Dynamic Beat-to-Beat Changes of the Cardiac Electric Field in Response to Situations with Increased Sympathetic Activity

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Abstract. *Only a few studies – evaluating body surface potential maps (BSPMs) from a selected single beat, or from an average constructed of some heart beats - have dealt with reactive changes of BSPMs in response to different physiological conditions. Our aim was to analyse the previously unexplored dynamic beat-to-beat pattern of the reactive changes in the ventricular depolarization and repolarization, induced by different physiological mechanisms – by tilt table test or by psycho-emotional stress. Continual records of body surface ECG and repetitive BP measurements were taken in supine rest, during tilting to 60°(TU,TI), back to supine and sitting (SIT), or seated during the mental arithmetic test (MA). R-R intervals and selected BSPMs parameters were evaluated for each heartbeat. With changing position from supine to TI, there was a significant gradual decrease of the QRSTampl, in the average to 73% and with SIT to 81% of the resting supine value. The MA stress induced changes began with a short latency, peaked significantly at 30-60 seconds, returning to the control values at the end of the test, or some heart beats after. The main parameter of repolarization BSPM –STampl fell to 81% of its control value. These reactions correspond to the pattern of the complex sympathergic cardiovascular responses to postural or mental tasks.*

Keywords: Integral ECG body surface maps, Beat-to-beat dynamism, Reactive changes, Head-up tilting Psycho-emotional stress.

1. Introduction

The body surface potential maps (BSPMs) are still an important source of information in the electrocardiographic research of autonomic nervous system control of cardiac function. Several papers offer basic data on the pattern of ventricular depolarization and repolarization time-integral BSPMs in clinically normal subjects at rest [1-7]. However, in subjects with no cardiovascular symptomatology, only a few studies have dealt so far with the problem of variability in the pattern of BSPMs, or with reactive changes due to different physiological conditions, involving variations in the autonomic drive of ventricles [2, 5-8]. However, there is a cogent limitation in interpreting these studies, as only a single BSPM from one selected heartbeat (technical bounds of the equipments), or averages from a short sequence of several maps were used to evaluate the significance of their changes in time or in different situations. Reliable testing of cardiovascular reactivity to somatic or psycho-emotional tasks, involves the monitoring of investigated parameters during the anticipation of, administration of, and recovery from stimuli or tasks. Computer based BSPMs recording enabled a beat-to-beat analysis of the dynamic behaviour of the cardiac electric field [9]. In our previous study we provided the first evidence of spontaneous, non-random, respiratory and low frequency oscillations of the ventricular repolarization pattern, and the first insight into the dynamics of body posture associated changes in ventricular recovery [10]. The aim of the present study was a comparative beat-to-beat description of the reactive changes of various parameters of the BSPMs in sympathergic states, but induced by different mechanisms - changing body posture, or using mental arithmetic (MA) as a consistent test which involves increased alertness with intellectual and emotional strain.

2. Subject and Methods

In two homogeneous groups of 9 men aged 19 and 29 y., with no history of cardiovascular diseases, using 64 torso electrodes, unipolar ECGs were continuously recorded in following postural situations: i) 300 sec - supine in quiet baseline conditions ii) passive head up tilting partitioned into 30 sec – starting supine position (SU), 90 sec – gradual tilting to plus 60° (TU) and 180 - 240 sec – in the passive tilted position (TI), iii) 90 sec - gradual head down tilting to horizontal (TD) and 180 - 240 sec – supine rest (SU 2) iv) 180 sec – sitting rest (SE), recorded immediately after active sitting up from the supine position (SU). Mental stress testing involved 30 s. in seated position at rest, 120 s. during mental arithmetic test (MA) and 120 s. during the recovery after the test. From the respective integral QRS, ST and QRST BSPMs, R-R intervals and selected parameters were evaluated for each heartbeat. In individual subjects, depending on their HR, 906 – 1262 postural and/or 335-426 MA BSPMs were evaluated. The blood pressure (BP) was measured repetitively by a semi-automatic oscillometric method, in each experimental situation. For details on data recording and processing see [4, 7, 10]. The minimal level of significance was set to $P < 0.05$.

3. Results

Representative beat-to-beat recordings of RR and of selected integral BSPMs parameters characterizing the ventricular depolarization (QRSampl), changes of myocardial recovery processes (QRSTampl or STampl), respective nondipolarity indices (NDI) and the angle between the QRS and QRST or ST eigenvectors (**α**), illustrate the effect of tilted semivertical and of seated body position (Fig. 1A) or of the emotional stress (Fig. 2A), in one subject.

