

Agreement between manual and automated measurements of simple QRS/T angle

Research Article

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Abstract: The spatial QRS/T angle (QRS/T) has been identified as a strong and independent predictor of adverse cardiac events. QRS/T can be determined from the electrocardiogram (ECG) by matrix transformation methods or formula which uses a combination of net QRS and T-wave amplitudes (QRS/T_{simple}). Amplitudes can be measured automatically by using dedicated software (QRS/T_{auto}) or can be manually measured on a computer screen (QRS/T_{manual}). This latter method allows analysis of QRS/T, when digital ECGs are not available. The aim of the study was to determine the agreement in the measurements between automatically derived QRS and T amplitudes and manually measured on the computer screen amplitudes. The relative error of the QRS/T between the two methods was estimated in 73 patients. In the case of QRS/T_{manual} the inter-observer as well as intra-observer variability was estimated. The relative error between QRS/T_{auto} vs. QRS/T_{manual} was 3.51%. Inter-observer and intra-observer variability of the QRS/T_{manual} was 1.19% and 1.18% respectively. Manual measurement of the QRS/T is reliable, however, the predictive value of this parameter should be tested in clinical trials, before QRS/T_{manual} can be considered a useful tool in clinical practice or retrospective studies.

Keywords: QRS/T angle • Risk prediction • Measurement agreement • Accuracy

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1. Introduction

Several recent studies have validated the role of QRS/T angle (QRS/T) as a sensitive, powerful and independent risk stratifier for cardiac events in the general population [1-3] as well as in various clinical settings [4-9].

The QRS/T can be generated automatically by some digital electrocardiographic (ECG) machines that are equipped with appropriate software using matrix transformation methods, or the QRS/T (QRS/T_{simple}) can be approximated from the standard ECG by a formula proposed by Rautaharju et al. [10] that uses a combination of peak-to-peak QRS and T amplitudes from three

ECG leads. Amplitudes needed to calculate QRS/T_{simple} are automatically calculated by some ECG analysis programs, or can be measured on a computer screen. This latter method allows analysis of QRS/T when digital ECGs are not available.

We designed this study to assess the agreement of the measurement of the QRS/T_{simple} calculated by using an ECG analysis program that automatically generate wave amplitude (QRS/T_{auto}) and QRS/T angle calculated using wave amplitudes measured on a computer screen (QRS/T_{manual}).

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2. Methods

2.1. Patients and ECG methodology

Seventy-three Caucasian subjects (37 men and 36 women), aged 23 to 71 years (mean, 55.28 ± 4.58) were selected from patients who came for routine physical checkups. The exclusion criteria were: inflammatory diseases (C-reactive protein > 5 mg/dl), severe liver or kidney damage, abnormal thyroid function tests, NYHA class $\geq$ III heart failure, myocardial infarction during last 6 months, serum potassium ≤ 3.8 or ≥ 5.5 mmol/l, cardiac pacing, Wolff-Parkinson-White syndrome, current atrial fibrillation or flutter, QRS duration ≥ 120 ms or uninterpretable T-wave axis. Also excluded from the study were subjects whose ECGs were of inadequate quality. All subjects gave written consent, and the studies were approved by members of the local ethics committees. All subjects were studied by analysis of surface 12-lead resting ECGs recorded with a computer-based electrocardiograph (Cardioperfect, version 1.1, Cardio-Control NV, Rijswijk, The Netherlands). Special attention was paid to locating the chest electrodes in precise positions. All amplitudes were calculated by a single observer in two ways: automatically by the Modular ECG Analysis System, and manually on a computer screen using a digitizer after scanning the printed ECGs and magnification. Manual measurements were repeated by the same observer on two different occasions and by an independent observer to assess intra-observer and inter-observer reproducibility. The QRS/T_{simple} was calculated by a following formula proposed by Rautaharju et al. [10] using automatically generated wave amplitudes (QRS/T_{auto}) and using wave amplitudes measured on a computer screen (QRS/T_{manual}):

