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VARIATIONS OF THE CARDIAC ELECTRIC FIELD

Mottto:
Inteligencia nemlčí, neuzatvára sa vo svojich drahých prácach, pokúša sa byť na výške novej zodpovednosti, ktorá robí "intelektuálov" dotieravými, nemožnými: zodpovednosti oddeľovať inteligenciu od paranoje, ktorú vytvorila modernosť. *

Our cities and buildings are products of fantasy as well as a lack of fantasy and because they are formed from hard material we have to adapt to them. A man is connected with primary nature even in space of technical civilization which surrounds him tighter and tighter. One of the ways how to get out from this grippe is to respect the rules of nature and return techniques to human being. In the frame of architecture the turning point is to get back to the paradigm of urban biotope. A modernistic trip of man from himself should to be end by returning to him. In the nature everything loves the balance. If the balance is upset, troubles, disturbances and diseases occur. Scientists of various fields try to understand material technologies of the life, behavior motivations and structures of human biology on different levels. The aim of this work is to open the window to our heart, to see what happens during a single heart beat.

Introduction

The main function of the heart is to sustain the circulation of the blood in the body by pumping oxygenated blood from the left ventricle into the body and deoxygenated blood from the right ventricle into the lungs. This function is provided by the temporal and spatial mechanical deformation of the heart. The deformation itself is strongly coupled to the electrical excitation in the heart. Each heart beat is implicated by biochemical and biophysical processes which precede cardiac electric activity. Action potential that spread throughout the heart is generated by autorhytmic cells in the conduction system. The excitation of one cardiac cell is propagated to its neighbor cells with regard to the electrophysiologic properties of the cells and surrounding extra cellular medium (1). The electrical excitation propagation is the origin for the evolution of a temporal and spatial distribution of extra cellular potential measurable on the body surface as electrocardiogram (ECG), vectorcardiogram and body surface potential maps (BSPM).
Abnormal electrical excitation propagation which may lead to pathological mechanical of the atrial and ventricle contraction and therefore to a malfunction of the heart, is of permanent interest in basic research in cardiology. Whereas one part is focused on a macroscopic level of simulation to enable fast calculations on models of the total heart, thorax and body (2), information about electrical activity of the heart in living persons we obtain from ECG, VCG or BSPM, which are non invasive and can be widely used. The main advantage of body surface potential mapping, compared to 12-lead ECG, is the ability to present the cardiac potential distribution recorded by electrodes on the whole thorax (Fig. 1). There are several ways how to distribute the electrodes over the chest (Fig. 2). Different applications may be found in the fields of diagnosis, therapy and medical education in cardiology based on either part of this research field.

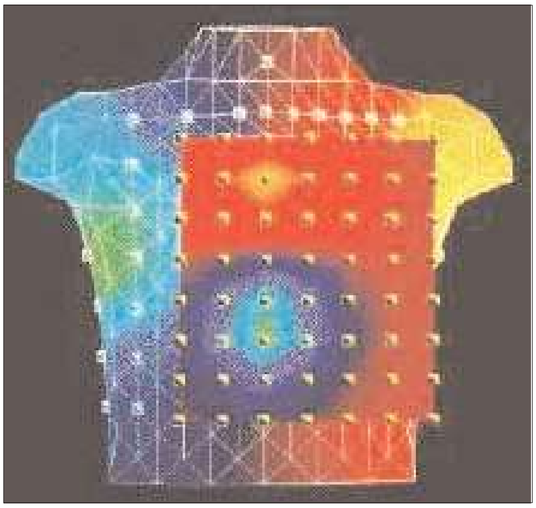


Figure 1

The intention of this work is to present pictures of cardiac electric field changing during each heart beat, to compare the state of human heart under physiological conditions (physical activity, psycho-emotional stress and changes of body position) in healthy persons. Visualization of these processes flow to the associations with other pictures existing in the nature. Various field distributionsas 3D scenarios and animations are shown as inspiration for artist.

