Ballistocardiogram in Chronic Severe Anemia


Serial ballistocardiograms of 30 patients with chronic severe anemia were studied to assess the cardiovascular state in anemia and after the cure of anemia. The findings in the ballistocardiogram have been compared to those in the electrocardiogram and the roentgenogram. Significance of an abnormal ballistocardiogram after the cure of anemia is stressed.

Cardiovascular disturbances and electrocardiographic abnormalities in chronic anemia have been extensively reported. The ballistocardiogram in chronic anemia has been reported to show large systolic complexes, minimal respiratory variation, a usually normal wave pattern but transient abnormal patterns when the hemoglobin is rapidly raised, abnormal patterns after relief of anemia in some older subjects known to have heart trouble, increased height of H, L, and N waves, and broad J waves in the presence of congestive heart failure. There has, however, been no large-scale study. Although the great majority of the alterations are nonspecific in character, ballistocardiography is believed to be a useful physiologic means of eliciting information about the force of cardiac contraction and ejection of blood in the vessels. It was thought that it might be of particular value in anemia, where there is no valvular, coronary, or other type of heart disease. The purpose of this paper is to report a study of serial ballistocardiograms on 30 patients with chronic severe anemia.

Material and Methods

Thirty patients with chronic anemia and hemoglobin levels of less than 7 Gm./100 ml., and with no other cardiovascular disease, were selected for this study. All of them were hospitalized until the anemia was cured. There were 20 males and 10 females; their ages (table 1) ranged from 12 to 50 years, with an average of 27 years. The hemoglobin level ranged from 2 to 6.5 Gm. per cent, with an average of 3.3 Gm. Cardiac enlargement was present in 22 cases; the cardiothoracic ratio ranged from 51 to 89 per cent, with an average of 61 per cent. Congestive heart failure was present in 7 cases, of whom 4 were females. The anemia was caused by chronic malaria in 13 cases, ankylostomiasis in 10, uterine bleeding in 2, bleeding hemorrhoids in 2, chronic dysentery in 1, and was of undetermined etiology in 2 cases.

A 2 coil electromagnetic ballistocardiograph of the Dock type with a 20 mfd. condenser in circuit and attached in series with limb lead II of a direct recording Burdick electrocardiograph was used. The sensitivity of the recorder was standardized so that 1 mv. produced a 1 cm. deflection. Some normal ballistocardiograms with this equipment are shown in figure 1 for comparison. Patients were studied in a basal state. Tracings were recorded after 15 minutes rest in the recumbent position, during normal respiration, deep inspiration, and deep expiration. An electrocardiogram, with standard leads I, II, and III, and unipolar leads aV_R, aV_L, aV_P, and V_1 to V_6, was recorded; blood pressure and hemoglobin levels were determined at the same time. Observations were made every 2 weeks until the anemia was cured, with a further follow-up period of 4 weeks to 18 months. The average period for cure of anemia was 48 days, the average period of observation, 90 days. The criteria of Dock and associates were employed to grade the ballistocardiograms. Grade 1 with a normal wave pattern was not considered abnormal. The study has been restricted to the qualitative aspect of the wave pattern. Chest roentgenograms were taken on admission and after cure of anemia. The heart was considered enlarged if the cardiothoracic ratio was more than 50 per cent or if it showed reduction in size after treatment.

Results

An abnormal ballistocardiogram was recorded in 28 cases, in 19 on admission and in 9 others after improvement of anemia. The ballistocardiogram remained abnormal in 25

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cases, despite cure of anemia. Ballistocardiographic findings, on admission, during the period of observation, and after cure of anemia, are given in Table 1.

The abnormalities consisted of tall or bifid H; plateau-type I valley; slurred, or notched I-J and J-K segments; broad or bifid J; fused H-J; short, absent, or notched K; tall H, L, or N; and totally bizarre complexes of low amplitude. The abnormalities, their appearance after improvement of anemia, their further course, and the persistence of abnormal records despite cure of anemia are illustrated in figures 2 to 5. Large systolic complexes were seen at the time of admission in 11 cases, 5 of which had an abnormal pattern. In significant contrast to these, totally bizarre complexes of small amplitude and grade 4 abnormality were seen in 5 cases, in 4 at the time of admission and in 1 after cure of anemia. In 3 of them, records with very low amplitude and in 1, grade 4 abnormality persisted despite cure of anemia.