$$QRS/T_{\text{simple}} = \frac{ACOS[(QRS_{\text{net}}V6 \times T_{\text{net}}V5) + (QRS_{\text{net}}aVF \times T_{\text{net}}aVF) + (QRS_{\text{net}}V2 \times T_{\text{net}}V2)]}{(QRS_{\text{sm}} \times T_{\text{sm}})}$$

where ACOS is the inverse cosine; $QRS_{\text{net}} = R - \text{abs}(S \text{ or } QS \text{ whichever is larger})$; $T_{\text{net}} = T_{\text{pos}} - \text{abs}(T_{\text{neg}})$, where T_{pos} and T_{neg} are the largest positive and negative values of the T wave; $QRS_{\text{sm}} = [(QRS_{\text{net}}V6)^2 + (QRS_{\text{net}}aVF)^2 + (QRS_{\text{net}}V2)^2]^{1/2}$; and $T_{\text{sm}} = [(T_{\text{net}}V5)^2 + (T_{\text{net}}aVF)^2 + (T_{\text{net}}V2)^2]^{1/2}$. The subscript abs refers to the absolute value and the subscript sm refers to spatial magnitude,

2.2. Statistical analysis

Statistical analysis was carried out using MedCalc Version 10.2.0.0. Data are expressed as mean $\pm$ SD. The agreement of QRS/T_{simple} measurements by the two

methods as well as the intra-observer and inter-observer agreement was assessed by relative errors calculated according to the formula $((A-B)/((A+B)/2)) \times 100$ [%], where A and B were the values of QRS/T angle measured by the two methods or A represents the first and B the second measurement. The agreement was demonstrated by Altman and Bland plot methods.

3. Results

Baseline clinical characteristics of the studied subjects are shown in Table 1. Women made up 49.3% of the study participants. The prevalence of hypertension was 53.%, and that of old myocardial infarction according to the patient's medical history was 6.9%. Diabetes was present in 15.1% of patients, and left ventricular hypertrophy by the Cornell voltage was observed in 8.2%. The mean heart rate was 73.8 ± 3.61 beats per minute, and QRS duration was 98.6 ± 4.97 ms. The mean QRS/T_{auto} was $76.7 \pm 29.35^\circ$ and QRS/T_{manual} was $79.44 \pm 28.34^\circ$. Abnormally wide QRS/T angles ($> 114^\circ$ for men and $> 97^\circ$ for women [10]) were detected in 13.7% of patients (16.2% in men and 11.1% in women).

The mean $\pm$ SD difference in QRS/T angle between the automatic and manual amplitude measurements (QRS/T_{auto} vs. QRS/T_{manual}) was 2.47 ± 2.39 , and the relative error, 3.51% (Figure 1). The mean bias was 0.6 degree, and 95% limits of agreement was from -6 to 7 degrees (Figure 1). The mean $\pm$ SD difference in QRS/T_{manual} between the two observers was 0.85 ± 1.14 ; the relative error, 1.19 %. The mean $\pm$ SD difference in QRS/T_{manual} angle between two measurements repeated by the same observer was 0.79 ± 0.87 ; the relative error was 1.18%.

Table 1. Baseline characteristics of the studied subjects

Parameter	
Men/women (n/n)	37/36
Age (years)	55.28 ± 4.58
Hypertension or antihypertensive treatment (%)	53.4
Old myocardial infarction by history (%)	6.9
Diabetes mellitus (%)	15.1
Heart rate (bpm)	73.8 ± 3.61
QRS duration (ms)	98.6 ± 4.97
LVH by the Cornell voltage (%)	8.2
QT _{CF} (ms)	389.8 ± 25.9

