DOI: https://doi.org/10.17816/cardar233537

Research article

Diagnostic Value of Slow Conduction Index in Differential Diagnosis of Wide *QRS* Complex Arrhythmias with Left Bundle Branch Block Morphology

Mikhail P. Chmelevsky, Margarita A. Budanova, Danila A. Stepanov, Ekaterina S. Zhabina, Tatiana E. Tulintseva

Almazov National Medical Research Centre, Saint Petersburg, Russia

BACKGROUND: Differential diagnosis of arrhythmias with wide *QRS* complexes remains an unresolved problem in clinical practice. After decades of careful research, many different criteria and algorithms have been proposed, but many of them are not quite accurate and effective in real clinical conditions. One of the approaches is to use ECG to estimate the speed of propagation of excitation through the ventricular myocardium. The estimation is based on the ratio of the amplitudes of the initial and final parts of the *QRS* complex, in particular, using the slow conduction index.

AIM: To study the possibility of using the slow conduction index in the differential diagnosis of arrhythmias with wide *QRS* complexes and to carry out a detailed comparative analysis of the diagnostic value of this criterion in all 12 ECG leads with evaluation and comparison of the obtained values of diagnostic accuracy.

MATERIALS AND METHODS: The study included 280 single wide *QRS* complexes with a form of left bundle branch block (LBBB) detected during one-day and multi-day ECG monitoring in randomly selected 28 patients. For a detailed analysis, a comparison of the original 12-lead ECG and individual scalable ECG graphs for selected leads was carried out, followed by measurement of the absolute values of the total amplitudes during the initial and final 40 ms wide *QRS* complexes. For a qualitative and quantitative assessment of diagnostic significance, ROC analysis was used to determine the informative value of a diagnostic test based on sensitivity (Sn), specificity (Sp) and diagnostic accuracy (Acc).

RESULTS: According to the obtained values of Sn, Sp and Acc, all 12 leads were arranged in the following order as the diagnostic value of the slow conduction index decreased: aVL, V2, aVF, V5, III, V1, V4, II, aVR, V6, V3 and I. In the first six ECG leads, Acc was consistently above 90%, gradually decreasing in the next six leads from 89% to 67%, respectively ($p < 0.001$ for all leads).

CONCLUSIONS: The results of this study showed that the slow conduction index can be used in any ECG leads as a criterion for the differential diagnosis of arrhythmias with wide *QRS* complexes with a form of LBBB. The study also demonstrated the importance of a comprehensive approach to the analysis of the form of the *QRS* complex and the need for a consistent detailed analysis of the existing criteria for the differential diagnosis of arrhythmias with wide *QRS* complexes in different clinical groups of patients.

Keywords: differential diagnosis; wide *QRS* complex; left bundle branch block.

To cite this article:
Chmelevsky MP, Budanova MA, Stepanov DA, Zhabina ES, Tulintseva TE. Diagnostic value of Slow Conduction Index in differential diagnosis of wide *QRS* complex arrhythmias with left bundle branch block morphology. *Cardiac Arrhythmias*. 2023;3(1):17–30. DOI: https://doi.org/10.17816/cardar233537

Received: 15.02.2023 **Accepted:** 07.03.2023 **Published:** 31.03.2023

УДК 616.12

DOI: https://doi.org/10.17816/cardar233537

Научная статья

Диагностическая ценность индекса медленного проведения в 12 отведениях ЭКГ при дифференциальной диагностике аритмий с широкими комплексами *QRS* и формой блокады левой ножки пучка Гиса

М.П. Чмелевский, М.А. Буданова, Д.А. Степанов, Е.С. Жабина, Т.Э. Тулинцева

Национальный медицинский исследовательский центр им. В.А. Алмазова, Санкт-Петербург, Россия

Обоснование. Дифференциальная диагностика аритмий с широкими комплексами *QRS* остается сложной и до конца не решенной проблемой в клинической практике. После десятилетий тщательных исследований было предложено множество различных критериев и алгоритмов, но многие из них являются недостаточно точными и эффективными в реальных клинических условиях. Один из подходов дифференциальной диагностики таких аритмий — оценка на ЭКГ скоростей распространения возбуждения по миокарду желудочков на основе соотношения амплитуд начальной и конечной части комплекса *QRS*, в частности с помощью использования индекса медленного проведения.

Цель. Изучение возможности использования индекса медленного проведения в дифференциальной диагностике аритмий с широкими комплексами *QRS* с последующим детальным сравнительным анализом диагностической ценности этого критерия во всех 12 отведениях ЭКГ и сопоставлением полученных значений диагностической точности с электрофизиологической точки зрения.

Материалы и методы. В исследование было включено 280 одиночных широких комплексов *QRS* с формой блокады левой ножки пучка Гиса), выявленных при односуточном и многосуточном мониторировании ЭКГ у случайно выбранных 28 пациентов. Для детального анализа проводилось сопоставление исходной 12-канальной ЭКГ и отдельных масштабируемых графиков ЭКГ для выбранных отведений с последующим измерением абсолютных значений суммарных амплитуд в течение начальных (V_i) и конечных (V_t) 40 мс широких *QRS* комплексов. Для качественной и количественной оценки диагностической значимости использовался ROC-анализ с определением информативности диагностического теста на основании чувствительности, специфичности и диагностической точности. При сравнении площадей ROC-кривых статистически значимыми принимались значения $p < 0{,}001$.

Результаты. Согласно полученным значениям чувствительности, специфичности и диагностической точности все 12 отведений расположились в следующим порядке по мере уменьшения диагностической ценности индекса медленного проведения: aVL, V2, aVF, V5, III, V1, V4, II, aVR, V6, V3 и I. При этом в первых шести ЭКГ-отведениях диагностическая точность была стабильно выше 90 %, постепенно уменьшаясь в последующих шести отведениях с 89 до 67 % соответственно ($p < 0{,}001$ для всех отведений).

Заключение. Результаты данного исследования показали, что индекс медленного проведения может использоваться в любых отведениях ЭКГ как критерий дифференциальной диагностики аритмий с широкими комплексами *QRS* и формой блокады левой ножки пучка Гиса. Также проведенное исследование продемонстрировало важность всестороннего подхода к анализу формы комплекса *QRS* и необходимость последовательного детального анализа существующих критериев дифференциальной диагностики аритмий с широкими комплексами *QRS* в разных клинических группах пациентов.

Ключевые слова: дифференциальная диагностика; широкие комплексы *QRS*; блокада левой ножки пучка Гиса.

Как цитировать:
Чмелевский М.П., Буданова М.А., Степанов Д.А., Жабина Е.С., Тулинцева Т.Э. Диагностическая ценность индекса медленного проведения в 12 отведениях ЭКГ при дифференциальной диагностике аритмий с широкими комплексами *QRS* и формой блокады левой ножки пучка Гиса // Cardiac Arrhythmias. 2023. Т. 3, № 1. С. 17–30. DOI: https://doi.org/10.17816/cardar233537

Рукопись получена: 15.02.2023 **Рукопись одобрена:** 07.03.2023 **Опубликована:** 31.03.2023

ЭКО•ВЕКТОР

BACKGROUND

Differential diagnosis of arrhythmias with wide *QRS* complexes remains an unresolved problem in clinical practice [1, 2]. Electrocardiography (ECG) and ECG Holter monitoring are key data interpretation tools in the differential diagnosis of these arrhythmias. After decades of careful research, many different criteria and algorithms have been proposed, but many of them are not sufficiently accurate and effective in real clinical conditions [3, 4]. This is confirmed by many scientific publications and individual clinical observations that demonstrate the insufficient effectiveness of most of these algorithms [5, 6].

The main problem in the differential diagnosis of arrhythmias with wide complexes is the need to analyze the relationship between atrial and ventricular rhythms to search for signs of atrio-ventricular (AV) dissociation and other criteria for ventricular tachycardia (VT), when high-quality visualization of atrial activity waves renders difficult. In this regard, it is often impossible to use this approach and it becomes necessary to assess the shape of wide *QRS* complexes (the so-called morphological features) characteristic of VT or aberrant ventricular conduction. Despite the ever-increasing number of algorithms for assessing the shape of *QRS* complexes, most of these criteria show low diagnostic accuracy in repeated studies on different groups of patients [5]. The reasons for this are, firstly, the high degree of subjectivity in the assessment of amplitude-time characteristics by different researchers, and secondly, the inability to take into account the individual characteristics of the propagation of the excitation wave through the myocardium using these criteria in arrhythmias with wide *QRS* complexes.