Of the 7 cases with heart failure 1 showed a normal ballistocardiogram on admission, which became abnormal later. Three cases showed large systolic complexes with abnormal patterns. Three of the 4 cases with tall N had heart failure, and tall H was seen in all 7 cases, though the former in each instance and the latter in 5 appeared after improvement of anemia.

Both cases with normal tracings throughout the period of observation had normal-size hearts. After the cure of anemia, 14 of the 15 cases with persistent cardiac enlargement showed abnormal ballistocardiograms and 12 had abnormal electrocardiograms, while in 15 cases with normal-size hearts the corresponding figures were 11 and 3 respectively.

At the time of admission the ballistocardiogram was abnormal in 19 cases, the electrocardiogram in 26 cases, and one or both in 28 cases; the corresponding figures after cure of anemia were 25, 15, and 26 respectively. One case with a pattern of left ventricular hypertrophy showed a normal ballistocardiogram at all times. Instances were noted where the ballistocardiogram showed severe abnormalities at the time of admission while the electrocardiogram was normal (fig. 6).

**Discussion**

In chronic anemia, decreased vascular resistance is likely to mask myocardial weakness, and abnormal patterns may thus be concealed even in the presence of severe myocardial damage. Again ejection by the left ventricle is facilitated by low aortic resistance with increased contribution of the left ventricle to I-J. The large impacts from the left ventricle decreasing on inspiration cancel the increase in the small impacts of the right ventricle and the respiratory variation may be minimal. We were therefore impressed by the high incidence of abnormal ballistocardiograms in this series, which is no doubt due to the intensity and the chronicity of the anemia in the cases included in this study. Abnormal patterns in the ballistocardiograms were concealed at the time of admission in only one third of the cases and were seen even when the systolic complexes were large. Many of the abnormalities, some of them transient, appeared after improvement of anemia. In cases of severe anemia where the heart itself
is injured by anoxia, the appearance of transient abnormalities when the hemoglobin is rapidly raised has been ascribed to myocardial recovery lagging behind vasoconstriction and increased resistance to ejection. Abnormal patterns have also been noted to appear after relief of anemia in some older subjects known to have heart trouble. In our cases, however, abnormal patterns appeared even though the rise in hemoglobin was, as a rule, gradual and irrespective of the age of the patient. The presence of abnormal patterns at the height of anemia and of abnormal respiratory variation in nearly two thirds of our cases was significant and can only be considered to indicate such severe myocardial damage that the left ventricle is unable to accelerate the blood in a normal manner, despite the low peripheral resistance.

No specific pattern in the ballistocardiogram in anemia was revealed in this study. Tall H, notched J, slurred or notched J-K, and short K were the most frequent abnormalities. Tall H has been reported in heart failure, coronary disease, mitral stenosis, and acute myocarditis. The 2 cases that showed tall H on admission had heart failure. In 5 cases with heart failure and in 10 others, however, tall H appeared after relief of heart failure or improvement of anemia, and in 16 cases it persisted despite cure of anemia. In some of these cases tall H was considered as relative to the small I-J. But in others it seems that, because of myocardial damage, upward motion of the blood in the atria during isometric contraction was increased and produced the tall H.

The K wave in the ballistocardiogram is due to deceleration of blood in the aorta and its impact on small peripheral vessels. Decreased peripheral resistance and low cardiac output diminish its amplitude. Short or absent K waves have been reported in coarctation of the aorta, aortic stenosis, occlusion of the aorta, some cases of congenital heart disease, and hypotension. The occurrence of a significantly short K wave in many of our cases was noteworthy, particularly since the records were obtained with the electromagnetic instrument with which the K wave is deeper than with other types of instruments and is stated to be the most prominent and deepest negative component. This has also been our experience in control tracings in normal subjects. In several instances in this series the K wave was even absent or cut off and often very much delayed owing to slurring of the J-K segment particularly in expiration, a pattern which has been stated to be quite specific for coarctation or other obstructive lesions of the aorta. A short K has been noted in association with vertical hearts but in our cases determination of the position of the heart from the roentgenogram and the electrocardiogram showed nearly an equal incidence in cases with horizontal and vertical hearts. The short K wave in those of our cases in which it was seen on admission can be attributed to decreased peripheral resistance. In others, however, in which it appeared after improvement or persisted despite cure of ane-
Fig. 3. Appearance of abnormal patterns after improvement of anemia in 3 cases (A, B, C) with normal pattern and with abnormally large, small, and normal amplitude of systolic complexes, respectively, on admission (first ballistogram). A, after cure of anemia short K waves; and 5 weeks later, tall H and slurred or notched J-K. B, after cure of anemia, grade 1 abnormality, and tall H, L, and N and short K waves; 5 weeks later, grade 2 abnormality with small complexes and broad, notched J waves. C, after cure of anemia, tall H and L waves.

