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Visual transform applications for estimating the spatial QRS–T angle from the conventional 12-lead ECG: Kors is still most Frank

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Abstract

Background: The 12-lead ECG-derived spatial QRS–T angle has prognostic and diagnostic utility, but most ECG machines currently fail to report it. The primary goal was to determine if reasonably accurate methods exist for rapid visual estimations of the spatial peaks QRS–T angle from conventional 12-lead ECG tracings.

Methods and Results: Simultaneous 12-lead and Frank XYZ-lead recordings were obtained from a publicly available database for 100 post-myocardial infarction patients and 50 controls. ANOVA, Pearson's correlation coefficients and concordance plots were used to evaluate agreement for spatial peaks QRS–T angle results from the true Frank leads versus from several visually applied 12-to-Frank XYZ-lead transforms. The latter included Kors et al.'s regression and quasi-orthogonal, Bjerle and Arvedson's quasi-orthogonal, Dower's inverse, and Hyttinen et al.'s, Dawson et al.'s and Guillem et al.'s transforms. Spatial peaks QRS–T angles derived from the true Frank leads were not statistically significantly different from those derived from any visually applied transform. Of the visually applied transforms, the Kors' regression and Kors' quasi-orthogonal yielded the highest Pearson correlation coefficients against the gold-standard true Frank lead results [0.84 and 0.77, respectively, when individuals with bundle branch blocks were included (N = 150), and 0.88 and 0.80, respectively, when individuals with bundle branch blocks were excluded (N = 137)]. Bland–Altman 95% confidence intervals showed similar results, with the two Kors'-related methods also having the narrowest confidence intervals.

Conclusions: When visually applied, the Kors' regression-related and quasi-orthogonal transforms allow for reasonably precise spatial peaks QRS–T estimates and thus a potentially practical way to visually estimate spatial peaks QRS–T angles from conventional 12-lead ECGs.

Keywords: Reconstruction; Transform; Vectorcardiography; Frank; Orthogonal

Introduction

The spatial QRS–T angle is a vectorcardiographic (VCG) parameter with notable diagnostic [1–5] and prognostic [2,6–15] utility. For example in a recent study by Borleffs et al. [6] of 412 patients who had coronary ischemia as well as implanted cardiac defibrillators (ICD's) and ejection fractions ≤40%, a spatial angle greater than 100 degrees was associated with a hazard ratio for appropriate ICD discharge of 7.3. In addition to assisting with risk stratification for cardiac events, the angle is also useful for evaluation of incident coronary heart disease [2,4,12], heart failure [4,11,13], and the efficacy of therapy for adult hypertension [1] and diabetes mellitus [5]. Most recently the spatial QRS–T angle has also been shown to be more useful than any parameter from the conventional scalar 12-lead ECG for identifying both adult and pediatric hypertrophic cardiomyopathy [3,16]. As noted in previous publications, of the various methods used for deriving the Frank XYZ leads from conventional 12-lead ECG recordings, and then in turn for estimating secondary parameters such as the spatial QRS–T angle, the regression method described by Kors

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et al. [17] has thus far tended to have the best overall performance [18,19].

At the present time, arguably the main practical impediment to day-to-day clinical use of the 12-lead ECG-derived spatial QRS–T angle is the fact that its expeditious derivation requires dedicated software code that most ECG manufacturers have not yet implemented. However given the important diagnostic and prognostic utility of the angle, and in the interim until more programs containing such code become available, it would be helpful to provide physicians the means to estimate, in a purely visual but still reasonably precise fashion, the value of the angle from any scalar 12-lead ECG. Also, if the value of the angle were calculable with reasonable precision from any 12-lead ECG, including from previous 12-lead ECG printouts that are no longer electronically available, then a wealth of additional information might also become available for further scrutiny of the utility of the angle from retrospective paper-based ECG studies. While derivation of the so-called spatial "mean" QRS–T angle requires the ability to fit the entire spatial QRS and T-loops into a complex function (see Appendix), thus making visual estimates of that angle very difficult to perform from strictly scalar 12-lead ECGs, the so-called spatial "peaks" QRS–T angle [18] on the other hand requires only the absolute ("peak") voltage values from the QRS and T waves ("loops") as inputs. These voltages can in turn be visually estimated from the scalar 12-lead ECG and their values entered into pre-existing derivation formulae (Appendix) to calculate the "peaks" angle. Once the maximum voltage values are visually estimated from the scalar 12-lead, they can also be easily entered into simple preformatted calculators. For example, online calculators or a spreadsheet on a clinician's personal cell phone or tablet, might be used to in turn derive the "peaks" angle.

