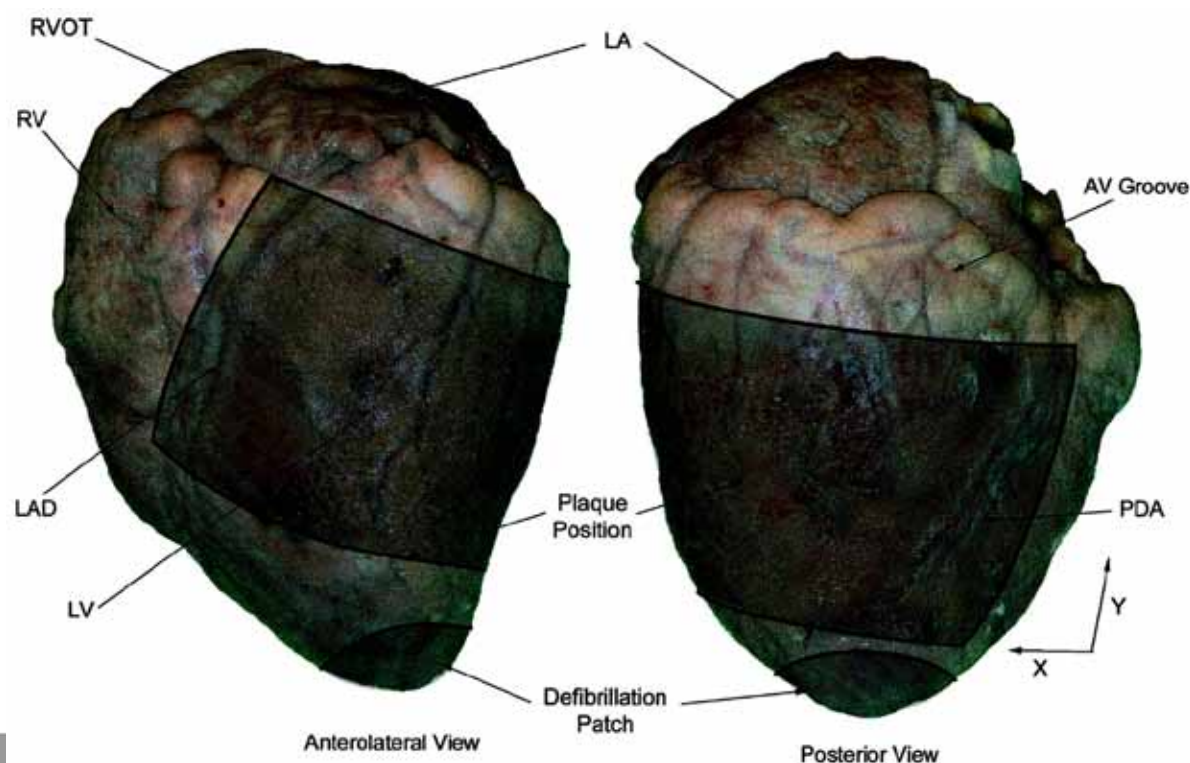


Epicardial Mapping

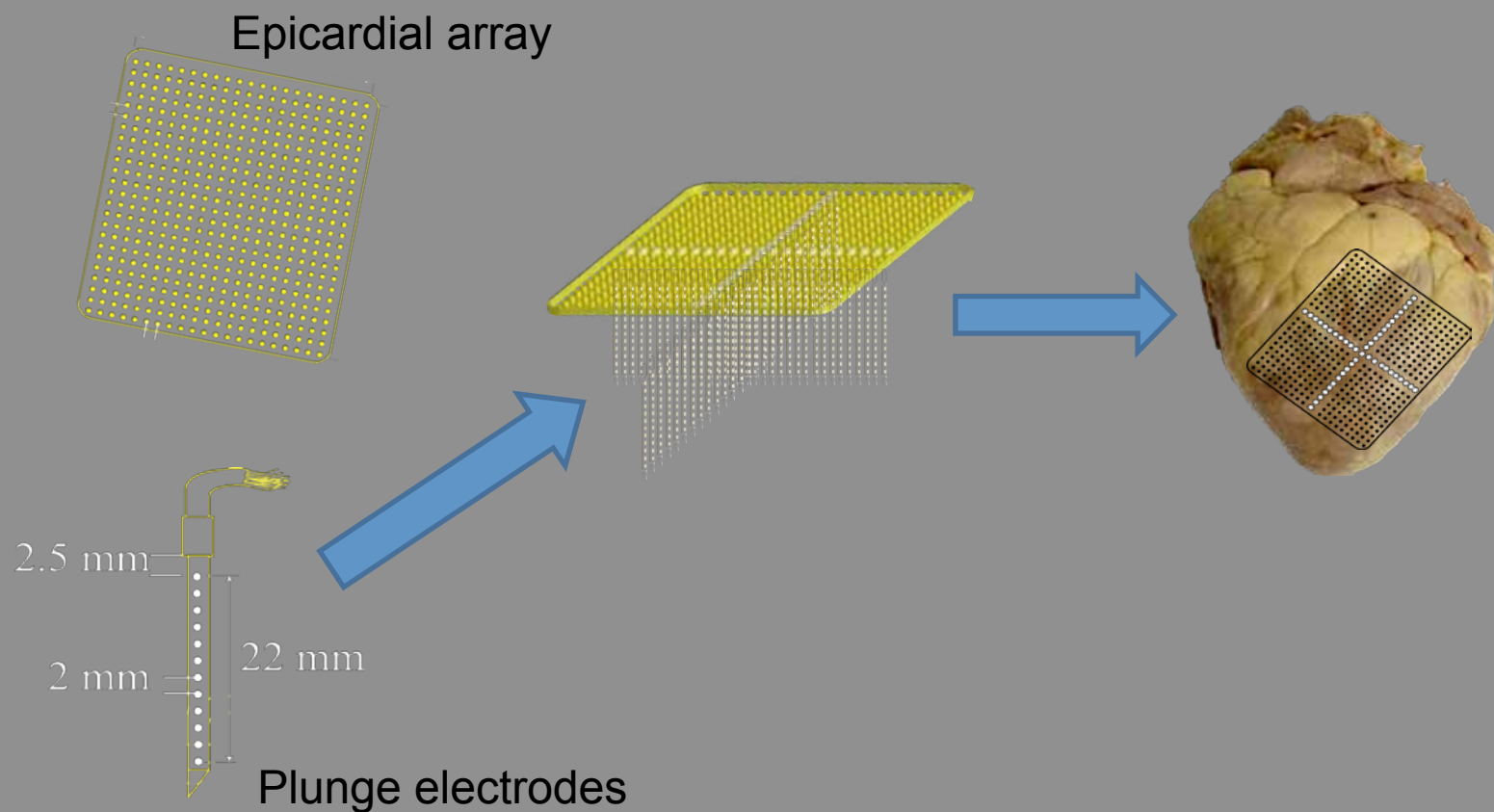
- Initially performed with a limited number of channels on the epicardial surface.
- Advances in computing power and storage have allowed for thousands of channels of data to be collected simultaneously.

