Report

Studies of natural changes in diastolic pressure in each cardiac cycle on the basis of digitally processed ECG and Rheo

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Abstract
Conventional methods for arterial pressure (AP) measurement are not capable of identifying it in each cardiac cycle. Besides, they ignore many significant factors. The paper reports on an innovative method based on cardiac cycle phase analysis for detecting systolic and diastolic AP changes in each cardiac cycle using synchronous digitally processed ECG and Rheo recordings. Considered is the phase mechanism of the natural diastolic pressure regulation. The diastolic AP changes referred to the physiological norm and aortic dilatation status are also assessed.

Keywords
Arterial pressure • Systolic • Diastolic • Hemodynamics • Cardiac cycle phase • ECG • Rheo

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Introduction

The most widely used hemodynamic parameter is arterial pressure (AP). It is easy to measure it for everybody and there upon to take necessary steps to normalize AP. Taking into account the fact that any measurement in cardiology relates to the field of cardiometry, it is reasonable to consider the natural mechanism of AP self-regulation in more detail. The more so as the widely used indirect method of AP measurements identifies the AP parameter not in each cardiac cycle, but by measuring separately the systolic pressure in one cardiac cycle and the diastolic pressure in the other cardiac cycle. This procedure ignores many factors which must be taken into consideration. First of all, it is an influence of respiratory rhythm. Cardiometry allows considering AP changes in every cardiac cycle. Besides, it is possible to detect and trace mutual relationship between systolic and diastolic AP changes, based on the cardiac cycle phase analysis. It is very important as the practice shows that the most critical mistake in medical practice is to decide on reducing high systolic pressure, while not taking into account the diastolic pressure changes [1-9].

Matherials and methods

Let us consider an ECG and a Rheo synchronously recorded with the Cardiocode device. It is the only PC-assisted device which is capable of detecting phase changes in each cardiac cycle and, that is important in our case, recording an AP characteristics curve and plus an ECG synchronously. In doing so, all the processes of the ascending aorta are traced, so that we can obtain the most spectacular picture of the actual cardiovascular system performance.

Fig.1 shows synchronously recorded ECG and Rheo curves which may be conditionally accepted as reference ones. The respective reactions of AP in the aorta captured by the Rheo and the ECG synchronously recorded can be accurately identified in each phase.

Figure 1. Synchronous recordings of AP changes and ECG of aorta made with the Cardiocode device

It is fundamentally important that the recorded ECG and Rheo curves are synchronized by the point S, i.e., by the point in the beginning of the cardiac muscle tension phase. The synchronization is required to define the Rheo curve isoline that makes possible to trace any Rheo changes in the cardiac muscle tension phase S-L. If an AP curve is of the same type as shown in Fig.1, then it corresponds to the norm. As a rule, the normal value is from 65 to 70 mm Hg.

The cardiac muscle tension phase ends at the point L. This point is described in the previous issue of our journal [10]. We have pioneered in describing this ECG point. That has been the idea of the authors hereof to introduce this new ECG point in order to complete the ECG analysis. It is impossible to evaluate biophysical processes in the cardiovascular system not using this point. Fig.1 shows the

L point in each cardiac cycle. According to our novel interpretation concept, the beginning of the rapid ejection phase corresponds to the point L. During the said phase the aortic valve opens, and blood starts entering the aorta. Pressure rising takes place. The L point indicates the very moment when the diastolic pressure is evaluated and measured with all known conventional indirect methods [11-17].

Let us note that the end of the rapid ejection phase on the ECG corresponds to point j (Fig.2). The location of this point as well as the specified sequence of the cardiac cycle phases remains fixed and unchanged under any conditions.

Figure 2. The Rheo derivative is added to the ECG and Rheo curves shown in Fig.1, and the derivative maximum indicates the rapid ejection phase end at the point j. The point of inflection of the Rheo front edge corresponds to the point j on ECG

The diastolic pressure is a pressure when aorta filling is completed in the beginning of the rapid ejection phase, to be more exact, at the time marked as point L on the ECG. It is a must to provide the completion of the filling procedure in the aorta, and any spaces not filled with blood are out of the question. Thus, both the phase mechanism of the heart performance and the heart anatomy are so designed that they sequentially generate and maintain the specific blood flow pattern in the aorta, fill the aorta with the specified volume of blood, that corresponds to the diastolic pressure, and provide the systolic pressure level by adding of stroke volume to the diastolic volume of blood. Reaching the required systolic pressure fires the baroreceptors that makes possible to move blood to the periphery.