Methods

The study group consisted of 215 healthy boys and men without signs of cardiac disease, with normal ECG, aged from 10 to 60 years. Electric potentials from the chest surface were recorded from 80 electrodes distributed regularly over the chest in 16 columns and 5 rows, in seated persons in mid respiration, during mental arithmetic, hand grip, supine position and head up tilt to 60ş from a single heartbeat using the computer system Cardiac 128 - PC (METE, Prague). The program for isocontour

* Jean Francois Lyotard, Hrobka intelektuála a iné články Archa, Bratislava 1997,

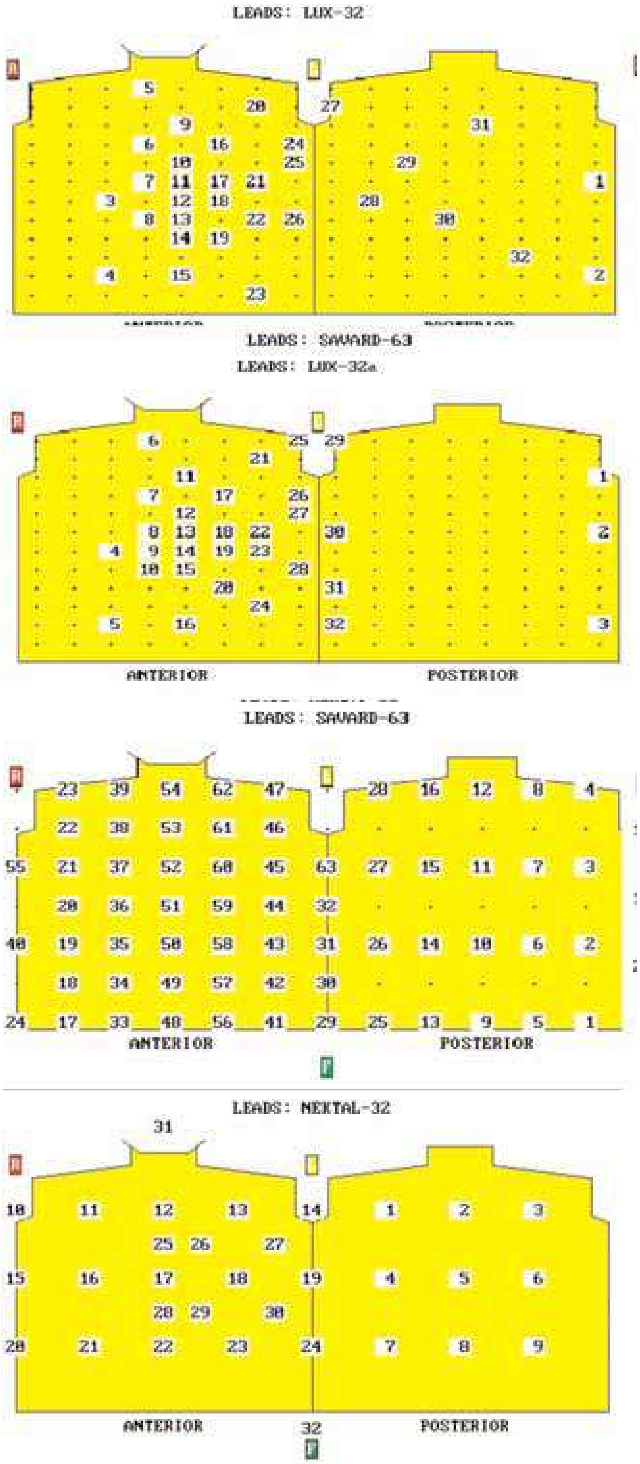


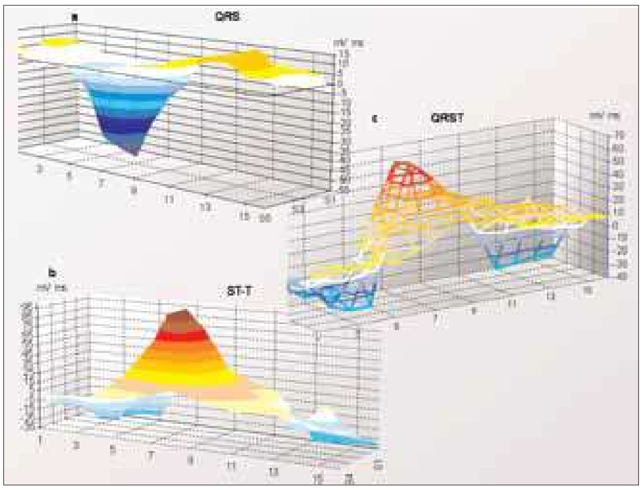
Figure 2

visualization features the creation of several different types of maps (isointegral, isopotential). All kinds of maps may be evaluated visually as well as by means of rational choice of parameters. For evaluation of BSIM, maximum, minimum and peak to through amplitude (AMPL) were selected.

Results

The integral maps may be computed and evaluated as average maps, which can be used as etalon for comparison with the patients´ maps. Cardiac potentials are projected on the unfolded thoracic surface, on the left part is displayed the front of the chest, on the right one is the back. Co-ordinates on the maps in the xy - plane signify positions of the electrodes mounted on the chest, potential values are projected on z-axis. In maps markers of the torso lines and mapping grid are shown. Textured fields on the scale represent negative potentials, full tones are positive potentials, white color indicate potentials close to zero (±0.1mV). QRS complex which represents ventricular activation is characterized by