REPORT

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Effects produced by electrode characteristics on the accuracy of formation of electrical cardiac signal parameters

Yeldos A. Altay[1]*, Artem S. Kremlev[1], Sergei M. Vlasov[1], Alexey A. Margun[1], Konstantin A. Zimenko[1]

[1] St Petersburg National Research University of Information Technologies, Mechanics and Optics
Russia, 197101, St. Petersburg, Kronverksky av. 49

* Corresponding author:
e-mail: aeldos@inbox.ru

Abstract

Our results of analyzing effects made by electrode characteristics on the accuracy of the ECG signal parameters formation are presented herein. Analyzed is a correlation between the measured characteristics of the electrodes and a probability value that determines accuracy of the ECG signal parameters formation. With the help of scatter plots demonstrated is the strength of the correlation between the assessed variables. Our analysis of the obtained results shows that the harder is the contact agent in an electrode, the more accurate are the formed ECG signal parameters.

Keywords

Algorithm of ECG signal processing, Statistical processing, Correlation analysis, Scatter plot, Measuring electrodes, ECG signal accuracy, ECG signal recording

Imprint

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Introduction

Nowadays an analysis of the measuring ECG data processing is an important issue in the field of modern methods of data processing. The ECG data are usually collected non-invasively by ECG signal recording with the use of different types of electrodes placed on the human chest surface.

In practice, the required analysis of ECG data is provided with the help of specialized algorithmic means of primary and secondary data processing for making diagnostic decisions on the state of the cardiovascular system [1-4].

It is known [5-8] that the signal is inevitably affected by noises of the physiological and electrical origin when recorded with the use of the electrodes. To reduce the noises, taking into account the noise origin, various algorithmic tools of primary signal processing, in particular, noise filter algorithms, are currently being improved [5-8]. The noise effect leads to reducing the ECG signal accuracy [7].

The reliability and efficiency of the algorithmic means of the primary and secondary ECG signal processing largely depend on the used instrumentation of recording, namely, electrodes, which are responsible for formation of informative parameters of the signal against the background of noises [9]. The efficiency of the ECG signal processing analysis results, as well as the degree of complexity of the algorithmic processing tools designed to separate the informative parameters of a signal against the background of noises, depend on the quality of recording equipment. In case of a low quality of the ECG signal recording due to the characteristics of the electrodes themselves, some errors, which are associated with the formation of the ECG signal informative parameters and which in the process of noise filtering can be recognized as distortions introduced by filter algorithms, might occur. In doing so, as a consequence, algorithmic processing instruments, due to the distorted ECG signal segments at the classifier output, may produce erroneous diagnostic classification findings [10].

In view of the above, to improve the efficiency of processing the ECG data at present there is a necessity to jointly consider the measuring electrodes for the purpose of evaluation of their quality, which makes effects on the efficiency and reliability of the ECG signal

processing analysis, in particular the means of noise filtering [11,12]. The necessity of such consideration consists in the following: first, characteristics of contact conductive agents have an influence on the accuracy of reproduction (formation) of the signal parameters, i.e. the minimization of losses of the obtained ECG signal informative segments in signal recording; second, it is required to increase accuracy of the ECG signal processing instrumentation against the background of affecting noises.

However, in [12] carried out is a comparative assessment of the characteristics of the wet electrodes for evaluating the accuracy of the formation of the ECG signal parameters formation during the long-term recording. In order to assess the quantitative indicators, characterizing the quality of the ECG signal recording instruments, measured are the values of electrical resistance in contact conducting agents (CCA) in different wet electrodes. The accuracy of the long-term ECG signal parameter formation in the process of recording has been evaluated with the use of the quantitative probability value. To calculate this value we have involved a highly experienced arrhythmia expert in our studies in order to properly count the number of correctly and erroneously recorded signal parameters referred to the total number of records. The recorded parameters are as follows: wave P, T and ECG signal complexes QRS. The result of the calculation of the above value shows that in all real long-term ECG signal records the most erroneous are the P wave records: the errors have been found for all leads there. The main error in the P wave formation has been detected in the form of splitting.

This article is a continuation of our study [12], where analyzed are the characteristics of wet electrodes and their collaborative evaluation of the accuracy of the signal parameters formation. In the present paper we analyze the effect of electric resistance in the contact conductive agents of different wet electrodes on the accuracy of the P wave formation in an ECG signal through correlation relationships.

Aims

The aim of this study is to evaluate the correlation relationships between the values of electric resistance in the conductive contact agents of different wet electrodes and probability values characterizing the accuracy of the ECG signal P wave formation.

