Chapter 11

Normal Limits of the Spatial QRS-T angle and Ventricular Gradient in 12-lead ECGs of Young Adults: Dependence on Sex and Heart Rate

Roderick WC Scherptong
Ivo R Henkens
Sum Che Man
Saskia Le Cessie
Hubert W Vliegen
Harmen HM Draisma
Arie C Maan
Martin J Schalij
Cees A Swenne

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ABSTRACT

Background & purpose

Normal limits of the spatial QRS-T angle and spatial ventricular gradient (SVG) are only available from Frank vectorcardiograms (VCGs) of male subjects. We determined normal limits for these variables derived from standard 12-lead ECGs of 660 male and female students aged 18 to 29 years.

Methods

A computer algorithm was used that constructed approximated VCG leads by inverse Dower matrix transformation of the 12-lead ECG and subsequently calculated the spatial QRS-T angle, SVG magnitude and orientation.

Results

In female subjects, the QRS-T angle was more acute (females: 66 ±23°, normal 20 – 116°; males: 80 ±24°, normal 30 – 130°; P<0.001) and the SVG magnitude was smaller (females: 81 ±23 mV·ms, normal 39 – 143 mV·ms; males: 110 ±29 mV·ms, normal 59 – 187 mV·ms; P<0.001) than in male subjects. The male SVG magnitude in our study was larger than that computed in Frank VCGs (79 ±28 mV·ms; P<0.001).

Conclusions

The spatial QRS-T angle and SVG depend strongly on sex. Furthermore, normal limits of SVG derived from Frank VCGs differ markedly from those derived from VCGs synthesized from the standard ECG. As nowadays VCGs are usually synthesized from the 12-lead ECG, normal limits derived from the standard ECG should preferably be used.

INTRODUCTION

The spatial QRS-T angle and the spatial ventricular gradient (SVG) are classical electrocardiographic parameters that provide information on functioning of the cardiac conduction system and on heterogeneity in ventricular action potential durations.[1, 2]

The spatial QRS-T angle is the angle between the QRS- and T-axis in the plane that these axes form. This angle differs from the commonly calculated angle between the projections of QRS- and T-axes in the frontal plane. In normal subjects, repolarization in the free lateral wall tends to proceed in opposite direction to that of depolarization. In the septum and other myocardial regions, these relationships vary. Overall, the mean direction of repolarization (T) is closer to perpendicular rather than strictly reverse to that of depolarization (QRS).[3] This results in an acute spatial QRS-T angle, which corresponds to a predominantly concordant ECG. When pathological changes occur, the ECG becomes more discordant and the spatial QRS-T angle widens.[4] A recent study by Kardys et al. demonstrated that in the general population the risk of cardiovascular death is higher for patients with a wide spatial QRS-T angle.[2] In a report by Yamazaki et al., a wide spatial QRS-T angle wider was associated with an increased risk of cardiovascular death in a clinical population.[5] Therefore, the spatial QRS-T angle is potentially a useful parameter for risk assessment in general and clinical populations.

The ventricular gradient (VG) is defined as the QRST integral and can be determined in any ECG or VCG lead [6] by calculating the total area under the curve over the QT interval (positive deflections are counted positive, negative deflections are counted negative). By including directional characteristics of the cardiac vector in the calculation, the *spatial* ventricular gradient (SVG) can be obtained. This SVG vector is the vectorial sum of the (spatial) QRS and T integral vectors, which have the same orientations as the QRS and T axes. Hence, the spatial QRS-T angle relates to the SVG in the sense that the spatial QRS-T angle is equal to the angle between the QRS and T integral vectors and the SVG is the vectorial sum of these vectors (Figure 1). From a theoretical point of view, the SVG is not influenced by changes in ventricular conduction pattern; it only changes if the distribution of the action potential morphology and/or duration across the myocardium is altered.[1, 7, 8] In agreement with this, Mashima and colleagues demonstrated, in patients with left ventricular hypertrophy, that presence or absence of left bundle branch block was not associated with a different ventricular gradient magnitude.[9]