In fact, all amplitude-time criteria can be divided into three groups. The first group includes signs that characterize the shape of individual deflections of the *QRS* complexes. The second group includes features that determine the duration of the individual components of the *QRS* complexes. The third one includes characteristics aimed at determining the rate of change in the amplitude of the initial and final parts of the *QRS* complexes and their ratio. At the same time, almost all amplitude-time criteria included in the first two groups show relatively low diagnostic accuracy in repeated studies on clinically different groups of patients [5]. Apparently, one of the reasons leading to such results is the presence of structural changes in the myocardium and a significant difference in the individual ratios of the shape of the chest and the location of the heart, which largely affect the amplitude characteristics of individual elements of the *QRS* complex and their duration.

As we pointed out in our previous publication [7], one of the approaches designed to solve these problems is the ECG assessment of the propagation velocities of excitation through the ventricular myocardium based on the ratio of the amplitudes of the initial and final parts of the *QRS* complex. The most well-known criterion for assessing the amplitude ratio is the slow conduction index proposed by A. Vereckei et al. [8]. This criterion allows for differential diagnosis of arrhythmias with wide *QRS* complexes based on the analysis of the ratio of the absolute values of the total amplitude of the *QRS* complex over the first and last 40 ms, which is calculated in each individual ECG lead. This approach greatly reduces the subjectivity of wide *QRS* morphology assessment by different specialists, especially in complex cases of arrhythmias with the form of a complex in the form of a left bundle branch block (LBBB).

One of the features of using the slow conduction index is the need to select an ECG lead with a wide RS-type complex according to the original concept of the authors of the proposed criterion [8]. However, the choice of an ECG lead is largely arbitrary, especially in the presence of several similar leads, which can show conflicting results. At the same time, in a number of other cases, the absence of an RS-type form of the complex leads to the formal impossibility of using the slow conduction index in practical work. Such features of the use of this criterion, in our opinion, are significant limitations. In this regard, in our previous publication, we presented the results of a study that showed the fundamental possibility of using the slow conduction index in the differential diagnosis of arrhythmias with wide *QRS* complexes in any ECG lead without the need to search for a biphasic wide complex with an RS-type shape [7]. In addition, it was shown that the diagnostic value of the slow conduction index was quite high in leads II, III, aVL, aVF, V1, V2, V4, V5 (8 out of 12). At the same time, upon careful study of the obtained results, it becomes obvious that a detailed comparison of the diagnostic value of this criterion in 12 ECG leads, as well as a detailed analysis of the obtained incorrect values, is necessary. It is also necessary to evaluate the results of the study in terms of analyzing the relationship between the obtained diagnostic characteristics and the electrophysiological features of the propagation of the excitation wave through the myocardium.

In this regard, this work continues the previous study on the possibility of using the slow conduction index in the differential diagnosis of arrhythmias with wide *QRS* complexes. It is also devoted to a detailed comparative analysis of the diagnostic value of this criterion in all 12 ECG leads with evaluation and comparison of the obtained values of diagnostic accuracy, as well as analysis of the obtained results from the electrophysiological point of view.

MATERIALS AND METHODS

Data processing and recording

The layout for recording and processing ECG data for subsequent analysis was described in detail in a previous publication [7]. In this work, a detailed analysis of the morphological characteristics of *QRS* and a consistent comparison of the total amplitude during the initial and final 40 ms wide

ventricular complexes were additionally carried out in those cases and ECG leads, when the use of the slow conduction index led to erroneous results. To do this, a comparison of the original 12-channel ECG and individual scalable ECG graphs for the selected leads was carried out, followed by the measurement of the absolute values of the total amplitudes during the initial and final 40 ms wide *QRS* complexes.

Building scalable ECG graphs

To build separate scalable graphs, ECG data was exported from the PhysioNet in the text format, which were then imported into Microsoft Excel spreadsheets (Microsoft Corporation, 2016). The amplitude-time values of the ECG were synchronized in 12 leads according to the sampling frequency of the original signal. After finding the boundaries of the *QRS* before its beginning and after its end, the values of 100–120 ms were plotted, which were used as points between which the ECG was visualized in a separately selected lead using the built-in tools for creating graphs in Microsoft Excel. As a result, for each separately selected ECG lead, two-dimensional diagrams were constructed, on which the time scale was plotted along the abscissa axis (*X*) with a scale corresponding to the minimum value of the sampling frequency of the original recording. The amplitude scale was plotted along the ordinate axis (*Y*) with automatic scaling according to the initial values of the potentials of the *QRS* complex. After that, on each ECG graph, 40 ms from the beginning and end of the wide *QRS* complex were plotted on the time scale, and the absolute values of the total amplitudes at these points were measured, followed by a comparison of the results obtained.

STATISTICAL ANALYSIS

The technique of statistical analysis is also described in detail in our previous publication [7].

In this work, a detailed study of the diagnostic value of the slow conduction index was carried out based on a comparison of the results of ROC analysis. To assess and compare the areas of ROC curves (AUC — Area Under Curve) in all 12 leads, a nonparametric approach was used according to the DeLonghi-Clark-Pearson method [9]. Further comparison of the areas under the curves was carried out based on the values of the standard error calculation method of Hanley and McNeil [10; 11], and an exact 95% confidence interval (CI) based on the binomial distribution [12]. To compare the results, baseline p values < 0.05 were assumed to be statistically significant. Diagrams of ROC curves were visualized using a color scale for each ECG lead (6 out of 12) on one graph.

For additional analysis of the results, a plot of the area difference (AUC difference) of the ROC curves and the corresponding significance level p was plotted by analogy with the method of constructing correlograms [13]. To visualize the change in the absolute values of the difference in the areas of the ROC curves and the corresponding significance levels, a color palette in the RYG (Red-Yellow-Green) format was used.

The calculated values of sensitivity (Sn), specificity (Sp) and diagnostic accuracy (Acc) for all 12 ECG leads were compared with each other and visualized in the form of color grouped bar graphs for clarity.

After analyzing the number of comparisons made with the p-level estimate and calculating the probability of an incorrect conclusion regarding at least one of the hypotheses that significantly exceeds the initial significance level (p < 0.05), it was decided to correct the obtained values for multiple testing using the Bonferroni corrections [14]. As a result, p values < 0.001 were finally considered statistically significant. The resulting AUC difference plots of the ROC curves were adjusted according to this final accepted level of statistical significance.

Complete statistical analysis was performed using Statistica v.12 (Statsoft Inc., USA), SPSS v.23 (IBM Corp., USA), and MedCalc Statistical Software v.20.115 (MedCalc Software Ltd, Ostend, Belgium).

RESULTS

Diagnostic value of slow conduction index in 12-lead ECG

According to the obtained values of Sn, Sp and Acc, all 12 leads were arranged in the following order as the diagnostic value of the slow conduction index decreased: aVL, V2, aVF, V5, III, V1, V4, II, aVR, V6, V3 and I. In the first six ECG leads, Acc was consistently above 90%, gradually decreasing in the next six leads from 89% to 67%, respectively (Fig. 1). All obtained values were statistically significant (p < 0.001).

Comparison of the Obtained Values of the Diagnostics of the Slow Conduction Index in 12 ECG Leads

Comparison of the ROC curves showed that the diagnostic value of the slow conduction index does not differ significantly in leads aVL, V2, aVF, V5, III, V1, while in leads V4, II, aVR, V6, V3, and I it clearly decreases (Fig. 2).

According to the ROC area difference chart, there were no significant differences in the diagnostic value of the slow conduction index for the first 8 leads (aVL, V2, aVF, V5, III, V1, V4 and II), while the remaining leads (aVR, V6, V3 and I) were statistically significantly different from them (Fig. 3).

