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THE DIFFERENTIAL DIAGNOSIS OF VENTRICULAR PREMATURE BEATS AND ABERRANT QRS COMPLEXES WITH A PICTURE OF COMPLETE RIGHT BUNDLE BRANCH BLOCK

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Approaches to the differential diagnosis of ventricular premature beats and aberrant QRS complexes with a picture of complete right bundle branch block are considered, based on the assessment of the rates of myocardial coverage by excitation, the similarity, and differences in the initial parts of "narrow" and "wide" QRS complexes, the presence of a low-amplitude onset of the QRS complex in several leads.

Key words: wide QRS complexes; ventricular premature beats; aberrant conduction; complete right bundle branch block; electrocardiography

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The search for a universal algorithm for the differential diagnosis of tachycardias with broad QRS complexes has been going on for more than 60 years and is apparently far from complete [1]. This is due to a number of reasons. First of all, this can be explained by a variety of tachycardias with broad QRS complexes, some of which cannot be distinguished on the basis of electrocardiographic (ECG) data obtained against a background of tachycardia alone. For example, completely different in their electrophysiological mechanisms, paroxysmal reciprocal atrioventricular antidromic tachycardia and ventricular tachycardia originating from the end point of an additional conduction pathway in the ventricular myocardium may look absolutely identical. Another important reason for the inadequacy of the available algorithms is the incomparability of the patient groups for which they were developed. In most studies, ventricular tachycardia was recorded in elderly patients with focal scarring changes and supraventricular tachycardia in young patients without structural cardiac changes.

Since the problem of differential diagnosis of tachycardias with broad QRS complexes "in general" presents considerable difficulties with an acceptable degree of sensitivity and specificity of the algorithms developed and the possibility of their application "at the bedside", we should probably try to solve it "step by step", moving from the particular to the general. As a first step, it seems useful to define criteria that allow differentiation between atrial premature beat (APB) with deviant conduction in the form of a complete right bundle branch block and ventricular premature beat (VPB) with the morphology of the same block. To reduce the influence of some factors, such as the presence or absence of cardiac pathology, it is obviously desirable to use for comparison APB and VPB recorded during daily ECG monitoring in the same patient. It is optimal to record such APB and VPB during nocturnal sleep, which should both improve the quality of the recording and exclude influences related to changes in body position, for example during the transition to orthostasis.

APB and VPB with a complete right bundle branch block pattern registered in patient M. are shown in Fig. 1. On the fragment of the daily ECG recorded at 05:33:00, the sinus complex P-QRS-T is followed by APB with aberrant conduction in the form of complete right bundle branch block. The arrow points to the P wave of this APB. At 03:28:00, VPB with a complete right bundle branch block pattern was registered. It is important that the durations of QRS complexes of both APB and VPB are comparable. In addition, it should be noted that both the sinus P-QRS-T complex as well as the APB and VPB QRS complexes show no evidence of anterior superior or posterior inferior left bundle branch block. On the third fragment of the daily ECG, for comparison, there is VPB probably originating from the posterior wall of the heart.

Before proposing new criteria for differential diagnosis of APB and VPB with a complete right bundle branch block pattern, it seems reasonable to check whether it is possible to separate them based on the generally accepted criteria [2, 3]. Interestingly, APB with complete right bundle branch block patterns show a number of signs characteristic of ventricular ectopy: RS Interval value in leads V5 and V6 exceeds 120 ms, the Q-wave width exceeds 50 ms in lead aVR. On the other hand, a ventricular extrasystole with a complete right bundle branch block pattern

demonstrates the absence of negative concordance, the presence of RS in the thoracic leads, and an R/S ratio in the V6 lead exceeding 1. Thus, the signs presented in the current Guidelines do not allow to interpret unambiguously the genesis of these wide QRS complexes.

ESTIMATING THE DYNAMICS OF AN EIGHT-DIMENSIONAL PSEUDOVECTOR

The methodology for constructing an eight-dimensional pseudovector that reflects the dynamics of the moment amplitude values of the electrocardio signal in eight primary recorded channels (from which twelve commonly used leads are subsequently calculated) has been published previously [1]. It is important that this approach analyzes the entire volume of incoming ECG information. Whereas previously we showed plots of the normalized value of the pseudovector and the linear and tangential myocardial excitation coverage rates, in constructing Figure 2 we limited outsleep to graphs of the normalized amplitude values of the pseudovectors of the four QRS complexes in question.