Electrical Epicardial Mapping

- Direct contact with plaques and socks



Epicardial & transmural arrays

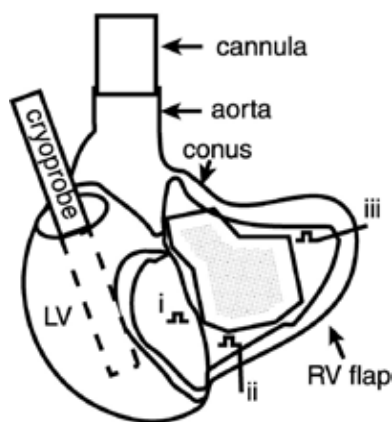


Electrical Endocardial Mapping

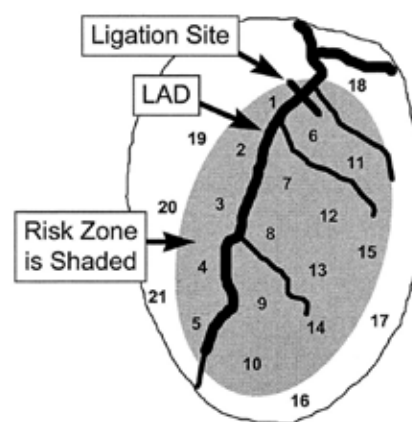
Endocardial baskets



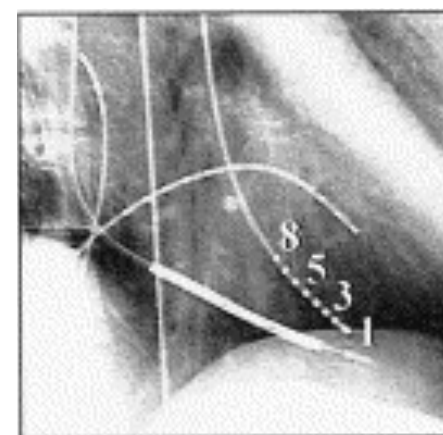
Open heart models



Plunge needles



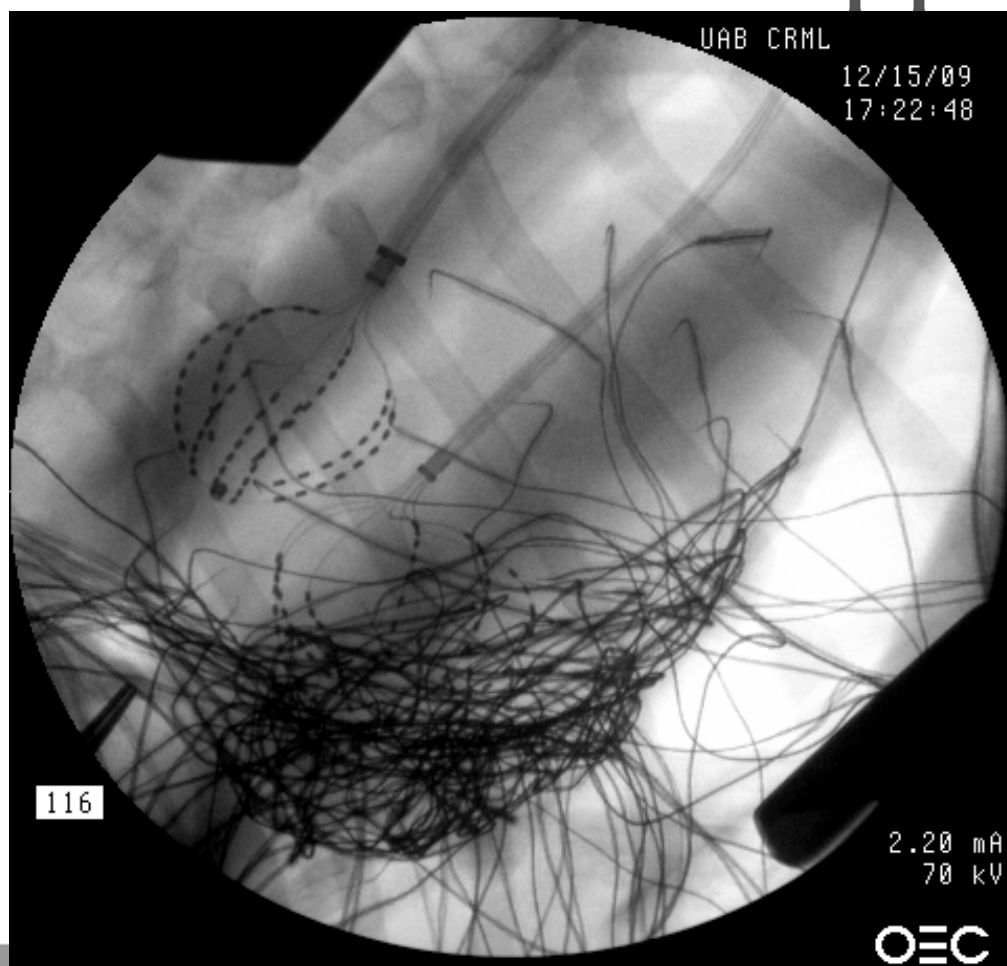
Endocardial catheter mapping



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

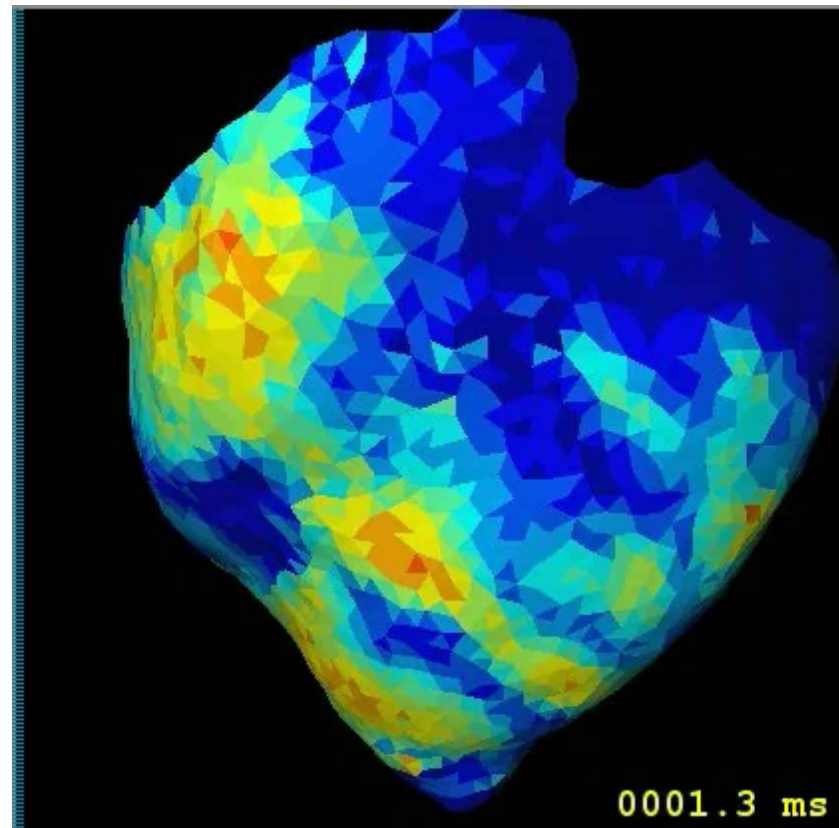
Current Optical Mapping

- 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

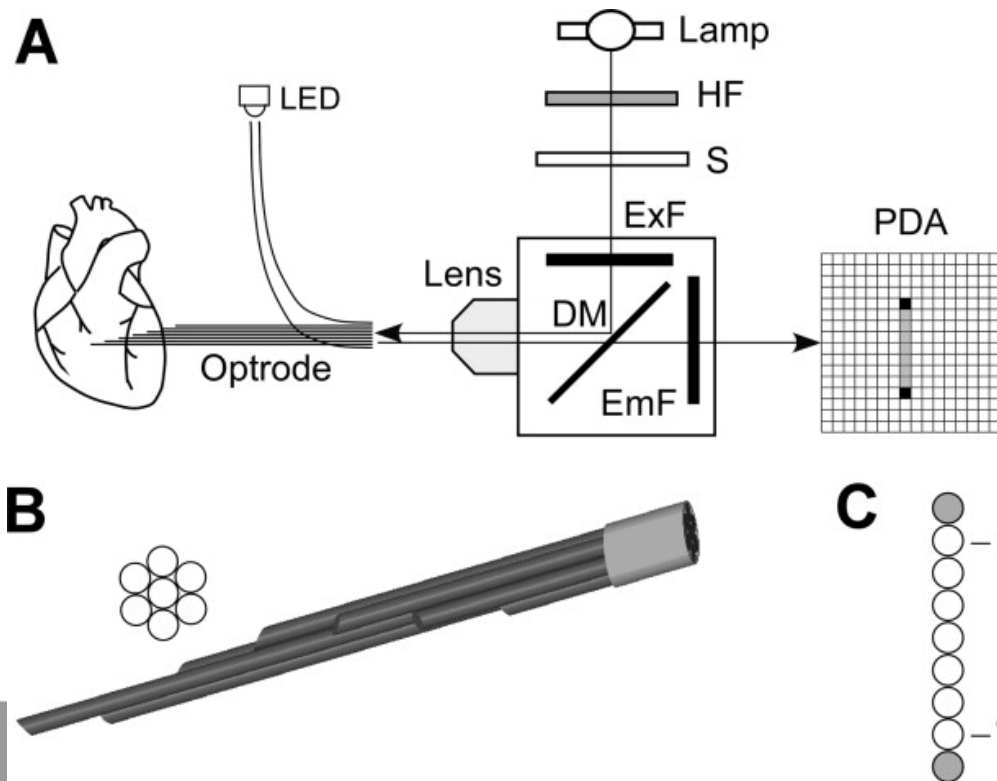
- Advantages
 - Simultaneous V_m and Ca_i^{++} possible
 - Large numbers of pixels and high resolution
- Disadvantages
 - Motion artifact problematic
 - Direct line of site required

Panoramic Optical Mapping of Vm

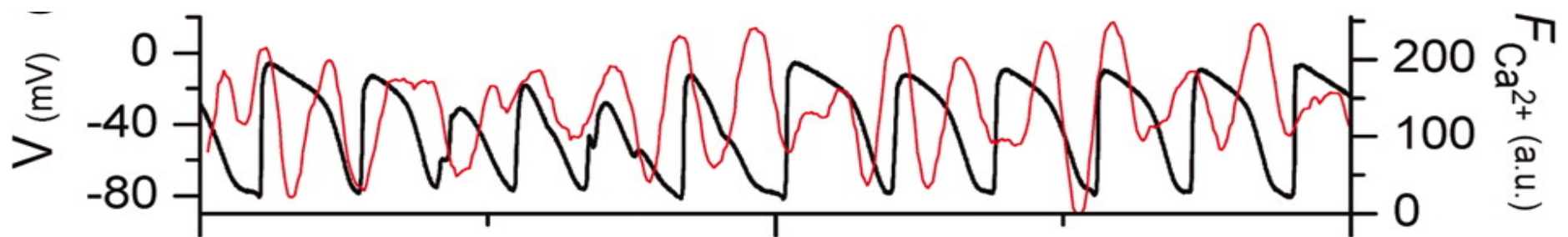


Optrode Recordings

- Fiberoptic bundles arranged in an optical plunge needle configuration



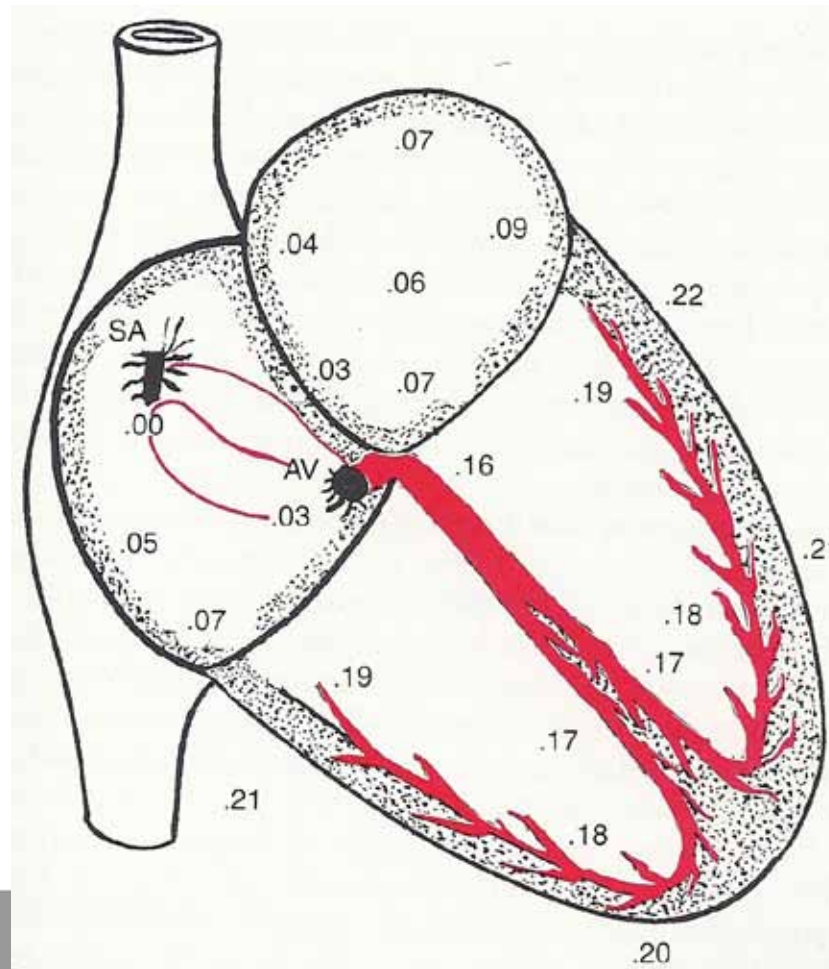
Simultaneous V_m and Ca_i^{++} measurements



