Body-Surface Electrocardiography Variations Caused by Changes in Cardiac Geometry Due to Diabetes and Obesity

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Abstract

Purpose: Myocardial disease is common in the diabetic, including elevated risk for myocardial infarction, heart failure, and sudden cardiac death. Both diabetes and obesity, which is common among diabetics, are responsible for deleterious electrophysiological and geometric changes to the heart. Here we investigate the effects on body-surface electrocardiograms (ECGs) of changes in cardiac geometry associated with both diabetes and obesity. Left ventricular hypertrophy (LVH) has been found to occur among diabetic and obese groups. Additionally, heart position and orientation can change inside the obese torso. To quantify effects of these geometric changes, we modified the realistic heart and torso models of the simulation package ECGSIM (http://www.ecgsim.org/)[1] as input to our bidomain forward-problem solution.

Method & Materials: To simulate LVH effects, both the inter-ventricular septum (IVS) and the posterior wall (PW) of a normal heart model were increased 5% (LVH5), and 20% (LVH20) for the diabetic and obese cases, respectively. Values were selected to match measured increases in the thickness of the IVS and PW of 2-9 and 1-8%, respectively, in diabetic patients [2]. In the obese group, IVS and PW increases of 11-22 and 13-25%, respectively, were seen [3]. To simulate the obese heart displacement, the heart was shifted (8% of the torso height) and rotated (6, 4.5 and 28 degrees in the coronal, frontal and sagittal planes). These values were taken from experimental measurements on normal and obese subjects made by our group. A bidomain forward-problem model was used to calculate ECGs from cardiac transmembrane potentials.

Results: Three measures were employed to evaluate the effects of geometric changes on ECGs over the body surface during the QT interval: 1) the relative root mean square differences (RD), 2) the correlation coefficient (CC), and 3) the average change in ECG value. During the QT interval, the RD was 3, 11 and 102 % for the LVH5, LVH20, and heart displacement cases, respectively. Corresponding CC values were 0.9998, 0.9974 and 0.5361. In the LVH5 and LVH20 models the average ECG value was raised in the precordial region by 4.3% and 16.9%, respectively, whereas heart displacement raised average ECG values by 508% on front of the upper left torso and reduced them by 60% over the lower left torso.

Conclusions: These results suggest that geometric changes accompanying diabetes and obesity may have a significant effect on ECG values compared to those expected for normal subjects. These effects demonstrate the limitations of using the standard 12-lead signals for diagnosing LVH in the presence of obesity, which often accompanies diabetes. The large error with heart displacement associated with obesity suggests the use of body-surface maps and inverse solutions on the heart-surface to get a comprehensive, stable measure of cardiac sources in obese subjects.

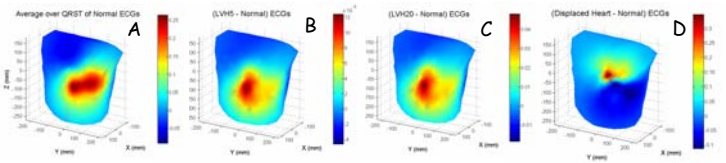

Figure 2. Temporal average over QRST of ECGs (TAECG) on the body surface. A) TAECG from the normal heart. B). Difference between TAECG from the LVH5 heart and the normal heart. C) Difference between TAECG from the LVH20 heart and the normal heart. D) Difference between TAECG from the displaced heart and the normal heart.

Methods

- Normal transmembrane potentials and heart-torso structures taken from ECGSIM [Fig 1A] [1].
- Simulated heart-torso geometries, based on obese anatomic body features, were calculated using the Geometrical Remodeling Module [Fig 1B]. In this study two obesity associated geometrical features are considered:
  - Left Ventricular Hypertrophy (LVH)
  - Heart displacement, including rotation and translation.
- Body-surface potentials, including standard 12-lead ECGs, were calculated from cardiac transmembrane potentials and heart-torso geometries using our Bidomain Forward-Problem Model [Fig 1C].