The abscissa axis shows the time from the onset of the QRS complex in milliseconds; the ordinate axis shows the moment-normalized amplitude of the eight-dimensional pseudovector in ppm from the amplitude of the integral pseudovector, reflecting the complete coverage of the myocardium by the excitation (see below). The graphs obtained in the analysis of sinus (supraventricular - S), aberrant as complete right bundle branch block (RBBB), ventricular as complete RBBB and ventricular from the posterior wall of the hear QRS complexes are presented. The graph of the moment normalized amplitude of the eight-dimensional pseudovector of the sinus QRS complex is compact (its duration does not reach 100 ms), the distribution is close to symmetric, there is a moderate bimodality, probably, associated with the presence of intraventricular conduction disorder. Comparing this graph with the APB graph with

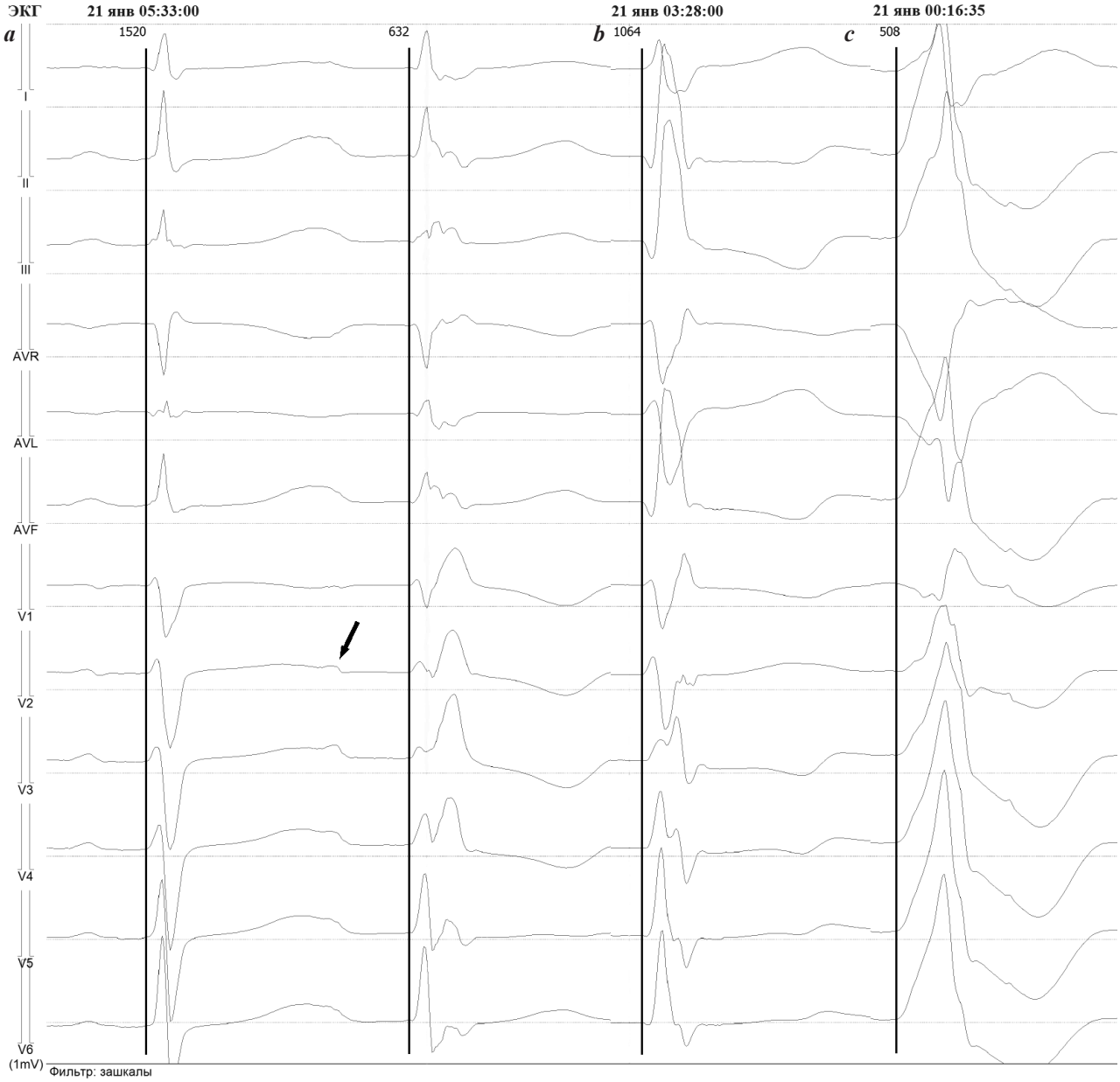

Fig. 1. Fragments of daily ECG monitoring of patient M.: a - with sinus complex P-QRS-T and atrial premature beat with aberrant complete right bundle branch block, b - with ventricular premature beat with complete right bundle branch block morphology, c - with ventricular premature beat from the posterior wall of heart. Explanations in the text.

a complete right bundle branch block pattern, we must state that their initial parts for about 30 ms are practically the same. This is a very important sign that can be used in the differential diagnosis of APB and VPB with a complete right bundle branch block pattern. Subsequently, the graph of the normalized APB pseudovector acquires a pronounced bimodality, and the duration of the second wave of this graph is approximately twice if the first wave, and the final myocardial excitation coverage rates are significantly lower than the initial ones.

A different picture is presented by the graph of the normalized VPB pseudovector with a complete right bundle branch block pattern. During the first 30 ms, the rate of myocardial coverage by excitation in this VPB is significantly lower than in supraventricular QRS complexes with absence and presence of aberration. This is probably due to the fact that excitation covers the myocardium from an ectopic focus (from a single point) rather than from branches of the Gis-Purkinje system. Then, the rate of