Quantitative VCG and BSPM Repolarization Parameters Evidence Increased Sympathetic Activation of the Ventricular Myocardium in Different Adrenergic Situations

V. Regecová, E. Kellerová

Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia

Email: valeria.regecova@gmail.com

Abstract. *Participation of the sympathetic nervous system (SNS) in normal or pathological regulations of the heart is in present studies documented mainly by blood pressure (BP) and heart rate (HR) derived indexes. The previously proposed parameters characterizing ventricular repolarization were used in this study to detect the presumed effect of SNS hyperactivity on the ventricular myocardium in prehypertensive subjects and in sympathergic situations. In 75 healthy boys and men, aged 15 – 35 years with optimal, normal and high normal BP and normal or increased body fat proportion (BF), the BP, HR, QTc index, rate pressure product (RPP), magnitude of the maximal spatial repolarization vector (sTmax) and amplitude of the isointegral repolarization map (RIMampl) were evaluated. Compared to subjects with optimal casual BP ≤120/80 mmHg, already in the class defined as normal and high normal BP (ESH/ESC 2013), the differences in repolarization parameters point to significantly higher sympathetic outflow to the ventricular myocardium at rest, similar to changes due to psycho-emotional or postural reactions. An additional factor – higher proportion of BF amplified the sTmax and RIMampl signs of the direct myocardial SNS effects.*

Keywords: Ventricular repolarization; VCG and BSPM; Sympathetic activation; Stress; Prehypertension; Obesity

1. Introduction

The first convincing evidence about the contribution of a permanently increased sympathetic drive of central origin to the onset of human primary hypertension came in the late 1950's, based on experimental studies by Brod et al.[1]. They documented in borderline hypertensives already at rest a cardiovascular pattern similar to that displayed in emotional defense reactions. Another study revealed a 70% prevalence of a hyperkinetic circulation in young hypertensives [2]. Increased HR, or low frequency components of the power spectral density of HR variability are the noninvasive, easily accessible parameters, most frequently used in clinical and physiological studies to estimate the enhanced sympathetic activation of the heart. However these measures reflect mainly the sympathetic and parasympathetic interaction in the control of the pacemaker activity, but not necessarily the specific sympathetic effect on ventricular myocardium. VCG and BSPM parameters characterizing ventricular repolarization - namely the magnitude of the maximal spatial repolarization vector (sTmax), the spatial angle between QRS and T vectors and the peak-to-trough amplitude of the integral STT BSPM (RIMampl) - have repeatedly been shown to carry information on the direct effect of sympathetic activation on the ventricular myocardium, in a variety of physiological situations involving autonomic cardiovascular control in normal subjects [3]. With the aim to assess the presumably increased sympathetic drive of the cardiac ventricles, these descriptors were analyzed in young subjects with optimal, normal and high normal BP (according the ESH/ESC 2013 stratification) - at rest, as well as during sympathergic psycho-emotional and postural reactions, and with respect to different body fat proportion.

2. Subject and Methods

A total of 75 healthy boys and men, aged 15 – 35 years were enrolled in the study, divided in subgroups, to investigate the effect of high normal BP, increased body fat percentage and of sympathergic situations (psycho-emotional stress, head-up tilting,). There were 23 subjects with optimal BP ≤ 120/80 mmHg and body fat percentage (BF) ≤15%, 46 in the range of normal and high normal BP, according to the ESH/ESC (2013) stratification, 21 of them were with BF proportion ≤ 15% and 31 with increased BF >15%.

PC based electrocardiographic system CARDIAG 128.1 was used to record, and partly processed by the Frank lead system VCGs and body surface potential maps (BSPM) from 80 electrode sites. Simultaneously BP was measured oscilometrically by an OMRON M10 IT device. From a selected single beat the maximal spatial vector of ventricular depolarization (sQRSmax) and repolarization (sTmax), spatial angle between integral QRS and STT vectors (QRS-T angle), the peak-to-trough amplitude of the isointegral repolarization maps (RIMampl), the RR and QTc intervals were evaluated. For the detailed processing of isointegral maps see [4]. As an estimate of the major determinant of the cardiac oxygen consumption, the rate pressure product (*RPP = BPsyst * HR/100*) was calculated.

The recordings were performed in following situations: lying supine at rest (SUP), tilted head-up to 60^{o} (TILT), after an intermission sitting rest (SIT) and using stressful mental arithmetic as an emotional stimulus (MA). Chi-square, Student-t tests and / or two-way ANOVA were used for statistical evaluation and the minimal level of significance was set to $P < 0.05$.

3. Results

Comparing to the control subgroup with BP ≤ 120/80 mmHg and BF proportion ≤ 15%, already in the group of subjects with normal and high normal BP (median 131/85 mmHg and BF ≤ 15%), all seated at rest, a significantly decreased magnitude of the maximal spatial repolarization vector (sTmax) by 25%, of amplitude of the STT body surface map (RIM ampl) by 20%, shortened R-R by 14% and an increased rate pressure product (RPP) by 35% were found. (Table 1, subgroup 2). There was an expected trend for increased QRS-T angle by 4%.