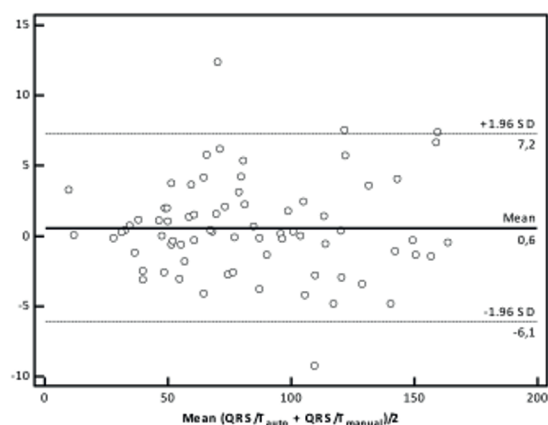
LVH = left ventricular hypertrophy by the Cornell voltage is defined by the (RaVL + SV3) amplitude $2800 \mu\text{V}$ or more in men and $2000 \mu\text{V}$ or more in women [10].
 QT_{CF} = QT interval corrected for heart rate using the Fridericia formula ($QT_{\text{CF}} = QT/RR^{1/3}$)

Table 2. Results of QRS/T_{simple} as well as measured amplitudes (components used for calculation of QRS/T) by automatic and manual measurements

parameter	QRS/T _{simple}		
	auto	manual	p
QRS/T _{simple} (°)	76.7±29.35	79.44±28.34	0.709
QRS _{net} V6 (μV)	1011.3±342.7	1000.8±344.2	0.699
QRS _{net} aVF (μV)	331.2±316.3	327.9±315.6	0.715
QRS _{net} V2 (μV)	-628.1±442.3	-634.5±431.8	0.764
T _{net} V5 (μV)	300.1±137.4	291.1±124.9	0.498
T _{net} aVF (μV)	139.4±39.6	134.4±32.8	0.873
T _{net} V2 (μV)	348.7±195.1	357.9±177.2	0.351

$QRS_{net} = R - \text{abs}(S \text{ or } QS \text{ whichever is larger})$;

$T_{net} = T_{pos} - \text{abs}(T_{neg})$, where T_{pos} and T_{neg} are the largest positive and negative values of the T wave.

**Figure 1.** Bland and Altman plots for agreement between automated and manual measurements of QRS/T_{simple}

4. Discussion

Our study revealed that agreement between automated and manual measurement of QRS/T_{simple} is highly acceptable. The mean bias as well as limits of agreement are small enough to be confident that QRS/T_{manual} can be used in place of QRS/T_{auto} for clinical purposes.

Increasing evidence suggests that QRS/T may be the strongest ECG-derived single independent predictor of adverse cardiac events [1,2], and is probably especially suited for the prediction of arrhythmic cardiac death [4]. The role of QRS/T as a risk predictor has been established both in the general population and in some clinical settings such as stable coronary heart disease, acute coronary syndromes, myocardial infarction, heart failure, and non-ischaemic cardiomyopathy [1-4, 6,11]. However, the wide application of QRS/T may

be challenging because of lack of wide use of digital ECG machines that automatically calculate QRS/T. Recently, Rautaharju et al. [10] found that spatial QRS/T estimated by the formula that uses a combination of net QRS and T-wave amplitudes from three standard leads is a satisfactory substitute for the QRS/T derived from the matrix transformation methods. Moreover, if digitally stored ECG wave amplitudes are not available, amplitudes can be measured manually on the computer screen. Our study shows that manual measurement of QRS/T ensures accurate and repeatable data compared with QRS/T generated from digitally stored ECGs using dedicated software, and that QRS/T_{manual} can be a satisfactory substitute for the QRS/T_{auto}. Additionally, data regarding intra- as well as inter-observer agreement was also accurate and repeatable. According to our knowledge, the agreement in the measurement of QRS/T_{simple} derived automatically and manually from the standard 12-lead ECG has not previously been reported in the literature. QRS/T_{manual} can be useful especially in the retrospective analysis, or in other situations where there is no digital ECG recording. We hope that digital ECG machines that can automatically generate the spatial QRS/T will soon be generally available. Although the QRS/T_{manual} ensures highly accurate and reproducible data, before QRS/T_{manual} can be considered a useful tool in clinical practice or retrospective studies, the predictive value of this parameter should be tested in clinical trials.

Conflict of interest statement

Authors state no conflict of interest.

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