

## Clinical application of the 22 lead derived electrocardiogram and a new cardiac electrical biomarker

**Purpose:** The cardiac electrical field is a dipolar 3 lead-vector space but there are 22 leads used in clinical practice including the 12-lead ECG, 3 right heart leads V3R-V6R, 3 posterior leads V7-V9, and 3 vectorcardiography (VCG) leads X, Y, Z. These leads can be derived from 3 measured leads using non-linear optimization (NLO). A cardiac electrical biomarker (CEB) is identified from the derivation process that can detect acute myocardial ischemic injury (AMII). The objective is to derive 22-lead ECGs from 3 measured ECG leads and use the CEB to detect AMII.

**Methods:** ECGs were measured (mECG) including 119 standard 12-lead ECGs, 117 VCGs, 119 right heart ECGs, and 39 posterior heart ECGs. Each ECG was interpreted by 2 blinded physician reference standards including 10.9% interpreted as acute myocardial ischemic injury (AMII). Leads I, aVF, and V2 were the 3 lead-vector set from which the derived ECGs (dECG) were synthesized. The derived vs. measured test case ECGs were compared quantitatively using Pearson correlation ( $r$ ), mean absolute deviation (MAD), root-mean-square error (RMSE), and a similarity coefficient. The CEB was constructed from the dECG and diagnostic accuracy was assessed by sensitivity and specificity measures.

**Results:** The dECGs showed very high quantitative correlations with mECGs with Pearson ( $r$ ) correlation  $0.881 \pm 0.065$  and similarity coefficient  $0.889 \pm 0.083$ . The average RMSE was  $16.178 \pm 9.554$ . The average MAD and normalized MAD were  $5.107 \pm 2.311$  and  $0.18 \pm 0.045$  respectively. No clinically significant differences were noted in 99.1% of dECGs. ECG rate, rhythm, segment, and axis interpretations showed 100% correlation. ECG morphologies interpreted as AMII showed 100% correlation. The CEB sensitivity and specificity for AMII was 92.3% and 84.6% respectively.

**Conclusions:** The 22-lead ECG is derived from 3 measured ECG leads. Comparison of mECGs and dECGs show high quantitative and qualitative correlations. The CEB differentiates ECGs with AMII morphology from non-acute ECGs. Using this technology a 22-lead derived ECG is displayed continuously on a cardiac monitor in real-time to enhance patient observation capabilities to detect AMII and will allow for convenient and cost effective acquisition and analysis of the ECG in acute cardiac care facilities.