The Time Course of the Extrema of Isopotential P Wave Maps in Young Adult Men and Women

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Abstract. *The electrical activity of the heart atria is represented by the P wave that can be recorded and analysed using different procedures. The aim of this retrospective study was to analyse the sequence of isopotential maps in young adults when using time standardisation of the P wave. We constructed 21 isopotential maps from 24-lead system after Barr in 88 young adult subjects without cardiovascular diseases (40 men). We analysed values and the time course of extrema. The mean P wave duration was (84 ± 10) ms. The potential values varied from – 187 μV to 193 μV in individual maps. We always found lower mean values of extrema (flatter maps) in women than in men. The mean absolute maximum appeared in the middle of the P wave and preceded the absolute minimum in average by 1 or 2 maps. The time courses of extrema were fitted by polynomial curves against the sequential map number x = 1, 2,....21. We have shown that a limited lead system can offer reasonable information comparable to full lead systems.*

Keywords: Body surface potential mapping; P wave; Time standardisation

1. Introduction

The electrical activity of the heart atria is represented by the P wave. This can be recorded and analysed using different procedures. As the research on body surface potential mapping concerned predominantly the ventricular excitation process, there is still only limited data available documenting body surface potential distribution during atrial electric events and is mainly devoted to maps recorded using full lead systems.

The aim of this retrospective study was to establish the distributions and selected quantitative parameters of the atrial isopotential maps recorded using a limited 24-lead system in the young adult subjects based on the P wave time standardisation.

2. Subject and Methods

Subjects

We studied 88 young adults, 48 women, 40 men, mean age (18.6 ± 0.4) years. None of the subjects had signs of cardiovascular diseases or cardiovascular risk. All subjects had normal 12-lead standard electrocardiographic and echocardiographic findings as well as blood pressure values.

Body Surface Potential Mapping

Unipolar electrocardiograms for body surface potential mapping were registered using the limited 24-lead system after Barr and processed using the mapping system ProCardio [1, 2]. All data were registered in supine position during normal expiration. Linear baselines were taken through TP segments in each electrocardiogram. The onset and offset of the P wave were established manually from the root mean square signal. The limiting points were set at

the end of a sequence of decreasing values when starting from the middle of the P wave. For better comparison, each P wave was divided into 20 equidistant intervals and 21 isopotential maps per each wave were constructed. The first map corresponded to the P wave beginning, the last map to its end (see Fig. 1). We analysed the values and the time course of extrema: maximum, minimum and peak-to-peak value (maximum minus minimum) [3].