Evaluation of the obtained incorrect values of the slow conduction index in individual ECG leads

A detailed examination of the results obtained revealed that in some cases the use of the slow conduction index led to errors in the differential diagnosis of wide *QRS* complexes. These cases were singled out and selected for further analysis. So, as a result of reviewing some ECGs with

Fig. 1. Histogram of slow conduction index Sensitivity (Sn), Specificity (Sp) and diagnostic Accuracy (Acc) for 12 lead ECG

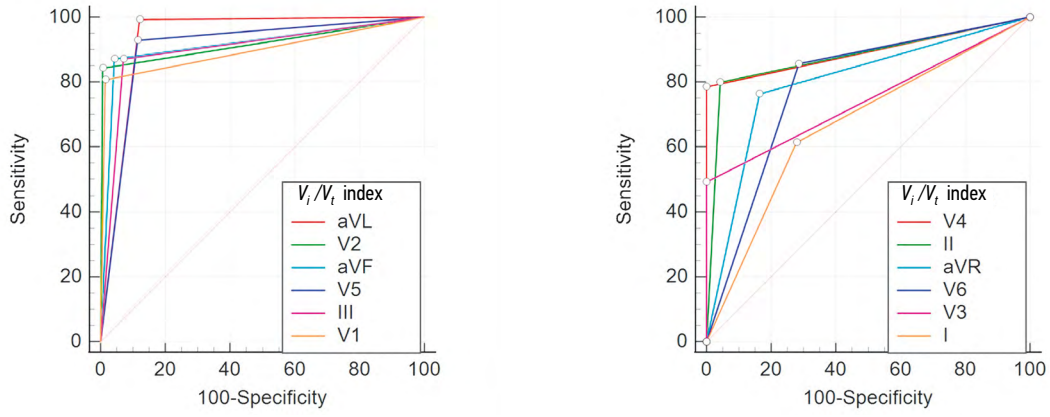

Fig. 2. ROC curves comparison charts as an illustration of slow conduction index diagnostic value difference for 12 lead ECG. Cut-off values are marked as red marker on each of ROC curves

premature atrial contractions (PAC) and aberrant conduction by the type of LBB block, it turned out that in one of the leads (aVL) the use of the obtained values of the slow conduction index $V_i / V_t < 1$) led to an erroneous diagnosis of premature ventricular contractions (PVC), while in in all other leads, the use of this criterion showed correct results (Fig. 4). Analysis of the scaled ECG plot in lead aVL showed that the absolute values of the amplitudes of the initial (V_i) and final (V_t) 40 ms of the *QRS* complex were 94 μV and 316 μV, respectively (Fig. 5). Similarly, reviewing some PVC ECGs with a form of LBBB, it was found that in some leads (aVR) the use of the obtained slow conduction index values ($V_i / V_t > 1$) led to an erroneous diagnosis of PAC, while in all other leads the use of this criterion showed correct results (Fig. 6). Analysis of the scaled ECG plot in lead aVL showed that the absolute values of the amplitudes of the initial (V_i)

Area under curve (AUC)		0.94	0.92	0.91	0.91	0.90	0.90	0.89	0.88	0.80	0.79	0.75	0.67
		AUC difference											
max	Lead	aVL	V2	aVF	V5	III	VI	V4	II	aVR	V6	V3	1
0.94	aVL		0.018	0.021	0.029	0.036	0.039	0.043	0.057	0.136	0.150	0.189	0.268
0.92	V2	0.407		0.004	0.011	0.018	0.021	0.025	0.018	0.096	0.111	0.150	0.229
0.91	aVF	0.268	0.884		0.007	0.014	0.018	0.021	0.036	0.114	0.129	0.168	0.246
0.91	V5	0.226	0.620	0.776		0.007	0.011	0.014	0.029	0.107	0.121	0.161	0.239
0.90	III	0.049	0.482	0.100	0.785		0.004	0.007	0.021	0.100	0.114	0.154	0.232
0.90	VI	0.078	0.239	0.312	0.671	0.671		0.004	0.018	0.096	0.111	0.150	0.229
0.89	V4	0.059	0.336	0.310	0.545	0.754	0.873		0.014	0.093	0.107	0.146	0.225
0.88	II	0.012	0.385	0.011	0.190	0.194	0.385	0.516		0.079	0.093	0.132	0.211
0.80	aVR	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001		0.014	0.054	0.132
0.79	V6	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.576		0.039	0.118
0.75	V3	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.076	0.218		0.079
0.67	1	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.002	0.023	
min		min	*p*-value										max

Fig. 3. Diagram of AUC difference between ROC curves (right upper triangle) and corresponding p-value (left bottom triangle) illustrating a difference of slow conduction index diagnostic value in 12 lead ECG. Leads are sorted towards a decrease of their diagnostic value from up to down (left column) and from left to the right (upper row) according to the calculated absolute value. A color palette of diagram shows changing of AUC difference absolute values from min (green) to max (red) and *p*-values from max (green) to min (red). AUC difference with corresponding $p < 0.001$ are marked with red font on white background

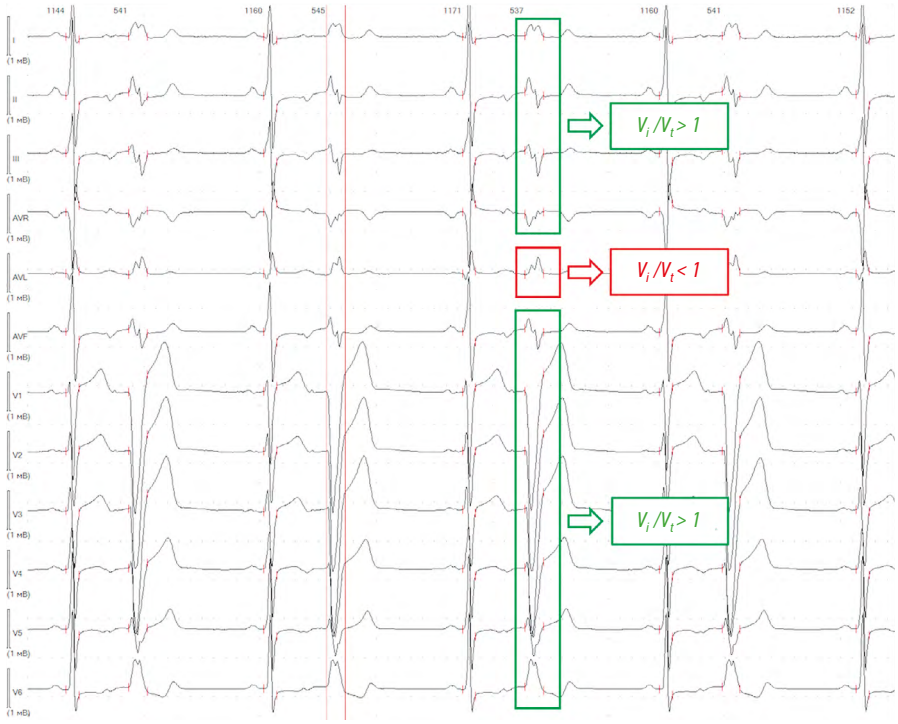

Fig. 4. ECG example of supraventricular extrasystoles with LBBB aberration. Borders of all *QRS* complex are marked with small red vertical lines. Borders of selected for analysis wide QRS complex are marked with solid red vertical lines in all 12 ECG leads. Leads with correct results ($V_i / V_t > 1$) of slow conduction index calculations in differential diagnosis are marked with green color while leads with wrong results ($V_i / V_t < 1$) for this case are marked with red color