the spread of the negativity wave (depolarization) through the ventricular musculature with the peak on the anterior wall of the chest left to sternum (Fig 2. a) Ventricular activation is followed by the T wave – ventricular recovery (repolarization) with prevailing positive potentials and the peak localized approximately at the same section as the peak of negativity during QRS (Fig 2. b). Course of the whole QRST complex with potential differences is displayed on the Figure 2. c. The greatest intra-individual variability of BSP distribution of the cardiac electric field was found during repolarization, which reflects also influences of vegetative nervous system (Fig. 3). Each of the tested situations is illustrated by map (left) and by position and magnitudes of their respective changes under different physical or psychical condition conditions (right). Changes in the autonomic nervous tonicity of the heart during deep inspiration resulted to substantial increase of positive maximum on the map and shift inferiorly. In the situations, where increased sympathetic activity proceeds (mental arithmetic, hand grip), the values of maxima decreased and shifted slightly superior. On the other hand the negative potentials on the opposite side of the chest moved to zero, or even positive values. Tilting to 60şled to considerable increase of pre-cordial potentials and to shift of the position of the maximum not only

Figure 3



superiorly but also to the right (supra-sternum section). Negative potentials on posterior chest changed to positive ones.
Modification of the scaling leads to creative expressions, which illustrate Fig. 4 -7 may be inspirative for designers or artists.