Gärtner et al.[10] investigated whether frontal projections of the VG can discriminate health from cardiac disease and concluded that the VG lacks diagnostic accuracy. Simonson commented on this research by stating that frontal projections of the VG do not sufficiently reflect electrical activity in the other directions.[6] Nonetheless, after the first disappointing results were reported on the clinical applicability of the VG, it was largely abandoned. Unfortunately, this left multiple questions concerning the *spatial* VG unanswered and the clinical value of

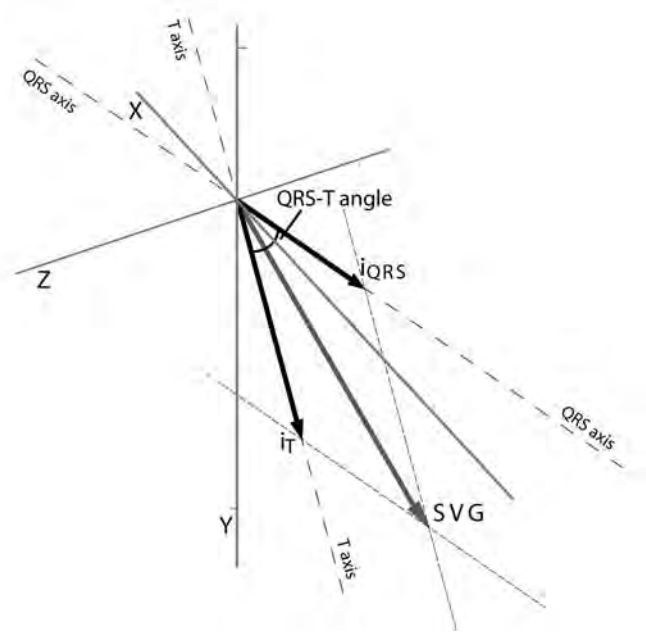

Figure 1. QRS- and T-integrals, spatial QRS-T angle and ventricular gradient. The black arrows denote the QRS- and T integrals, which have the same orientation as the QRS- and T axes (dashed lines). The spatial QRS-T angle is the angle between the QRS- and T axes and the spatial ventricular gradient (SVG, grey arrow) is the vectorial sum of the QRS- and T integrals. The geometrical relation between iQRS, iT, spatial QRS-T angle and SVG is important for understanding the factors that affect the spatial ventricular gradient: the SVG decreases with decreasing iQRS and/or iT and with increasing spatial QRS-T angle. For further explanation, see Draisma et al..[1]

the SVG, in combination with the spatial QRS-T angle, as general descriptors of the ECG, remains to be studied.

For use of these parameters in clinical practice, knowledge about normal variations and the availability of normal limits, derived from healthy subjects, is of unequivocal importance. Pioneering work in this field was done by Pipberger and colleagues. They were the first to publish normal limits of spatial QRS-T angle and the SVG derived from 8-electrode 3-lead Frank vectorcardiograms (VCGs) of 518 normal men.[11, 12] Nowadays, the recording of Frank VCGs has passed into disuse and is replaced by VCGs that are synthesized from standard ECGs, using a conversion matrix.[13] To the best of our knowledge, no studies have been published that define standard ECG-based normal limits of the spatial QRS-T angle and SVG computed from large samples of young healthy males and females.

Therefore, the aim of our study was to determine normal limits of the spatial QRS-T angle as well as the spatial ventricular gradient magnitude and orientation, as derived from synthesized VCGs of young adult males and females.

METHODS

The research protocol of this study was approved by our institutional Medical Ethics Committee.

Subjects

In the course of their education, standard 10-second 12-lead ECGs were obtained from medical students of the Leiden University. Participation was voluntary and all students gave written informed consent. Height and weight were measured, body mass index (BMI) was calculated, and body surface area (BSA) was assessed using Mosteller's formula.[14] All ECGs were scrutinized for normality based on the Minnesota ECG coding protocol[15] by an attending cardiologist. Normal ECGs were included when subjects fulfilled the following criteria: age between 18 yrs and 29 yrs and heart rate between 50 beats per minute (bpm) and 100 bpm (Minnesota criterion 8-7, 8-8). All ECGs were recorded with Megacart electrocardiographs (Type 4.9, Siemens, Germany) and electronically stored in a Megacare ECG management system (VF 2.1, Dräger, Germany.)