It is important to know what is the primary factor in the development of hypertension: an improper rise in systolic or diastolic pressure?

The systolic pressure is required to provide a difference in pressures between the aorta and the venous blood flow circuit to organize blood circulation in the body. When the blood vessel resistance changes, the systolic pressure increases. But the pressure rising cannot be infinitely provided with increasing systolic AP only. The normal upper limit of the AP is 140 mm Hg in case if the diastolic AP remains at a level of 70 mm Hg.

The systolic AP over 140 mm Hg is an indicator of pathology in blood vessels. In this case it is necessary to examine the situation and decide on an appropriate therapy. As a rule, an abnormally high AP is lowered by dilatation of blood vessels, i.e., by reduction of their resistance to blood flow. At the same time, it is necessary to control the diastolic AP. It is allowed to lower the systolic AP until the diastolic one starts rising. It is not acceptable to continue lowering the systolic AP if the diastolic pressure starts its uncontrollable increase.

Fig.1 shows the diastolic pressure in S-L tension phase. It should be noted that the diastolic AP can naturally change in this phase, but the change is not significant, approximately 5 mm Hg. Fig. 3 gives a segment in the said phase, where the Rheo curve segment is elevated and not straight as it is the case in Fig.1. It is the very rise in the diastolic pressure. Let us note again that the Rheo isoline location has been identified by the point S. The S-point synchronization is a prerequisite for an extensive analysis and assessment of a huge volume of data which can be delivered with the Cardiocode device only.

Figure 3. Insignificant natural changes of 5 mm Hg in the diastolic AP in the cardiac muscle tension phase S-L. Sometimes it may be detected during orthostatic test.

Let us consider a more complicated case with the diastolic AP rising (Fig.4). The diastolic AP starts rising at the point Q. Actually, it is 100 mm Hg. Such Rheo behavior may indicate the weakness of the aortic valve. There are some causes to explain the abnormality:

1. Significant increase in the blood vessel resistance to blood flow;

2. Significant dilatation of the aorta;

3. Some specific changes in valve anatomy.

Due to an increase in the blood vessel resistance to blood flow, a specified amount of blood is naturally expelled from the blood vessels. Of course, this amount of blood is an integral part of the full blood volume within the circulatory system because it is a closed circuit. Therefore, during the diastolic phases the specified blood amount is pumped into the ventricles increasing load applied thereon, and prior to opening of the aortic valve, the total blood amount in question should penetrate through the closed aortic valve. It is very important since the initial pressure, namely: the diastolic pressure must reach a specified pressure level to overcome the elevated resistance to the blood flow. After the point L, the total ejected blood volume should be considered as stroke volume. But this volume is added to the diastolic volume. In this case, the systolic pressure will be higher than the normal one. Therefore, it is necessary not to reduce the systolic AP because it results in elevating of the diastolic pressure and dilatation of blood vessels that in its turn may cause even greater problems. Naturopathic clearing of blood vessels can eliminate this problem, and it is the only appropriate therapy.

Figure 4. Early rise in the diastolic AP

Special attention should be paid to a “step” on the Rheo curve in the S-L phase representing the cardiac muscle tension as shown in Fig.4 herein. It reflects a natural reduction in blood flow through the valve when the valve area is narrowing under the influence of cardiac muscle tension. This “step” may serve as an indicator of an abnormally elevated diastolic AP.

Another cause of the diastolic AP elevation is a significant aortic dilatation. Two signs indicate this case. The first sign is an early AP elevation detected on the Rheo curve, that is similar to case one as described above, and the second sign is a not bell-shaped, but cusped peak on the Rheo curve. It indicates a greater blood flow with an increased diameter of the aorta. At the same time, the T wave on the ECG shows smaller amplitude (Fig.5). In the case illustrated it is not available at all. We can detect just the final stage of the wave as the systolic end.