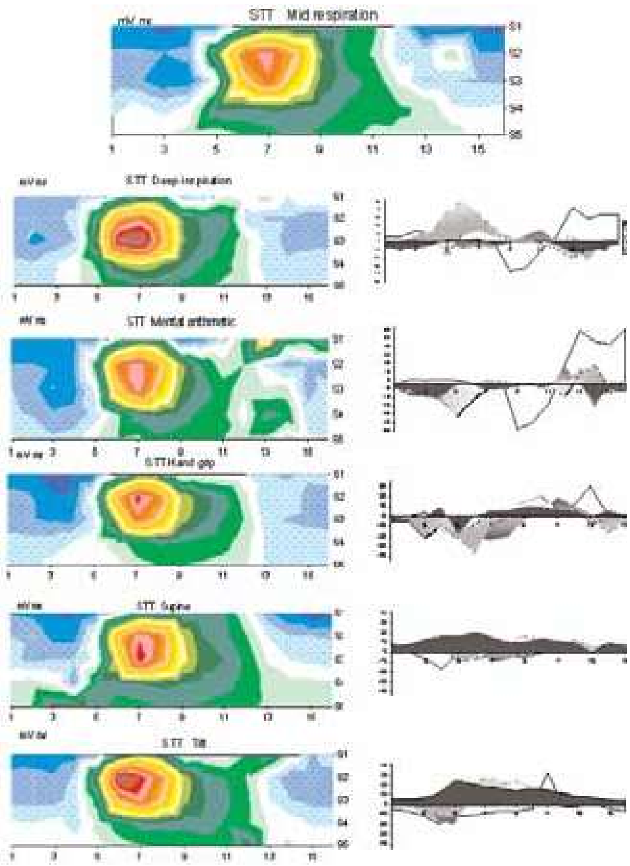
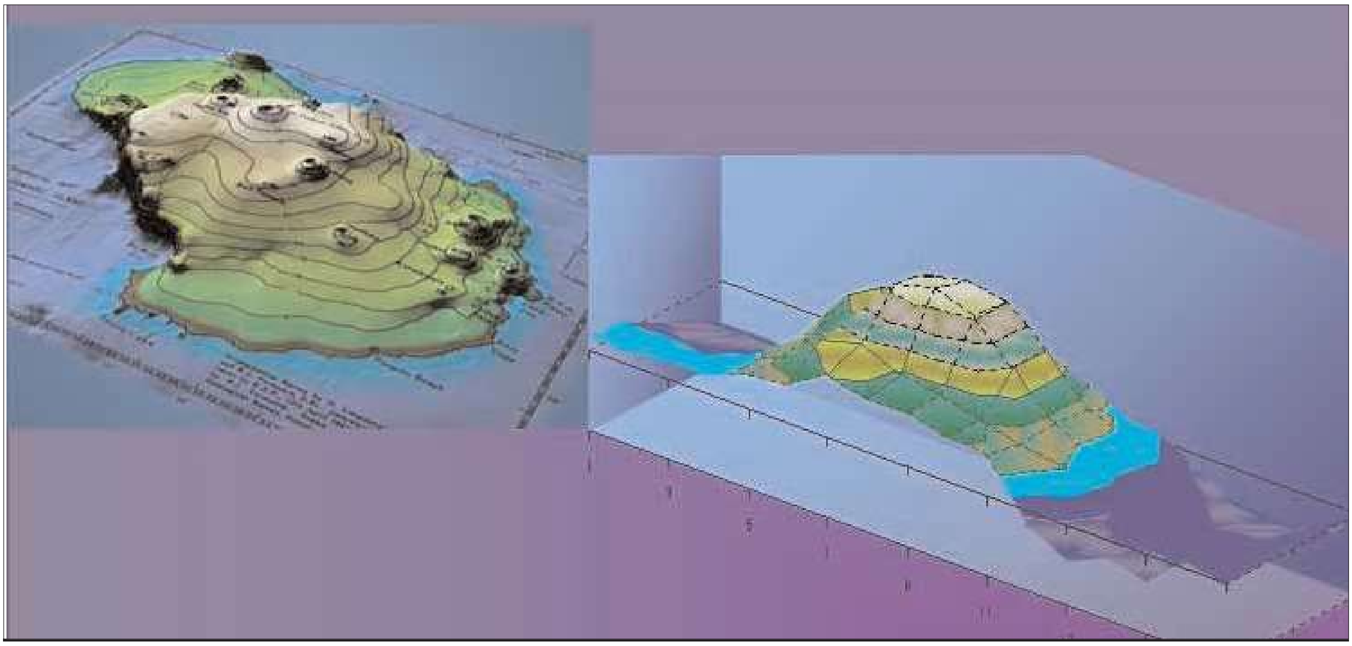


