Klinische Ergebnisse des elektrokardiographischen und magnetokardiographischen Körperoberflächen-Mapping

Zusammenfassung Die Ausbreitung der elektrischen endo- und epikardialen Aktivierung ist auch auf die Körperoberfläche projiziert und kann dort von einer Vielzahl von dosalen und ventralen Ableitungspunkten als Körperoberflächen-Mapping (BSM) registriert werden.

Um diese Aktivierung zu diagnostischen Zwecken zu charakterisieren, werden die früheste Erregung, die Extremata und die dazwischen liegende Nulllinie verwendet.

Um den Datenumfang zu minimieren, wird die Fläche unter dem QRS bestimmt und ein Iso-Area-BSM gebildet. Diese Maps werden durch visuellen Vergleich oder durch die Berechnung der Korrelation miteinander verglichen.

Abnorme Änderungen der De- und Repolarisation werden damit ebenso ermittelt wie die Lokalisation von Arrhythmie-Herden. Letzteres erfolgt im Vergleich zu zuvor durch Stimulation ermittelten Map-Konfigurationen.


Verschiedene klinische Anwendungsbeispiele werden in dieser Arbeit referiert und diskutiert.

Schlüsselwörter Körperoberflächen-Mapping – Magnetokardiographie – nicht-invasive Arrhythmie-Lokalisation

Summary The spread of electrical endo- and epicardial activation is projected also to body surface and can be deducted from various numbers of recording points at the front or the back of the thorax. The resulting data are visualized in a body surface map (BSM).

To characterize this activation, the amplitudes are measured and then evaluated according to the origin, the position of the extrema, and the zero line between them.

To minimize the BSM data during the activation cycle, the area underneath the QRS complex and/or the ST-T wave may be calculated and plotted as an iso-area BSM.
Similarities between the various BMSs are evaluated either by visual comparison or by means of correlation algorithms.

The results exceeded the precision of standard ECG recordings in measuring de- and repolarization. Comparison between a succession of paced maps resulted in the precise localization of arrhythmogenic sources.

Due to the inhomogeneities of the human thorax direct measurement of the position of an electric source, e.g., the focus of ventricular tachycardia or extrasystole, has not yet been accomplished.

Magnetocardiographic mapping, a novel method to record the heart’s magnetic field, however, allows for direct measurement of the arrhythmic origin since this method is not sensitive to these inhomogeneities.

Various examples of the clinical application of BSM have been described in this paper and their results discussed.

Key words Body surface mapping – magnetocardiography – non-invasive localization – arrhythmia sources

Introduction

Non-uniform recovery of ventricular excitability has been shown to be one factor to facilitate the reentry circuits and consequently the development of ventricular tachyarrhythmias (19). Body surface potential mapping (BSM) has been proved to be a useful method for detecting heterogeneities of ventricular de- and repolarization, even though they are not identified in the standard ECG (5, 6, 36).

For the catheter ablation of hemodynamically stable ventricular tachycardias (VT) endocardial catheter mapping is applied to target the arrhythmogenic site. Various invasive methods have been developed to facilitate endocardial catheter mapping such as activation mapping – using a basked-shaped mapping electrode catheter (28), electroanatomical mapping – using three-dimensional electromagnetic catheter technology (17, 18), and non-contact multielectrode-catheter mapping, reconstructing thousands of virtual electrograms (14). BSM prior to the application of endocardial mapping might facilitate and speed up invasive diagnostics.

Spatial resolution of body surface mapping

The spatial resolution of BSM, either to localize arrhythmogenic foci or to detect areas of abnormal electrical activation, has to be determined. This was done by Hren and Punske (12) who used an anatomically accurate computer model of the human ventricular myocardium which incorporates the bidomain model for simulating the realistic activation sequences. The oblique dipolar model was applied in combination with the boundary element method in order to calculate extracardiac potentials.

During virtual pacing of the right and left ventricle they compared various simulated QRS isointegral maps resulting from pacing at adjacent sites with each other. Significant differences in these maps obtained from 258 virtual pacing sites occurred as soon as the distances exceeded 4 mm (12).

This model had been validated before in a comparative study between simulated activation sequences, as described by isochronal maps, and measured sequences of real body surface maps as reported in the literature (11).

Similar experiments applying a computer heart model with realistic geometry were performed by Xu et al. (37) who investigated the patterns of QRS integrals of BMS with anisotropic excitation of the myocardium. Xu’s model meticulously reproduced clinically recorded body surface potential distributions obtained through endocardial stimulation; however, stimulation at the left septum and anteroseptal regions was described as weak.

To investigate the spatial resolution in vivo, Green et al. (7) studied six dogs during stimulation of the left ventricle, and applied the cross correlation calculation to compare the obtained QRS isopotential maps. These maps only varied when the distance between the pacing sites exceeded 4 mm.

Non-invasive localization of arrhythmogenic foci

Atlas of paced BSM

Since the inverse solution, i.e., the calculation and localization of the source out of the BSM information, is not possible using electrocardiography, the BSM under investigation has to be compared to maps obtained by pacing at well defined sites. This reference atlas was obtained in normal and diseased ventricles, respectively.

BSM in normals

To establish a detailed reference database of body surface QRS-integral maps characteristic of the onset of ectopic ventricular activation in localized endocardial segments, SippensGroenewegen et al. recorded BSM in 12 patients without structural heart disease during left and right ventricular pacing at 182 distinct endocardial sites (33). After visually selecting subgroups with nearly identical total QRS integral morphologies, a database of 38 characteristic maps was established. This database showed considerable intra-subgroup variation but per-