

SIGNIFICANCE OF THE OUTPUT OF THE RIGHT AND LEFT VENTRICLES IN THE FORMATION OF THE IJ WAVES OF THE BALLISTOCARDIOGRAM

UDC 616.12-073.96

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Translated from *Byulleten' Éksperimental'noi Biologii i Meditsiny*, Vol. 57, No. 4, pp. 8-11, April, 1964

Original article submitted March 8, 1963

Despite the widespread clinical application of ballistocardiography a large number of problems associated with this method remain unsolved. No explanation is available of the origin of the different waves. The waves which have been most studied are the IJ waves which are associated with the systolic outflow: wave I is related to the force with which blood is propelled out of the ventricles, and wave J with the shock wave of the blood at the bifurcation of the pulmonary artery and the aortic arch. The experiments of Starr on corpses has shown that the amplitude of the IJ waves depends on the rate of systolic outflow and upon its volume [12].

The idea has taken root in the literature that the contribution of the right ventricle to the amplitude of the IJ wave of the ballistocardiogram (BCG) is greater than that of the left [1, 2, 5, 7]. This notion has its origin in observations on the relationship between the amplitude of the IJ waves and the phase of the respiratory cycle. In a healthy human subject at the moment of strongest inspiration, when the suction of the thoracic cage is increasing its strength, the output of the right ventricle also increases, and the amplitude of IJ is usually greater than at expiration, when the output of the left ventricle is increased.

However recently a number of works have appeared [4, 8, 9] which indicate that changes in the position of the heart within the thoracic cage during the respiratory act play a significant part in the fluctuations of the amplitude of the IJ during the respiratory cycle.

It is extremely difficult to evaluate the separate contributions of the right and left ventricles to the IJ waves in animal experiments or in experiments on human subjects because all factors which affect the systolic output of one ventricle inevitably causes a simultaneous change in the other ventricle also.

Here patients with certain forms of congenital heart disease are of the greatest use; in them as a result of an anomalous development of the cardiovascular apparatus the minute and systolic volume of the left ventricle is not equal to that of the right. Two examples of this condition are patent ductus arteriosus and atrial septal defect. In subjects with these congenital defects, to determine the contribution of the left and right ventricles to the IJ waves we compared the systolic volumes of the right and left ventricles with the amplitude of the IJ waves.

EXPERIMENTAL METHOD

We recorded the direct velocity BCG by means of Smith's magnetic element. The amplitude of the IJ was measured in millimetres and a standard amplification and was compared with the systolic outputs of the right and left ventricles as determined by the direct Frick method by use of a cardiac catheter introduced by the method of Yu. D. Volynskii and R. S. Vinnitskya. The volumes thus determined were expressed as percentages of the correct volume calculated for each patient separately.

TABLE 1. Amplitude of the IJ Wave in Relationship to the Systolic Output of the Right and Left Ventricles

| Surname | Systolic volume (as % of normal) | | Amplitude (in mm) |
|---------|----------------------------------|----------------|-------------------|
| | right ventricle | left ventricle | |
| M | 96 | 180 | 22 |
| S | 100 | 400 | 41 |
| G | 138 | 400 | 38 |
| B | 83 | 270 | 28 |
| G | 133 | 200 | 22 |

TABLE 2. Amplitude of the IJ Wave and Its Relationship to the Systolic Output of the Right and Left Ventricles

| Surname | Systolic volume (as % of normal) | | Amplitude (in mm) |
|---------|----------------------------------|----------------|-------------------|
| | right ventricle | left ventricle | |
| L | 300 | 98 | 16 |
| G | 200 | 94 | 15-18 |
| M | 200 | 92 | 15 |
| Kh | 180 | 160 | 32 |

TABLE 3. Mean Values of the Right and Left Ventricles, and Amplitude of the IJ Wave

| Disease | Group of patients | Systolic volume (as % of normal) | | Amplitude (in mm) |
|----------------------|-------------------|----------------------------------|----------------|-------------------|
| | | right ventricle | left ventricle | |
| Patent ductus | A | 90 | 125 | 16±3.5 |
| | B | 115 | 252 | 31±7.7 |
| Atrial septal defect | C | 110 | 82 | 16±1.7 |
| | D | 273 | 100 | 19±5.0 |

We investigated 100 patients with patent ductus, and 40 patients with atrial septal defect.