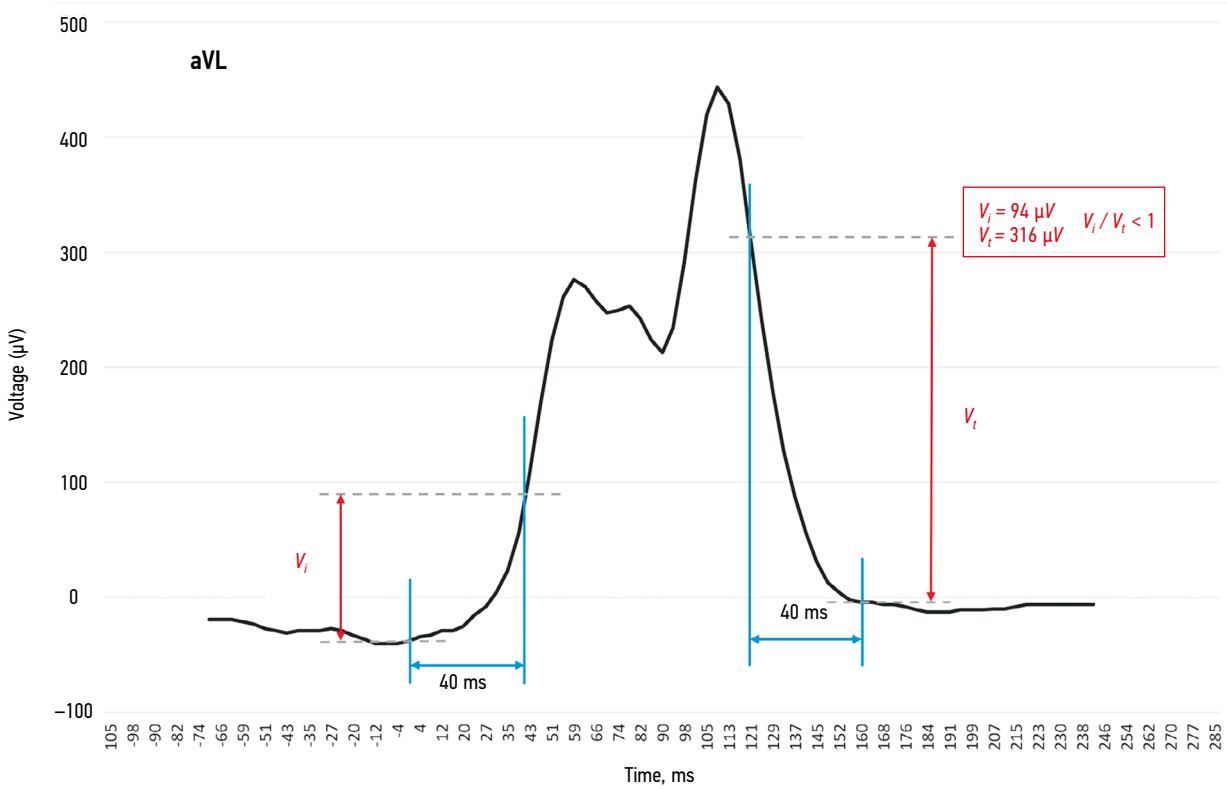

Fig. 5. ECG plot in aVL lead and determination of an absolute values of initial (V_i) and terminal (V_t) 40 ms of wide *QRS* complex for the case of supraventricular extrasystoles with LBBB aberration where calculation of slow conduction index (V_i / V_t) shows wrong results (V_i / V_t < 1) in differential diagnosis. Voltage (μV) — ECG amplitude (microVolts), time in ms

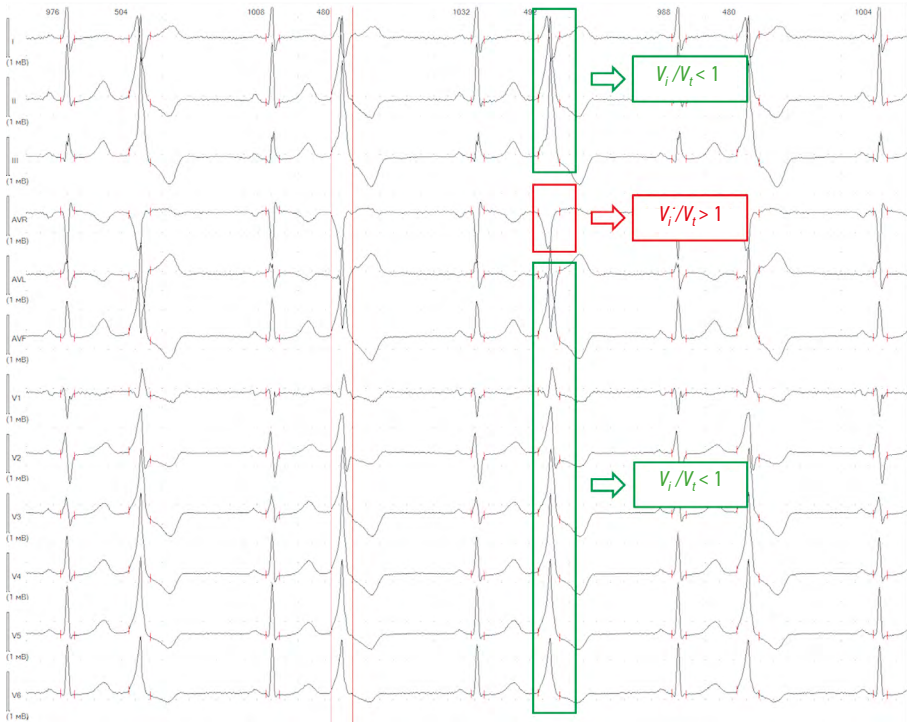

Fig. 6. ECG example of ventricular extrasystoles with LBBB type morphology. Borders of all *QRS* complex are marked with small red vertical lines. Borders of selected for analysis wide QRS complex are marked with solid red vertical lines in all 12 ECG leads. Leads with correct results (V_i/ V_t < 1) of slow conduction index calculations in differential diagnosis are marked with green color while leads with wrong results (V_i/ V_t> 1) for this case are marked with red color

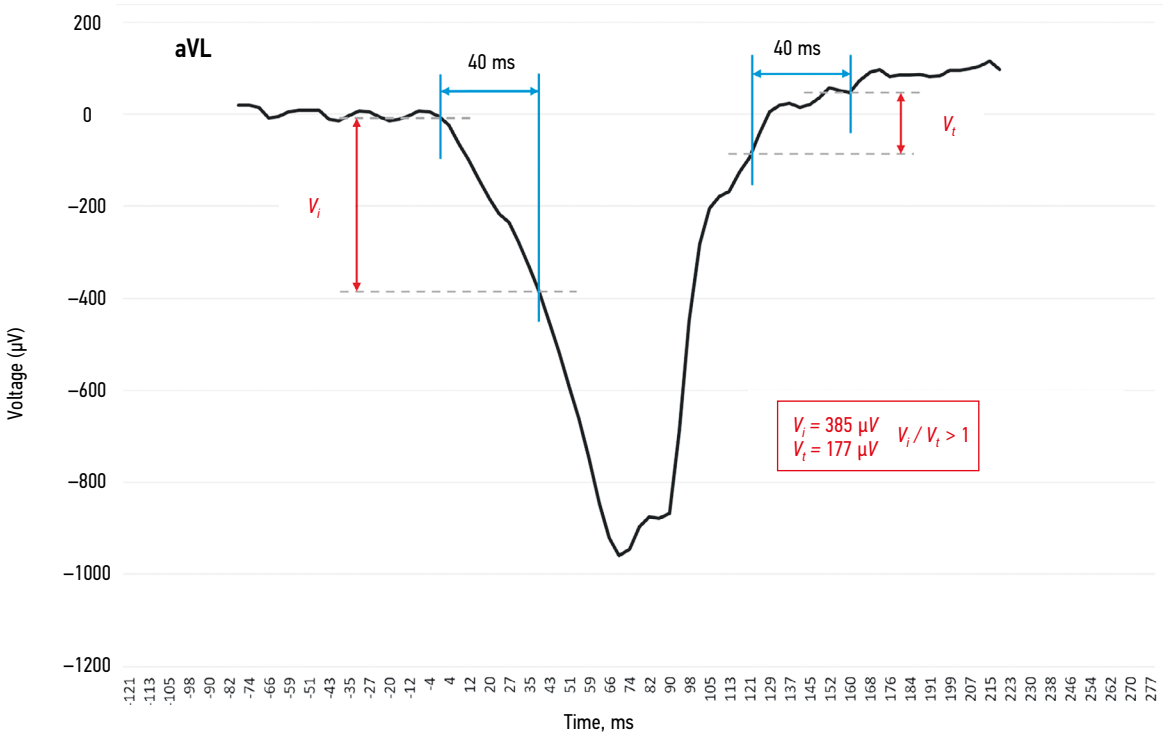

Fig. 7. ECG plot in aVR lead and determination of an absolute values of initial (V_i) and terminal (V_t) 40 ms of wide *QRS* complex for the case of ventricular extrasystoles with LBBB type morphology where calculation of slow conduction index (V_i / V_t) shows wrong results (V_i / V_t > 1) in differential diagnosis. Voltage (μV) — ECG amplitude (microVolts), time in ms

and final (V_t) 40 ms of the *QRS* complex were 385 μV and 177 μV, respectively (Fig. 7).

Further consideration of the obtained results showed that the frequency of occurrence of such cases with incorrect values of the slow conduction index, leading to erroneous results in the differential diagnosis of arrhythmias with wide *QRS* complexes, directly corresponds to the values of the diagnostic accuracy of this criterion in each ECG lead shown in Fig. 1.

