Analysis of Beat-to-Beat QT Interval Variability in 12-lead ECG Signals

by

Muhammad Asraful Hasan

BSc. Eng. (Computer Science and Engineering),
University of Dhaka, Bangladesh, 2006

MSc. Eng. (Electrical and Computer Engineering),
International Islamic University Malaysia, Malaysia, 2009

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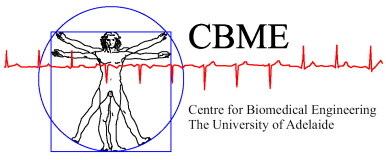
Supervisors:

Assoc Prof Mathias Baumert, School of Electrical & Electronic Engineering

Prof Derek Abbott, School of Electrical & Electronic Engineering



THE UNIVERSITY of ADELAIDE

Dedication

To fulfill every ambition needs self-effort as well as adroit directions of elders especially those very close to our heart and feelings.

My humble effort I dedicate to my sweet and loving

Parents,

Whose love, affection, encouragement and prayers of day and night enable me to have such success and honour.

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Abstract

The human heart is a significant research topic in biomedical engineering due to the high incidence of heart disease in the developing world. Electrocardiography (ECG) is considered the primary diagnostic tool for the assessment of cardiac diseases and various heart arrhythmias. Note that ECG is the electrical representation of heart activity and can be recorded noninvasively by placing electrodes on the limbs and chest of the body. It is stated that certain heart diseases affect depolarization and repolarization. While the entire depolarization and repolarization of the heart is important, there is significant interest in the study and investigation of the ventricular depolarization and repolarization that is reflected by QT interval duration. The main reason for studying ventricular depolarization and repolarization is that some cardiac diseases, which are associated with ventricles of the heart, have an immediate effect on the body and can cause sudden cardiac death. Further, the knowledge of ventricular activation sequence and its abnormalities has contributed to our understanding of cardiac arrhythmias, but the underlying mechanisms and role of repolarization abnormalities is still not completely known. Therefore, this thesis presents several studies to explain more about the instability of repolarization duration in various cardiac patients by analysing different QT parameters.

The main results of the thesis are: (i) Beat-to-beat QT interval variability (QTV) varies between the 12 standard ECG leads and caution should be paid when comparing beat-to-beat QTV results obtained from different leads across studies. (ii) The inter-lead correlation of beat-to-beat QTV is lead dependent. (iii) A negative correlation exists between beat-to-beat QTV and T-wave amplitude. (iv) No significant effect of mean heart rate, age and gender on beat-to-beat QTV in 12-lead resting ECG in healthy subjects. (v) An improved ECG-preprocessing technique is introduced and recommended for accurate measurement of beat-to-beat QTV. It substitutes the R-peak detection algorithm and implements an efficient baseline removal algorithm in the existing template matching approach. (vi) Effects of T-wave amplitude and ECG lead on beat-to-beat QTV in patients with Myocardial Infarction (MI) compared to healthy subjects are studied and suggest that increased beat-to-beat QTV in patients with MI is partly due to the lower T-wave amplitudes and some other unknown reason. (vii) The study also confirms that patients with MI have lower heart rate variability (HRV) compared to

healthy subjects. (viii) Moreover, beat-to-beat QTV remains higher in patients with MI even after controlling the T-wave amplitudes. (ix) Two new beat-to-beat VCG (vectorcardiography) descriptors that have independent diagnostic attributes for assessing patient populations are introduced. (x) Overall spatial and temporal VCG descriptors may provide markers of electrical instability in the heart of patients with MI but need further research for the quantification and analysis of beat-to-beat VCG descriptors. (xi) Effect of pacing and pharmacologically induced autonomic nervous system modulation on VCG parameters and on beat-to-beat QTV is limited in heart failure patients.

In addition to this, the thesis offers an introductory background and overview chapter revolving around repolarization lability. The results should be taken into account in further studies, so that the beat-to-beat variations of QT interval in ECG parameters and VCG descriptors can be utilized more effectively in clinical applications.

Statement of Originality

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Muhammad Asraful Hasan and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Signed

Date

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Thesis Conventions

The following conventions have been adopted in this Thesis:

1. **Spelling.** Australian English spelling conventions have been used, as defined in the Macquarie English Dictionary, A. Delbridge (Ed.), Macquarie Library, North Ryde, NSW, Australia, 2001.

2. **Typesetting.** This document was compiled using LaTeX2e. TeXnicCenter was used as text editor interfaced to LaTeX2e. Inkscape was used to produce schematic diagrams and other drawings.

3. **Mathematics.** MATLAB code was written using MATLAB Version R2010a; URL: http://www.mathworks.com.

4. **Referencing.** The Harvard style has been adopted for referencing.

5. **URLs.** Universal Resource Locators are provided in this Thesis for finding information on the world wide web using hypertext transfer protocol (HTTP). The information at the locations listed was current on 17 December 2009.

