Patient-Specific Modeling of Defibrillation in Children

Collaborators:

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  Steve Pieper
  Gordon Kindlmann
The Need ....

• Implantation of defibrillators in children is relatively rare
• However at centers like CHB, >50/year
• No child-sized defibrillators available

- Variable anatomy: Leads/Can may not fit in standard positions
- Ad-hoc solutions tried on a case-by-case basis
- No systematic study yet available to guide practice
Examples

Adult

Child
Examples Developed at CHB

Berul et al, 2001
Novel Configurations
Solution Approach

Requires a rapid pipeline … with interactive control

From images to model
- Segmentation
- Mesh generation
- Assigning properties
- Create equations
- Solve equations

From model to clinically relevant parameters

Requires a rapid pipeline ...

Tissue properties
Electrode locations
Stimulus protocols

Triedman

SCI Institute
CIBC
Acquisition of volume image sets

Source

- Routine CT scans of trauma cases
- CHB and Boston Medical Center (BMC)

Challenges

- Small number of children (1:200) receive full scan
- Low radiation levels and contrast agent dosage
- Limited compliance with children

Solutions

- MRI scans
- Better blood/myocardium contrast
- But harder to acquire
Segmentation / Label Mapping

Open software approach

- 3D Slicer (thresholding, level sets, atlas building): active collaboration with BWH investigators
- SCIRun segmentation app (coming)
- Other choices possible
- NRDD standard to bridge
Geometric Model Building

Challenges

- Respect segmented organ boundaries
- Refine mesh for interactive electrode movement and efficient computations

SCIRun/BioPSE tools

- Tetrahedral and hexahedral meshes
- Tetgen for variable-density meshing
- Mesh smoothing/refinement
Solving for clinical parameters

Metrics

• Percentage (90%?) of myocardium > voltage threshold
• DFT (requires computation of current to find time constant of electrode discharge)
• Localization of defibrillated myocardium: integrated visualization

Interactions

• Explore dependence on electrode, lead locations, stimulus characteristics
Current status

Data acquisition in rapid progress (15 from CHB, 8 from BMC)

Assistance from Medtronic, Guidant to obtain electrode parameters

Active progress on segmentation and model generation at both CIBC and NAMIC

Interactive FEM pipeline built and functioning

Ready to begin studies ….
Modeling Pipeline

Extracting surfaces from labeled images
Segmentation with Slicer
Model Construction Pipeline

From segmented images to tet mesh
The current through the plane = -0.0104102 A
The estimated tissue impedance = 96.0599 Ohm
Estimated volume fraction over 1.5 V/m = 0.397667

Electrode 1

Electrode 2
Volume Rendering
Links to other collaborators

Image-to-model pipeline

- Broad-based need
- Makeig/Worrell, McIntyre, Ntziachristos, Isaacson, etc.

Improved FEM tools

- Of general interest for tissue level as well as organ/body level applications

Visualization

- Tools from Taccardi project useful here
Some future directions …

Use same approach with MR prior to interventional EP (ablation) in kids

• Already being studied in adults
• Greater variability in pediatric anatomy suggests even greater utility possible
• XMR devices becoming available

Children’s atlas useful for other biomedical studies

• Developmental studies
• Surgical planning

Connect image-to-model pipeline to inverse electrocardiography

• Geometry for forward models
• Setting for validation in EP procedures
• Statistical models for EIT solutions