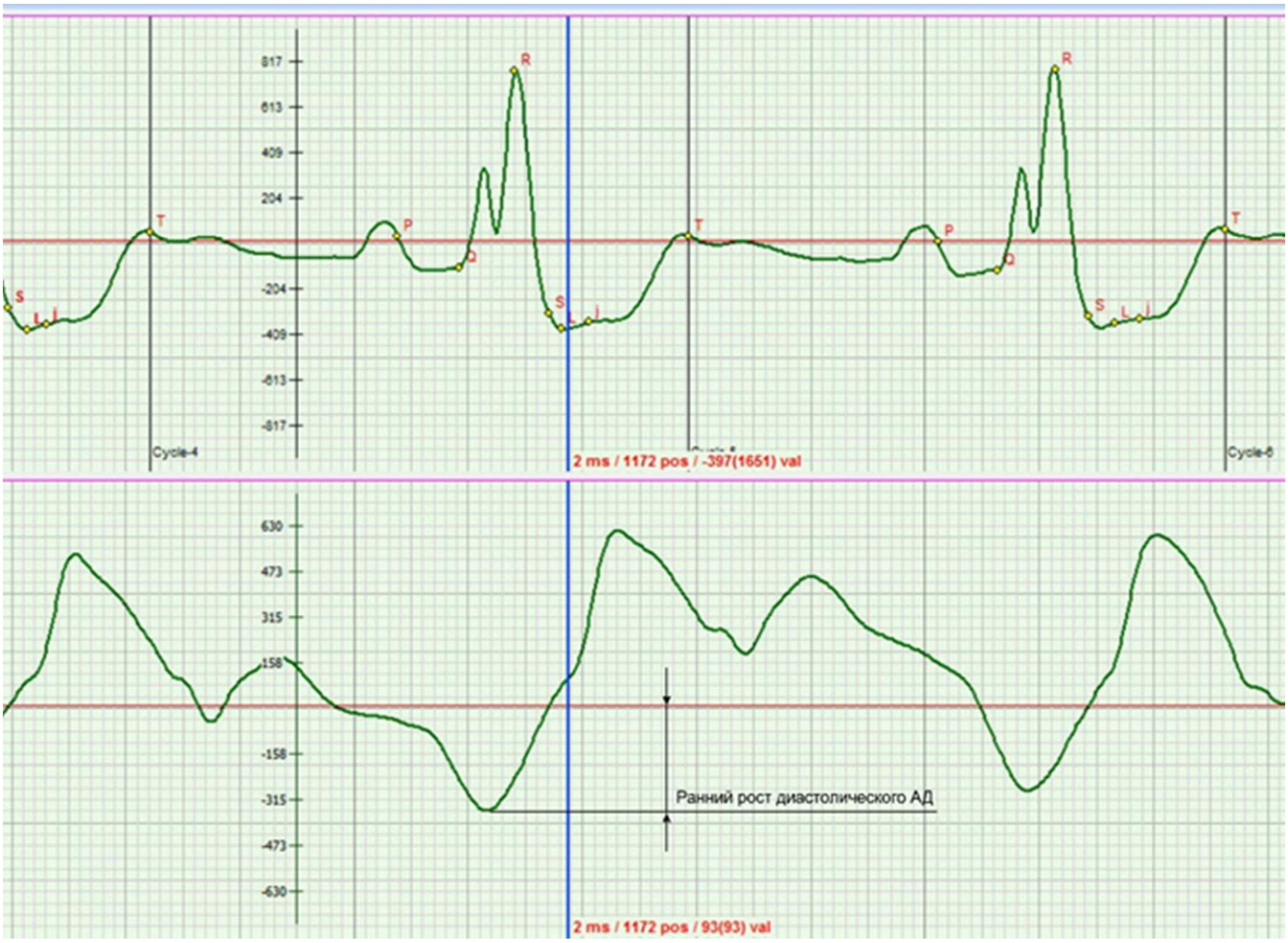

Figure 5.

A combination of the low T-wave amplitude and the normal bell-shaped Rheo peak may very often occur.

To treat the third cause with specific aortic valve anatomy problems, as indicated above, it should be stated that a small blood volume ejection into the aorta is observed owing to blood flow regurgitation. On the Rheo curve it can be found as a small slope angle of the curve segment in the L-j rapid ejection phase. There is no such sign available in Fig.5. Thus, we deal with the aortic dilatation.

Conclusions

We have considered the phase mechanism of the natural diastolic pressure regulation. Many cardiovascular system functions are involved therein, therefore the presented analysis may offer much useful information. Primarily, the following information can be extracted:

1. Assessment of actual diastolic AP changes referred to the physiological norm;

2. Aortic dilatation status assessment;

3. Control & monitoring of the therapy efficacy, when lowering the systolic pressure.

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 author prepared the manuscript, analyzed the data, read the ICMJE criteria for authorship and approved the final manuscript.

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