myocardial excitation coverage in VPB with a complete right bundle branch block pattern increases and aligns with that of supraventricular QRS complexes (the graphs are almost parallel). In general, the graph of the normalized VPB pseudovector with the a complete right bundle branch block pattern looks asymmetrical (the initial myocardial excitation coverage rates exceed the final ones), there is a moderate bimodality, expressed significantly less than in APB with a complete right bundle branch block pattern.

The graph of the normalized VPB pseudovector from the posterior wall of the heart, presented for comparison, demonstrates an extremely low initial rate of myocardial excitation coverage, which persists for approximately 120 ms. This is probably related both to the location of the ectopic focus in the epicardial layer of the myocardium and to the location of the ectopic focus itself. In general, the graph of this VPB demonstrates monomodality and asymmetric distribution with the predominance of the final rate of myocardial coverage by excitation, over the initial one. Interestingly, the last sections of the graphs of all three extrasystoles run almost parallel, showing that the myocardium is equally affected by the excitation. Thus, even a visual analysis of the normalized pseudovector graphs allows us to reveal regularities that can be used in the differential diagnosis of APB and VPB with a complete right bundle branch block pattern.

EVALUATING THE DYNAMICS OF THE EIGHT-DIMENSIONAL PSEUDOVECTOR INTEGRAL

Somewhat different opportunities in the differential diagnosis of APB and VPB with a complete RBBB pattern are related to the integral representation of the pseudovec-

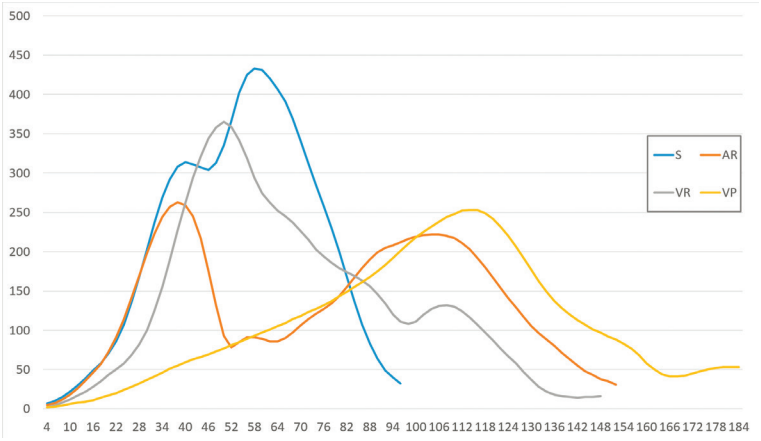

Fig. 2. Graphs of changes in the normalized eight-dimensional pseudovector over time. The abscissa axis is the time from the beginning of the QRS complex in milliseconds, the ordinate axis is the moment amplitude of the pseudovector in ppm of the total coverage of the myocardium by excitation, taken as a unit. Hereinafter: S - supraventricular QRS complex, AR - atrial premature beat with aberration as complete right bundle branch block, VR - ventricular premature beat with complete right bundle branch block morphology, VP - ventricular premature beat from the back wall of heart. Explanations in the text.