Example of Multiple Mapping Techniques in Research

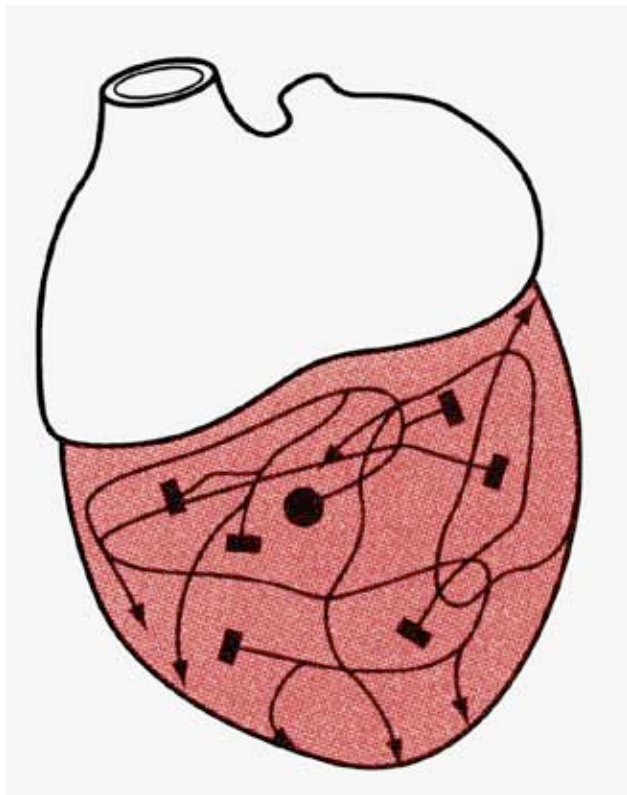
Role of Purkinje Fibers in
Long Duration Ventricular Fibrillation

Purkinje Fibers in Sinus Rhythm

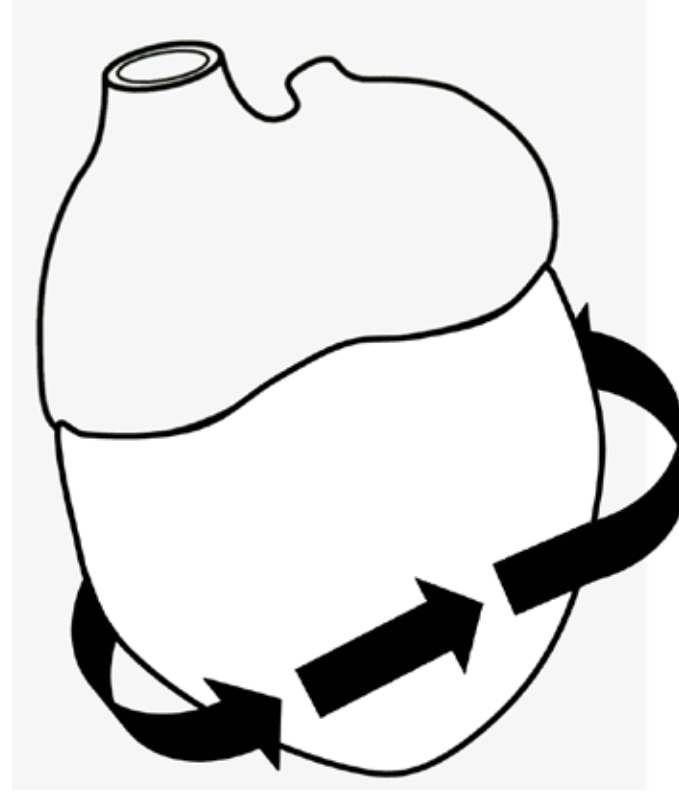


Traditional Mechanisms of VF Maintenance

Wandering Wavelets



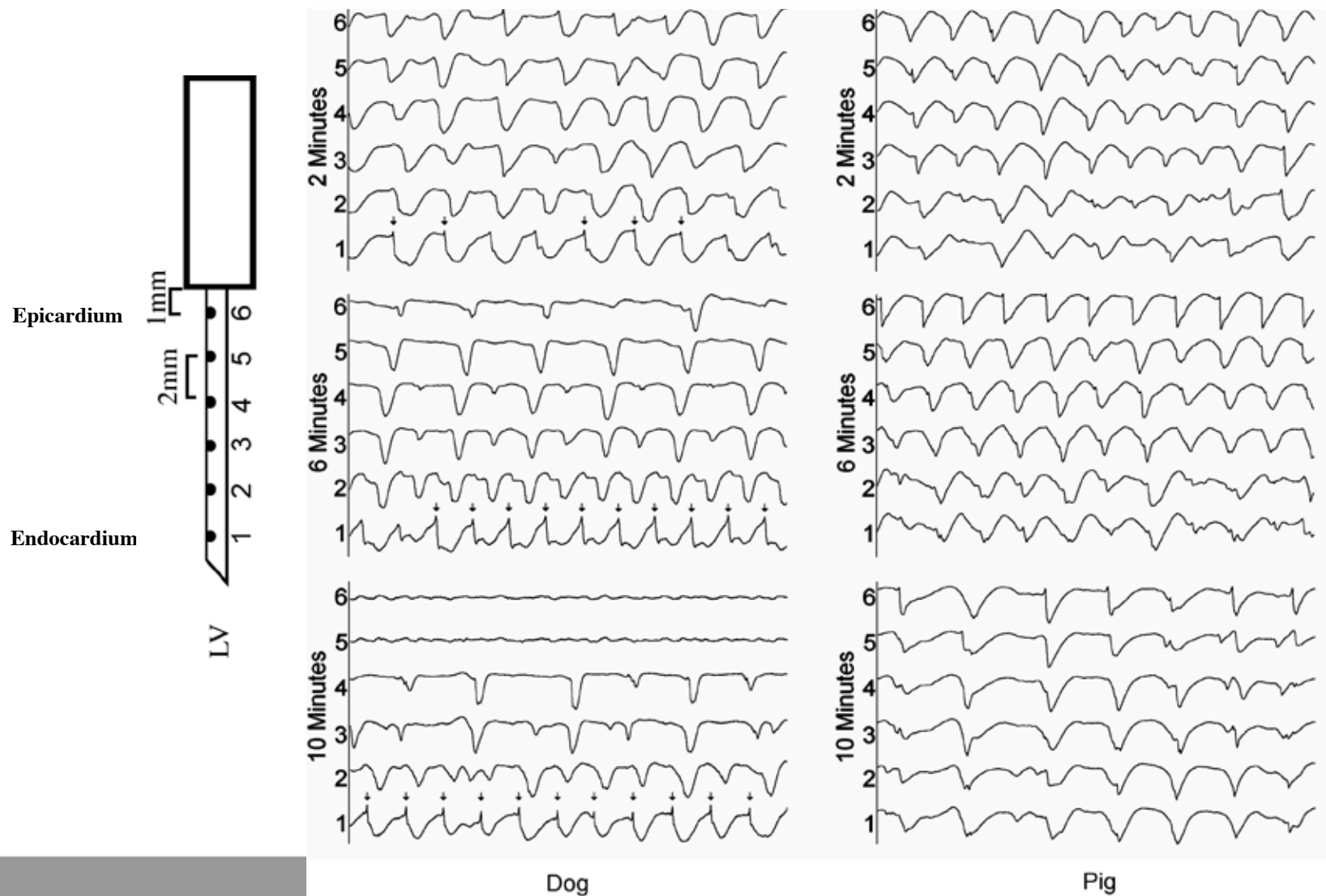
Mother Rotor Reentry



Development of Activation Rate

- Several groups have observed an activation rate gradient in LDVF
- Present in dogs but not pigs