In spite of the substantial inter-individual variability, the highly significant body position dependent differences of the selected group-mean parameters QRSTampl and QRSampl document the dynamic pattern and proportions of the reactive postural depolarization and repolarization BSPMs changes. With head-up tilt, there was a significant gradual decrease in the QRSTampl, in the average to 73% and with sitting to 81% of the resting supine value ($p<0.001$) (Fig. 1B). Simultaneously the angle **α** significantly increased in the average by 12.3° in tilted and by 13.0° in the seated position, and the nondipolarity QRST BSPM indexes fell, to 87%, resp. to 78% of their respective supine values. All these reactive changes were significant, characterized by transition phenomena and prolonged after-effects. Tilting back to horizontal restored the resting supine values within 3 – 4 minutes, in all subjects.

The stress induced changes (Fig. 2B), began in all subjects with a short latency after initiation of the mental task, usually peaked significantly at 30-60 seconds, returning to the control values to the end of the test, or some heart beats after. The HR rose from 75 to 98 beats/min, the BP from 118/69 to 137/76 mmHg, the main parameter of the integral repolarization BSPM – the QRSTampl fell to 81% from 154 to 126 µVs,

The pattern of both responses was inter-individually conformable, however variable in magnitude and pronounced in about 2/3 of subjects. The effects of both situations on depolarization were individually more variable and in the average caused only minimal QRSampl increases.

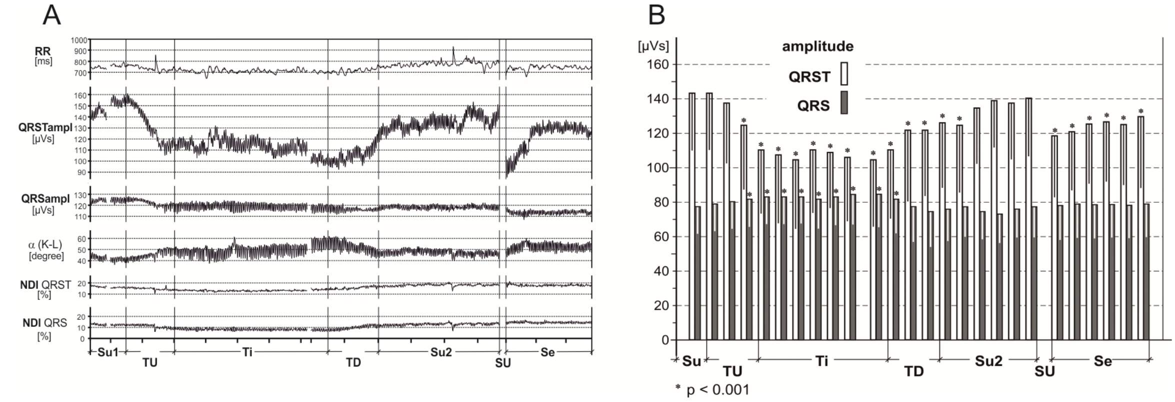

Fig. 1 **A)** Representative continual body posture dependent beat-to-beat recording of **RR** and of selected QRST and QRS BSPMs parameters from one subject. **Su1** - baseline, supine; **TU** - gradual tilting up to +60^o; **Ti** - tilted; **TD** - gradual tilting down to horizontal; **Su2** - supine; **SU -** active sitting up; **Se** - seated..

B) Mean group values ±SD of **QRSTampl** and **QRSampl,** averaged in 30 s intervals during consecutive body position changes.

Time scale unit – 1 min

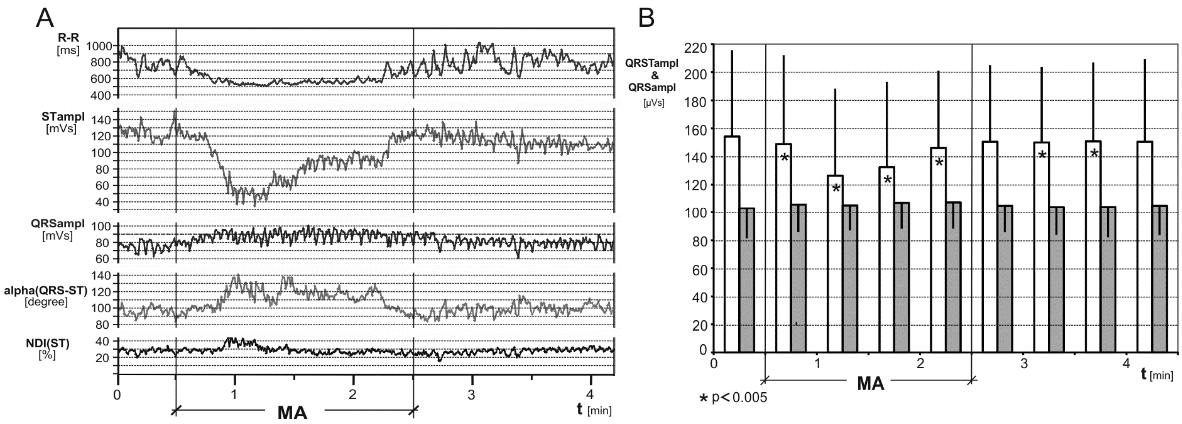

Fig. 2 **A)** Representative continual beat-to-beat recording of **RR** and of selected ST and QRS BSPMs parameters from one subject, before, during and after the mental arithmetic test (MA) .