EXPERIMENTAL RESULTS

It is known that in the condition of patent ductus part of the blood from the greater circulation enters the lesser circulation. Results obtained by catheterization of the heart in such patients have shown that in most of them there is a considerable increase of the systolic volume of the left ventricle (from 130 to 400%); it was only in certain of the subjects that it lay within normal limits. The systolic volume of the right ventricle varied from 80 to 140% of the normal amount.

Many authors [3, 6, 10-11] who have carried out ballistocardiographic investigations on patients with patent ductus have noticed a characteristic sign is a high amplitude of the IJ wave. In most of the patients we have studied we have noticed that the amplitude of the IJ wave is $1\frac{1}{2}$ -2 times as great as in healthy subjects. (With the method of investigation which we used the amplitude of this wave lay between 13 and 20 mm in healthy subjects.)

In six patients with a narrow patent ductus and who showed either no increase or a small increase up to 130% in the systolic volume of the left ventricle the amplitude of the IJ wave was not increased; neither was it increased in four patients with marked changes in the myocardium.

When we compare the amplitude of the IJ wave with the systolic output of the right and left ventricles in the different patients it was found that for comparable systolic volumes of the right ventricle the amplitude was greater in patients having the greater left systolic output (Table 1, patients Mr. M and Mr. C). In patients with equal left systolic volumes an increase of right systolic volume was not associated with any increase in the amplitude of the IJ wave (patients S, G, M, and G). Finally, in patients with a high right systolic but low left systolic output the amplitude was less than it was in patients with a low right but higher left systolic output (female patients B and G).

Therefore in patent ductus a high amplitude of the IJ wave of the BCG is associated with an increased left systolic output. It was essential to exclude the possibility that the relationship observed was associated with hemodynamic features associated with this defect, i.e., that it was not brought about by the fact that in this condition there is a reduced peripheral resistance of the vessels of the greater circulation and usually also an increased resistance of the left circulation. We therefore made a study of patients with atrial septal defect. In this condition the minute volumes of the two ventricles are also unequal but the difference in comparison with patent ductus is that it is the volume of the output not of the right but of the left ventricle which is increased because blood passes from the left to the right atrium. The peripheral resistance of the vessels of the greater circulation is usually not affected.

Ballistocardiography showed that in these patients despite an increase of up to 300% in the volume of the right ventricle the amplitude of the IJ wave was less than it was in patients with patent ductus, who showed the same degree of increase of systolic volume, but on the left side.

In a further analysis of the results obtained on patients with differences in the systolic outputs of the right and left ventricles it was found that when the systolic volumes of the left ventricle were comparable, an increase in systolic volume of the right ventricle did not influence the amplitude of IJ wave (Table 2, female patients L and G). At the same time for comparable outputs of the right ventricle, an increase in systolic volume of the left ventricle caused a marked increase in the amplitude of this wave (male patient M, and female patient Kh).

The results of investigations on all patients are given in Table 3. Here are listed the mean values calculated for the patent ductus group in which the systolic volume of the left ventricle was not increased by more than 130% (A), and for patients with a raised left systolic output (B); also listed are figures for patients with atrial septal defect and a right systolic volume increased by not more than 130% (C), and for patients with an increased right systolic output (D). From these results it follows that an increased output of the right ventricle of up to 273% does not lead to any increase in the amplitude of the IJ wave, whereas an increased output of the left ventricle up to 252% causes a marked increase in amplitude.

In both congenital heart diseases the minute volume of the blood passing through the lungs is greatly increased while the total minute volume passing through the capillaries of the greater circulation is approximately normal. The principal difference is that in patent ductus the increased pulmonary flow is produced by an increased left systolic minute volume, whereas in atrial septal defect the increased output has its origin in the right ventricle. The amplitude of the IJ wave was increased in cases where the left systolic volume was markedly raised (see Tables 1, 2, and 3).

Thus in the formation of the ballistic impulse responsible for the IJ wave of the BCG, it is the activity of the left ventricle which is of principal importance.

We must note that despite the correspondence between the systolic volume and the amplitude of the IJ wave there is no precise and direct proportionality between these two quantities. Neither would such a relationship be expected, because for a given increase in systolic volume the velocity of expulsion which is represented by the amplitude of the IJ wave may vary in different patients according to the characteristics of the expulsion process.

SUMMARY

Ballistocardiography applied to patients with patent ductus arteriosus or atrial septal defect showed an increased IJ wave in cases where the left systolic volume was increased, an effect which was independent of the right ventricular output. It is concluded that it is the activity of the left ventricle which is of principal importance in the genesis of the IJ wave.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