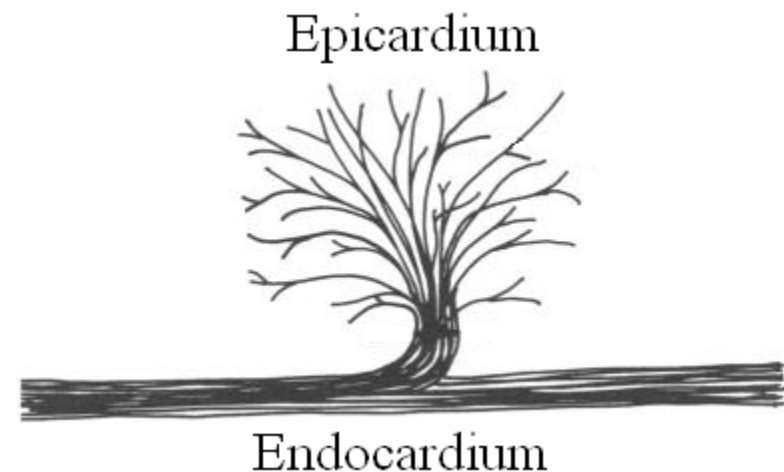
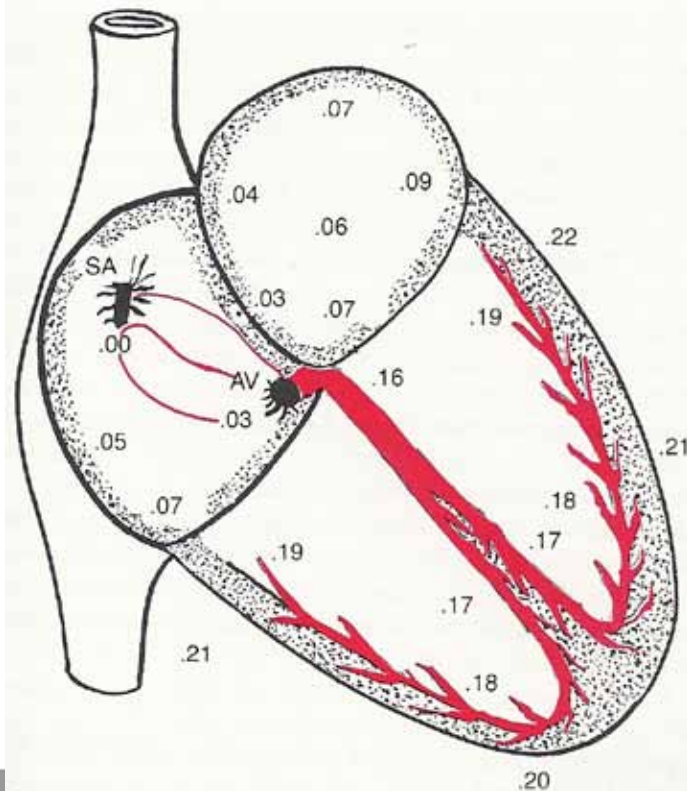
Needle Electrode - Endocardial (1) to Epicardial (6)

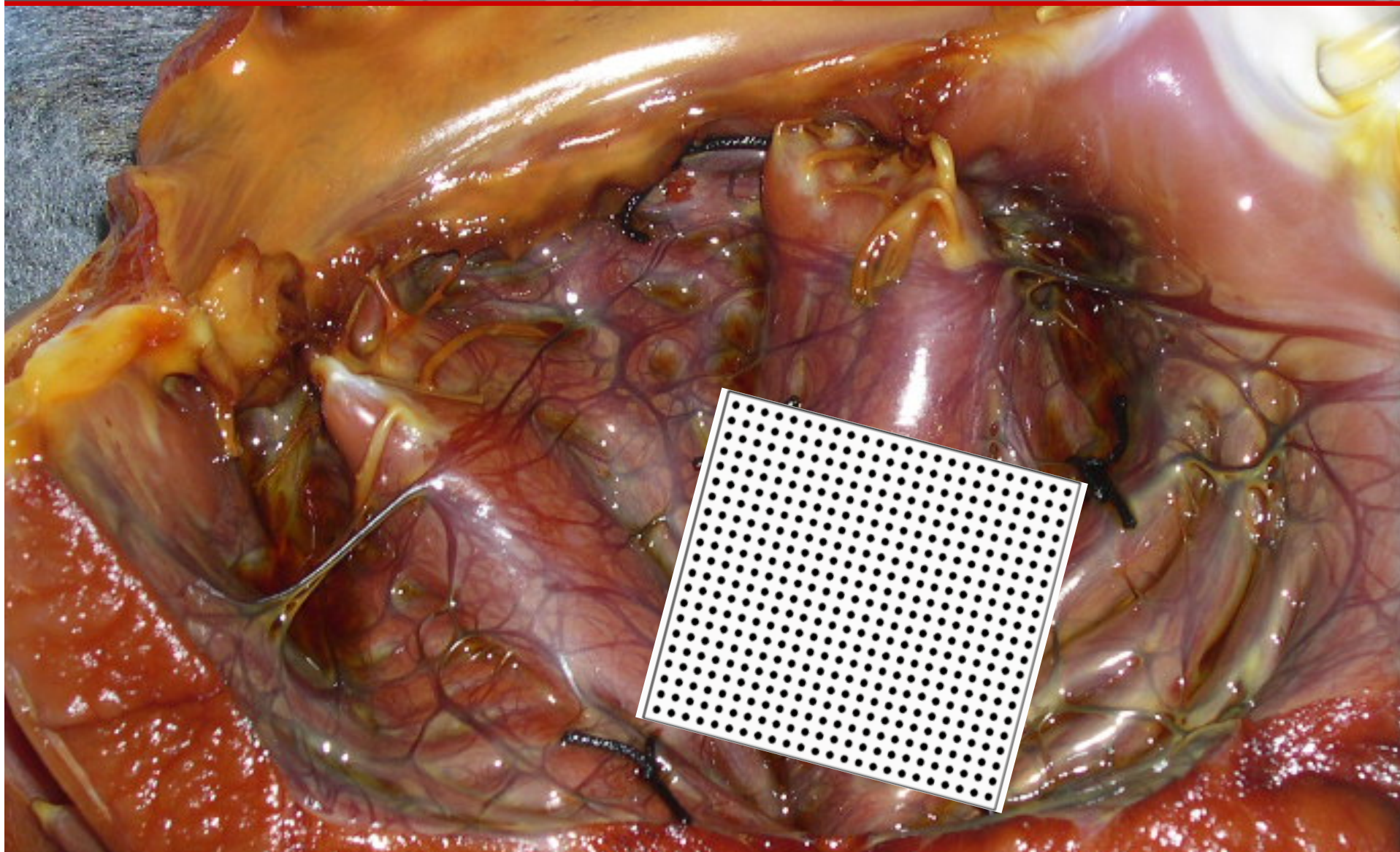


Purkinje Fiber Distribution

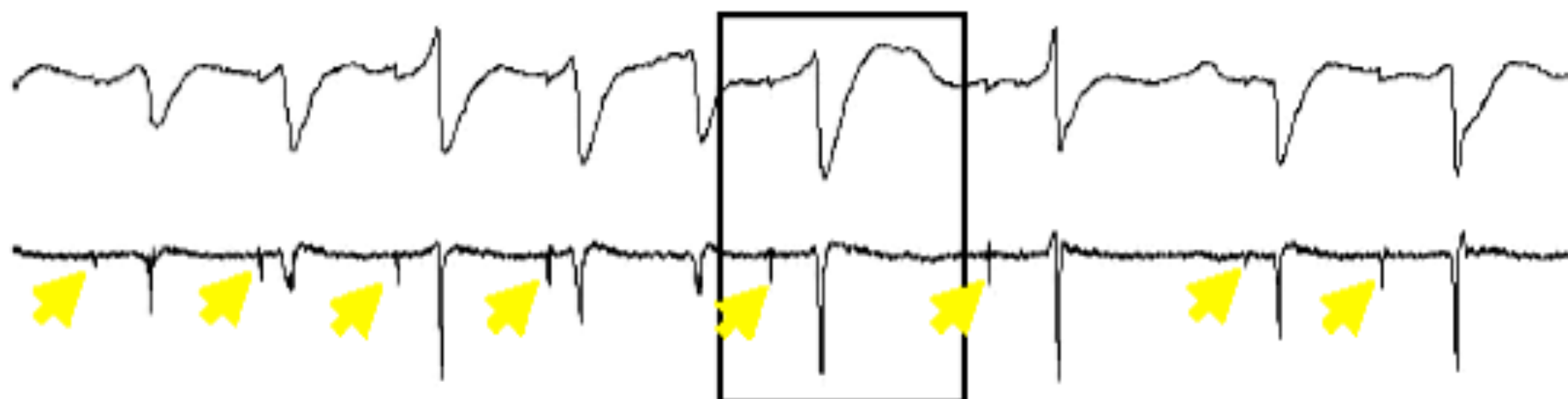
In humans, dogs, primates, and rabbits:

In pigs, sheep, cows, ungulates, whales:

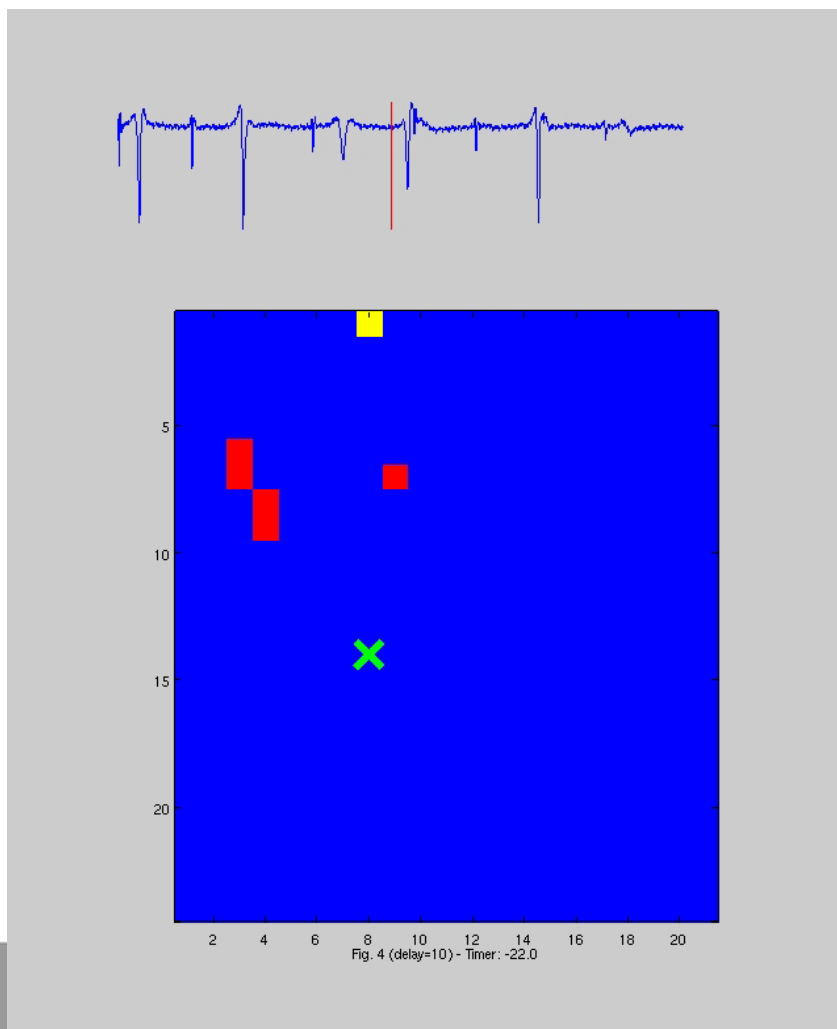




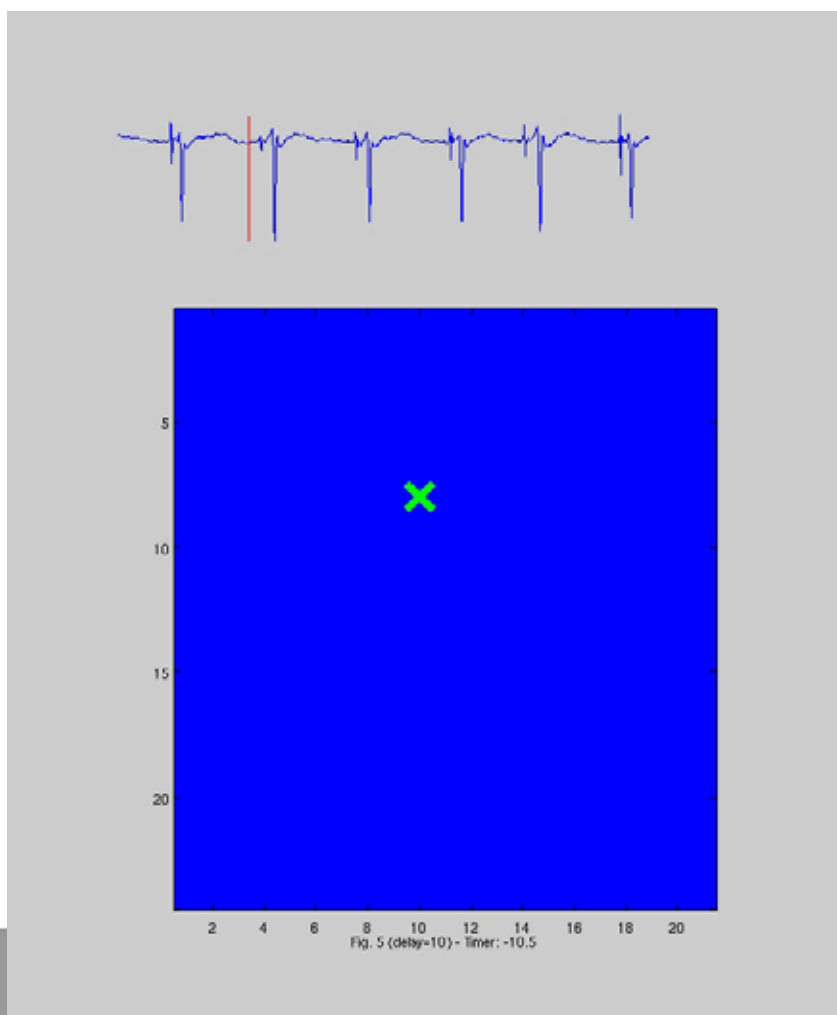
Purkinje Potential During VF



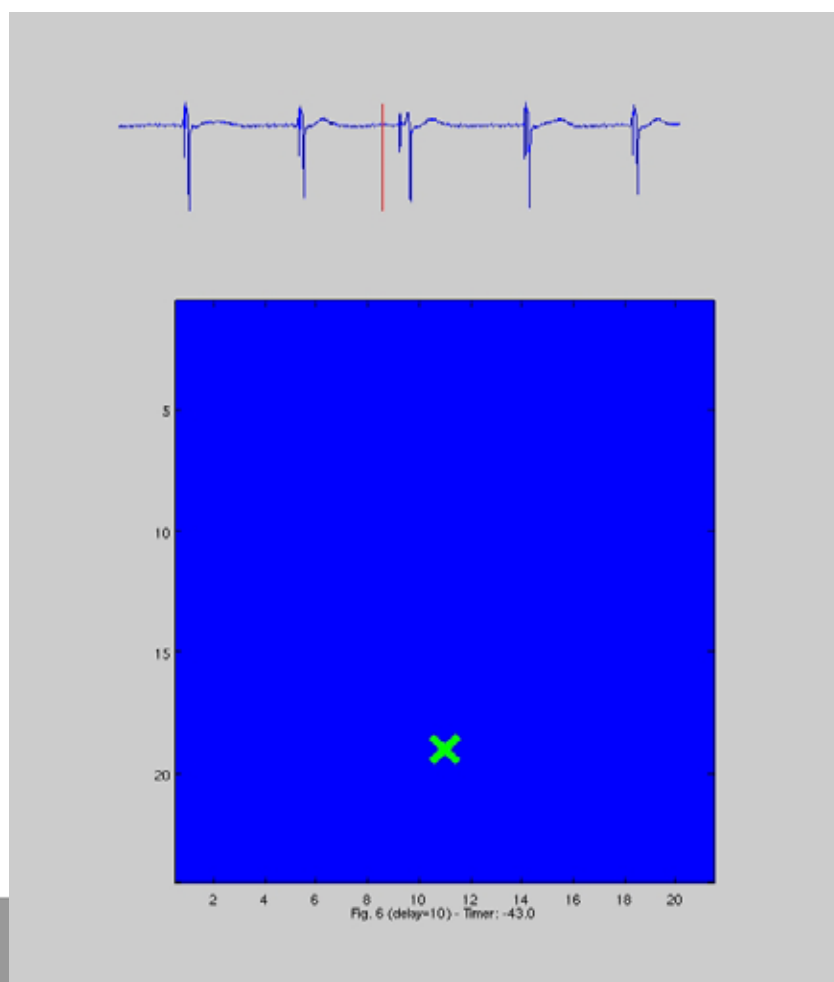
V to PF Activation

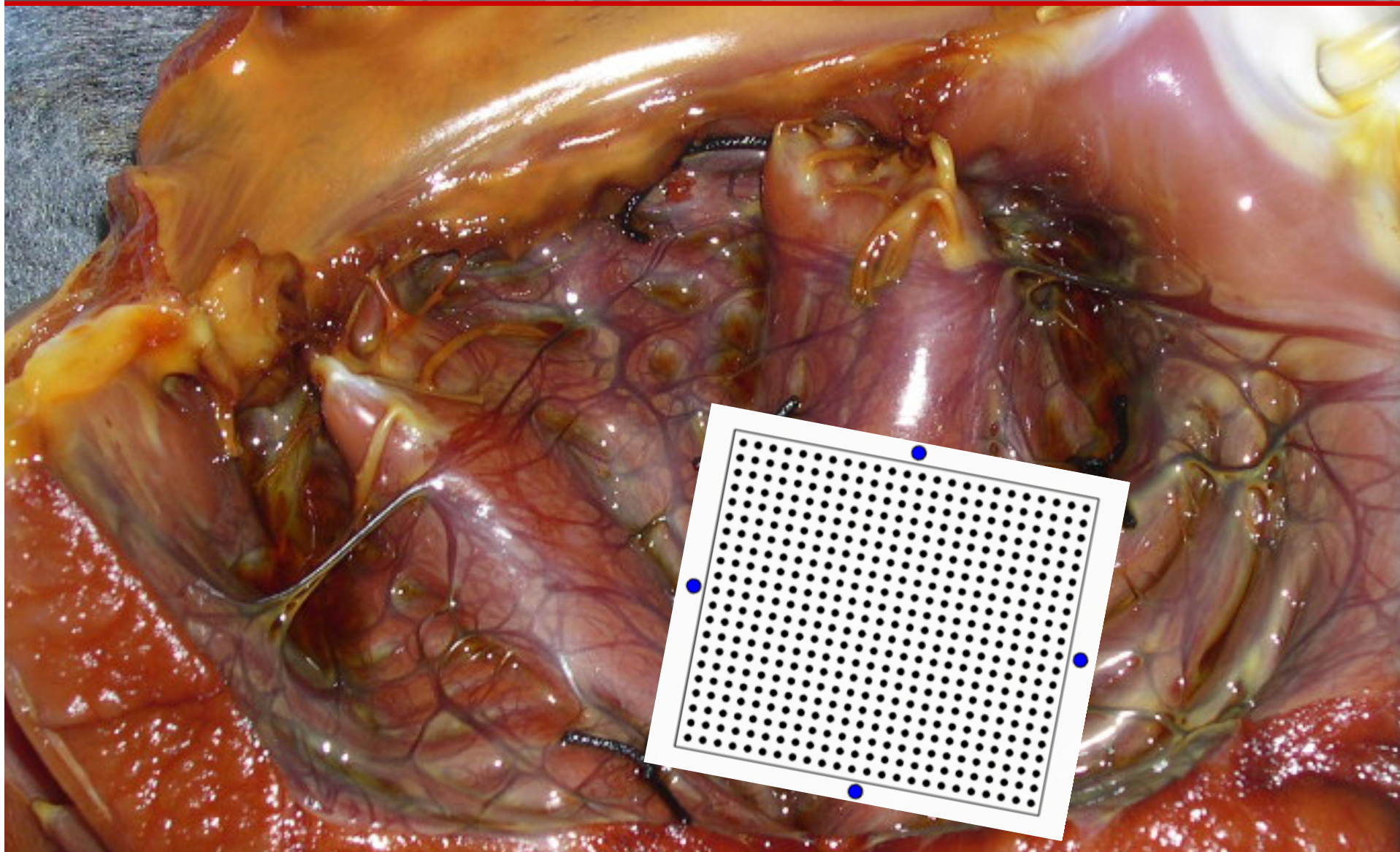


PF to V Pattern