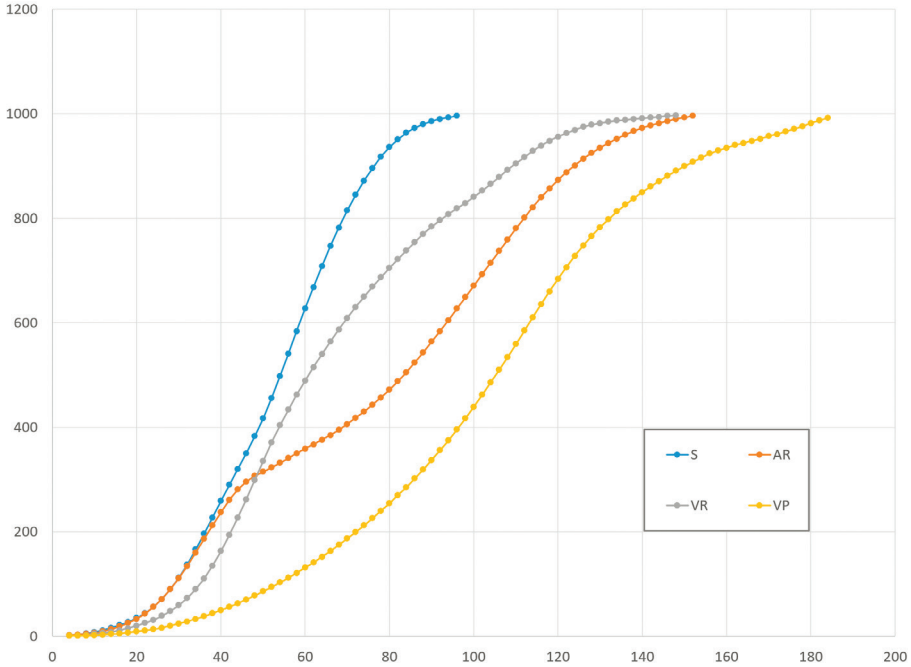

Fig. 3. Graphs of changes in the integral of an eight-dimensional pseudovector over time. The abscissa axis is the time from the beginning of the QRS complex in milliseconds, the ordinate axis is the moment integral amplitude of the pseudovector in ppm of the total coverage of the myocardium by excitation, taken as a unit. Explanations in the text.

tor (Fig. 3). Each instant on the abscissa axis does not correspond to the instant value of the normalized value of the pseudovector, but to the sum of the normalized instant values at all previous points. With this approach, each of the graphs reaches a value of 1000 ppm, corresponding to the full coverage of the myocardium by excitation.

The graph of myocardial coverage by excitation of the supraventricular QRS complex over a prolonged period is practically a straight line, indicating the formation of a single excitation front and its uniform propagation. The integral graph of APB with a complete right bundle branch block pattern initially coincides with that of the supraventricular QRS complex, and then there is a sharp decrease in the rate of excitation propagation associated with complete RBBB. The initial part of VPB with a complete right bundle branch block pattern is very similar to that of the supraventricular QRS complex, but lags in time by about 10-15 ms. Subsequently, the rate of myocardial excitation in VPB also decreases, but not as dramatically as in APB. Finally, the graph of myocardial coverage by excitation from the posterior wall of the heart in general resembles that of the supraventricular QRS, but with a pronounced almost twofold decrease in the coverage rate.

By comparing these four graphs, we can find the time points where they differ most in the proportion of depolarized myocardium, which can be used in the differential diagnosis of APB and VPB with a complete RBBB pattern. With regard to the beginning of myocardial excitation coverage, it is reasonable to use the value of 30 ms from the beginning of QRS complexes as such a point. At this point, the fractions of myocardial excitation coverage for supraventricular QRS and APB are almost identical (112 and 111 ppm, respectively), while for VPB with a complete right bundle branch block pattern it is only 59 ppm. Thus, the ratio of the proportion of myocardial coverage by excitation in APB and VPB with a complete right bundle branch block pattern by the 30th ms from the beginning of the QRS complex reaches the number 1.88. It should be noted that this is the maximum value, on the basis of which the point 30 ms from the beginning of the QRS complexes was selected. It is worth recalling that in a number of publications the determination of the initial rate of myocardial excitation coverage was performed 40 ms from the beginning of the QRS complex. Probably, it was dictated not by the search of optimal result, but using ECG taken on the "paper carrier" at 25 mm/s, when the interval of 1 mm, corresponds to 40 ms [4, 5].