The primary goal of this study was to explore whether a reasonably precise method could be derived for rapid *visual* estimations of the spatial peaks QRS–T angle from strictly conventional 12-lead ECG tracings. A secondary goal was to determine whether the precisions of the best method(s) for visually estimating the peaks angle from scalar 12-lead ECGs approach those that occur when the same angle is quantified purely mathematically (automatically and non-visually) from the underlying digital data using advanced ECG software.

Methods

Data collection

All data were obtained from a publicly available source, the Physikalisch-Technische Bundesanstalt (PTB) Diagnostic ECG Database available at: http://www.physionet.org/physiobank/database/ptbdb/ [20]. This was the same database used for the Physionet/Computers in Cardiology Challenge 2006 [21]. The PTB ECG data were collected in the 1990s by Dr Michael Oeff et al. at the Department of Cardiology of University Clinic Benjamin Franklin in Berlin, Germany. These investigators used a non-commercial prototype recorder that allowed for the simultaneous acquisition of both 12-lead and true Frank XYZ-lead ECG data stored at 1000 samples per second per channel. Although the PTB ECG database contains data from 290 subjects, we focused our own analyses on data from: *1*) PTB patients 001 through 101, all of whom were being evaluated

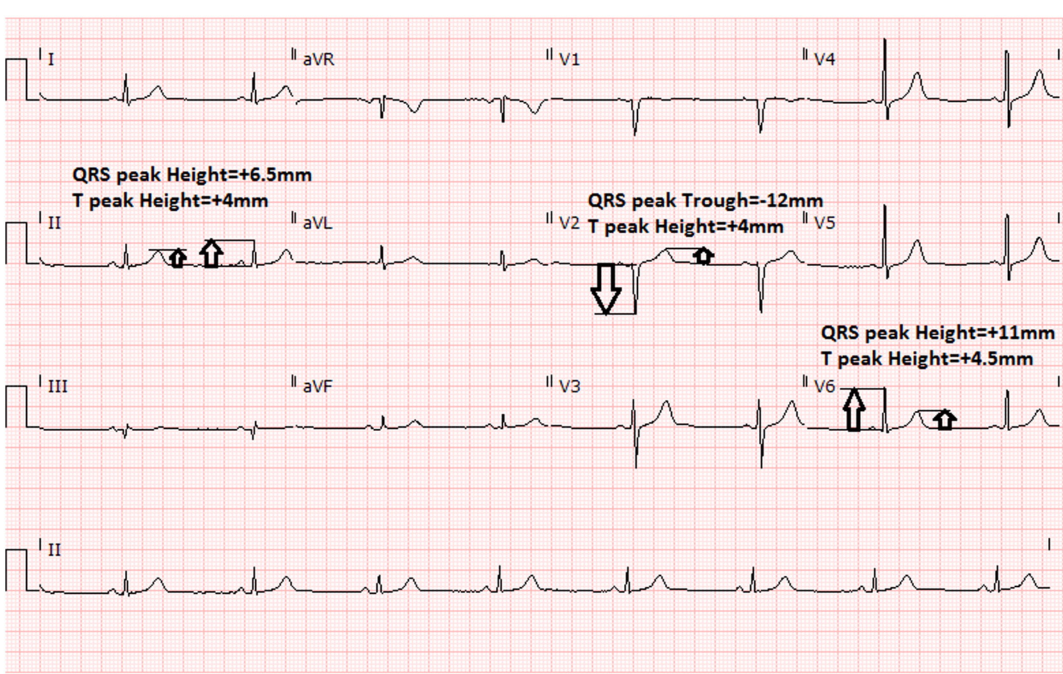

Fig. 1. Example electrocardiogram showing the visual estimates necessary for a spatial peaks QRS–T angle calculation according to Kors' quasi-orthogonal transform. Inserting these visual estimates into the formulas shown in the Appendix: RPx = 11, TPx = 4.5; RPy = 6.5, TPy = 4; RPz = (−0.5 * −12), and TPz = (−0.5 * 4); therefore: $|\mathrm{RP}| = \sqrt{(11)^2 + (6.5)^2 + (-0.5 * -12)^2}$, $|\mathrm{TP}| = \sqrt{(4.5)^2 + (4)^2 + (-0.5 * 4)^2}$ SP QRS−T angle = $\cos\left(\frac{\mathrm{RP}x\mathrm{TP}x+\mathrm{RP}y\mathrm{TP}y+\mathrm{RP}z\mathrm{TP}z}{|\mathrm{RP}||\mathrm{TP}|}\right)^{-1} = 44.8$ degrees.