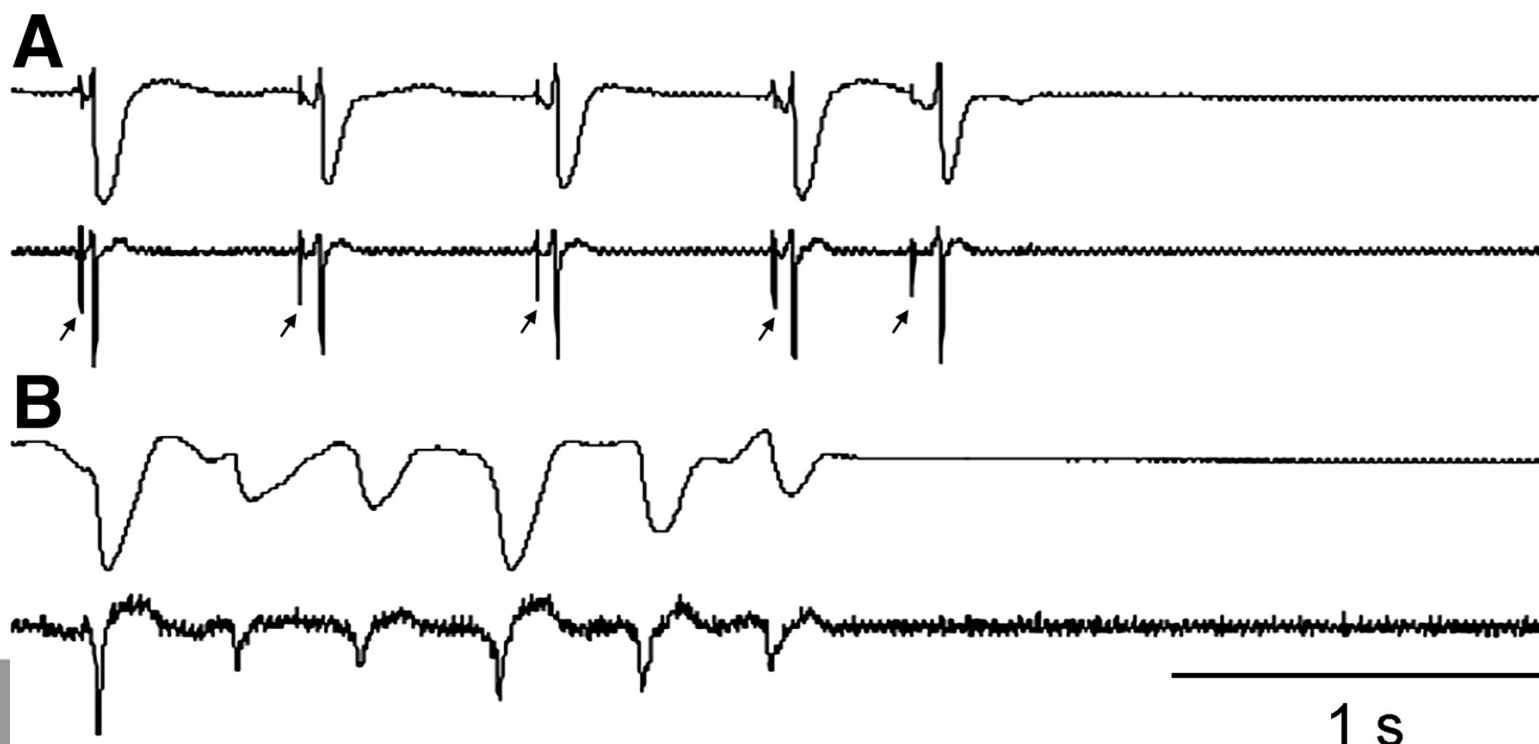
Focal PF Activation Pattern



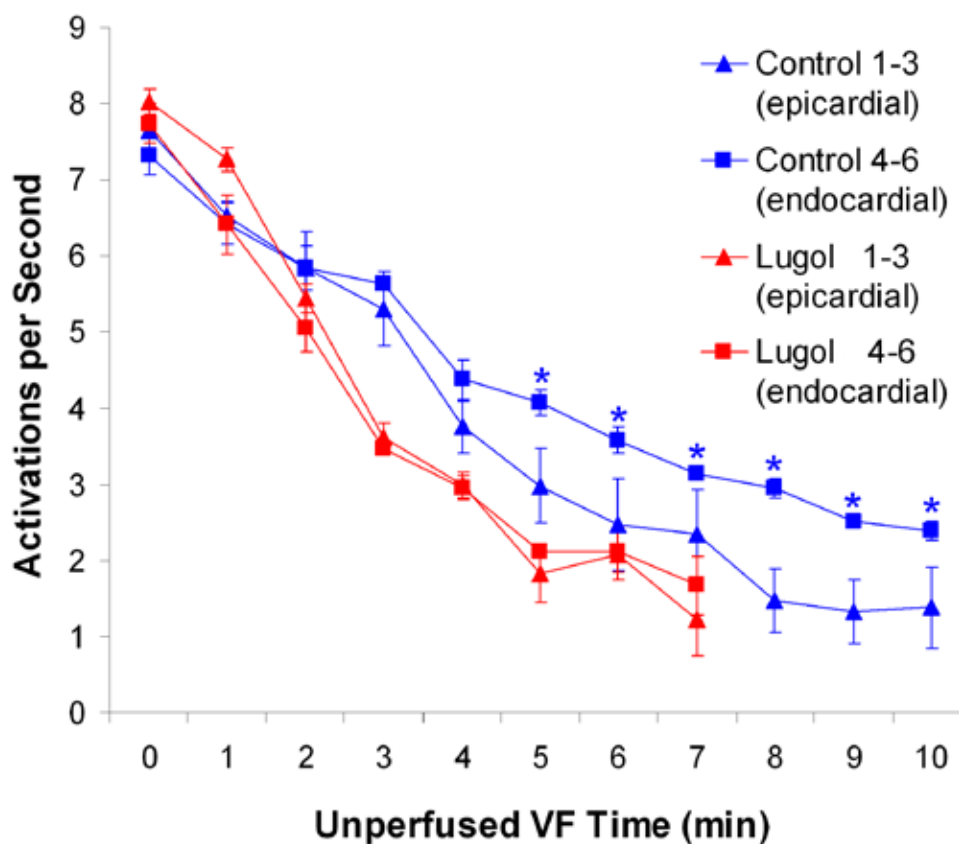


Lugol's Ablation

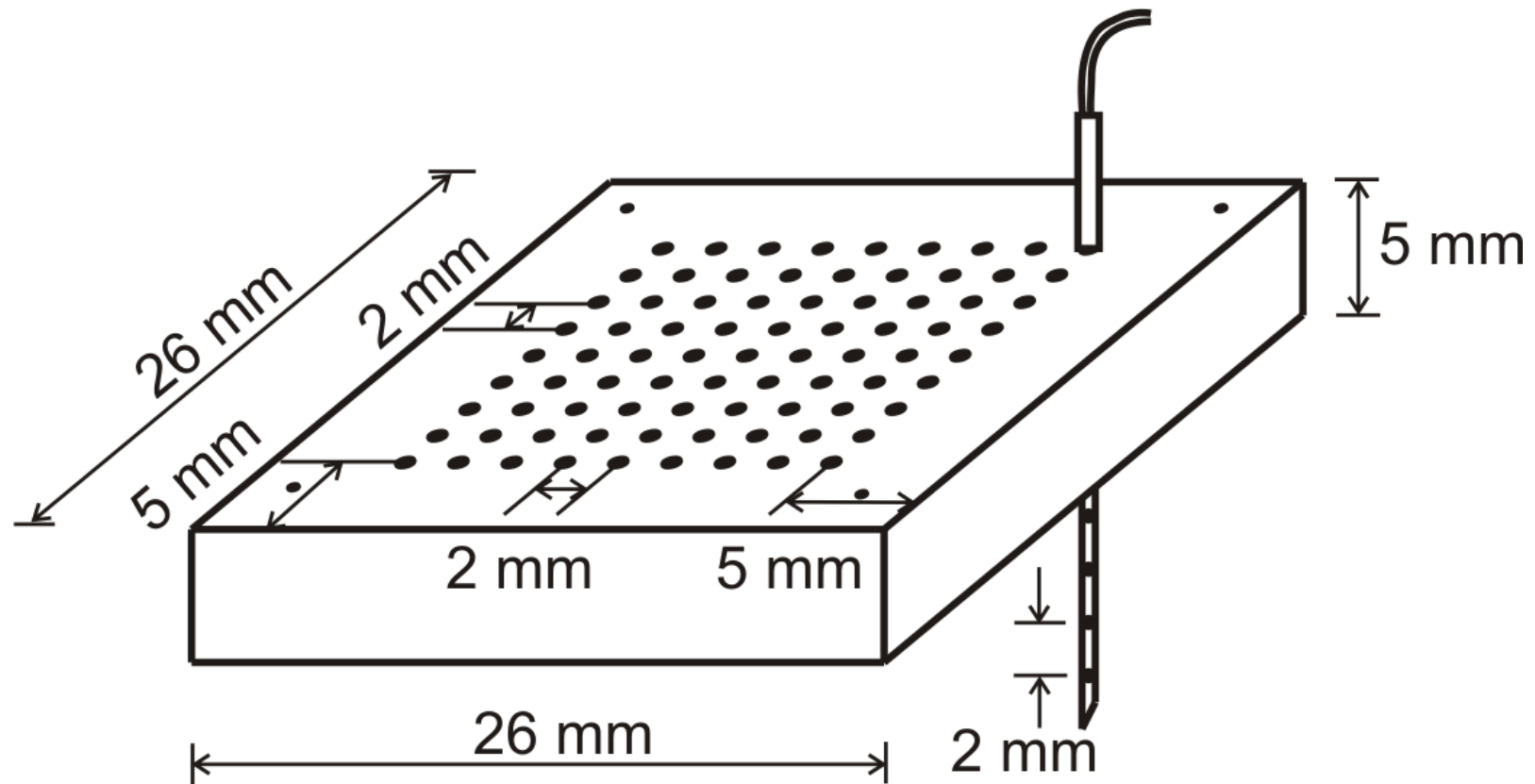
Caused VF to terminate after 4.9 min in treated hearts vs 9.2 min in control hearts

