An activation-repolarization time metric to predict localized regions of high susceptibility to reentry

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Ventricular Tachycardia (VT)

**Clinical Presentation**
- Chest discomfort
- Fainting, Light-headedness
- Chest Palpitations
- Shortness of breath

**Prevalence**
- 300,000 SCD deaths a year in US

**Clinical Diagnosis - ECG**
- Rapid and irregular heart beats

**Management of VT**
- Pharmacotherapy
- Ablative therapy
- Bioelectric therapy
VT Mechanisms

1. Unidirectional Block
   - Functional (prolonged refractoriness)
   - Anatomic (Scar tissue)

2. Reentrant Path (Substrate)
   - Region of slowed conduction
Heart Rhythm Paper

An activation-repolarization time metric to predict localized regions of high susceptibility to reentry

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Hypothesis

Algorithm to calculate the reentry vulnerability index (RVI) can successfully identify site of reentry

Study Goals

- Test the algorithm on animal model (sheep)
- Computer simulation
Time interval between the arrival of the wave at the distal region and the regaining of excitability in the proximal region is the reentry vulnerability index (RVI)

Matrix analysis of multiple points and spatial relationship between subsequent activation and repolarization intervals between pairs of electrodes during S1-S2 stimulation
Approximate error in RVI measurement increases by 2 ms for every 1 mm increase in electrode spacing (based on normal CV of 50 cm/s)

Translates to 10 ms error in measurement of RVI over the standard clinical catheter 5 mm electrode spacing
1. Experimental Animal Model

- Langendorff pig hearts
- APD prolongation (Sotalol)
- APD shortening (Pinacidil)
- Premature S2 stimulation
- Unipolar EGMs (121 electrodes, 2 mm spacing)
- Act and Rep times calculated

2. Computational Simulations

- 2D mono domain model
- ten Tusscher Cell model
- Isotropic conductivity
- CARP software

3. Optical Mapping Studies

- Sheep LV Wedge Preparation
- Di-4-ANBDQBS

4. Clinical Validation on VT ablation patient

- 63 year old male
- History of IHD, inferior MI, and VT
- Pacing from LV apex S1S2 (8 beat S1 drive train CL 600 ms followed by S2 at 500 ms
- Unipolar electrograms (2mm inter electrode distance, 5 mm spacing)
Langendorff Pig Experiment

A. Premature S2
   Case (i): bidirectional block

B. Case (ii): unidirectional block & reentry

C. Reentry Vulnerability Index
   No Reentry

D. Point of reentry

E. First Reentry Beat

Methods
Clinical Data - VT ablation patient

A

LV1
LV2
LV3
LV4
LV5
LV6
LV7
LV8
LV9
LV10

S1  S1  S2

B

ICD
D
R
A

C

APD

ARI
Computational Simulation

A Voltage Maps of First Premature Beat

B Activation Map - First Premature Beat

C RVI Map

D Voltage Maps of First Premature Beat

E Activation Map - First Premature Beat

F Activation Map - First Re-entry Beat

G RVI Map

H PS ‘Hot-Spot’ Map
Optical Mapping
Clinical RVI Map

A

B

LL

RAO

Low RVI = High Reentry Risk

A

Scarc

VT Exit point

VT Activation Sequence

Low RVI

B

VT Exit point

Low RVI

VT Activation Sequence

Ablation points

SCAR
Clinical Data - Unipolar Electrograms & Voltage Maps
Clinical Data - Diastolic potentials during VT & Entrainment with concealed fusion
Clinical Data - RF ablation sites & Activation Map

Region of very slow conduction or unidirectional block.
Reentry and Bidirectional Block movies
1. **Optimization and experimental validation of RVI mapping algorithm**
   - RVI is based on interaction between the front and the tail of activation wave across unidirectional block
   - Site of reentry identified without addressing the underlying mechanism of reentry (leading circle or rotor)
   - RVI does not require induction of arrhythmia unlike phase singularities (strong correlation with PS)

2. **Clinical Application**
   - Site of lowest RVI corresponds to site of reentry
   - Does not require induction of tachycardia and employee noncritical prematurity of extra stimulation
   - Applicable in treatment of VT by RF ablation
1. Clinical efficacy, sensitivity, and specificity of RVI remains to be evaluated
   - Clinical data from 1 patient only
**What did they do?**

Design an algorithm to calculate the time interval between local repolarization and activation measurements to identify sites of reentry.

**What did they find?**

Reentry vulnerability Index (RVI) Algorithm was able to identify sites of reentry in pig and sheep models, as well as in 1 VT ablation patient.

**What’s next?**

- Efficacy, Sensitivity and specificity evaluation of RVI in clinical setting.

**What does it mean?**

- RVI algorithm could be used to identify sites of reentry for VT ablation therapy.