Electrocardiographic Analysis

ECGs were exported from the ECG database management system and analyzed with the MATLAB-based (The MathWorks, Natick, USA) computer program LEADS (Leiden ECG Analysis and Decomposition Software).[16] LEADS first detects all QRS complexes and corrects the baseline. Then, supervised beat selection for subsequent beat averaging is done; acceptation/rejection of beats is based on signal-to-noise ratio, on interbeat interval regularity and on representative QRS-T morphology. After computation of the averaged ECG complex, an averaged VCG complex is synthesized using the inverse Dower matrix.[13, 17] In the averaged ECG complex, the onset of the QRS complex, the J point and the end of the T wave are detected automatically. The default position of the J point can be adjusted manually with a crosshair-cursor procedure, facilitating accurate placement according to the Minnesota ECG coding protocol. Global end of T is calculated in the vector magnitude signal as the intersection of the steepest tangent to the descending limb of the T wave and the base-line.[18] Given these landmarks in time, the spatial QRS-T angle as well as the SVG azimuth, elevation and magnitude are computed as follows. First, the QRS and T integrals, i_{QRS} and i_T, are both approximated by calculating the numerical sum of X-Y-Z deflections (amplitudes of positive deflections are added and of negative deflections are subtracted) in 2 ms intervals (corresponding to 500 samples/s) covering the QRS complex and T wave. The spatial QRS-T angle is the angle between i_{QRS} and i_T and the SVG is calculated as the vectorial sum of i_{QRS} and i_T. Axis directions, defined as azimuth and elevation, are represented in accordance with the AHA vectorcardiography coordinates standard[19] in our study.

Statistical Analysis

SPSS (12.0.1, SPSS Inc., USA) was used for statistical analysis. Where appropriate, data are reported as mean with standard deviation (SD). Values of the spatial QRS-T angle and SVG were calculated separately for males and females and compared using an unpaired Student t-test. To identify factors that potentially explain differences in spatial QRS-T angle and SVG between males and females, differences in electrocardiographic characteristics (mean QRS vector magnitude/orientation, mean T vector magnitude/orientation, QRS integral, T integral) and anthropomorphic measurements (height, weight, BMI, BSA) were computed and compared. Moreover, Pearson correlation coefficients were calculated between the aforementioned electrocardiographic characteristics and the spatial QRS-T angle and SVG. Furthermore, Spearman rank correlations were calculated between the anthropomorphic measurements and the spatial QRS-T angle and SVG. Thereafter, multiple linear regression was used to correct male/female differences in spatial QRS-T angle and SVG for dissimilarities in anthropomorphic measurements between males and females.

Normal limits were set at the 2nd and 98th percentile.[11] Single linear regression was used to calculate normal limits for SVG magnitudes depending on heart rate. Here SVG was logarithmically transformed to meet the assumptions for single linear regression (constant variance). Normal limits (2nd and 98th percentile) were obtained for the log-transformed SVG by adding and subtracting 2.05 times the residual SD to/from the regression equation. The obtained normal limits were then transformed back into the original scale.

RESULTS

ECGs were made in 804 subjects. The ECGs of 67 subjects were excluded because of technical reasons (electrode displacement, missing leads, signal noise), 22 ECGs were considered abnormal according to the Minnesota criteria, in 41 subjects the heart rate criteria were not met and 14 subjects did not meet the age criteria. Thus, the ECGs of 660 (449 female, 211 male) subjects were included in the analysis. The anthropomorphic and demographic characteristics of this study group are presented in Table 1.

Table 2 summarizes the descriptive statistics and the observed normal limits in the form of the 2nd and 98th percentile of all electrocardiographic characteristics. Furthermore, a graphical representation of SVG orientation in relation to SVG magnitude is given in Figure 2. The mean values of the spatial QRS-T angle and the SVG in males differed significantly from the mean values of female subjects. Male subjects had significantly wider spatial angles and larger SVG magnitudes as compared to female subjects. Furthermore, the SVG orientation in males was more anterior and slightly more superior than in female subjects.

Table 1. Characteristics of the female and male subjects.