Fig. 4. Abnormal wave pattern in the presence of large systolic complexes on admission in 2 cases with heart failure; abnormal records after cure of anemia. A, on admission, tall H, fused H-J, and tall L; after cure of anemia, decreased amplitude, tall H, notched J and slurred J-K; 2 months later, bizarre complexes. B, on admission, grade 1 abnormality, tall H, slurred J-K, and short K; 6 weeks after cure of anemia, tall H, notched J, short K, and variation of H-K time from 0.28 to 0.34 second.

4 abnormality at the time of admission in 4 cases of which only 1 had heart failure, and in 1 after cure of anemia. The former 4 were females with ages of 25, 30, 30, and 39 years, and the latter was a boy of 14 years. There was therefore little possibility of coincident coronary artery disease. The boy has been admitted 3 times in 2 years, each time with recurrence of heart failure due to hookworm reinfection and recurrence of anemia, thus demonstrating the prognostic value of the ballistocardiogram at this young age.

The incidence of abnormal electrocardiograms was greater on admission. After cure of anemia, however, the incidence of abnormal ballistocardiograms was greater and while only 1 case with cardiac enlargement and 1 with an abnormal electrocardiogram (L.V.H. pattern) showed a normal ballistocardiogram, 11 cases with a normal electrocardiogram and
Persistence of abnormal ballistocardiograms, even several months after cure of anemia, in many of our cases all of whom were below this age, would therefore indicate persistence of impaired mechanical efficiency of the heart, which may be permanent. With passage of time the ballistocardiogram may yet become normal in some of these cases.

It is concluded that chronic severe anemia often leads to such a severe myocardial damage that abnormal ballistocardiograms, including maximum abnormality, may be recorded despite decreased peripheral resistance, and that some damage often persists despite cure of anemia. It is stressed that in the interpreting of an abnormal ballistocardiogram in an otherwise normal individual and in the attributing of it to a possible coronary artery disease, a previous history of anemia must be excluded, particularly in countries where such anemias are not uncommon.

**Summary**

Results of a study of serial ballistocardiograms in 30 cases of chronic severe anemia are reported. An electromagnetic ballistocardiograph of the Dock type was used.

Many of the abnormal patterns appeared after improvement of anemia. An abnormal pattern was seen in 28 cases and persisted in 25, despite cure of anemia. Maximum grade 4 abnormality was seen in 5 cases, in 4 at the time of admission and in 1 after cure of anemia. Slurred or notched J-K, tall H, and short K were the most frequent abnormalities.
No specific pattern of anemia was revealed in the ballistocardiogram.

The electrocardiogram was abnormal in 26 cases on admission and in 15 after cure of anemia. The ballistocardiogram was abnormal in 19 cases on admission and in 25 after cure of anemia.

The results of this study show that there is usually severe impairment of the functional state of the circulatory system in chronic severe anemia, that some impairment often persists despite cure of anemia, and that ballistocardiography is a valuable adjunct in its determination.

SUMMARIO IN INTERLINGUA
Es reportate le resultatos del studio de ballistocardiogrammas serial in 30 casos de sever anemia chronic. Esseva utilissit un ballistocardiographo electromagnétique del tipo Dock.


Le electrocardiogramma esseva anormal al tempore del admission in 26 casos. In 15, illo esseva anormal post le curation del anemia. Le ballistocardiogramma esseva anormal al tempore del admission in 19 casos. In 25, illo esseva anormal post le cura del anemia.

Le resultatos del presente studio indica que in sever anemia chronic il ha usualmente un compromisso sever del stato functional del sys-

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