Appraisal of BSPM obtained from the limited lead system

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ABSTRACT

Objective: Study goal was a comparative analysis of the characteristics of the isopotential maps, registered originally in the body surface potential mapping (BSPM) 87-lead (complete) cylindrical system, which were then transformed to the 30-lead (limited) spherical subsystem.

Methods: The comparative studies were carried out on the electrocardiogram (ECG) recordings recorded originally in the 87-lead BSPM Fukuda Denshi system (HPM-7100; Fukuda Denshi, Co., Tokyo, Japan) in a group of 21 patients with right bundle branch blocks (RBBB) with the mean age of 61.3±10.2 years.

Results: It was found that the body surface maps from the two multielectrode recording systems did not show any significant difference as to heart potential migration and distribution. It is worth noting that the maps created in the limited lead, spherical system gained the more realistic image, resulting from the effect of cardioelectric space symmetrization.

Conclusion: The results led to conclusion that a procedure of spherical transformation to the system with the reduced number of the recording electrodes did not influence the core features of the body surface heart potential maps.*(Anadolu Kardiyol Derg 2007: 7 Suppl 1; 11-3)*

Key words: body surface potential mapping, limited lead system, cylindrical system, spherical system

Introduction

One of the numerous approaches to the inverse problem in electrocardiology was a concept of assessing the cardiac electric field with the help of a dense body surface multielectrode network treated as a reliable outer representation of the cardiac generator. This idea was introduced by Rijlant (1957), who constructed the 72-lead network supplied with the resistors (1). Shortly afterwards, the 30-lead network was built by Kowarzyk and co-workers (1961) (2, 3). In the last decades of XXth century, considerable advances in computer technology made possible the heart potentials to be recorded and digitized simultaneously from up to about 260 points on the body surface (4). On the other hand, in order to reduce the redundant pool of electrocardiogram (ECG) information needed to be analyzed, various recording systems with limited number of electrode points were tested. Among many of them, there were the 32-lead surface heart potential map systems created by Lux et al. (5, 6) and Barr and Spach (7), or the arrays with various number of electrodes (from 48 to 9) proposed by Titomir et al. (8, 9).

A goal of the present study was a comparison of the features of body surface heart potential maps (BSPMs) collected in the two multielectrode arrays: 87-lead cylindrical system and 30-lead subsystem obtained after spherical transformation of the previous one.

Methods

The ECG multielectrode network, constructed in our lab according to the original concept of H. Kowarzyk et al. (2, 3), was a framework of equal resistors interconnected after the topological pattern of Platonian polyhedra, in which each resistor corresponded to a side, and each connection to a corner of the polyhedron. A couple of regular polyhedra is a dual, if each corner of one polyhedron corresponds to the midpoint of the opposite face of the other one. For an icosahedron has twelve corners and twenty faces, and a dodecahedron has twenty corners and twelve faces, it was possible to coupling them into a dual figure. In this manner, using the additional resistors, the multielectrode network based on the dual figure, called icosadodecahedron, was constructed.

One network was built up of the side midpoints of the dodecahedron and the second one of the side midpoints of the icosahedron. The corners of the first polyhedron constituted the thirty input terminals, and the corners of the second polyhedron the thirty output terminals. This 30-electrode spherical arrangement was named "diamentoid". An input of the diamentoid network was fed by electrodes distributed over the chest wall, whereas the output yielded the measurement of electrocardiograms. Thirty corners of the network corresponded to the thirty recording electrode sites distributed symmetrically and regularly on the thorax. It is worth emphasizing that outer surface of the diamentoid network approximates the thoracic surface in a spherical manner and makes the electric field of the heart symmetric (2, 3).

As the time went by, since 1992, we have exploited the 87-electrode commercial system for registering body surface potential mapping (HPM-7100; Fukuda Denshi, Co., Tokyo, Japan). In this system, an array of the electrodes on the thoracic surface is consistent with a presentation of the human torso in form of cylindrical layout.

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In Fukuda Denshi system, 87 electrodes are arranged in rectangular framework, with a different density on the anterior and the posterior surface of the thorax. This system could be called a cylindrical one. Because of the huge number of the electrodes, it was assumed as a "complete" system. The second system, called spherical, consisted of 30 electrodes, with 15 electrodes on the both sides of the thorax, placed symmetrically (see Fig. 1). This spherical system was considered as a "limited lead" system, since its 30 ECG recordings were selected from 87 ECG waveforms obtained from the cylindrical system, and then subjected to spherical transformation.