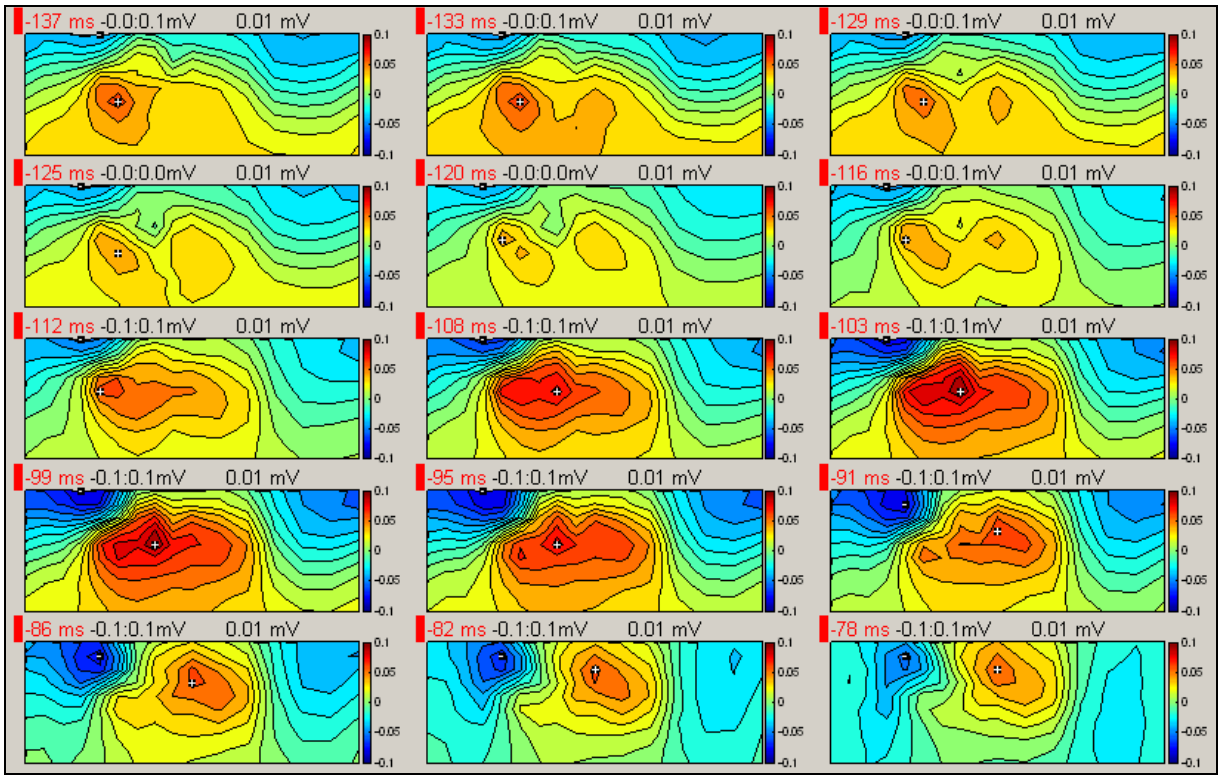

Fig. 1. Example of a sequence of P wave isopotential maps in a young man. Maps 4 to 18 are displayed. The left half of each rectangle corresponds to the anterior chest, the right half to the back. Step between isopotential lines is 0.01 mV.

Statistical Evaluation

Statistical evaluation was done using unpaired two-tailed Student's t-test for means of normally distributed data or the chi-square test with Yates´ correction for frequencies [4]. The value of $p < 0.05$ was considered as statistically significant.

3. Results

The mean P wave duration measured in the root mean square signal was (84 ± 10) ms, significantly longer in men ((86 ± 9) ms versus (82 ± 10) ms, $p < 0.05$). The potential values varied from – 187 µV to 193 µV in individual maps. We always found lower mean values of extrema (flatter maps) in women than in men (see Fig. 2). Statistically significant differences between men and women were found in 19/21 comparisons of maxima, in 19/21 of minima comparisons, and in all peak-to-peak value comparisons ($p < 0.05$). The time courses of mean extrema of all subjects (expressed in µV) were very good fitted by polynomial curves against the sequential map number $x = 1, 2, ..., 21$:

Table 1. Polynomial curves for map extrema

Regression curve	Correlation coefficient r
Maximum $= -0.7 \cdot x^2 + 15.2 \cdot x + 3.3$	0.992
Minimum $= -0.006 \cdot x^4 + 0.3 \cdot x^3 - 4.0 \cdot x^2 + 10.7 \cdot x - 22.8$	0.991
Peak-to-peak value $= 0.008 \cdot x^4 + 0.4 \cdot x^3 + 4.2 \cdot x^2 + x - 28.7$	0.999