DISCUSSION

Main results

The study showed that the diagnostic value of the slow conduction index does not differ significantly in leads aVL, V2, aVF, V5, III, V1, V4, and II, while for the remaining leads aVR, V6, V3, and I, it clearly decreases (Figures 1 and 3). These facts once again confirm the results of the previous study [7], which showed the fundamental possibility of using this diagnostic criterion in any ECG leads. In addition, the obtained results show in which leads the use of the slow conduction index leads to the best results in the differential diagnosis of arrhythmias with wide *QRS* complexes with LBBB.

Analysis of the results of comparing the values of the diagnostics of the slow conduction index in 12 ECG leads

A detailed analysis of color grouped bar graphs with the values of diagnostics showed that the spread of Sn and Sp values in leads aVL, V2, aVF, V5 and III does not exceed 10% at the level of Acc from 94% to 90%, respectively (Fig. 1). This fact testifies to the significant robustness of the slow conduction index against changes in the shape of wide *QRS* complexes with the form of LBB blockade as a criterion for the differential diagnosis of such arrhythmias. This is confirmed by a direct comparison of the shape of the ROC curves in these leads (Fig. 2), as well as a sequential pairwise comparison of the difference in their areas (AUC) and the corresponding significance levels p (Fig. 3). For the remaining leads V1, V4, II, aVR, V6, V4 and I, the spread of Sn and Sp values increases significantly, reaching 51% in lead V3, and the values of Acc, respectively, begin to decrease markedly from 89% to 67%. This, in turn, may indicate a significant sensitivity of the slow conduction index to changes in the shape of wide *QRS* complexes in these leads. At the same time, sequential pairwise comparison of the area difference (AUC) and the corresponding significance levels p for these leads in Fig. 3 shows that for leads aVR, V6, V3, and I, the difference in diagnostic values reaches the level of statistical significance adopted in this study ($p < 0.001$). These facts confirm that these leads are not the best choice for using the slow conduction index as a criterion for the differential diagnosis of arrhythmias with wide *QRS* complexes with a form of LBBB.

In general, the analysis of the color palette of the diagram of the difference in the areas of ROC curves shows a gradual significant and pronounced decrease in the diagnostic value of the slow conduction index from its central part towards

the right and lower borders, while there is no such significant difference in the upper-central part of the diagram.

Analysis of cases of incorrect differential diagnosis of wide QRS complexes when calculating the index of slow conduction in some individual ECG leads

According to the results obtained, the use of the slow conduction index in some cases led to erroneous results in the differential diagnosis of wide *QRS* complexes. As the most illustrative cases, ECGs of one of the patients with PAC and aberrant conduction in the form of LBBB were selected and it was shown that in one of the leads (aVL) the calculated index of slow conduction incorrectly indicates the ventricular genesis of these wide *QRS* ($V_i / V_t < 1$) complexes, while in the remaining 11 leads diagnostics is correct (Fig. 4). When considering the scaled ECG graph in lead aVL, it turned out that the absolute value of the amplitude of the initial 40 ms of the *QRS* complex (V_i) is three times less than the corresponding value of the final 40 ms (Fig. 5). The reason for this is, apparently, that the first 20 ms of the *QRS* complex are almost isoelectric and a significant increase in amplitude begins only from the 30th ms. However, this does not mean that during the first 20 ms, excitation spreads slowly through the myocardium. In this case, such individual anatomical features of this patient as the location of the heart in the chest and its shape relative to the recording leads, as well as the electrophysiological features of the course of excitation in the myocardium lead to the fact that the main vector of the first 20 ms of depolarization is directed almost perpendicular to aVL lead, which results into isoelectric form of this section of the ECG.

A similar situation arises when considering another selected case of PVC with LBBB, when in one of the leads (aVR) the calculated slow conduction index also incorrectly indicates the supraventricular genesis of wide *QRS* ($V_i / V_t > 1$), while in the other 11 leads, this criterion correctly diagnoses PAC (Fig. 6). When considering the scaled ECG plot in aVR lead, it turns out that the absolute value of the amplitude of the initial 40 ms of the *QRS* complex (V_i) is more than twice the corresponding value of the final 40 ms (Fig. 7). Similar to the previous case, when analyzing the terminal part of the *QRS* complex, it becomes apparent that the last 30 ms is almost isoelectric. The reasons for this, apparently, are the same as in the situation described above with incorrect diagnosis of PVC in lead aVL in a patient with PAC and aberrant conduction like LBBB.

When analyzing the remaining cases of incorrect results of differential diagnosis, it turned out that in the vast majority of cases the causes are similar to those described above. From our point of view, these facts testify that with an arbitrary choice of one of the 12 ECG leads for calculating the slow conduction index, erroneous results may spontaneously appear. In this regard, to use this criterion in the differential diagnosis of arrhythmias with wide *QRS* complexes, it is necessary to choose ECG leads with the highest diagnostic value.

Evaluation of the results of using the slow conduction index in connection with the electrophysiological features of the propagation of excitation through the myocardium

As shown above, in some cases, the use of the slow conduction index in individual ECG leads may show incorrect results in the differential diagnosis of wide *QRS* complexes. This raises the question: are these erroneous results random or are there any definite patterns? To answer this question, we must first consider more detail the electrophysiological basis for the use of the slow conduction index.

The original algorithm of A. Vereckei is based solely on the hypothesis of differences in the direction and speed of initial and final myocardial activation during ventricular and supraventricular arrhythmias with aberrant conduction [8]. The electrophysiological rationale for the slow conduction index criterion is that during arrhythmias with wide *QRS* due to PAC, the initial activation of the interventricular septum (occurring either from left to right or from right to left, depending on the type of BBB) occurs at a rate slightly slower than during normal conduction of the excitation wave according to the His-Purkinje system, and intraventricular conduction delay, causing a wide *QRS* complex, occurs in its middle and final parts. As a result, the increase in the amplitude of the initial part of the *QRS* complex will occur more rapidly than the final one. Therefore, the slow conduction index is greater than 1 ($V_i / V_t > 1$) during supraventricular tachycardias with aberrant conduction. In arrhythmias with wide *QRS* due to PVC, the slower propagation of the excitation wave through the contractile myocardium occurs until the impulse reaches the His-Purkinje system, after which the rest of the myocardium is activated more rapidly. As a result, the amplitude of the initial part of the *QRS* complex rises much more slowly, so the slow conduction index is less than 1 ($V_i / V_t < 1$) during ventricular tachycardias. According to the authors, this assumption should be true regardless of the mechanism of occurrence of VT, the presence or absence of structural heart disease [3]. At the same time, the authors point to the use, among other things, of another assumption when developing the criterion for the slow conduction index (V_i / V_t) that the steepness of the initial part of the wide *QRS* complex is directly proportional to the conduction velocity of the excitation wave propagating in the ventricles [3].

A critical analysis of the electrophysiological foundations of these hypotheses shows that these assumptions, from our point of view, only partially reflect the real relationship between the shape of the *QRS* complex and the nature of the propagation of the excitation wave through the ventricles of the heart. First, the assumption that the degree of increase in the amplitude of the initial part of the *QRS* complex is directly proportional to the rate of conduction of excitation in the ventricles is based on a simplified idea of the shape and homogeneity of the excitation wave front. In fact, as shown in experimental studies, when various conduction blockades

occur, the excitation waveform can vary significantly and be divided into several fronts [15–18]. Secondly, according to the accepted dipole ECG model, the propagation of excitation can be described by the vector theory in the form of the dependence of the amplitude of the *QRS* complex on the location of the recording electrode on the body surface with respect to the front of the excitation wave in the ventricles of the heart [19]. However, this dependence is not linear and also implies the use of a significantly simplified dipole model, when the ECG is a total reflection of the electrical activity of the heart [20, 21]. Thus, the magnitude of the amplitude of the initial and final parts of the *QRS* complex is not a direct reflection of the nature of the propagation of the excitation wave in the heart.

