Title

QTc Prolongation May Be a Late Biomarker of Orthotopic Heart Transplantation (OHT) Rejection

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Improving STEMI Screening by Utilizing a Diagnostic ECG Algorithm in the Monitoring Environment

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Background: In a monitoring environment, ST segment elevation myocardial infarction (STEMI) due to the blockage of coronary artery is often detected by elevation of the ST-segment outside pre-defined thresholds. However, other conditions can also cause similar ST segment elevation which will lead to false alarms. Preventing such false notifications may be achieved by detecting ST-elevation confounders such as acute pericarditis and benign early repolarization or by analyzing variations in, not absolute values of, ST deviation. Diagnostic 12-lead algorithms are capable of such processing, but they are designed to analyze resting ECGs with lower level of noise than found in a monitoring environment. In this study, we report on a hybrid algorithm combining real-time selection of low noise ECG segments with analysis by a diagnostic 12-lead algorithm.
Methods: We combined the Philips DXL algorithm and our signal quality indicator (SQI) module as follows. The SQI module selects a 10-second segment in each one-minute data interval with the lowest noise level. The DXL algorithm analyzes these selected segments to generate the representative beats, measure the lead-wise ST-segment levels and other cardiac ischemia features, and detect the ST-elevation confounders. We ran the hybrid algorithm on a total of 1171 continuous 24-hour standard 12-lead ECG Holter recordings from the THEW Chest Pain database, University of Rochester. The STEMI episodes were detected by the algorithm in each ECG recording according to the 2013 ACCF/AHA guidelines for the management of STEMI. The hybrid algorithm excluded sections of noisy leads from the analysis, as well as whole segments where a high noise level was observed on many leads.
Results: Recordings from patients with acute myocardial infarction were reviewed by experts to identify the STEMI episodes. A total of 13 STEMI cases were detected and annotated. The algorithm output was compared against the reviewers' annotations to generate the per-patient STEMI detection performance for multiple values of minimum episode duration.

Minimum episode duration (minute)	1	2	3	4
Se (%)	100	100	85	85
Sp (%)	80	93	95	96

Conclusion: We presented an algorithm which may improve STEMI detection in the monitoring environment by excluding the ST-elevation confounders and handling noisy signal to reduce the number of false positives. This is a successful example of utilizing a diagnostic resting ECG algorithm in an ischemia monitoring application.

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Extraction of CPR Compression Rate from Continuous Patient Monitoring Pediatric ECG Waveforms

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Introduction: Optimal CPR methodology for adults has been comprehensively studied, and the AHA periodically releases guidelines for chest compression (CC) rate and depth. Data from neonatal and pediatric patients experiencing cardio/pulmonary arrest (CPA) have been harder to obtain and thus guidelines for this population are not as well developed. Compression rate and depth can be obtained from defibrillator CPR "meters", but these devices, if used at all, may not capture the initial set of compressions. Due to the general lack of detailed data from pediatric patients, every recorded case from this population contains valuable information, and determination of CC rate (CCR) alone may provide insights. In this observational study, we examine if CCR can be visually extracted from continuous patient-monitoring ECG waveforms by examination of the CC-induced "artifact".
Methods: Fifty-four neonatal/pediatric CPA patients in the cardiothoracic and pediatric ICUs at CHLA were examined (Sep/2013–Nov/2015). Routinely monitored ECG waveforms from the Philips patient-monitoring system were retrospectively reviewed. CO2, ABP, and plethysmograph waveforms were also captured when present. CPA episodes were identified by ECG rhythm or drops in EtCO2 or ABP. CC onset was determined by the sudden appearance of cyclical artifact in the ECG. CCR was measured with cycle-adjusted electronic calipers spanning a 6–8 second window centered at both 30 and 90 seconds post onset, and extrapolated to compressions-per-minute (cpm). When available, maximum systolic ABP and EtCO2 in the same regions were measured. The methodology was repeated for up to three subsequent CC periods following pauses.
Results: ECG-extracted CCR could be determined with a high degree of certainty in all but a few waveform regions where CC artifact could not be positively distinguished from the underlying ECG (e.g., Torsades). PEA and bradycardia were the most frequent cause of CPA. Distinguishing CC from VT was challenging but possible. Mean CCR was 118 cpm, ($n = 226$) with range from 73 to 183 cpm and SD ± 20.2; 48% were above the 2015 AHA upper guideline limit of 120 cpm; 16% below 100 cpm. Measured 30, 90 s post compression onset, mean EtCO2: 22 ± 13 mmHg; mean ABP: 71 ± 28 mmHg. In this small database, no significant correlation between CCR and EtCO2 or ABP was observed.
Discussion and Conclusion: Large studies validating the current CPR guidelines for the neonate/pediatric population are still needed. Although the combination of CCR and depth would ideally be measured, we have shown that CCR can be extracted from routinely monitored in-hospital continuous ECG and could be used for guideline refinement and compliance studies. Future work could be the development of algorithms for automated CCR extraction.