	Female subjects (n=449)	Male subjects (n=211)
Age (yrs)	19.6 ± 1.1	20.1 ± 1.6
Height (m)	1.71 ± 0.06	1.82 ± 0.07
Weight (kg)	62.8 ± 8.1	74.3 ± 10.0
BMI (kg/m^2)	21.4 ± 2.4	22.2 ± 2.7
BSA (m^2)	1.7 ± 0.13	1.9 ± 0.14
Heart rate (bpm)	73 ± 11	72 ± 11

BMI: Body Mass Index; BSA: Body Surface Area; bpm: beats per minute. All data are presented as mean ±SD.

Table 2. Normal limits of the spatial QRS-T angle and ventricular gradient.

	Female subjects					Male subjects				
	Mean	**SD**	**Median**	**2%**	**98%**	**Mean**	**SD**	**Median**	**2%**	**98%**
QRS-T angle (°)	66 a	23	67	**20**	**116**	80 [a]	24	81	**30**	**130**
$SVG_{magnitude}$ (mV*ms)	81[a]	23	79	**39**	**143**	110[a]	29	107	**59**	**187**
$SVG_{azimuth}$ (°)	-13[a]	14	-15	**-38**	**20**	-23[a]	15	-24	**-52**	**13**
$SVG_{elevation}$ (°)	30[a]	8	30	**12**	**48**	27[a]	9	28	**8**	**47**
QRS duration (ms)	87[a]	8	86	**70**	**104**	94[a]	9	94	**76**	**112**
Mean QRS vector (µV)	405[a]	131	395	**182**	**724**	499[a]	174	501	**179**	**939**
QRS $axis_{azimuth}$ (°)	37	24	37	**-16**	**96**	41	27	27	**-16**	**90**
QRS $axis_{elevation}$ (°)	32	12	32	**3**	**57**	30	12	32	**1-**	**53**
QRS integral (mV*ms)	34.8[a]	11.3	34.0	**15.9**	**62.3**	46.5[a]	15.6	46.0	**16.2**	**83.3**
QTc interval (ms)	406[a]	23	407	**360**	**456**	390[a]	22	390	**339**	**440**
Mean T vector (µV)	214[a]	64	210	**96**	**360**	348[a]	93	338	**156**	**580**
T $axis_{azimuth}$ (°)	-36[a]	13	-37	**-60**	**-5**	-47[a]	13	-48	**-71**	**-15**
T $axis_{elevation}$ (°)	21[a]	9	21	**-1**	**37**	16[a]	8	16	**1**	**36**
T integral (mV*ms)	60.8[a]	19.0	58.2	**28.3**	**102.7**	91.4[a]	24.4	89.3	**41.9**	**150.0**

Descriptive statistics and normal limits for females and males separately. SVG: spatial ventricular gradient. Bold numbers represent normal limits. [a] Difference between males and females, significant at the 0.001 level.

Table 3 lists the correlations between SVG magnitude, spatial QRS-T angle and vector characteristics, for males and for females. A weak inverse correlation was present between the spatial QRS-T angle and the SVG magnitude in males and females, indicating that wide spatial QRS-T angles were associated with small SVGs. The mean QRS vector magnitude and QRS integral correlated positively with the SVG magnitude and the correlation was stronger in females as compared to males. Strong, positive, correlations, similar in both sexes, were observed between the mean T vector magnitude, the T integral and the SVG magnitude. The correlation between the QRS and T integrals on one hand and SVG magnitude on the other hand is depicted in Figure 3. QRS duration was not correlated to SVG magnitude in females, but demonstrated a weak positive correlation in males. JT interval was correlated with SVG magnitude similarly in both sexes.

The Spearman rank correlations between, on one hand, the spatial QRS-T angle and the SVG and, on the other hand, the anthropomorphic subject characteristics and heart rate are listed in