Transformation symmetrizing cardioelectric space

A formula expressing a relation between the heart potential values found at the output and at the input points of the spherical electrode network is given as the square matrix of the diamentoid transformation. The diamentoid matrix makes a transformation of the heart potential values collected from the thirty input points to the same number of the output values. The individual elements of the matrix determine a contribution of the potential at each input point to generating the potential at each output point.

The comparative studies were carried out on the ECG recordings recorded originally in the 87-lead BSPM Fukuda Denshi system in a group of 21 patients with right bundle branch blocks (RBBB) with the mean age of 61.3±10.2 years.

Results

It seemed interesting to evaluate possible alterations of ECG waveforms collected originally from the 87-lead cylindrical system after performing a spherical transformation using the 30-lead subsystem. As an example of the comparison performed between the body surface heart potential mapping obtained in the complete system and the limited lead system, the isopotential maps of the QRS complex recorded in the same patient with right bundle branch blocks are displayed in the Figure 2 and Figure 3, respectively.

Going from the top to the bottom of the mentioned-above figures, the maps present the 15 time instants with the equal time intervals - from the onset of the QRS complex to the R wave peak, designated as I1-I7, and from the R wave peak to the offset of the QRS complex, designated as I9-I15. The map reflecting the R wave peak (the 8th in the row; I8) is delineated with the thicker line. Next to each of the maps, the standard II lead ECG curve, with the time instant of the given map recording and the time (in ms) from the start of the QRS complex, is presented. Dashed fields in the maps designate the negative potential areas.

It should be stressed that heart potential distribution in the maps obtained from the two analyzed electrode systems, 87-lead and 30-lead, did not differ from each other concerning a migration trajectory of the positive and negative potential over the thorax. In contrast to this, a significant difference was observed concerning morphology of the potential areas. Contours of the potential areas in the complete (cylindrical) system seemed to be of irregular shape, whereas in the limited lead system the borderlines were smooth, elliptic or circular. In addition, maxima and minima of the heart potential in the limited (spherical) system looked like shifted in relation to each other, and therefore were

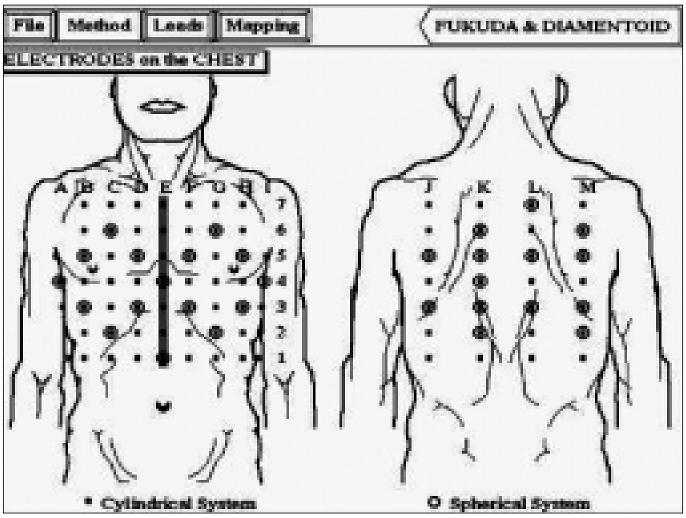

Figure 1. Arrangement of electrodes on the thoracic surface in the two systems compared: cylindrical=complete (designated by squares) and spherical=limited (designated by circles)

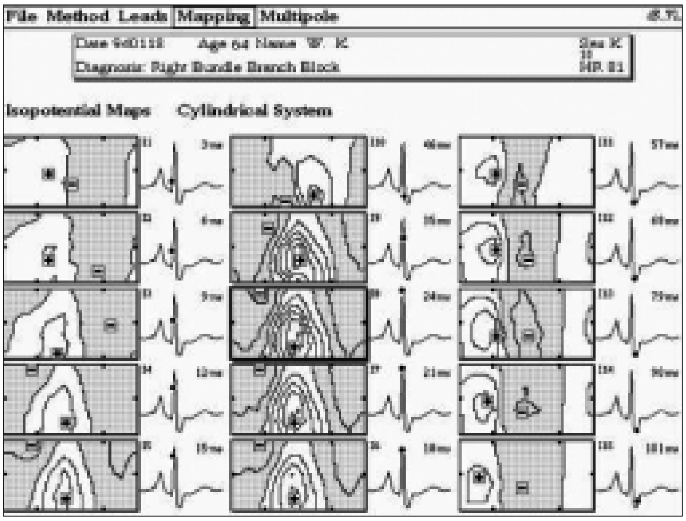

Figure 2. A sequence of 15 isopotential maps of the QRS complex from the cylindrical (complete) system of the patient with RBBB