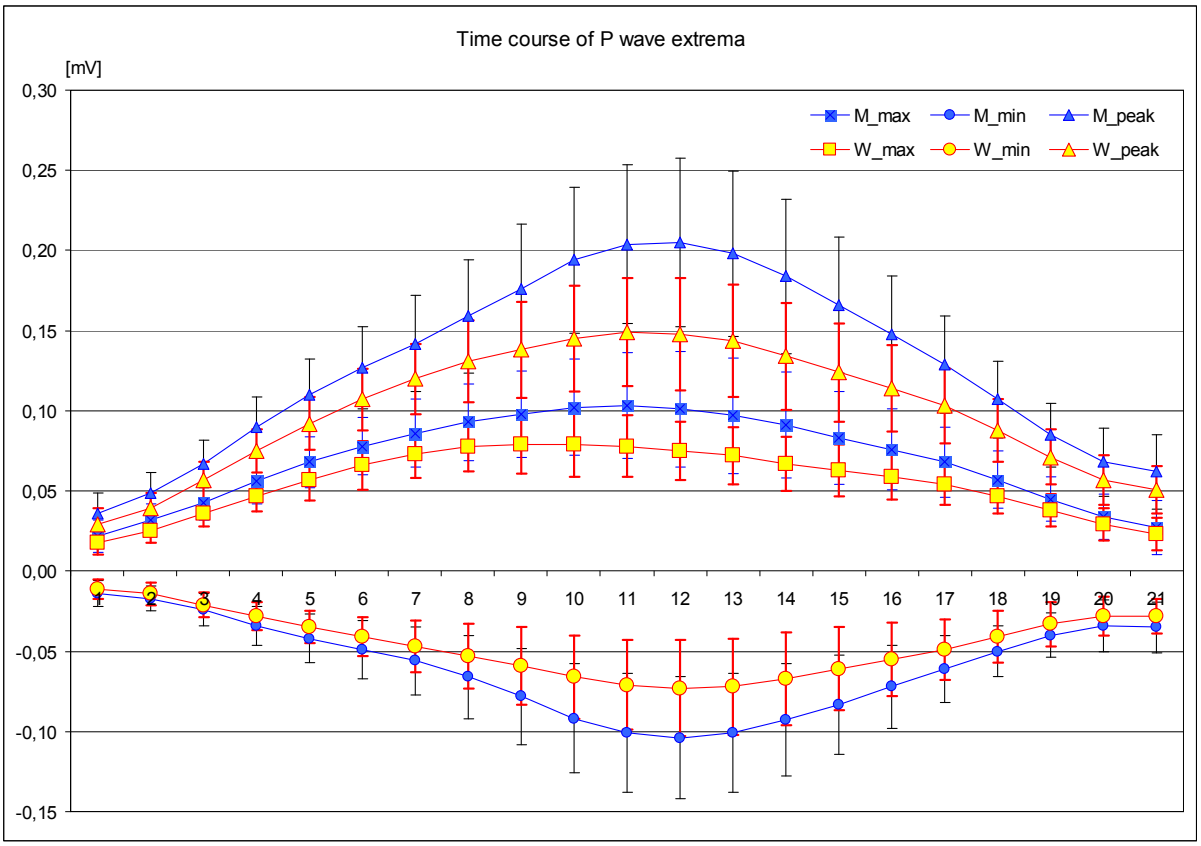

Fig. 2. Time courses of mean extrema values and standard deviations during the P wave in men and women.

During the time course of map maxima and/or minima in individual subjects, two or three maxima appeared in maps of 19/48 women and of 7/40 men ($p < 0.05$) and two or three minima appeared in maps of 14/48 women and of 3/40 men ($p < 0.05$). The absolute (highest) maximum appeared mainly in the middle of the P wave (women: map number 10 ± 2, mean value (79 ± 20) µV; men: map number 11 ± 2, value (103 ± 33) µV ($p < 0.05$); all subjects: map number 10 ± 2, mean value (89 ± 29) µV) and preceded the absolute (deepest) minimum that appeared in average map number 12 ± 2 in both men and women (mean values women: $(- 73 \pm 30)$ µV; men: $(- 104 \pm 33)$ µV ($p < 0.05$); all subjects: $(- 87 \pm 37)$ µV).

4. Discussion and Conclusions

The distributions of potentials on the chest surface during atrial activation were in accordance with published results although obtained with different lead systems [5 – 9]. The position of maxima and minima corresponded to the previously published data for isointegral P wave maps [10]. The values of absolute maxima in our study corresponded to the published data in [6, 9], but were significantly higher compared to the data from [8]. The values of absolute minima are more positive than those published in [8, 9]. These differences could be caused by

divers age of the examined subjects in the studies as the potential amplitudes change with the age [11].
The time standardisation allowed to compare various durations of the P wave in separate subjects. We have shown that a limited lead system can offer reasonable information comparable to full lead systems. We provided a quantitative evaluation of isopotential map extrema that can be useful for diagnostic purposes.

Acknowledgements

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References

[1] Barr RC, Spach MS, Herman-Giddens GS. Selection of the number and positions of measuring locations for electrocardiography. *IEEE Transactions on Biomedical Engineering,* 18 (1): 125 – 138, 1971.

[2] Rosík V, Tyšler M, Turzová M. Portable device of for ECG mapping. In Proceedings of International Conference of Measurement. Frollo I and Plačková A, (Eds.), SAV, Bratislava, 1997, 367 – 370.

[3] Kozlíková K. Surface integral maps, their characteristics and methods of quantitative analysis. *Bratislavské lekárske Listy*, 91 (11): 815 – 823, 1990 (Slovak).

[4] Kozlíková K, Martinka J. *The Essentials of Biomedical Measurement Processing II*. Asklepios, Bratislava, 2009 (Slovak).

[5] Mirvis DM. Body surface distribution of electrical potential during atrial depolarization and repolarization. *Circulation,* 62 (1): 167 – 173, 1980.

[6] Kawano S, Sawanobori T, Hiraoka M. Human body surface mapping during atrial depolarization in normal and diseased subjects. *Journal of Electrocardiology,* 16 (2): 151 – 159, 1983.

[7] Popperová E, Sabolová K, Maco M et al. Two types of atrial activation in children during puberty. *Bratislavské lekárske Listy*, 89 (10): 766 – 769, 1988 (Slovak).

[8] Stilli D, Musso E, Barone P et al. Newer data on the configuration and variability ranges of body surface maps in a sample of normal subjects. *Journal of Electrocardiology,* 21 (1): 1 – 14, 1988.

[9] Jagielski J, Kałka D, Sobiesczańska M. Estimation of the chosen parameters of the body surface maps recorded during atrial excitation in normal subjects. In Electrocardiology 96. Liebman J. (Eds.), World Scientific, Singapore, 1997, 511 – 514.

[10] Kozlíková K. P-Wave body surface isointegral maps in children and in young adults. *Physiological Research*, 56 (Suppl. 1): S123 – S128, 2007.

[11] Appendix 1: Adult Normal Limits, in Comprehensive Electrocardiology. Macfarlane P et al. (Eds.), Springer, London, 2011, 2058 – 2083.