In addition, it is important to note that the original concept of using the slow conduction index for the differential diagnosis of arrhythmias with wide *QRS* complexes, proposed by the authors, involves only assessing the ratio of the amplitudes of the initial and final parts of the *QRS* complex (V_i / V_t) relative to each other. Moreover, not only the values of the amplitudes themselves, but also the absolute value of this ratio are not used in the analysis, which leads to the loss of a significant part of the information, since these values also register the features of the rate of change in the *QRS* amplitude as an indirect characteristic of the speed and direction of propagation of the excitation wave through the myocardium. It should also be added that the assessment of these parameters in the sections of the initial and final part of the *QRS* complex with a duration of 40 ms poses a significant number of questions without an obvious electrophysiological justification.

Thus, the incorrect results of the differential diagnosis of wide *QRS* complexes when using the slow conduction index are, apparently, a reflection of the limitations of this criterion as a characteristic that actually reflects the course and nature of the propagation of the excitation wave through the ventricles of the heart. These limitations, most likely, are systematic rather than random and lead to an understanding of the need for a deeper and more detailed analysis of the relationship between the surface ECG and the electrophysiological features of the conduction of excitation through the myocardium.

Analysis of the methodology used and evaluation of the results of the study in connection with previously published data

In their original work, the authors of the proposed slow conduction index criterion showed that their algorithm was generally superior to the P.Brugada algorithm in terms of diagnostic accuracy (90.3% vs. 84.8%, respectively) [3]. At the same time, the superiority of the A. Vereckei algorithm was mainly due to the significantly better overall accuracy of testing the V_i / V_t criterion at the 4th step compared to the 4th step of the P. Brugada algorithm (82.2% versus 68%, respectively). Later proposed by A. Vereckei et al. the algorithm for the differential diagnosis of arrhythmias with wide *QRS* complexes based on only one aVR lead showed that the overall accuracy of testing the new criteria was similar to the accuracy of the first A. Vereckei algorithm and exceeded the accuracy of the P. Brugada algorithm (91.5% versus 90.7% and 85, 5%, respectively) [22].

However, when analyzing subsequent publications, it turned out that independent assessments of different research groups did not show such high diagnostic characteristics as described in the original publications by A. Vereckei et al. [23–28]. For example, one of the groups showed that, when independently tested, the A. Vereckei algorithm showed high sensitivity, but very low specificity (29%) [26].

From our point of view, the published results show that the algorithm used has been tested on different groups of patients, as well as by different researchers, without using a common standardized approach. Moreover, the ECG analysis and calculation of the slow conduction index were carried out manually without the use of modern digital information processing methods. In addition, it becomes obvious that the subjective method of selecting different ECG leads was used to calculate the index of slow conduction according to the first original algorithm of A.Vereckei. When using the new aVR algorithm, the degree of subjectivity, apparently, was lower, however, the use of different groups of patients and the lack of digital methods for recording and processing ECG do not allow an objective comparison of previously published research results. Similar conclusions are reached by other scientific groups that have conducted a detailed analysis of the results of using various algorithms for the differential diagnosis of arrhythmias with wide *QRS* complexes [29].

In this regard, it should be noted in general that the method of calculating the slow conduction index is extremely important. Firstly, the ECGs selected for analysis should initially be recorded digitally at a high sampling rate, and not on paper at a speed of 25 mm/s, as is often described in many publications. Secondly, a detailed analysis of the initial and final parts of the *QRS* and an assessment of the characteristics of its shape in different ECG leads is necessary. That is why the ECG analysis technique used by us in this study was initially developed taking into account all the above features. Moreover, this method of analysis of the results was subjected to a thorough retrospective analysis, and the results obtained were analyzed in detail using modern digital information processing methods and the possibility of detailed scaling of the ECG.

It also becomes apparent that one of the important components of any study in the differential diagnosis of arrhythmias with wide *QRS* complexes is the analysis of the ECG in all 12 leads. From our point of view, the algorithm for using a single lead aVR (proposed by A. Vereckei et al.) has significant drawbacks, since it completely ignores all other information from the remaining 11 ECG leads. In this regard, the obtained high values of the diagnostic accuracy of the algorithm of A. Vereckei et al. in their original study are questionable, despite the relatively

large group of patients used for analysis. Later publications of the results of an independent assessment of various research groups showed a rather low specificity of these criteria. In our work, we also received confirmation of these data, since the results of this study indicate that aVR lead was not the best choice for calculating slow conduction index in the differential diagnosis of wide *QRS* arrhythmias. Moreover, we have shown that in a number of cases, it is in lead aVR that the calculation of the slow conduction index leads to an incorrect result due to the final isoelectric part of the wide *QRS* complex. From our point of view, this is yet another confirmation of the need to analyze all ECG leads in the differential diagnosis of this type of arrhythmias.

Assessment of the representativeness and limitations of the study

The possible limitations of this study were detailed in our previous publication [7]. However, it should be noted that certain limitations may also apply to the limits of applicability of the slow conduction index criterion from an electrophysiological and anatomical point of view. So, the analysis of later publications shows that the authors of various studies also noted certain limitations when using the slow conduction index as a criterion for differential diagnosis [6, 28–30]. In particular, it was pointed out that myocardial diseases with local changes in different segments of the ventricles can lead to changes in the rates of excitation propagation, and, accordingly, incorrect values of the slow conduction index [3]. For example, in the case of local fibrotic changes in the myocardium, the use of this criterion cannot be used in the differential diagnosis of arrhythmias with wide *QRS* complexes. These situations require further research.

CONCLUSION

In the study, the diagnostic value of the slow conduction index in all 12 ECG leads was analyzed, and a detailed analysis of the results obtained from the electrophysiological and clinical points of view was carried out.

The results of this study showed that the slow conduction index can be used in any ECG leads as a criterion for the differential diagnosis of arrhythmias with wide *QRS* complexes with a form of LBBB. According to the obtained values of Sn, Sp and Acc, all 12 leads were sequentially arranged as the diagnostic value of the slow conduction index decreased from 94% to 67% in the following order: aVL, V2, aVF, V5, III, V1, V4, II, aVR, V6 , V3 and I. In these circumstances, in the first 4 leads (aVL, V2, aVF, V5 and III), the level of Acc was from 94% to 90%, respectively.

The study also demonstrated the importance of a comprehensive approach to the analysis of the form of the *QRS* complex and the need for a consistent detailed analysis of the existing criteria for the differential diagnosis of arrhythmias with wide *QRS* complexes in different clinical groups of patients.

ADDITIONAL INFORMATION

Funding. The study was carried out within the framework of the state task of the Ministry of Health of the Russian Federation (No. 123021000126-0) [31].

Conflict of interest. The authors declare the absence of obvious and potential conflicts of interest related to the publication of this article.

REFERENCES

1. Abedin Z. Differential diagnosis of wide QRS tachycardia: A review. *J Arrhythm*. 2021;37(5):1162–1172. DOI:10.1002/joa3.12599

2. Medvedev M.M. Differential diagnosis of tachycardia with wide QRS complexes: from «classical» signs to the first algorithms. *Journal of Arrhythmology*. 2019;26(3):48–56. (In Russ.). DOI: 10.35336/ VA-2019-3-48-56

3. Vereckei A. Current algorithms for the diagnosis of wide QRS complex tachycardias. *Curr Cardiol Rev*. 2014;10(3):262–276. DOI: 10.2174/1573403x10666140514103309

4. Kashou AH, Evenson CM, Noseworthy PA, et al. Differentiating wide complex tachycardias: A historical perspective. *Indian Heart J*. 2021;73(1):7–13. DOI: 10.1016/j.ihj.2020.09.006

5. Kashou AH, Noseworthy PA, DeSimone CV, et al. Wide Complex Tachycardia Differentiation: A Reappraisal of the State-of-the-Art. *J Am Heart Assoc*. 2020;9(11):e016598. DOI: 10.1161/JAHA.120.016598

6. May AM, Brenes-Salazar JA, DeSimone CV, et al. Electrocardiogram algorithms used to differentiate wide complex tachycardias demonstrate diagnostic limitations when applied by non-cardiologists. *J Electrocardiol*. 2018;51(6):1103–1109. DOI: 10.1016/j.jelectrocard.2018.09.015

7. Chmelevsky MP, Budanova MA, Treshkur TV. Differential Diagnostics of Wide QRS Complex Arrhythmias with Left Bundle Branch Block Morphology Using Slow Conduction Index. *Cardiac Arrhythmias*. 2022;2(3):49–59. DOI: 10.17816/cardar112593

8. Vereckei A, Duray G, Szenasi G, et al. Application of a new algorithm in the differential diagnosis of wide QRS complex tachycardia. *Eur Heart J*. 2007;28(5):589–600. DOI: 10.1093/eurheartj/ehl473

9. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics*. 1988;44(3):837–845.

10. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*. 1982;143(1):29–36. DOI: 10.1148/radiology.143.1.7063747

11. Hanley JA, Hajian-Tilaki KO. Sampling variability of nonparametric estimates of the areas under receiver operating

characteristic curves: an update. *Acad Radiol*. 1997;4(1):49–58. DOI: 10.1016/s1076-6332(97)80161-4
12. Hilgers RA. Distribution-free confidence bounds for ROC curves. *Methods Inf Med*. 1991;30(2):96–101.
13. Friendly M. Corrgrams: Exploratory Displays for Correlation Matrices. *The American Statistician*. 2002;56(4):316–324. DOI: 10.1198/000313002533
14. Dunn OJ. Multiple Comparisons among Means. *Journal of the American Statistical Association*. 1961;56(293):52–64. DOI:10.1080/01621459.1961.10482090
15. Auricchio A, Fantoni C, Regoli F, et al. Characterization of left ventricular activation in patients with heart failure and left bundle-branch block. *Circulation*. 2004;109(9):1133–1139. DOI: 10.1161/01.CIR.0000118502.91105.F6
16. Fantoni C, Kawabata M, Massaro R, et al. Right and left ventricular activation sequence in patients with heart failure and right bundle branch block: a detailed analysis using three-dimensional non-fluoroscopic electroanatomic mapping system. *J Cardiovasc Electrophysiol*. 2005;16(2):112–119; discussion 120–121. DOI:10.1046/j.1540-8167.2005.40777.x
17. Tan NY, Witt CM, Oh JK, Cha YM. Left Bundle Branch Block: Current and Future Perspectives. *Circ Arrhythm Electrophysiol*. 2020;13(4):e008239. DOI: 10.1161/CIRCEP.119.008239
18. Vijayaraman P, Panikkath R, Mascarenhas V, Bauch TD. Left bundle branch pacing utilizing three dimensional mapping. *J Cardiovasc Electrophysiol*. 2019;30(12):3050–3056. DOI:10.1111/jce.14242.
19. Geselowitz DB. Dipole theory in electrocardiography. *Am J Cardiol*. 1964;14:301–306. DOI: 10.1016/0002-9149(64)90072-4
20. Versaci M, Angiulli G, La Foresta F. A Modified Heart Dipole Model for the Generation of Pathological ECG Signals. *Computation*. 2020;8(4):92. DOI: 10.3390/computation8040092
21. Westwood JD. *Medicine meets virtual reality 17: NextMed design forthe well being*. Amsterdam, Washington DC: IOS Press; 2009. P. 477.
22. Vereckei A, Duray G, Szénási G, et al. New algorithm using only lead aVR for differential diagnosis of wide QRS complex tachycardia. *Heart Rhythm*. 2008;5(1):89–98. DOI: 10.1016/j.hrthm.2007.09.020
23. Jastrzebski M, Sasaki K, Kukla P, et al. The ventricular tachycardia score: a novel approach to electrocardiographic diagnosis of ventricular tachycardia. *Europace*. 2016;18(4):578–584. DOI: 10.1093/europace/euv118
24. Chen Q, Xu J, Gianni C, et al. Simple electrocardiographic criteria for rapid identification of wide QRS complex tachycardia: The new limb lead algorithm. *Heart Rhythm*. 2020;17(3):431–438. DOI: 10.1016/j.hrthm.2019.09.021
25. Jastrzebski M, Kukla P, Czarnecka D, Kawecka-Jaszcz K. Comparison of five electrocardiographic methods for differentiation of wide QRS-complex tachycardias. *Europace*. 2012;14(8):1165–1171. DOI: 10.1093/europace/eus015
26. Kaiser E, Darrieux FCC, Barbosa SA, et al. Differential diagnosis of wide QRS tachycardias: comparison of two electrocardiographic algorithms. *Europace*. 2015;17(9):1422–1427. DOI: 10.1093/europace/euu354
27. Baxi RP, Hart KW, Vereckei A, et al. Vereckei criteria as a diagnostic tool amongst emergency medicine residents to distinguish between ventricular tachycardia and supra-ventricular tachycardia with aberrancy. *Journal of Cardiology*. 2012;59(3):307–312. DOI: 10.1016/j.jjcc.2011.11.007
28. Szelényi Z, Duray G, Katona G, et al. Comparison of the "real-life" diagnostic value of two recently published electrocardiogram methods for the differential diagnosis of wide QRS complex tachycardias. *Acad Emerg Med*. 2013;20(11):1121–1130. DOI: 10.1111/acem.12247
29. Medvedev MM, Parizhskiy AB. Why "don't work" electrocardiographic algorithms for differential diagnostics of wide QRS tachycardia. *Journal of Arrhythmology*. 2020;27(2):54–66. DOI: 10.35336/VA-2019-3-48-56
30. Vereckei A, Miller JM. Classification of pre-excited tachycardias by electrocardiographic methods for differentiation of wide QRS-complex tachycardias. *Europace*. 2012;14(11):1674; author reply 1674–1675. DOI:10.1093/europace/eus110
31. EGISU NIOKTR (Unified State information system for accounting the results of research, development and technological work) [Internet]. Sozdanie algoritmov vedeniya patsientov s narusheniyami ritma serdtsa s primeneniem tekhnologii obyasnimogo iskusstvennogo intellekta pri analize bolshikh dannykh (big data), poluchennykh s pomoshch'yu telemetricheskikh metodov. Registration number 123021000126-0. Almazov National Medical Research Centre. 2023. (In Russ.). [cited 2023 April 11]. Available from: https://rosrid.ru/nioktr/detail/18QYKT1WFLZRDAIM06P301DI

СПИСОК ЛИТЕРАТУРЫ

1. Abedin Z. Differential diagnosis of wide QRS tachycardia: A review // J Arrhythm. 2021. Vol. 37, No. 5. P. 1162–1172. DOI: 10.1002/joa3.12599
2. Медведев М.М. Дифференциальная диагностика тахикардий с широкими комплексами QRS: от «классических» признаков к первым алгоритмам // Вестник аритмологии. 2019. Vol. 26, No. 3. С. 48–56. DOI: 10.35336/VA-2019-3-48-56
3. Vereckei A. Current algorithms for the diagnosis of wide QRS complex tachycardias // *Curr Cardiol Rev*. 2014. Vol. 10, No. 3. P. 262–276. DOI: 10.2174/1573403x10666140514103309
4. Kashou A.H., Evenson C.M., Noseworthy P.A., et al. Differentiating wide complex tachycardias: A historical perspective // Indian Heart J. 2021. Vol. 73, No. 1. P. 7–13. DOI: 10.1016/j.ihj.2020.09.006
5. Kashou A.H., Noseworthy P.A., DeSimone C.V., et al. Wide Complex Tachycardia Differentiation: A Reappraisal of the State-of-the-Art // J Am Heart Assoc. 2020. Vol. 9, No. 11. e016598. DOI: 10.1161/JAHA.120.016598
6. May A.M., Brenes-Salazar J.A., DeSimone C.V., et al. Electrocardiogram algorithms used to differentiate wide complex tachycardias demonstrate diagnostic limitations when applied by non-

cardiologists // J Electrocardiol. 2018. Vol. 51, No. 6. P. 1103–1109. DOI: 10.1016/j.jelectrocard.2018.09.015

7. Chmelevsky M.P., Budanova M.A., Treshkur T.V. Differential Diagnostics of Wide QRS Complex Arrhythmias with Left Bundle Branch Block Morphology Using Slow Conduction Index // Cardiac Arrhythmias. 2022. Vol. 2, No. 3. P. 49–59. DOI: 10.17816/cardar112593

8. Vereckei A., Duray G., Szenasi G., et al. Application of a new algorithm in the differential diagnosis of wide QRS complex tachycardia // Eur Heart J. 2007. Vol. 28, No. 5. P. 589–600. DOI: 10.1093/eurheartj/ehl473

9. DeLong E.R., DeLong D.M., Clarke-Pearson D.L. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach // Biometrics. 1988. Vol. 44, No. 3. P. 837–845.

