Implementation of Body Surface Potential Map of QRST Integral

600.446: Computer Integrated Surgery II, Spring 2012

Project Proposal

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Stated Topic and Goals:
Our goal is to use the concept of Sum Absolute QRST Integral (SAI QRST) from body surface electrocardiograms (ECGs) to build a Body Surface Potential Map (BSPM). We are hoping that this information will provide diagnostic and/or prognostic insight into preventing lethal ventricular arrhythmias (VA).

Background:
Approximately 350,000 people die of sudden cardiac death every year in the United States [1]. Sudden deaths are responsible for half of the deaths related to cardiovascular disease, and are primarily caused by Ventricular Tachyarrhythmia or Ventricular Fibrillation (VT or VF), which is rapid or abnormal contraction of the ventricles [2]. To diagnose these patients, doctors use ECGs to try and understand what is happening within the heart's conduction systems.

Normal ECG waveforms (the QRST regions are shown below as well):
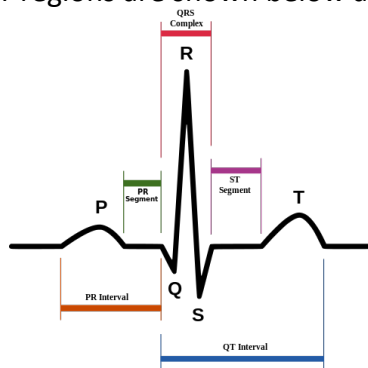
It has been shown in large group studies that SAI QRST can be used to predict ventricular arrhythmia in 12-lead electrocardiograms [3]. The figure below shows a SAI QRST calculated from an orthogonal ECG (different from a body surface ECG) [3]:
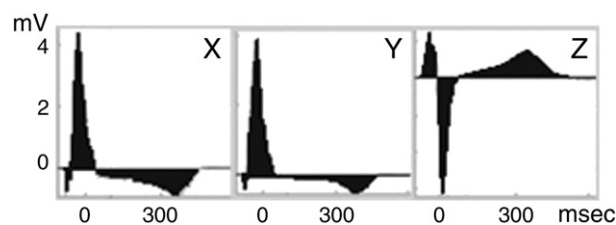

Fig. 1. Example of SAI QRST measurement. The sum of the areas under QRST curve on 3 orthogonal ECG leads is calculated.

However, SAI QRST has never been used to create BSPMs from body surface ECG data, which is what we want to accomplish.

Furthermore, body surface potential maps are "comparable" to information gathered from invasive catheter-fed electrodes [2], but in many ways are better. They have better spatial resolution, meaning that the arrhythmic substrate can be better localized in the patient. In addition, they take into account patient variability, and can map single heartbeats, which allows for greater diagnostic information about the arrhythmia.

Motivation and Significance:
VT and VF are highly lethal conditions and once diagnosed, require immediate attention. In order to do so, it would be far more useful to preoperatively determine electrical maps of patients rather than intraoperatively, which carries far greater risks. Furthermore, work has not been done to combine SAI QRST with BSPMs, which will likely have a tremendous, non-invasive prognostic value. This method of joining SAI QRST with body surface mapping would allow for the screening of the general population at risk of sudden cardiac death.

BSPMs, particularly when used in conjunction with other imaging modalities such as CT or MRI, known as Electrocardiographic Imaging or ECGi, have much better prognostic value over conventional potential maps generated by catheter-fed electrodes [2].

One final motivation for the use of SAI QRST is to determine whether or not cardiac resynchronization therapy (CRT) will be successful. Currently around one third of patients do not improve with CRT but recent studies have shown that patients with longer QRS widths are more likely to respond positively to CRT while those with shorter QRS intervals are not [4]. We believe that by using SAI QRST we will be able to figure out whether a patient will respond well to CRT or whether other options should be considered.

Technical Approach:

The data being used is from patients with heart failure due to electrical dyssynchrony (left-bundle branch block) who are receiving a bi-ventricular pacing.

Our approach for analyzing this data, involves four main stages: pre-processing, averaging, constructing a body surface map of the SAI QRST interval, and constructing an inverse map of the heart.

In our pre-processing stage, we will use several methods developed by Zong et. al [8,9] to automatically detect the beginning and end of the QRST interval. With these points, we will then calculate the sum absolute and native integral of the QRST interval for each lead.