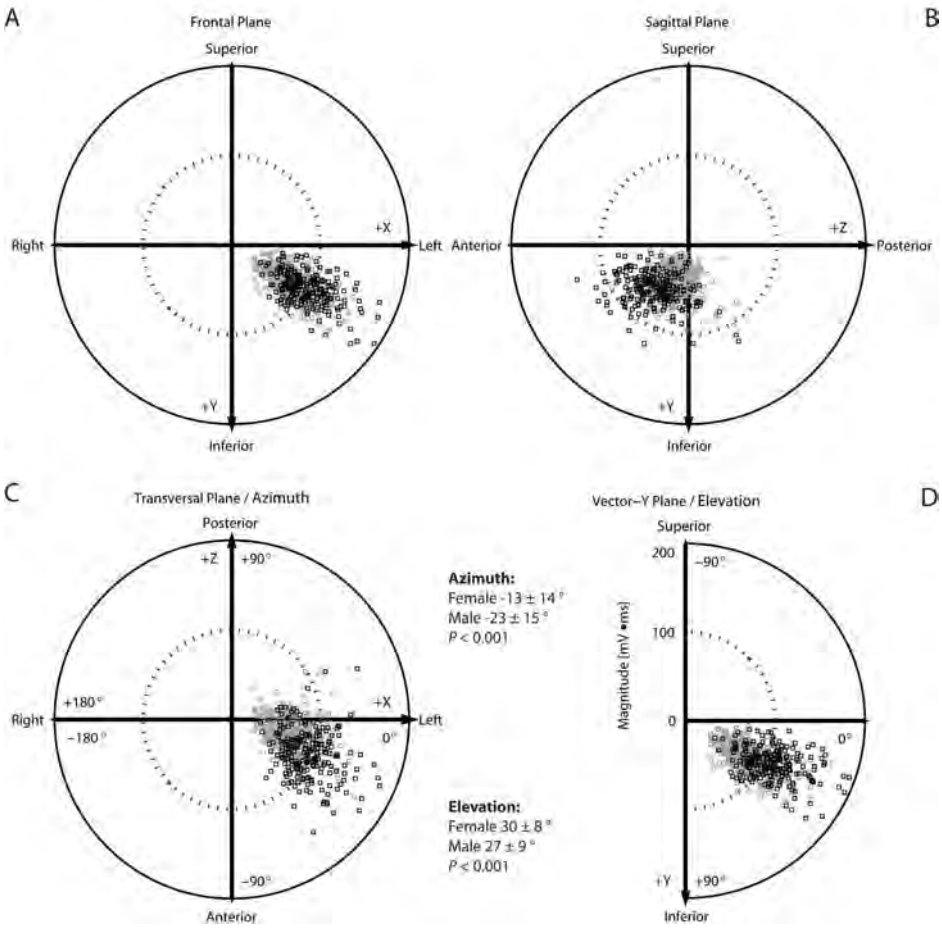

Figure 2. Orientation and magnitude of the spatial ventricular gradient. Spatial ventricular gradients as measured in our study group. Grey squares = female subjects; black squares = male subjects. Panels A, B and C: Projections of the spatial ventricular gradients in the frontal, sagittal and transversal planes. The azimuth of SVG can readily be seen in the transversal plane. Combination of these figures demonstrates that the ventricular gradient vector points to the left, forward and downward, which is in the direction of the cardiac apex. Panel D: Elevation and magnitude of the spatial ventricular gradient. Azimuth, elevation, and directions of the positive X-, Y- and Z-axes are in accordance with the AHA vectorcardiography coordinate standard.[19]

Table 4. Several correlations reached significance but were weak. A relatively strong correlation of -0.36 in females and -0.46 in males was found between SVG magnitude and heart rate.

As readily appreciable in Figure 4, the distribution of the SVG magnitudes was wider for lower heart rates than for higher heart rates. Therefore, SVG magnitudes were logarithmically transformed after which a single linear regression of log ($SVG_{magnitude}$) on heart rate (HR) was made. The following regression equations were found:

Table 3. Correlation between the spatial ventricular gradient, QRS-T angle and the cardiac vector for males and females.

	QRS-T angle	Mean QRS vector	QRS duration	QRS integral	Mean T vector	JT interval	T integral
Males							
SVGmagnitude	-0.46[a]	0.24[a]	0.17[b]	0.30[a]	0.72[b]	0.29[a]	0.82[a]
Females							
SVGmagnitude	-0.35[a]	0.56[a]	0.03[c]	0.58[a]	0.80[a]	0.27[a]	0.86[a]

Pearson correlation coefficients between SVG, QRS-T angle and vector characteristics. SVG, spatial ventricular gradient. a Significant at the P= 0.01 level; b Significant at the P= 0.05 level; c NS