The final rates of myocardial coverage by excitation do not differ significantly. In the compared APB and VPB compared with a complete right bundle branch block pat-

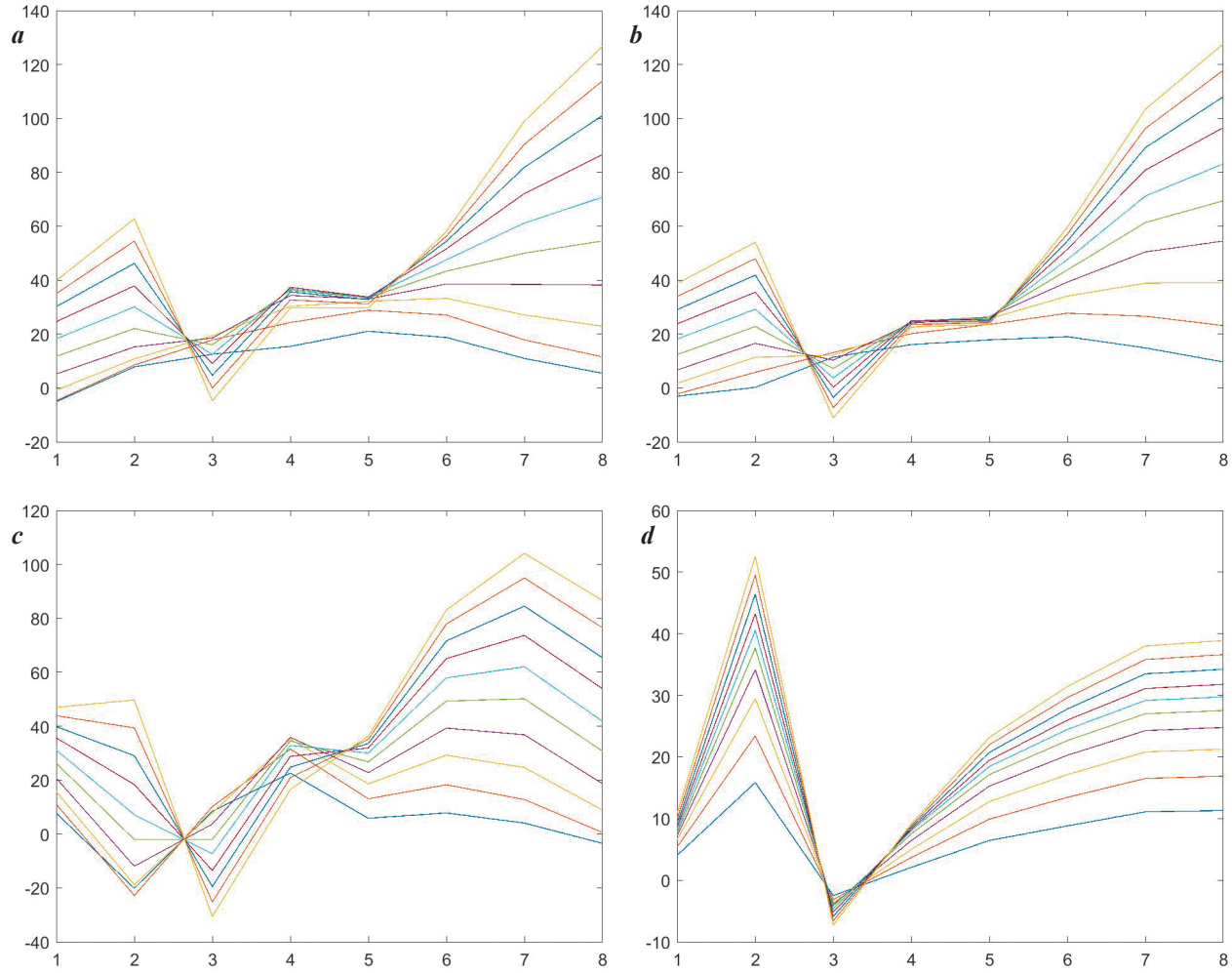

Fig. 4. Graphs of distribution of 13 first readings in eight initially recorded leads of electrocardiogram: a - supraventricular QRS complex, b - atrial premature beat with aberration as complete right bundle branch block, c - ventricular premature beat with complete right bundle branch block morphology, d - ventricular premature beat from the posterior wall of heart. There is a marked similarity between graphs a and b. Explanations in the text.