RBBB- right bundle branch block

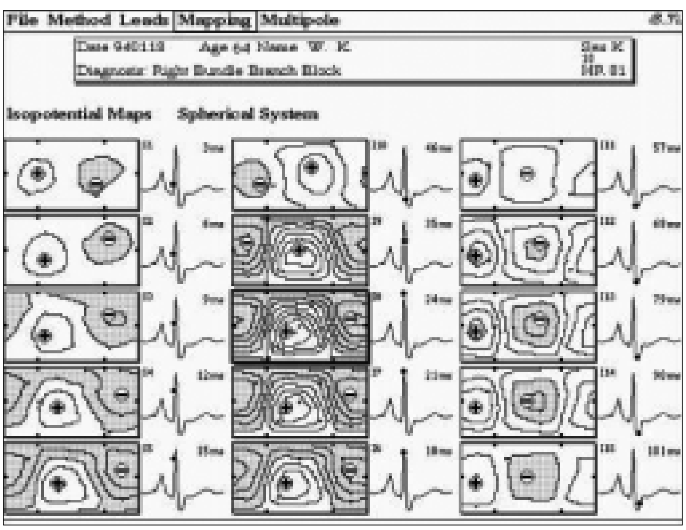

Figure 3. A sequence of 15 isopotential maps of the QRS complex from the spherical (limited) system of the patient with RBBB

RBBB- right bundle branch block

situated at the symmetry axis running through the center of the sphere, just in the site, where the heart is thought to be placed in the spherical system.

In the both compared systems, the sequences of the isopotential maps representing the QRS complex were characteristic for conduction disturbances ongoing within the right bundle branch. However, advantage of the spherical system, supplied with the reduced number of the recording electrodes, was a symmetrical distribution of local potential extrema (maxima and minima) with regard to the center of the sphere displaying the thorax surrounding the heart.

Discussion

In the present study, an original source of electrocardiographic information were the ECG recordings collected in the 87-electrode BSPM system. In this system, the maps are created using body surface electrode array consistent with a cylindrical layout. On that basis, a subsystem of the 30 lead points was selected and then the ECG data were subjected to diamentoid transformation. In result, the 30 newly created ECG waveforms were obtained in the spherical array, which symmetrized the cardioelectric space.

A subject of comparison were isopotential maps created in the BSPM system from the patients with right bundle branch blocks. The maps reflect a distribution of the heart potential on the body surface for the particular time instants of the cardiac cycle. Potentials distribution is assessed using descriptions of extension and shape of the areas of positive and negative potentials, likewise by determining a localization of the regional extrema (minima and maxima). During a single heart cycle, a sequence of the isopotential maps for the successive time instants enables precise monitoring of a trajectory of potential migration on the thoracic surface (11, 12).

Application of the 30-electrode spherical network, constituting a system of the limited number of recording electrodes, in comparison with the complete, 87-electrode array, yields some cognitive and diagnostic usefulness. Firstly, according to the initial assumption, the number of the ECG recording electrodes was significantly decreased, nearly three times. Furthermore, an arrangement of the lead points in the limited system was not confined to the selected portion of the body, but electrodes covered evenly the entire surface of the thorax.

Secondly, we have found a new possibility of using the diamentoid, spherical network, which was constructed in the 1960th for vectorcardiographic registrations. The diamentoid enabled displaying vectorcardiographic loops, regardless of any geometric thorax irregularities and asymmetric location of the heart. It was able to restore the vectorcardiograms, basing only on the cardioelectric potentials distribution on the body surface, without using the network (2, 3).

Nowadays, as it was proved by our investigations, the spherical system can be used successfully for more precise presentation of the maps collected originally from the updated BSPM system. A transformation of the ECG data from the cylindrical to the spherical system appeared to neither reduce nor distort the body surface isopotential maps, in spite of simplification of the isolines course. Contrary, the spherical system, owing to the effect of spatial symmetrization, gives more realistic and reliable images of the cardiac electric field, which can be of benefit not only in the theoretical, but also in the clinical aspects.

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