In the remaining stages, we will average the data across all beats for each lead and then create our body surface and inverse heart maps. For the final two stages, we will rely heavily on previously validated packages for creating body surface maps and computing the inverse solution.

Deliverables:

Minimum:
- Semi-Automatically pre-processing the data
- Automatically detecting fiducial points in data
- Calculating the SAI QRST for each data set
- Averaging SAI QRST integral for each data set

Expected:
- Semi-Automatically pre-processing the data
- Automatically detecting fiducial points in data
- Calculating the SAI QRST for each data set
- Averaging SAI QRST integral for each data set
- Constructing a body surface map of the SAI QRST

Maximum:
- Semi-Automatically pre-processing the data
- Automatically detecting fiducial points in data
- Calculating the SAI QRST for each data set
- Averaging SAI QRST integral for each data set
- Constructing a body surface map of the SAI QRST
- Computing an inverse map of the heart using the body surface map

Milestone Validations:
- Automatically detecting fiducial points of ECG
  - Criteria: graphical confirmation that our method is identifying the correct fiducial points
  - Projected Date: March 16
- Automatically calculating sum absolute and native integrals of QRST interval
  - Criteria: graphical confirmation that method is calculating integral (shaded region under curve)
  - Projected Date: March 16
- Averaging the sum absolute and native integrals per beat on each of the 120 leads
  - Criteria: see if averaging works for test data
  - Projected Date: March 30
- Constructing a body surface map
  - Criteria: confirmation of method and results with mentor
  - Projected Date: April 20
- Constructing an inverse heart map
  - Criteria: confirmation of method and results with mentor
  - Projected Date: May 4

(Gantt chart presented on final page)

Management Plan:
- Weekly meetings with Dr. Tereshchenko 3:00 PM-4:30 PM on Friday
- Partner meetings every Monday and Wednesday from 4:30 PM – 6:30 PM.

Dependencies and Resolutions:
- IRB Approval
  - Mentors need IRB approval to release data
  - Status: Resolved
- Data Source
  - See above
  - Status: Resolved
- Weekly support meetings with Dr. Tereshchenko
  - Assistance with first two stages of project
  - Status: Resolved
- Packages to help solve the inverse problem and create body surface and heart maps
  - When we reach Stage 3 (projected March 20), we can acquire these from Fady
  - Status: Pending
- Meetings with Dr. Lardo or Fady for help with constructing body surface and heart maps
  - Fady (Dr. Lardo's PhD student) will be primary contact and provide assistance with constructing these maps
  - Status: Pending

References:

[1] Lloyd-Jones D, Adams R, Carnethon M, et al. Heart disease and stroke statistics—2009 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Circulation 2009;119:480.

[2] Wang Y, Cuculich PS, Zhang J, Desouza KA, Smith TW, Rudy Y. Noninvasive Electroanatomic Mapping of Human Ventricular Arrhythmias with Electrocardiographic Imaging (ECGI). Science Translational Medcine 2011;84.

[3] Tereshchenko LG, Cheng A, Fetics BJ, et al. A new electrocardiogram marker to identify patients at low risk for ventricular tachyarrhythmias : sum magnitude of the absolute. Journal of Electrocardiology 2011;44(2):208-216.

[4]. Ghosh S, Silva JN a, Canham RM, et al. Electrophysiologic substrate and intraventricular left ventricular dyssynchrony in nonischemic heart failure patients undergoing cardiac resynchronization therapy. Heart rhythm : the official journal of the Heart Rhythm Society 2011;8(5):692-9.

[5]. Zong W, Saeed M, Heldt T, America N, Manor B. A QT Interval Detection Algorithm Based on ECG Curve Length Transform Materials and methods. Computers in Cardiology 2006:377-380.

[6]. Zong W, Moody B, Jiang D. A Robust Open-source Algorithm to Detect Onset and Duration of QRS Complexes. Computers in Cardiology 2003;30:737-740.

Reading List:

1. Ghosh S, Silva JN a, Canham RM, et al. Electrophysiologic substrate and intraventricular left ventricular dyssynchrony in nonischemic heart failure patients undergoing cardiac resynchronization therapy. Heart rhythm : the official journal of the Heart Rhythm Society 2011;8(5):692-9.