Figure 4

Discussion

Body surface potential mapping has perhaps long been viewed as a peculiar research tool with limited clinical utility, because of the distinct physical characteristics of the method like the number of electrodes — is always going to be a factor limiting the clinical use. As body surface potential maps imply a dimensional problem, evaluation of their characteristics should take into account the descending dependability between points with increasing distance in the space. Advanced statistical methods like surface penalized parametrical and non parametrical regression models would be more helpful by assessing dimensional relationship among particular points (3). It seems, that the next challenge will be to develop suitable automated analysis methods for fast clinical application of body surface potential mapping. Nevertheless, there are already several common cardiac disorders like life-threatening arrhythmias, ischemia, hypertrophy, and infarction and in post infarction patients, where the method has proven its diagnostic power. Our clinical recordings even in normal subjects showed a large variation in body surface potential maps, especially in repolarization, which reflects also influences of vegetative nervous system (4). It is known, that the vegetative nervous system hangs together with state of emotivity. Emotions also include aesthetic sense. Relationship between aesthetical experience and vegetative parameters in humans is anticipated and may become an interesting topic of research. On the other hand fine artists, architects and designers often look for inspiration in forms, shapes and colors in nature. As a man is a part of nature and cardiac activity is the main vital function, no wonder, that pictures of cardiac electric field, which changes with each heart beat, offer interesting graphical inspirations.

Figure 5



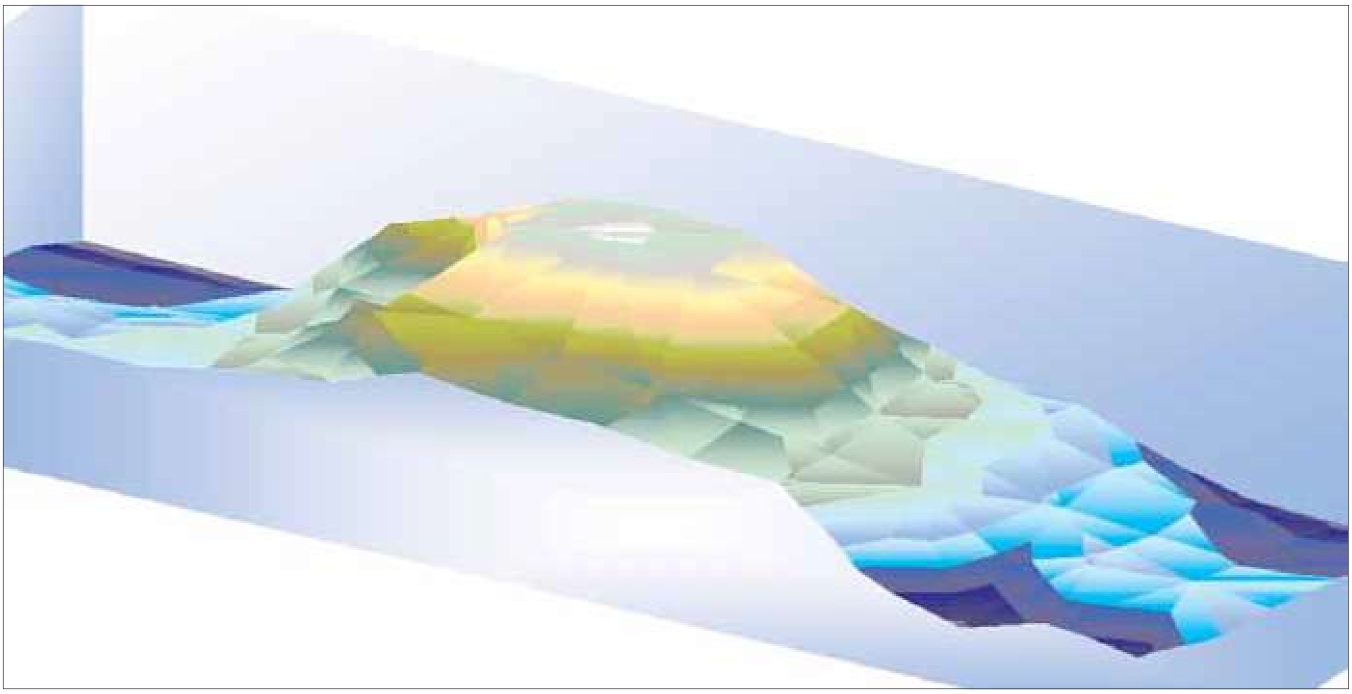


Figure 6

Figure 7

Conclusion

Comparative analysis of the 6 physical situations showed a large intra-individual variability of the picture of the ventricular recovery. Morphologic variations of the ST-T complex reflect various alterations that electrical stimuli face during recovery of cardiac tissues and are rather characteristic for each type of either body positions, mental or physical load. The study of electrical potentials using body surface potential maps may contribute to improve differentiate diagnostic and better orientation (distinguishing) between physiological and pathological changes of cardiac electric field. Moreover the graphical representation of original results can be used as basis for future motif or art design