Materials and methods

The material for the study are the measured values of electric resistance of CCA, which are a widely used in models of wet electrode for ECG signal recording, namely: H92SG, H99SG, MSGLT-05MGRT, M2202A, and the calculated probability values characterizing the accuracy of the P wave formation during signal recording [12]. The values of electrical resistance for the confidence probability of Student distribution quantile P=0,95 at (n-1) tα=0,05 are presented in Table 1 herein. The probability values of true recording for different electrodes are shown in Table 2 given herein. Table 2 shows the probability value without leads aVL, II. It is feasible to present the obtained data in order to evaluate the accuracy of the P wave formation in 10 electrodes of each trade name during long-term recording, similar to the case described in [12].

Table 1
Resistance of CCA in wet electrodes

№	Electrode type	Measurement results for confidence probability P=0,95 (α=0.05 → $t_{\alpha,9}$=2,26; n-1)
		R, кОм
1	H92SG	(79,348±0,313)
2	H99SG	(174,46±0,452)
3	MSGLT-05MGRT	(30,623±0,443)
4	M2202A	(21,523±0,359)

Our evaluation of the correlation relationship between two variables for better vizualization is analyzed by scatter plotting. Scatter plotting is a statistical method that shows the distribution of two variables: a dependent variable and its predictor [13]. The dependent variable is selected as a result of a direct measurement of electrical resistance in the electrode CCA, and for the predictor we use in our case an indirect measurement result, i.e. the probability value. The predictor is a variable in the context of the present study. The plausibility of the obtained scatter plot is checked using the trend line with specified values of the confidence probability intervals. To construct the confidence probability intervals, selected is probability value P=0.95 for significance level α=0.05, respectively. The scatter plot is analyzed with the use of the STATISTICA 10.0 software (StatSoft) [14].

Results

The results of the evaluation of the correlation relationship of the analyzed variables with the use of scatter plots are shown in Figures 1-4 herein. The calculated correlation coefficient is indicated in Table 3 herein.

Table 2
Probability of true recording in a lead

№		V1	V2	V3	V4	V5	V6	I	III	aVR	aVF
PT(P)	*	0,65	0,64	0,75	0,53	0,62	0,70	0,68	0,63	0,68	0,62
	**	0,80	0,70	0,85	0,86	0,89	0,85	0,54	0,78	0,86	0,80
	***	0,95	0,94	0,97	0,96	0,94	0,95	0,96	0,92	0,95	0,97
	****	0,70	0,74	0,88	0,89	0,79	0,74	0,54	0,69	0,92	0,89

Note: Results of probabilities calculation for the electrodes are indicated
* - «H92SG», ** - «H99SG», *** - «MSGLT-05MGRT», **** - «M2202A»

Table 3
Coefficient of correlation between values from electrodes

№	Electrode type	Coefficient of correlation between values R:P
1	H92SG	0,4809
2	H99SG	0,3526
3	MSGLT-05MGRT	0,3280
4	M2202A	- 0,0343

The obtained results given in Table 3 and illustrated by Figures 1–3 show that the correlation relationship exists between the values of electric resistance and the probability value. The correlation relationship between the probability value for H92SG is r = 0.4809, for H99SG r = 0.3526, and for MSGLT-05MGRT r = 0.3280, respectively. Our analysis of scatter plots in Figures 1-3 shows that apparent outliers have not been found, and the observation points are within the confidence interval. However, in each of the H92SG, H99SG and MSGLT-05MGRT electrodes, two observations go beyond the confidence limits that indicates the absence of outliers.

However, the correlation analysis of the dependence for the M2202A electrode gives us a negative value of this ratio, namely r = - 0.0343. The analysis of the scatter plots for the given electrode shows that there are four outliers beyond the confidence limits of the probability interval P = 0.95.

We should note that in [12] the H92SG, H99SG, MSGLT-05MGRT and M2202A electrodes differed from each other in the state of their contact conductive agents, namely, liquid and solid. The M2202A electrode, during the long-term evaluation of its CCA, demonstrated changes in its reference characteristics due to an error, which occurred because of spreading of liquid CCA beyond the specified area of the electrode measuring cell. The calculated error in [12] for the M2202A electrode shows that there are outliers beyond the confidence limits of probability interval P = 0,95 and a negative correlation between the variables. The lower the outliers on a scatter plot, the more variables are grouped around the trend