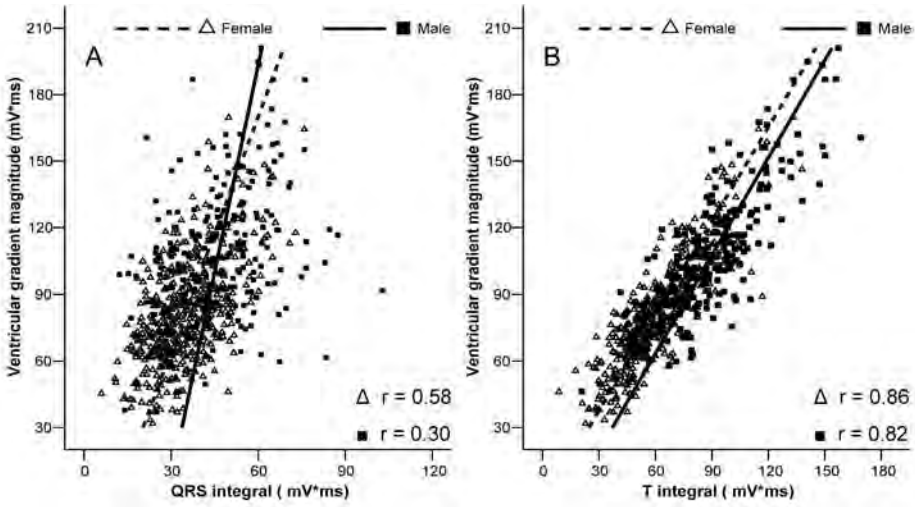

Figure 3. Association between QRS integral, T integral and SVG magnitude. Linear correlations between the integrals of QRS and T on one hand and SVG magnitude on the other hand. Panel A shows that a weak correlation was present between the QRS integral and SVG magnitude, whereas panel B demonstrates a strong correlation between the T integral and SVG magnitude, indicating that repolarization characteristics are most important for the SVG magnitude.

Female subjects: $^{10}\log(SVG_{magnitude}) = 2.18 - 3.95 * 10^{-3} \cdot HR$ (SD = 0.12)

Males subjects: $^{10}\log(SVG_{magnitude}) = 2.38 - 4.89 * 10^{-3} \cdot HR$ (SD = 0.11)

Multiple linear regression analysis was performed to investigate the potential influence of height, weight, BMI and BSA on the female-male differences found in the SVG and the spatial QRS-T angle. This, however, did not yield significant further explanation of the female-male differences observed. Also, the sex coefficient did almost not change in the multiple linear regression model.

Table 4. Correlation between anthropomorphic characteristics, the QRS-T angle and the spatial ventricular gradient.

		HR	Height	Weight	BMI	BSA
Female	QRS-T angle (°)	0.11[b]	0.05	-0.07	-0.13[b]	-0.04
	$SVG_{magnitude}$ (mV*ms)	-0.36[a]	0.14[a]	0.11[b]	0.05	0.12[b]
	$SVG_{azimuth}$ (°)	-0.06	0.07	0.08	0.03	0.08
	$SVG_{elevation}$ (°)	0.00	0.05	-0.05	-0.10[b]	-0.03
Male	QRS-T angle (°)	0.21[a]	0.03	-0.04	-0.01	-0.02
	$SVG_{magnitude}$ (mV*ms)	-0.46[a]	0.06	0.01	-0.04	0.03
	$SVG_{azimuth}$ (°)	0.09	-0.02	-0.13	-0.12	-0.12
	$SVG_{elevation}$ (°)	0.13	0.05	-0.12	-0.20[a]	-0.09

Spearman rank correlation coefficients between subject characteristics, the QRS-T angle and the SVG. SVG: spatial ventricular gradient; HR: heart rate; BMI: body mass index; BSA: body surface area. [a]Correlation is significant at the 0.01 level. [b]Correlation is significant at the 0.05 level.