2. Ambroggi LD, Corlan AD. Body Surface Potential Mapping. In: Comprehensive Electrocardiology., 2011:1376-1413.

3. Rudy Y. Cardiac repolarization : Insights from mathematical modeling and electrocardiographic imaging (ECGI). HRTHM 2009;6(11):S49-S55.

4. Wang Y, Cuculich PS, Zhang J, Desouza KA, Smith TW, Rudy Y. Noninvasive Electroanatomic Mapping of Human Ventricular Arrhythmias with Electrocardiographic Imaging (ECGI). 2011;84.

5. Tereshchenko LG, Cheng A, Fetics BJ, et al. A new electrocardiogram marker to identify patients at low risk for ventricular tachyarrhythmias : sum magnitude of the absolute. Journal of Electrocardiology 2011;44(2):208-216.

6. Tereshchenko LG, Cheng A, Fetics BJ, et al. Ventricular arrhythmia is predicted by sum absolute QRST integral but not by QRS width. Journal of Electrocardiology 2010;43(6):548-552.

7. Sornmo L, Laguna P. ELECTROCARDIOGRAM (ECG) SIGNAL PROCESSING. Wiley Encyclopedia of Biomedical Engineering 2006:1-16.

8. Zong W, Saeed M, Heldt T, America N, Manor B. A QT Interval Detection Algorithm Based on ECG Curve Length Transform Materials and methods. Computers in Cardiology 2006:377-380.

9. Zong W, Moody B, Jiang D. A Robust Open-source Algorithm to Detect Onset and Duration of QRS Complexes. Computers in Cardiology 2003;30:737-740.

Project Gantt Chart

Milestone	Task	Dates (filled)
Milestone 1	Project Proposal Presentation	20-Feb, 22-Feb
	Investigating Literature for Noise Reduction	24-Feb
	Investigating Literature for Fiducial Recognition	27-Feb, 29-Feb, 2-Mar, 5-Mar
	Implementation of Noise Red. and Fiducial Recog.	27-Feb, 29-Feb, 2-Mar, 5-Mar, 7-Mar, 9-Mar
	Code Validation, Testing, and Debugging	27-Feb, 29-Feb, 2-Mar, 5-Mar, 7-Mar, 9-Mar, 12-Mar, 14-Mar
	Checkpoint	16-Mar (gray)
Milestone 2	Investigating Literature for Averaging Beats	16-Mar
	Implementation of Averaging Beats	26-Mar
	Code Validation, Testing, and Debugging	26-Mar, 28-Mar
	Checkpoint	30-Mar (gray)
Milestone 3	Investigating Literature for Body Surface Maps	2-Apr, 4-Apr, 6-Apr, 9-Apr, 11-Apr
	Construction of Body Surface Map	9-Apr, 11-Apr, 13-Apr, 16-Apr
	Verification of Technique with Dr. Lardo and Fady	13-Apr, 16-Apr, 18-Apr
	Checkpoint	20-Apr (gray)
Milestone 4	Investigating Literature for Inverse Solution	13-Apr, 16-Apr, 18-Apr, 20-Apr, 23-Apr, 25-Apr, 27-Apr, 30-Apr
	Discussion of Technique to Create Inverse Solution	20-Apr, 23-Apr, 25-Apr, 27-Apr, 30-Apr
	Construction of Inverse Solution Map	20-Apr, 23-Apr, 25-Apr, 27-Apr, 30-Apr
	Verification of Technique with Dr. Lardo and Fady	30-Apr
	Checkpoint	4-May (gray)
	Poster Preparation	2-May, 4-May, 7-May
	Poster Presentation	

Column headers (left to right): February — 20-Feb (M), 22-Feb (W), 24-Feb (F); 27-Feb (M), 29-Feb (W); March — 2-Mar (F), 5-Mar (M), 7-Mar (W), 9-Mar (F), 12-Mar (M), 14-Mar (W), 16-Mar (F), 19-Mar (M), 21-Mar (W), 23-Mar (F), 26-Mar (M), 28-Mar (W), 30-Mar (F); April — 2-Apr (M), 4-Apr (W), 6-Apr (F), 9-Apr (M), 11-Apr (W), 13-Apr (F), 16-Apr (M), 18-Apr (W), 20-Apr (F), 23-Apr (M), 25-Apr (W), 27-Apr (F), 30-Apr (M); May — 2-May (W), 4-May (F), 7-May (M), 10-May (W).

SPRING BREAK spans 19-Mar through 23-Mar.