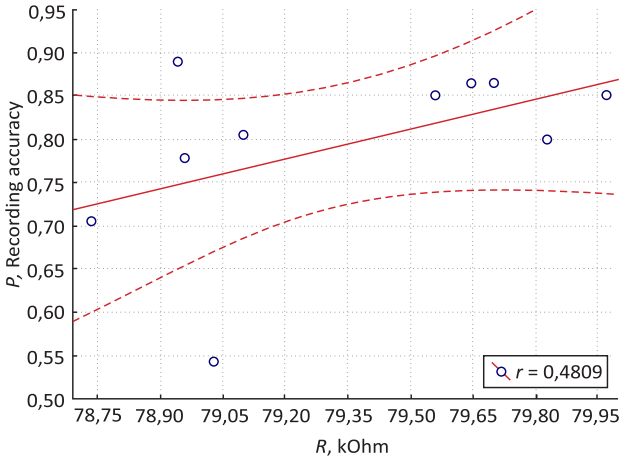

Figure 1. Scatter plot of correlation for electrode H92SG

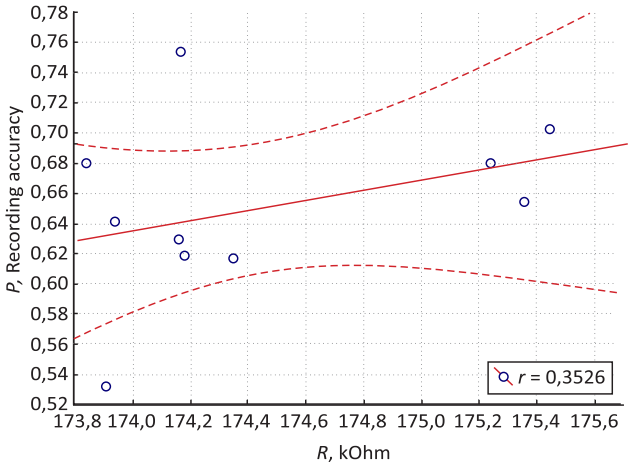

Figure 2. Scatter plot of correlation for electrode H99SG

lines, and, accordingly, the greater is the correlation value, that is different from zero, between the studied variables.

Thus, systematizing the results obtained above, we can conclude that the accuracy of the ECG signal parameters formation during long-term signal recording is influenced by liquid state of CCA in electrodes. As a consequence, electrodes with solid CCA have the most appropriate characteristics for use in long-term monitoring of the ECG signal parameters. This conclusion can be supported by the results of study [12] and the evaluation of the relationship between the electrodes characteristics with

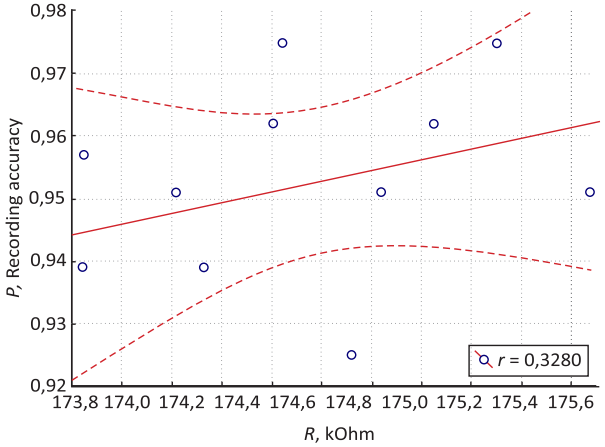

Figure 3. Scatter plot of correlation for electrode MS¬GLT-05MGRT

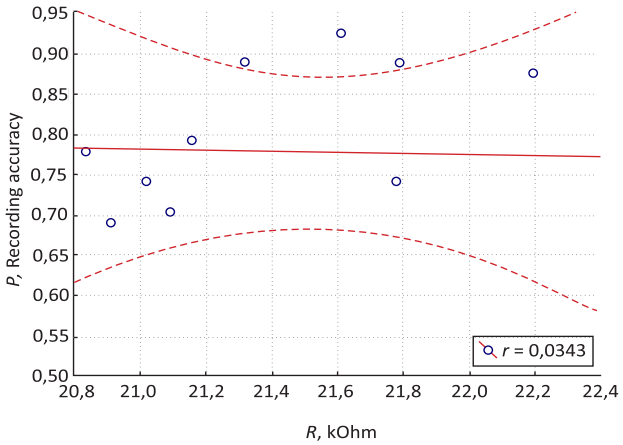

Figure 4. Scatter plot of correlation for electrode M2202A

the use of the scatter plots. The scatter plots allow us to visually assess the strength of the correlation between the studied variables and outliers beyond the confidence limits of the probability interval that makes it possible to identify the effect produced by the electrodes characteristics on the accuracy of the formation of electrical cardiac signal parameters for each electrode in the scope of the considered trademarks.

Conclusions

Thus, the results of our analysis of the effects produced by the respective electrode characteristics on the accuracy of the formation of the ECG signal parameters are presented herein. In electrodes with solid CCA the accuracy level of the formation of the ECG signal parameters is significantly higher as compared with the electrodes containing liquid CCA.

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Statement on ethical issues

Research involving people and/or animals is in full compliance with current national and international ethical standards.

Conflict of interest

None declared.

Author contributions

The authors read the ICMJE criteria for authorship and approved the final manuscript.

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