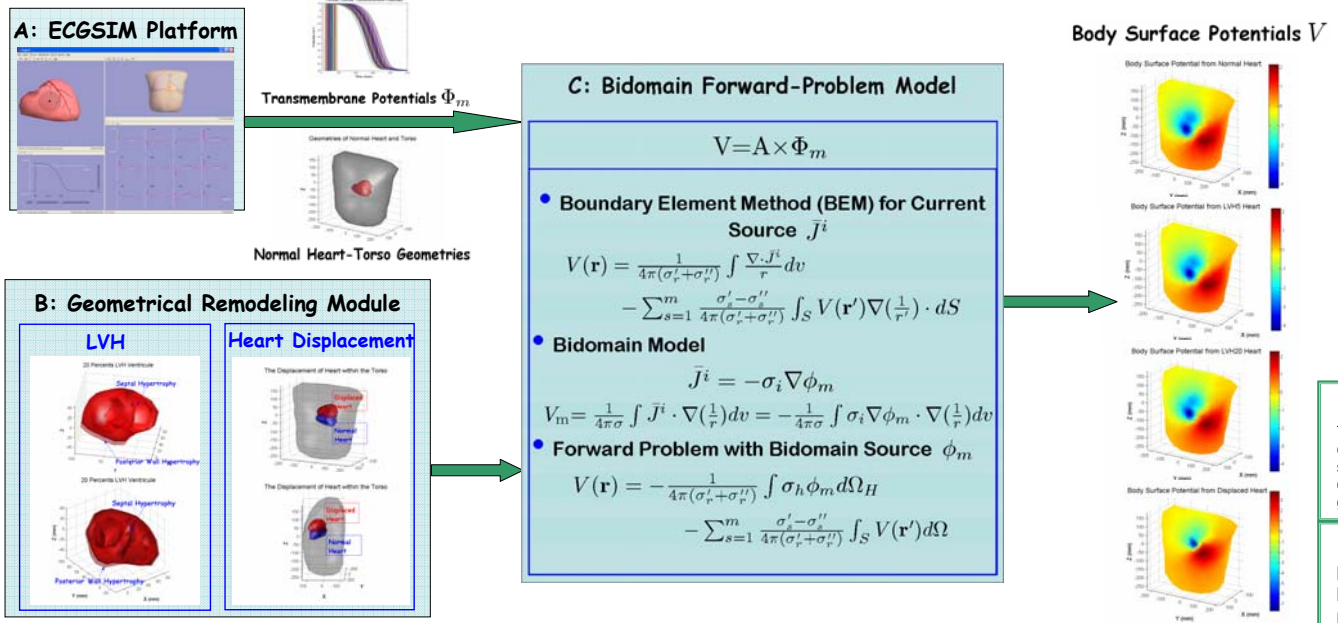

Figure 1. System used to estimate the variation in body-surface potentials related to heart geometry changes in obsesity. A) ECGSIM Platform used to provide transmembrane potentials Φ_m, and normal heart and body geometry. B) Geometrical Remodeling Module developed to simulate obesity-associated geometrical changes in heart shape, position and orientation. C) Bidomain Forward-Problem Model developed to estimate body-surface potentials from cardiac transmembrane potentials and heart-torso geometries.

Results

In this study, body-surface ECGs from normal, LVH5, LVH20, and Displaced hearts were compared.:

- The ECG temporal average showed that LVH raised potentials in the precordial region by 4.3% for LVH5 and 16.9% for LVH20. Heart displacement raised average ECG values by 508% on front of the upper left torso and reduced them by 60% over the lower left torso [Fig 2].
- ECG relative differences (RD) and correlation coefficients (CC) over QRS & T are recorded in [Table 1].
- Spatial Averages over the body surface during the T-wave suggest that LVH will increase the average T-wave magnitude depending on the amount of hypertrophy, whereas obesity-related heart displacement will reduce the T-wave amplitude [Fig 3].
- Calculated 12-Lead ECGs showed LVH is likely to increase the T-wave values slightly, whereas obesity-associated heart displacement is likely to significantly change precordial lead values [Fig 4].

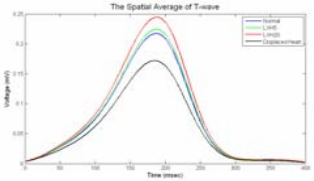

Figure 3. The spatial average of body-surface ECGs during the T wave.

	LVH5		LVH20		Heart Displacement	
	QRST	T	QRST	T	QRST	T
Relative Difference (%)	2.83	3.24	11.15	12.66	100.87	80.97
Correlation Coefficient	0.9998	0.9999	0.9975	0.9991	0.5412	0.6719

Table 1. The RD and CC between Normal and LVH5, LVH20, and Displaced Heart.

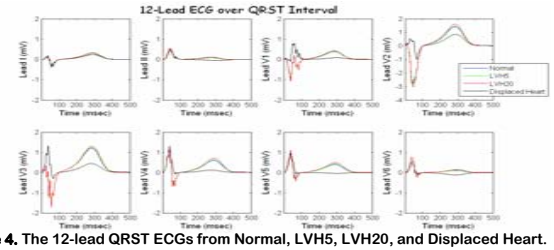

Figure 4. The 12-lead QRST ECGs from Normal, LVH5, LVH20, and Displaced Heart.

Conclusion

The results suggest that geometric changes accompanying diabetes and obesity may have a significant effect on ECG values compared to those expected for normal subjects. These effects demonstrate the limitations of using the standard 12-lead signals for diagnosing LVH in the presence of obesity, which often accompanies diabetes. The large error with heart displacement associated with obesity suggests the use of body-surface maps and inverse solutions on the heart-surface to get a comprehensive, stable measure of cardiac sources in obese subjects.

Reference

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