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QTc Prolongation May Be a Late Biomarker of Orthotopic Heart Transplantation (OHT) Rejection

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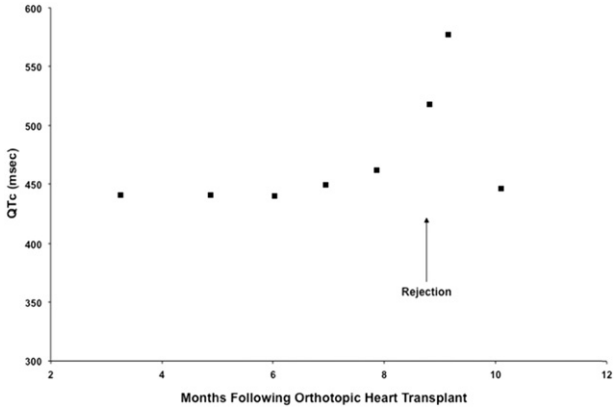
This is a case of a 43-year-old black male with no history of hypertension, diabetes, dyslipidemia, or smoking. The subject underwent an OHT for worsening heart failure due to an idiopathic cardiomyopathy. Three endomyocardial biopses acquired during the first 8 months following transplant surgery did not show acute allograph rejection and the QTc was not prolonged on electrocardiogram (ECG). However, a 2R rejection was noted on an endomyocardial biopsy acquired 9 months following transplant

surgery which correlated with prolongation of the QTc to 518 ms on an ECG obtained the following day and to 577 ms on an ECG acquired 11 days later. In the two months following this episode of acute allograph rejection, the endomyocardial biopses showed no rejection and the QTc interval returned to normal. Upon review of pre and post rejection ECGs, prolongation of the QTc was only observed following a positive endomyocardial biopsy (Fig. 1).

Conclusion: Noninvasive ECG monitoring may not be an early biomarker for predicting OHT rejection.



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A Cardiologist-centered App Designed for Faster Inter-hospital ECG Tele-consultation

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With the technology of medical informatics and telecommunication, the development of 12-lead electrocardiography (ECG) telemedicine still faces many challenges. For instance, heterogeneous ECG data formats and databases impede interoperability of ECG reports among hospitals. In addition, the delivery of ECG telemedicine service via smart phones has to rely on the phone operation systems (O.S.). The objective of this study is to develop a cardiologist-centered app that is independent of O.S. of cardiologists' phones and has fast access to ECG reports from heterogeneous ECG databases of different hospitals so that inter-hospital tele-consultation is faster and more convenient. In this study, a Web service, which performs applications running on heterogeneous platforms, is used to integrate heterogeneous ECG databases across hospitals. Notably, various ECG formats, including SCP, XML, and DICOM, are converted into HTML5, which is a standardized Web format and can be directly accessed and visualized on cross-platform phones. Cardiologists can read present and past ECG records across hospitals via a common app when inter-hospital telemedicine consultation is needed. This app can be easily applied on the ECG telemedicine services of a hospital alliance, with which patient transfer is conducted among the participating hospitals. In conclusion, this app proves to be an effective and time-saving tool for cardiologists performing ECG tele-diagnosis, especially during inter-hospital emergency consultations.

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Very-Low Frequency Heart Rate Variability is Depressed During Hemodialysis Session

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Introduction: Patients with end-stage renal disease on chronic hemodialysis have a high mortality rate, due to increasing prevalence of cardiac complications. Analysis of heart rate variability (HRV) is used for identifying patients at increased risk of death. However, previous studies were limited up to 48 h ECG recordings; recently continuous long-term (~14 days) ECG monitoring became available through which cyclic components of variations within very low ranges of frequency can be quantified more reliably. The purpose of this study was to compare HRV measures before, during and after hemodialysis sessions.

Methods: One-lead surface ECG, digitized at 200 Hz, was recorded continuously for up to 14 days using ECG patch (ZioPatch, iRhythm Technlogies, Inc.) in 28 participants (53.9 ± 12.5 y, 59% men) of a prospective cohort of incident hemodialysis patients. ECG R-peaks were detected using parabolic fitting. Movement artifacts and ectopic beats, as detected by our software (developed using Matlab) and later reviewed from R-R tachogram, were excluded, resulting in a normal-to-normal (NN) time series. For spectral analysis, the time series were linearly interpolated by equidistant 500-ms samples. The power density spectra were estimated using the Fast Fourier Transform. High frequency (HF, 0.15 –0.4 Hz), low frequency (LF, 0.04–0.15), very low frequency (VLF, 0.0033–0.04 Hz), meanNN, SDNN and LF/HF ratio were measured during dialysis (D), 6 hours before (preD), 6 hours after (postD), and in between dialysis sessions (bwD).

Results: Using ANOVA, a significant decrease in log-transformed VLF HRV (LnVLF) was observed during D, as compared to preD, postD and bwD (8.8 ± 1.2 vs. 9.3 ± 1.1, $p < 0.01$; 9.0 ± 1.1, $p < 0.05$ and 9.5 ± 0.9, $p < 0.001$, respectively). The LF/HF ratio also decreased during D as compared to preD and bwD (3.4 ± 2.0 vs. 4.2 ± 2.2, $p < 0.05$ and 4.5 ± 1.9, $p < 0.01$, respectively). In addition, SDNN reduced significantly during D (0.057 ± 0.04 vs. preD: 0.069 ± 0.03, $p < 0.01$; postD: 0.063 ± 0.03, $p < 0.05$ and bwD: 0.078 ± 0.03, $p < 0.001$). However, no significant changes in meanNN, LF and HF HRV were observed with hemodialysis sessions.

Conclusion: Depressed VLF HRV is associated with hemodialysis treatment. Further studies of VLF on long-term ECG in hemodialysis patients are needed for timely detection and management of the associated risk.

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Repolarization Abnormalities Associated with Consumption of Energy Drinks

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