10. Hanley J.A., McNeil B.J. The meaning and use of the area under a receiver operating characteristic (ROC) curve // Radiology. 1982. Vol. 143, No. 1. P. 29–36. DOI: 10.1148/radiology.143.1.7063747

11. Hanley J.A., Hajian-Tilaki K.O. Sampling variability of nonparametric estimates of the areas under receiver operating characteristic curves: an update // Acad Radiol. 1997. Vol. 4, No. 1. P. 49–58. DOI: 10.1016/s1076-6332(97)80161-4

12. Hilgers R.A. Distribution-free confidence bounds for ROC curves // Methods Inf Med. 1991. Vol. 30, No. 2. P. 96–101.

13. Friendly M. Corrgrams: Exploratory Displays for Correlation Matrices // The American Statistician. 2002. Vol. 56, No. 4. P. 316–324. DOI: 10.1198/000313002533

14. Dunn O.J. Multiple Comparisons among Means // Journal of the American Statistical Association. 1961. Vol. 56, No. 293. P. 52–64. DOI: 10.1080/01621459.1961.10482090

15. Auricchio A., Fantoni C., Regoli F., et al. Characterization of left ventricular activation in patients with heart failure and left bundle-branch block // Circulation. 2004. Vol. 109, No. 9. P. 1133–1139. DOI: 10.1161/01.CIR.0000118502.91105.F6

16. Fantoni C., Kawabata M., Massaro R., et al. Right and left ventricular activation sequence in patients with heart failure and right bundle branch block: a detailed analysis using three-dimensional non-fluoroscopic electroanatomic mapping system // Journal of Cardiovascular Electrophysiology. 2005. Vol. 16, No. 2. 112–119; discussion 120–121. DOI: 10.1046/j.1540-8167.2005.40777.x

17. Tan N.Y., Witt C.M., Oh J.K., Cha Y.M. Left Bundle Branch Block: Current and Future Perspectives // Circulation: Arrhythmia and Electrophysiology. 2020. Vol. 13, No. 4. e008239. DOI: 10.1161/CIRCEP.119.008239

18. Vijayaraman P., Panikkath R., Mascarenhas V., Bauch T.D. Left bundle branch pacing utilizing three dimensional mapping // J Cardiovasc Electrophysiol. 2019. Vol. 30, No. 12. P. 3050–3056. DOI: 10.1111/jce.14242

19. Geselowitz D.B. Dipole theory in electrocardiography // Am J Cardiol. 1964. Vol. 14, P. 301–306. DOI: 10.1016/0002-9149(64)90072-4

20. Versaci M., Angiulli G., La Foresta F. A Modified Heart Dipole Model for the Generation of Pathological ECG Signals // Computation. 2020. Vol. 8, No. 4. P. 92. DOI: 10.3390/computation8040092

21. Westwood J.D. Medicine meets virtual reality 17 – NextMed: design for/the well being. Amsterdam: Washington DC: IOS Press, 2009. P. 477.

22. Vereckei A., Duray G., Szénási G., et al. New algorithm using only lead aVR for differential diagnosis of wide QRS complex tachycardia // Heart Rhythm. 2008. Vol. 5, No. 1. P. 89–98. DOI: 10.1016/j.hrthm.2007.09.020

23. Jastrzebski M., Sasaki K., Kukla P., et al. The ventricular tachycardia score: a novel approach to electrocardiographic diagnosis of ventricular tachycardia // Europace. 2016. Vol. 18, No. 4. P. 578–584. DOI: 10.1093/europace/euv118

24. Chen Q., Xu J., Gianni C., et al. Simple electrocardiographic criteria for rapid identification of wide QRS complex tachycardia: The new limb lead algorithm // Heart Rhythm. 2020. Vol. 17, No. 3. P. 431–438. DOI: 10.1016/j.hrthm.2019.09.021

25. Jastrzebski M., Kukla P., Czarnecka D., Kawecka-Jaszcz K. Comparison of five electrocardiographic methods for differentiation of wide QRS-complex tachycardias // EP Europace. 2012. Vol. 14, No. 8. P. 1165–1171. DOI: 10.1093/europace/eus015

26. Kaiser E., Darrieux F.C.C., Barbosa S.A., et al. Differential diagnosis of wide QRS tachycardias: comparison of two electrocardiographic algorithms // EP Europace. 2015. Vol. 17, No. 9. P. 1422–1427. DOI: 10.1093/europace/euu354

27. Baxi R.P., Hart K.W., Vereckei A., et al. Vereckei criteria as a diagnostic tool amongst emergency medicine residents to distinguish between ventricular tachycardia and supra-ventricular tachycardia with aberrancy // Journal of Cardiology. 2012. Vol. 59, No. 3. P. 307–312. DOI: 10.1016/j.jjcc.2011.11.007

28. Szelényi Z., Duray G., Katona G., et al. Comparison of the "real-life" diagnostic value of two recently published electrocardiogram methods for the differential diagnosis of wide QRS complex tachycardias // Acad Emerg Med. 2013. Vol. 20, No. 11. P. 1121–1130. DOI: 10.1111/acem.12247

29. Медведев М.М., Парижский А.Б. Почему «не работают» электрокардиографические алгоритмы дифференциальной диагностики тахикардий с широкими комплексами QRS // Вестник аритмологии. 2020. Т. 27, № 2. P. 54–66. DOI: 10.35336/VA-2020-2-54-66

30. Vereckei A., Miller J.M. Classification of pre-excited tachycardias by electrocardiographic methods for differentiation of wide QRS-complex tachycardias // EP Europace. 2012. Vol. 14, No. 11. 1674; author reply 1674–1675. DOI: 10.1093/europace/eus110

31. ЕГИСУ НИОКТР [Электронный ресурс]. Создание алгоритмов ведения пациентов с нарушениями ритма сердца с применением технологий объяснимого искусственного интеллекта при анализе больших данных (big data), полученных с помощью телеметрических методов. Регистрационный номер 123021000126-0. Национальный медицинский исследовательский центр имени В.А. Алмазова. 2023 [дата обращения: 11.04.2023]. Доступ по ссылке: https://rosrid.ru/nioktr/detail/18QYKT1WFLZRDAIM06P3O1DI.

AUTHORS INFO

***Mikhail P. Chmelevsky,** senior scientific researcher;
eLibrary SPIN: 6445-1447;
ORCID: https://orcid.org/0000-0002-8985-4437;
e-mail: boxmch@gmail.com

Margarita A. Budanova, scientific researcher,
eLibrary SPIN: 1890-7821;
ORCID: https://orcid.org/0000-0002-7189-8773;
e-mail: budanovamargarita@gmail.com

Danila A. Stepanov, junior scientific researcher;
eLibrary SPIN: 9013-5135;
ORCID: https://orcid.org/0000-0001-7032-8800;
e-mail: daniel36611b@gmail.com

Ekaterina S. Zhabina, PhD, scientific researcher;
eLibrary SPIN: 5964-5382;
ORCID: https://orcid.org/0000-0002-9001-8743;
e-mail: zhabina-ekaterina@mail.ru.

Tatiana E. Tulintseva, PhD, senior scientific researcher;
eLibrary SPIN: 6076-0246;
ORCID: https://orcid.org/0000-0001-6843-302X;
e-mail: tulinta@mail.ru

ОБ АВТОРАХ

***Михаил Петрович Чмелевский,** старший научный сотрудник; eLibrary SPIN: 6445-1447;
ORCID: https://orcid.org/0000-0002-8985-4437;
e-mail: boxmch@gmail.com

Маргарита Александровна Буданова, научный сотрудник;
eLibrary SPIN: 1890-7821;
ORCID: https://orcid.org/0000-0002-7189-8773;
e-mail: budanovamargarita@gmail.com

Данила Александрович Степанов, младший научный сотрудник; eLibrary SPIN: 9013-5135;
ORCID: https://orcid.org/0000-0001-7032-8800;
e-mail: daniel36611b@gmail.com

Екатерина Сергеевна Жабина, научный сотрудник;
eLibrary SPIN: 5964-5382;
ORCID: https://orcid.org/0000-0002-9001-8743;
e-mail: zhabina-ekaterina@mail.ru.

Татьяна Эдуардовна Тулинцева, старший научный сотрудник; eLibrary SPIN: 6076-0246;
ORCID: https://orcid.org/0000-0001-6843-302X;
e-mail: tulinta@mail.ru

* Corresponding author / Автор, ответственный за переписку