tern, it is reasonable to compare the proportions of myocardial coverage by excitation at about 70 ms from the onset of the QRS complex. By this point, the respective coverage fractions were 815, 406, and 609 ppm for supraventricular QRS complex, APB, and VPB with a complete right bundle branch block pattern. The ratio of the proportion of APB and VPB coverage is 0.666, which allows this indicator to be used in differential diagnosis. It is important to emphasize that closer to the end of APB and VPB QRS complexes, this difference is significantly leveled. Thus, at a point 40 ms from the end of APB and VPB QRS complexes (used in the studies we cited), the ratio of the coverage fraction is 0.86. Thus, it approaches unity at this point and will have significantly less influence on a correct diagnosis.

SIMILARITY OF THE INITIAL PARTS OF THE NARROW AND WIDE QRS COMPLEXES

An important sign indicating the aberrant genesis of the wide QRS complex with a complete RBBB pattern is the similarity of its initial part with the initial part of the narrow supraventricular complex. A number of conditions must be met when comparing such complexes. A wide QRS complex should show only complete RBBB without anterior superior or posterior inferior left bundle branch block. The comparison should be made with the patient in the same body position (optimally lying on the back during night sleep). It is desirable to compare complexes that are in close proximity to each other. The comparison can be made visually by evaluating the initial parts of the QRS complexes in each of the 12 leads. It is possible to compare using the construction of special diagrams. Finally, a mathematical approach seems optimal, comparing the matrices of the samples forming the compared complexes and calculating an indicator reflecting their similarity.

When visually comparing the sinus QRS complex (see Fig. 1) and APB with a complete right bundle branch block pattern, we can note a high degree of similarity between their initial parts. In all leads, these complexes begin approximately the same way. This is not the case when comparing the sinus QRS complex and VPB with a complete right bundle branch block pattern. For example, in the lower leads, the sinus complex begins with low-amplitude r wave, and the QRS VPB complex with a complete right bundle branch block pattern begins with q wave, Specialized charts are designed to facilitate the visual comparison (Fig. 4). In these graphs, eight primary ECG signal channels are plotted on the abscissa axis, and the values of the first 13 samples are plotted on the ordinate axis. For clarity, the corresponding readings in each of the channels are connected by lines. The resulting figures are compared visually. The graphs obtained in the supraventricular QRS complex and in the APB with a complete right bundle branch block pattern are almost identical, whereas the other two graphs differ significantly from them.

These visual assessments are confirmed by the results of a mathematical comparison of the sampling matrices that form the initial parts of the compared complexes. As a result of the pairwise comparison of these matrices, the so-called “difference matrices” were created, in which, as the name suggests, the differences between the moment pseudovectors of pairs of QRS complexes are displayed. Complete similarity of pseudovectors should correspond to the value of the index equal to 0 (not achievable), their maximum difference corresponds to the value of the index equal to 2 (in the considered complexes its maximum value was 1.495). When comparing the matrices of the sine QRS complex and APB with a complete right bundle branch block pattern, the minimum value of the pseudovector difference was 0.76, the average value of the fourteen minimum difference indicators (the number corresponds to the dimensionality of the matrix) was 0.82 and the average value of the difference indicators that formed the diagonal of the matrix was 0.182. When comparing the sinus QRS complex and VPB with a complete right bundle branch block pattern, the values of these indices were equal to 0.294, 0.392, and 0.463, respectively. The findings confirm the high level of similarity of the initial part of the sinus QRS complex with APB with a complete right bundle branch block pattern, but not with VPB with a complete right bundle branch block pattern.