B) Mean group values ± SD of **ST ampl** and **QRS ampl,** averaged in 30 s intervals during the test

Time scale unit - 1 minute

* significantly different in relation to respective baseline supine values.

4. Discussion

The presented qualitative and quantitative characteristics of depolarization and repolarization time-integral BSPMs at rest are concordant with previous reports for clinically normal males [1-7]. Circulatory adaptations, involving autonomic control, constitute an essential part of the "spontaneous" intra-individual variability of these electrophysiological functions. Results of this study call attention to the body position and emotional stress dependent beat-to-beat variations of the investigated cardiac electric field. These stimuli of different physiological meaning, deviate substantially, in particular the repolarization BSPM parameters from their respective means, in a dynamic way, with evident transition periods in reaching new levels, or with several minutes lasting after-effects.

They are in agreement with previous studies reviewed by Ruttkay-Nedecky [11], documenting on selected small samples or single heart beats, the responsiveness of ventricular repolarization to a variety of sympathergic situations – as upright posture, hand grip test, psycho-emotional load, smoking, adrenergic agonists or specific changes in subjects with high normal blood pressure at rest [12]. It is concluded, that these findings are explained by stimulus specific pattern of the sympathetic response, which involves selective activation of the ventricular myocardium in reaction to different physiological situations.

Detailed analysis of the beat to beat BSPMs variability allows a more accurate definition of the autonomic modulation of the ventricular activation with a promising possibility to discover subjects with abundant sympathetic activity and higher risk of ventricular dysfunction.

We point to the importance of including these aspects of dynamic intraindividual variability of the cardiac electric field influenced by the manifest or latent stimuli, into the ECG assessment both for interpreting current cardiac state, for ambulatory monitoring, laboratory testing etc.

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References

[1] Montague TJ, Smith ER, Cameron DA, Rautaharju PM, Klassen GA, Flemington CS, Horacek BM: Isointegral analysis of body surface maps: Surface distribution and temporal variability in normal subjects. *Circulation* (63): 1166-1172, 1981.

[2] Sutherland DJ, McPherson DD, Spencer CA, Armstrong CS, Horacek BM, Montague TJ: Effects of posture and respiration on body surface electrocardiogram. *Am J Cardiol* (52): 595- 600, 1983.

[3] Green LS, Lux RL, Haws CW, Williams RL, Hunt SC, Burgess MJ: Effects of age, sex and body habitus on QRS and ST-T potential maps of 1100 normal subjects. *Circulation* (71): 244-253, 1985

[4] Kozmann G, Farkas N, Sandor G, Szakolczai K, Szathmary V, Tysler M, Turzova M: QRST integral maps of normal subjects. Statistical analysis and simulation study. *Comput Cardiol* (25): 521-524, 1998.

[5] Slavíček J, Kittnar O, Trefný Z, Horáček Bm: ECG body surface isointegral and isoarea maps (BSM) in 30- and 60-year-old healthy humans. *Sbor lék* (102): 369-374, 2001.

[6] Ruttkay-Nedecký I, Regecová: Normal variability of the peak-to through amplitude of isointegral QRST body surface maps. *J Electrocardiol* (35): 327-332, 2002.

[7] Kellerová E, Regecová V, Katina S, Titomir Li, Aidu Eai, Trunov Vg, Szathmáry V: The effect of psychoemotional load on ventricular repolarization reflected in integral body surface potential maps. *Physiol Res* (55) (Suppl1): 99-105, 2006.

[8] Schusterman V, Aysin B, Shah I, Flanigan S, Anderson KP: Autonomic nervous system effects on ventricular repolarization and RR interval variability during head-up tilt. *Comput Cardiol* (25): 717-720, 1998.

[9] Kozmann Gy, Haraszti K: Importance of body surface potential field representation fidelity: analysis of beat-to-beat repolarization measurements. *Anadolu Kardiyol Der* [7](Supl.1):5-7 2007

[10] Kellerová E, Szathmáry V, Kozmann G, Haraszti K, Tarjányi Z: Spontaneous variability and reactive postural beat-to-beat changes of integral ECG body surface potential maps. *Physiol Res,* (59): 887-896, 2010.

[11] Ruttkay-Nedecký I: The effect of the autonomic nervous system on the heart. Electrocardiographic evaluation: Problems and concerns. Cardiol. (10): 42-48, 2001.

[12] Kellerová E, Regecová V Repolarization pattern indicates enhanced sympathetic drive of the ventricular myocardium already at normal and high-normal blood pressure. *Kidney & Blood Pressure Research*, (32): 310-331 , 2009.