Publications

A brief list of selected publications are as follows:

Journal Articles

Hasan M. A., Abbott D., & Baumert M. (2013). Beat-to-beat QT interval variability and T-wave amplitude in patients with myocardial infarction, *Physiological Measurement*, **34**, pp. 1075–1083.*

Nayyar, S., Roberts-Thomson, K. C., **Hasan M. A.**, Sullivan, T., Harrington, J., Sanders, P., & Baumert M. (2013). Autonomic modulation of repolarization instability in patients with heart failure prone to ventricular tachycardia, *American Journal of Physiology–Heart and Circulatory Physiology*, **305**, pp. H1181–H1188.*

Hasan M. A., Abbott D., & Baumert M. (2012). Beat-to-beat vectorcardiographic analysis of ventricular depolarization and repolarization in myocardial infarction, *PLoS ONE*, **7**, art. no. e10602.*

Hasan M. A., Abbott D., & Baumert M. (2012). Relation between beat-to-beat QT interval variability and T-wave amplitude in healthy subjects, *Annals of Noninvasive Electrocardiology*, **17**, pp. 1249–1259.*

Hasan M. A., & Reaz M. (2012). Hardware prototyping of neural network based fetal electrocardiogram extraction, *Measurement Science Review*, **12**, pp. 52–55.

Hasan M. A., & Reaz M. (2012). Hardware approach of R-peak detection for the measurement of fetal and maternal heart rates, *Journal of Applied Research and Technology*, **10**, pp. 835–844.

Hasan M. A., Reaz M., Ibrahimy M., Hussain M., & Uddin J. (2009). Detection and processing techniques of FECG signal for fetal monitoring, *Biological Procedures Online*, **11**, pp. 263–295.

HASAN M. A., IBRAHIMY M., & REAZ M. (2009). An efficient method for fetal electrocardiogram extraction from the abdominal electrocardiogram signal, *Journal of Computer Science*, **5**, pp. 619–623.

Conference Articles

HASAN M. A., STARC V., PORTA A., ABBOTT D., & BAUMERT M. (2013). Improved ECG pre-processing for beat-to-beat QT interval variability measurement, 35th *Annual International Conference of the IEEE Engineering in Medicine and Biology Society 2013*, Osaka, Japan, pp. 4193–4195.*

HASAN M. A., ABBOTT D., & BAUMERT M. (2013). Dynamic repolarization variability in patients with myocardial infarction, *Australian Biomedical Engineering (ABEC) 2013*, Sydney, Australia, (Abstract based).*

HASAN M. A., ABBOTT D., & BAUMERT M. (2012). Beat-to-beat spatial and temporal analysis for QRS-T morphology, 34th *Annual International Conference of the IEEE Engineering in Medicine and Biology Society 2012*, San Diego, CA, USA, pp. 4193–4195.*

HASAN M. A., ABBOTT D., & BAUMERT M. (2011). Beat-to-beat QT interval variability in the 12 lead ECG, 38th *Annual Scientific Conference of Computing in Cardiology 2011*, Hangzhou, China, pp. 61–64.*

HASAN M. A., REAZ M. B. I., & IBRAHIMY M. I. (2011). Fetal electrocardiogram extraction and R-peak detection for fetal heart rate monitoring using artificial neural network and correlation, *The 2011 International Joint Conference on Neural Networks (IJCNN) 2011*, San Jose, CA, USA, pp. 15–20.

HASAN M. A., IBRAHIMY M. I., & REAZ M. B. I. (2008). NN-Based R-peak detection in QRS complex of ECG signal, 4th *Kuala Lumpur International Conference on Biomedical Engineering*, Kuala Lumpur, Malaysia, pp. 217–220.

Note: Articles with an asterisk (*) are directly relevant to this Thesis.

Awards

A list of award achievements are as follows:

- Australian Endeavour International Postgraduate Research Scholarship (**EIPRS**) for PhD research at The University of Adelaide, Australia, 2010.
- The University of Adelaide Scholarship (**UAS**) for PhD research at The University of Adelaide, Australia, 2010.
- **SMBE SA/NT ABEC Travel Grant** awarded to attend and present research paper in the Australian Biomedical Engineering Conference, 13-16 October, Sydney, Australia, 2013.
- **IEEE SA Travel Grant** awarded to attend and present research paper in the 34th Annual International Conference of the IEEE Engineering and in Medicine & Biology Society, 28 August-1 September, San Diego, USA, 2012.
- **IEEE SA Travel Grant** awarded to attend and present research paper in the Computing in Cardiology Conference, 18-21 September, Hangzhou, China, 2011.
- **Silver Medal** awarded in International Islamic University Malaysia Research, invention and Innovation (IRIIE'11) for Research performance, in International Islamic University Malaysia 2011.
- **Bronze Medal** awarded in International Islamic University Malaysia Research, invention and Innovation (IRIIE'10) for Research performance, in International Islamic University Malaysia 2010.
- **IEEE Student Scholarship** awarded to attend and present paper in the IEEE-ICIT'09 conference, 10–13 February, Monash University, Australia, 2009.
- **Silver Medal** awarded in Kulliyyah (Faculty) of Engineering Research and Innovation Exhibition (KERIE'09) for Research outstanding performance, in International Islamic University Malaysia 2009.

- **Travel Scholarship** received from Center for Postgraduate Studies (CPS), International Islamic University Malaysia to attend and present paper in 38th International Conference on Computer and Industrial Engineering, Oct–Nov, Beijing, China, 2008.
- **Dean's** award from Military Institute of Science and Technology for the outstanding performance in B.Sc. Engineering, 2006.

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