When an additional risk factor - higher body fat proportion >15% was considered (Table1, subgroup 3), all above mentioned differences were amplified - decrement of sTmax was 39%, RIM ampl 40%, R-R 19%, increase of RPP 55% and of the QRS-T angle 10%.

The differences between subgroups 1 – 3 are evident also in horizontal and tilted body posture (Table 2) and in the MA test (Table 1).

Changes in the repolarization parameters due to the elevated BP and increased BF%, are similar to those, which were evoked by sympathergic test situations, namely by emotional stress induced by MA in sitting position (Table 1, subgroup 1 - 3), compared to rest supine, with significant diminution of sTmax by 17 - 24%, RIM ampl by 30 - 42%, R-R by 25 – 31%, an increase of RPP by 53% and of the QRS-T angle by 27– 49%

Tilting head-up (Table 2, subgroup 1 - 3) caused significant diminution of sTmax by 16 -25%, RIM ampl by 10 - 12%, R-R shortening by 16 -20%, change of RPP from –16 to +26% and an increase of QRS-T angle by 27 – 41%.

The sQRSmax vector as a parameter defining depolarization did not change meaningfully in any situation. Interestingly some correlations of sTmax and RIMampl, with BP and QTc significant at rest, decrease or disappear in reactive situations.

Table 1. Mean values of blood pressure, R-R and QTc intervals, magnitude of maximal spatial repolarization vector (sTmax) and amplitude of integral repolarization map (RIMampl), during the test of mental arithmetics (MA), compared with values sitting at rest (SIT).

	Blood pressure [mm Hg]		R-R interval [ms]		QTc interval [ms]		sTmax [μV]		RIMampl [μVs]	
	SIT	MA	SIT	MA	SIT	MA	SIT	MA	SIT	MA
1	112/75	**129/85**	959	**775**	392	**420**	588	**538**	162	**146**
2	132/81 *	**142/91 ***	821 *	**648 ***	403	**436**	442 *	**393 ***	130 *	**114 ***
3	132/83 *	**140/90 ***	781 *	**652**	397	**416**	360 *	**329 ***	98 *	**87 ***
All	124/80	**135/88**	846	**694**	397	**423**	452	**415**	128	**115**

Table 2. Mean values of blood pressure, R-R and QTc intervals, magnitude of maximal spatial repolarization vector (sTmax) and amplitude of integral repolarization map (RIMampl), in head-up tilted position to 60° (TILT), compared with values at rest supine (SUP)

	Blood pressure [mm Hg]		R-R interval [ms]		QTc interval [ms]		sTmax [μV]		RIMampl [μVs]	
	SUP	TILT	SUP	TILT	SUP	TILT	SUP	TILT	SUP	TILT
1	118/72	**116/83**	1074	**861**	392	**417**	648	**542**	209	**188**
2	135/76*	134/**92 ***	941 *	**792**	402	**416**	554*	**424 ***	199	**181**
3	135/79*	**131/88 ***	873 *	**715 ***	395	**410**	433*	**326 ***	149 *	**131 ***
All	128/76	**125/87**	948	**786**	398	**414**	529	**424**	179	**159**

Subgroups: 1= BP ≤ 120/80 mmHg with BF ≤15 % (control)
2 = BP normal and high normal with BF ≤15 %
3 = BP normal and high normal with BF >15 %

Bold – significant change vs sitting / supine rest p<0.05

* significant vs control subgroup p<0.05

4. Discussion and Conclusion

The discriminative power of the VCG and BSPM repolarization parameters was strong enough to distinguish the changes in the cardiac electric field in adolescents and young adults with elevated BP - just above the limit of its optimal value, and in subjects with increased body fat proportion. Decreased sTmax as well as of the RIM ampl in these subgroups, are similar to changes registered during mental or postural reactions in this and earlier studies [3,5]. Comparable results in the repolarization pattern were described in patients with no cardiovascular diseases but suffering from panic disorder [6] treated by antidepressant drugs [6], or in normal subjects under the infusion of dopamine [8]. These findings support our interpretation of the ventricular recovery pattern in young subjects with elevated BP and higher BF% as well as of its reactive changes in sympathergic situations as an effect of direct sympathetic nervous drive of ventricular myocardium.

Present data in agreement with a previous study [4] document, that the effect of the body fat percentage on the repolarization characteristics goes over the extend of the physiological interindividual variability, and as it differs from the negligible effect on depolarization, it cannot be explained only by physical reasons (increased distance of electrodes from the heart, impedance of the fat tissue, etc.), but indicates with a high probability the contribution of an augmented sympathetic activation of the ventricular myocardium in the obese.

As all these phenomena are related to some individual trait, characterized by predisposition to activate the sympathetic drive of ventricles, there is an intra-individual variability in their intensity and appearance.

Our conclusions hold true above all in subjects between the dividing lines for normotension, and hypertension, still with no clinical signs of some target organ damages, but – more often than not – with an autonomic imbalance, playing not only a primary pathogenetic part, but amplifying the adverse effects of other cardio-vascular risk factors as well. As in Slovakia 51% of the adolescent and young men are in the category of high normal BP and 22% are overweight or obese, present analysis may be of value in characterizing a certain individual state of the sympathetic regulation of the cardiac ventricles and also instrumental in studies of cardiovascular risk prediction.

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