PRESENCE OF AN INITIAL LOW-AMPLITUDE PART IN WIDE QRS COMPLEXES

Another important sign that can be used in the differential diagnosis of APB and VPB with complete right bundle branch block is the presence of a low-amplitude initial part of the QRS complex, recorded in the thoracic leads. The mechanism of formation of such a low-amplitude component of the QRS complex is shown in Fig. 5. If, in the case of an VPB, excitation begins to spread in all directions from a point located in the endocardial layer of the myocardium, the vectors directed in opposite directions will be leveled, and the total initial vector will be oriented

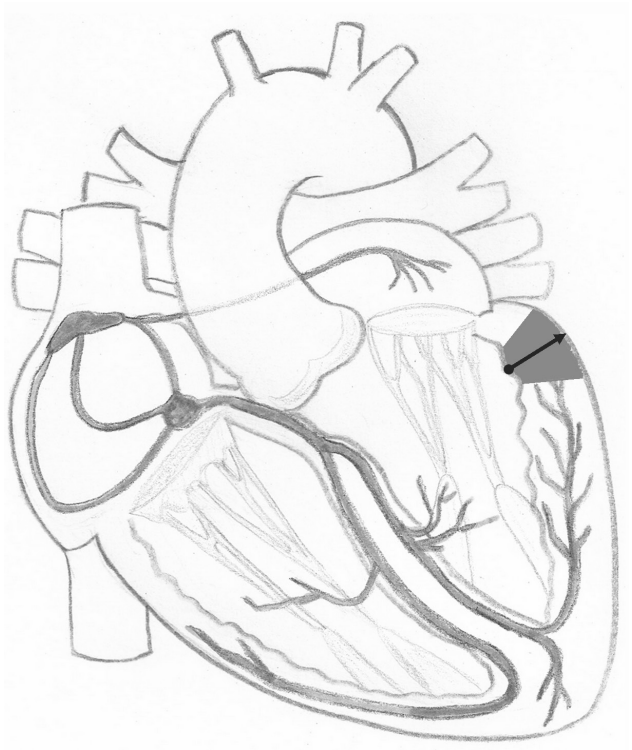

Fig. 5. Scheme of the cardiac conduction system with the initial vector of ventricular premature beat. Explanations in the text.

in the direction from the endocardium to the epicardium. This vector may be perpendicular to the axes of any leads, so that a low-amplitude initial part of the QRS complex will be formed there.

It should be recalled that vector theory is based on the idea of the heart as a point from which the resultant torque vector emanates, varying in time and space. The termination of this vector within one cardiocycle forms vector loops P, QRS, and T. Correct mapping of these loops due to the distance of the electrodes on the limbs from the heart is only possible in the frontal plane. The precordial leads, because of their proximity to the heart, do not allow adequate calculating the directions and amplitudes of the momentum vectors, but they do allow identifying the perpendicularity of certain vectors to the axes of some leads. However, it should be noted that in recent years there have been attempts to use vector analysis (including horizontal and sagittal planes) in differential diagnosis of tachycardias with wide QRS complexes [6].

The presence of low-amplitude or isoelectric regions at the beginning of the QRS complex when recording leads from the extremities is quite common. This is due to the fact that the axes of the limb leads are 60 degrees apart, and the initial QRS vector may be close to the perpendicular to one of these leads. For example, in the sinus QRS complex (see Fig. 1a), such an isoelectric region is recorded in the aVR lead. For this reason, when determining the boundaries of QRS complexes, it is necessary to identify their earliest and latest points in the synchronous registration of the twelve commonly used leads. We do not consider it correct to determine the width of the QRS complex in a single line, in groups of 3 or 6 lines, or in the eight channels originally recorded.

On the other hand, when recording thoracic leads, due to their precordiality, in the case of sinus QRS complexes (see Fig. 1a) and in the case of APB with a complete right bundle branch block pattern (see Fig. 1b), there are no isoelectric or low-amplitude areas and the starting points of the QRS complexes are (as they should be) on a vertical. A different picture is observed in VPB with a complete right bundle branch block pattern. In the V4 and V5 leads, the initial isoelectric areas are registered, which, in our opinion, confirms the ventricular genesis of these complexes. Obviously, in the future it will be necessary to develop criteria for quantifying such low-amplitude sections of the record.

CONCLUSION

Our proposed approaches to the differential diagnosis of APB and VPB with a complete right bundle branch block pattern undoubtedly require further analysis and evaluation of sensitivity and specificity of each of the signs. Subsequently, with the help of an appropriate training sample, it is possible to create an algorithm for the differential diagnosis of APB and VPB with complete right bundle branch block pattern using both the proposed approaches and "classical" signs. In addition, the developed algorithms will need to be tested on an independent control sample.

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