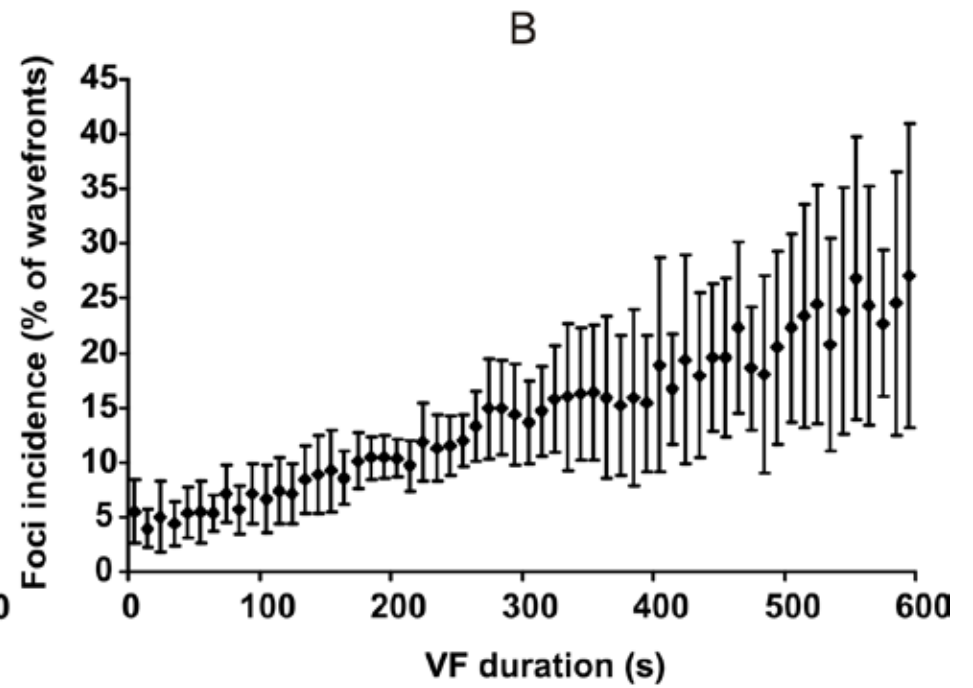
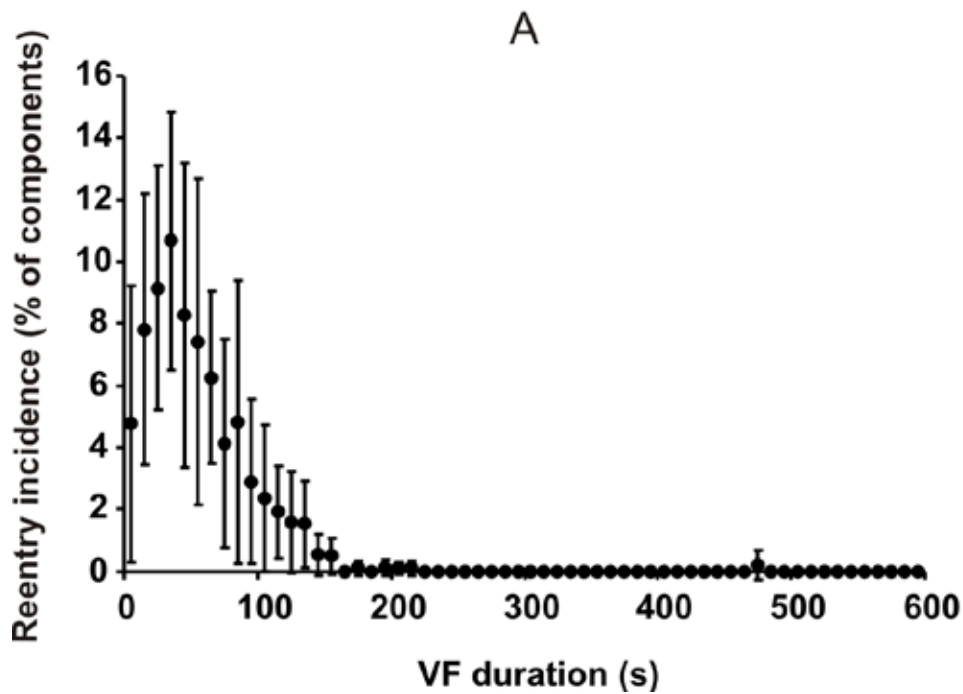