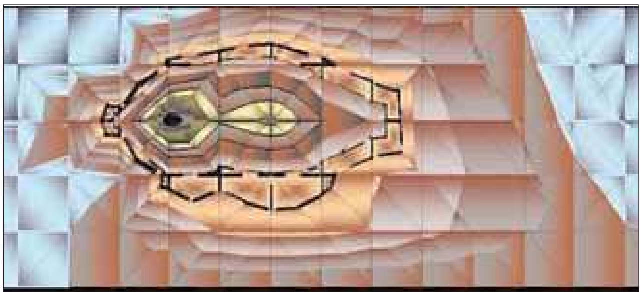


Figure 8

Acknowledgement

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Figure captions

Figure 1. Model of cardiac electric field on a body surface potential map. Data generated in Dr. Gerhard Stroink's lab. www. .
Figure 2. Positions of electrodes in lead sets of different mapping systems.
Figure 3. Body surface potential map. Potential distribution during one cardiac cycle. a. – QRS (depolarization), b – ST-T (repolarization), c. – Gradient during the course of the whole QRST complex.
Figure 4. Changes of the pictures of the cardiac electric field during repolarization in different physiological conditions (mid respiration, deep inspiration, mental arithmetic, hand grip, head up tilt to 60ş). Sequences of the graphs on the left indicate the amplitudes and the localizations of the reactive changes (right).
Figure 5. Earth surface (Island of Prince Edward) and the shape of the relief of positive and negative potentials.
Figure 6. Compilation of 12 body surface potential maps like an art graphic
Figure 7. Body surface potential distribution like a window pane (vitrage).
Figure 8. Body surface potential map like the head of a falcon.

Cieľom práce bolo prezentovať výsledky získané pri štúdiu elektrickej aktivity srdca zdravých ľudí a súčasne prispieť k vzájomnej informovanosti nielen medzi odborníkmi navzájom zdanlivo nesúvisiacich oblastí. Zatiaľ čo výsledky práce niektorých odvetví vedy, techniky a kultúry sú viac viditeľné a využívané celou spoločnosťou, mnohé poznatky prírodných vied a biomedicíny zostávajú širokej verejnosti a dokonca aj samotným odborníkom z príbuzných odvetví skryté. Pritom každý sa v tom "svojom" snaží o hlbšie pochopenie hmotných podmienok technológie nášho života, motívov správania a štruktúr humánnej biológie na rôznej úrovni. Príkladom je jednoduchá paralela srdca a mesta, ktoré má svoju tvár, tvárnosť, anatómiu a je vlastne živým organizmom. Chyby pri urbanistickom plánovaní majú za následok to isté, čo narušenie rovnováhy fyziologických procesov živého organizmu (človeka) - infarkty, kolapsy a choroby, ktoré potenciálne ohrozujú mesto aj jeho obyvateľov, najmä tých slabších, alebo tých, ktorí sa nedokázali prispôsobiť masovej priemyselnej civilizácii. Kde je však hranica medzi úspešným prispôsobením a biopatológiou? Toto je tiež jedna z mnohých rovnakých otázok, ktoré riešia viaceré navzájom nepríbuzné odvetia. Skúmanie normálnej variability elektrického poľa srdca v bežných životných situáciách (zmena polohy tela, psycho-emočná a fyzická záťaž) u zdravého človeka je základom pre odlíšenie patologických stavov. Grafické zobrazenie exaktných dát je naším oknom do srdca: odborníkom poskytuje informácie o stave srdcovej aktivity v danom okamihu, pre ostatných sa môže stať zaujímavou inšpiráciou a estetickým zážitkom.