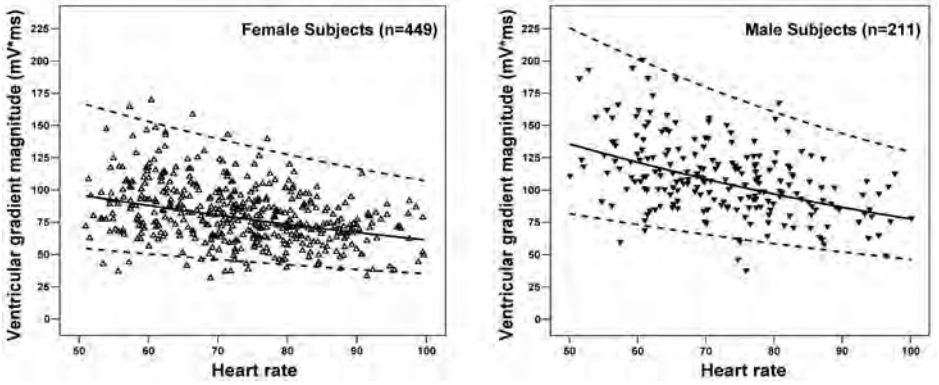

Figure 4. Heart rate and the spatial ventricular gradient magnitude. Logarithmic regression of the spatial ventricular gradient magnitude on heart rate in male and female subjects. The upper and lower (dashed) lines denote the 96% prediction interval.

DISCUSSION

In the present study, we established normal limits of the spatial QRS-T angle and the SVG in young adults. Key findings were that all values of male and female subjects, even after correction for anthropomorphic measurements, differed significantly. This underscores the necessity for defining distinct normal limits for male and female subjects. In addition, the correlation of SVG magnitude with the T integral was stronger than the correlation with the QRS integral, signifying that repolarization characteristics are more important than depolarization characteristics for the magnitude of SVG in ECGs of young adult normal subjects. Moreover, there was a significant influence of heart rate on the spatial ventricular gradient magnitude: Higher heart rates were associated with smaller magnitudes of the spatial ventricular gradient.

Differences between male and female subjects

The spatial QRS-T angle and SVG both strongly depended on sex. In our study, male subjects had a larger spatial QRS-T angle and a larger SVG magnitude than female subjects. The most important sex-dependent difference in SVG orientation was found in the SVG azimuth, which was directed more anteriorly in males than in females. The difference in SVG elevation between males and females, albeit significant, was small (3°). Also, normal limits of SVG elevation were almost equal in males and females, the actual difference in lower and upper bound of normal limits being 4° and 1° respectively.

In our study, the mean spatial QRS-T angle was 80° for males and 66° for females. In a study by Rautaharju et al.,[20] in which ECG predictors of mortality were investigated in a large (n=4,912) community-based population of older subjects (ages>65 yrs), similar differences between male and female subjects for the spatial QRS-T angle were found. They reported a mean spatial QRS-T angle of 81° for males (mean age 72.8 ± 5.7 yrs) and a mean spatial QRS-T angle of 67° for females (mean age 72.2 ± 5.3 yrs).

Sex-related differences in SVG magnitude were investigated in a small young (ages 20–30 yrs) group of 30 male and 30 female Japanese subjects, by Yamauchi and colleagues.[21] They found comparable differences between the SVG magnitude in males (105 mV·ms vs. 110 mV·ms in our subjects) and females (81 mV·ms, vs. 81 mV·ms in our subjects).

It is unclear where the differences in spatial QRS-T angle and SVG between male and female subjects exactly originate. The orientation of the QRS axis was similar in male and female subjects (Table 2). The orientation of the T axis, however, was significantly more anterior in male (-47°) as compared to female subjects (-36°). As a consequence, the angle between the QRS- and T axis, the spatial QRS-T angle, was wider in male subjects. In general, widening of the angle between two vectors results in a smaller vectorial sum of these vectors (assuming a constant magnitude of these vectors, Figure 1). The inverse correlation between the spatial QRS-T angle and the SVG in the present study population underscores this principle (wide spatial QRS-T angles were associated to small SVGs). However, in our population, male subjects have larger QRS and T integrals and therefore we observed a greater SVG magnitude in spite of a wider spatial QRS-T angle in male subjects.