Eliminated the activation rate gradient



3-D Plunge Needle Mapping



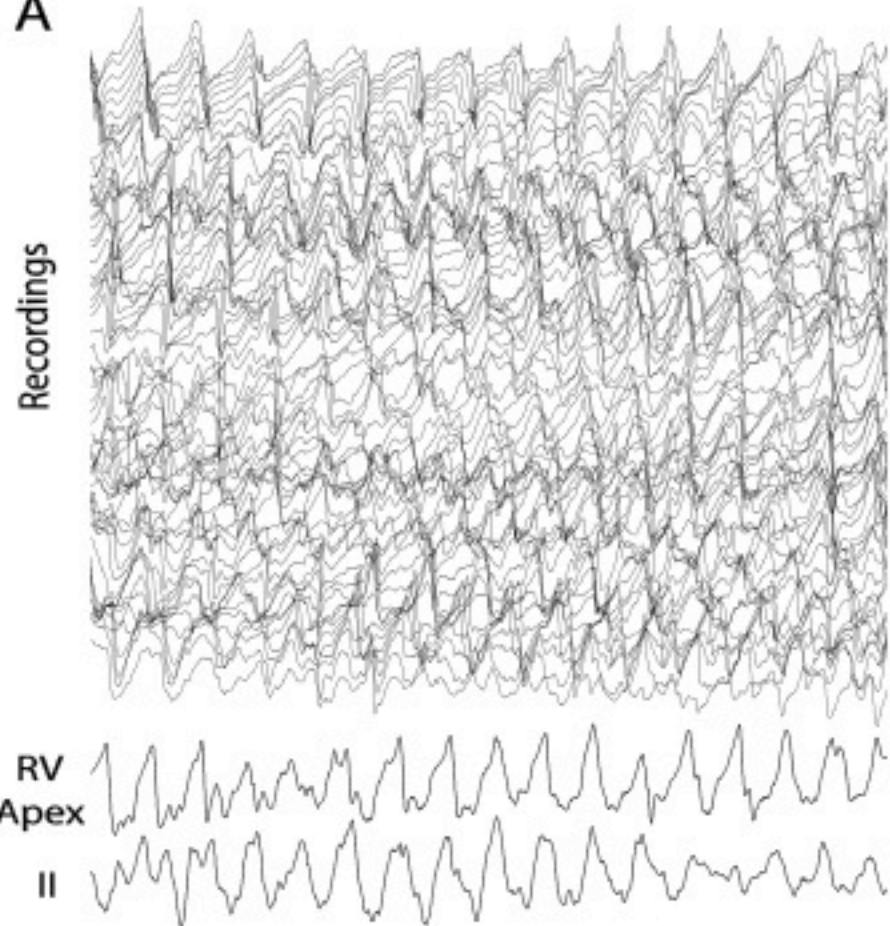


Intact Endocardial Mapping

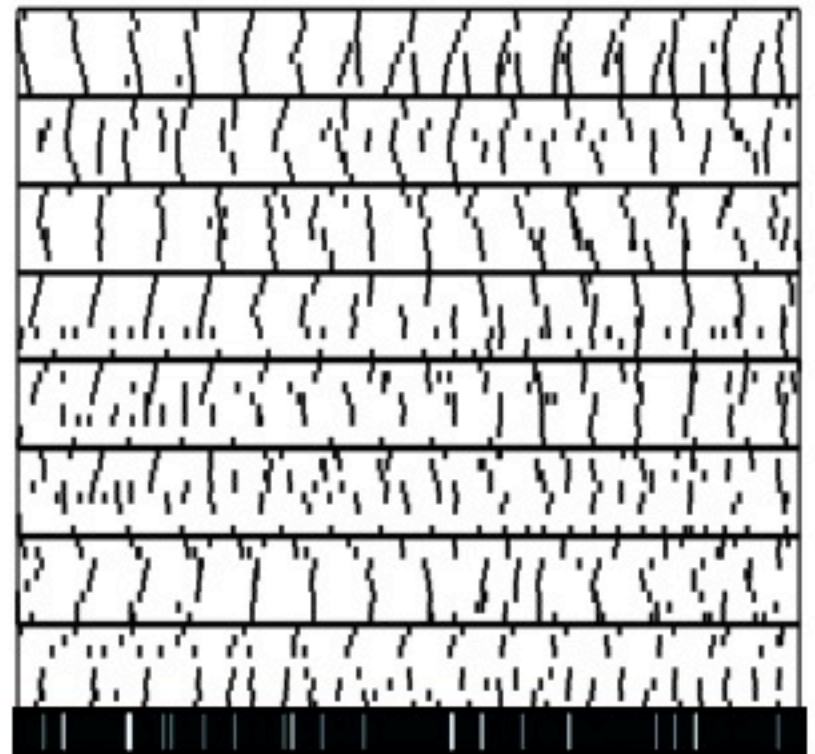


At VF Onset

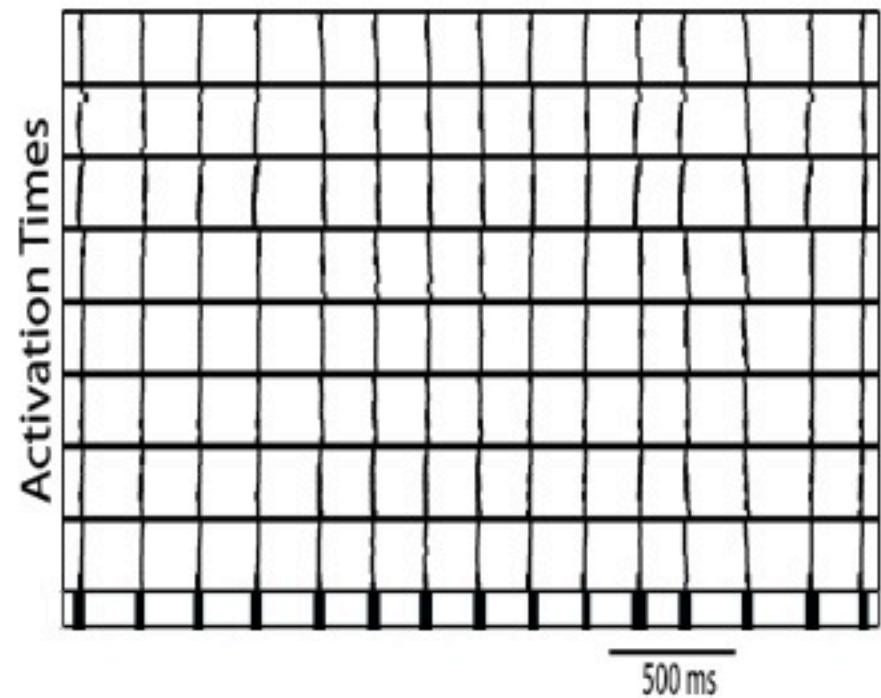
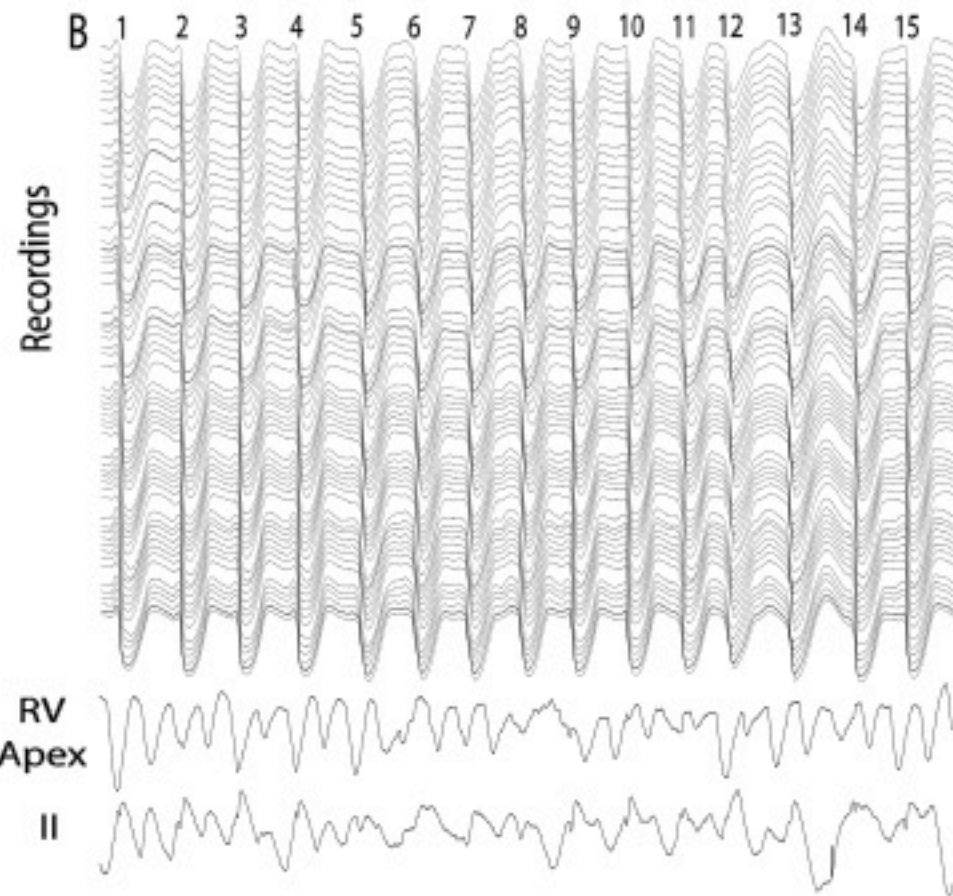
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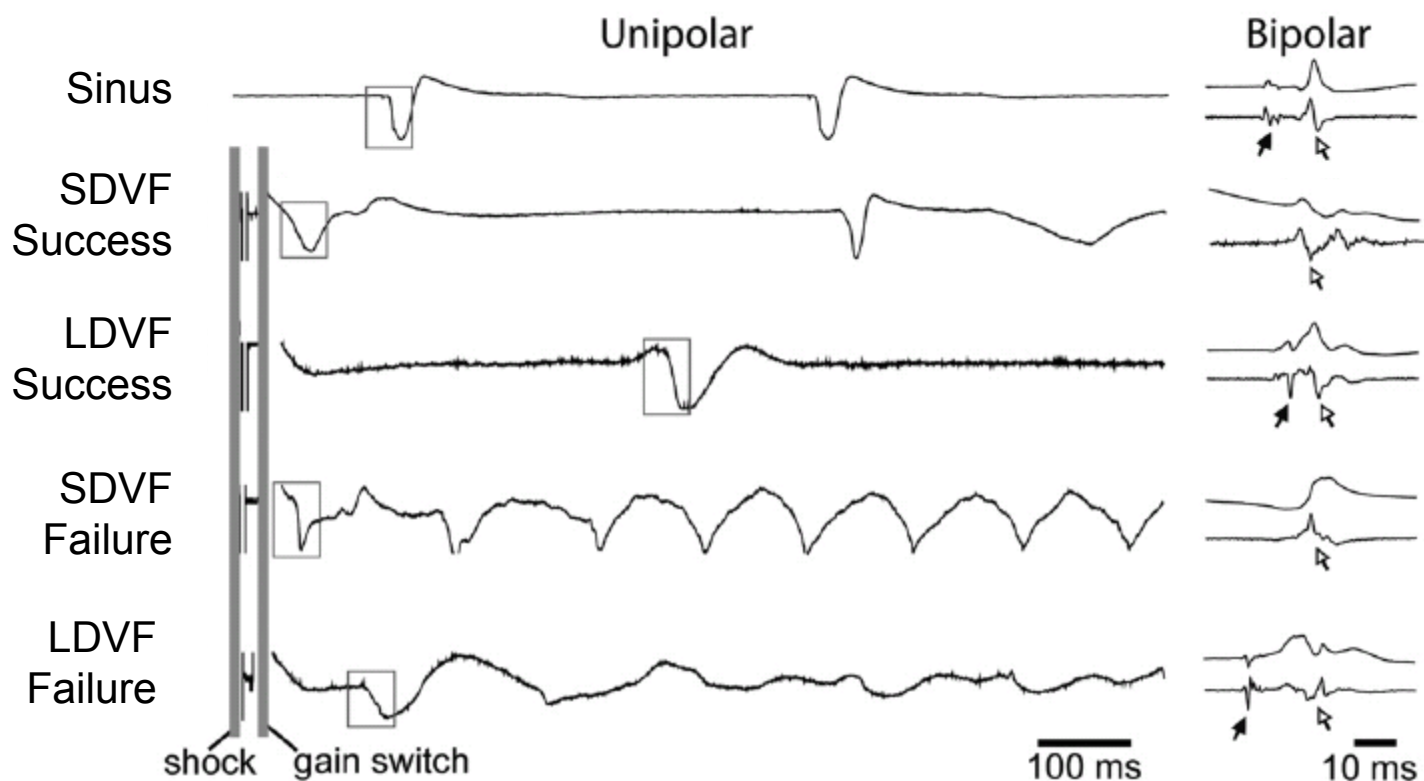
Activation Times



5 Minutes of VF



Purkinje in Defibrillation

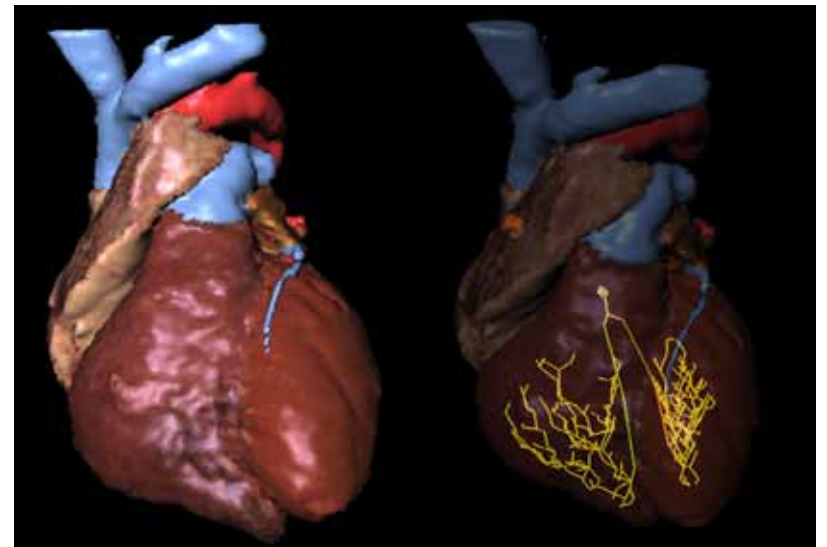


Purkinje System in LDVF:

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.)