In our population of normal subjects, significant correlations between the SVG magnitude and vector characteristics were present. Whereas the correlation between SVG magnitude and mean QRS vector magnitude was relatively weak, the correlation between SVG magnitude and the mean T vector magnitude was much stronger in both male and female subjects (Figure 4). This observation demonstrates that, in the normal heart, repolarization (T-wave) characteristics are more important for the magnitude of SVG than depolarization (QRS complex) characteristics. As a consequence, the observed differences in the spatial QRS-T angle and SVG between males and females are likely to originate from repolarization rather than from depolarization characteristics. The anthropomorphic measurements weight, height and

thereof derived parameters correlated only weakly correlated to SVG and the spatial QRS-T angle (Table 3) in the present study. In a multiple linear regression model, these parameters were not explanatory for the differences in the SVG and the spatial QRS-T angle between male and female subjects. Possibly, explanation of the male-female difference is partially to be found in a different ratio between thorax dimensions and heart size, a different amount of subcutaneous fat, and presence of breast adipose tissue in female subjects.[22] Furthermore, parameters that relate to the difference in cardiac morphology between males and females (e.g., ventricular mass, wall thickness) may further explain the difference in spatial QRS-T angle, SVG magnitude and SVG orientation.[23, 24]

Comparison with earlier published normal limits

Until now, the publications of Pipberger and associates[11, 12] were the only source for normal limits of the spatial QRS-T angle and SVG. Important differences in both normal limits and means of the SVG magnitude and SVG elevation are present between our study and these former studies. The most striking differences in normal limits are found in the ventricular gradient magnitude and the ventricular gradient elevation upper limits. In our study, the upper normal limit of the ventricular gradient magnitude is 47 mV·ms larger and the elevation is 16° smaller than reported by the Pipberger group.[11, 12] Moreover, differences of the same order of magnitude and direction are seen in the mean value of these parameters (31 mV·ms and 9°, respectively).

Diversity in the composition of the study groups and/or a methodological difference may underlie these differences. Firstly, the study group of Pipberger and colleagues consisted of hospitalized men without evidence for cardiac disease. In that study group, non-cardiac disease and the administration of non-cardiac medication could have induced changes in cardiac electrophysiology resulting in (temporary) changes of the spatial QRS-T angle and/or SVG.[25] Secondly, life-style, dietary and racial differences between the study populations may also explain part of the observed differences.[26, 27] Thirdly, Pipberger and colleagues excluded heart rates lower than 60 bpm and, because lower heart rates are associated with larger SVG magnitudes (Figure 4), this may have selectively filtered out large SVG magnitudes. Finally, Pipberger and associates used 8-electrode 3-lead Frank VCGs instead of VCGs synthesized from standard 10-electrode 12-lead ECGs which is most commonly used nowadays.[2, 20] Obviously, this affects the shape of the vector loop and, consequently, may influence the spatial QRS-T angle and/or SVG.

Limitations

In our study, normality of the subjects was not confirmed by obtaining a history, a physical exam or complementary investigations. However, the ECGs of included subjects were closely scrutinized for abnormalities, which makes the likelihood of systematical inclusion of abnormal subjects small. A second limitation is that only young subjects (18–29 yrs) were investigated in our study. Previous studies demonstrated that particularly SVG is a parameter that decreases with age.[12, 21] Therefore, further studies should include subjects from all ages.

Implications

Recently, the spatial QRS-T angle was described as a risk stratifier for cardiovascular death in a study by Kardys et al.[2] and by Yamazaki and colleagues.[5] In these studies, the upper limit of the spatial QRS-T angle in the low risk group was defined as 105° and as 100°, respectively. However, our study demonstrates that the normal spatial QRS-T angle can range up to 116° in females and 130° in males. In our study group, 44 males and 33 females have a spatial QRS-T angle wider than 100° and 32 males and 22 females have a spatial QRS-T angle wider than 105°. It is unlikely that all these subjects should be classified as at high risk for cardiovascular death. This indicates that risk stratification criteria for the occurrence of cardiovascular death as applied by Kardys and by Yamazaki may have been too strict. In addition, they should have been different for male and female subjects.

CONCLUSIONS

The spatial QRS-T angle and the spatial ventricular gradient orientation and magnitude differ significantly between female and male subjects. In male subjects, the spatial QRS-T angle is wider and the spatial ventricular gradient magnitude is larger. Furthermore, the spatial ventricular gradient orientation is more anterior in male subjects as compared to female subjects. In addition, the spatial ventricular gradient magnitude strongly depends on heart rate. High heart rates are associated with small spatial ventricular gradient magnitudes; this should be taken into account when assessing the normality of a spatial ventricular gradient magnitude.

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