Studies Utilizing the Portable Electromagnetic Ballistocardiograph

IV. The Clinical Significance of Serial Ballistocardiograms Following Acute Myocardial Infarction

By Harry Mandelbaum, M.D., and Robert A. Mandelbaum, M.D.

One hundred patients, who had survived their first episode of myocardial infarction, were studied by serial ballistocardiograms which provided a reliable index in determining myocardial functional recovery. The degree of ballistocardiographic reversion toward normal, as judged by an 18-month or longer follow-up period, has proved to be a valuable standard for prognosis.

The BALLISTOCARDIOGRAPHIC findings in acute myocardial infarction were first completely described by Starr. With rare exceptions, these variations from the normal pattern are the most marked to be found in clinical ballistocardiography. They recently have been restudied by various observers. The phenomenon of ballistocardiographic recovery toward normal from the abnormalities of acute myocardial infarction was also described by Starr. It is our purpose, in this paper, to present our experiences with serial ballistocardiograms following acute myocardial infarction, in order to demonstrate their clinical value to the physician responsible for the care of the patient with this illness.

The clinical study group was composed of 67 men and 33 women (table 1). The 12 fatalities in this group occurred later than six months following the onset of the myocardial infarction. The 88 surviving patients were the objects of our follow-up study for 18 months or longer. The diagnosis of acute myocardial infarction was established by the present accepted criteria. Subjects who had suffered a previous myocardial infarction, as well as those who did not survive more than six months, were excluded from the study. The 100 cases of acute myocardial infarction were subjected to serial ballistocardiographic stud-

ies, using the portable electromagnetic ballistocardiographic technics previously described. The abnormalities in the ballistocardiograms were graded I to IV in degree, following the criteria of Brown and co-authors. The exercise test, which was part of the ballistocardiographic study as our patients recovered, consisted of 10 trips over a standard two-step platform.

In 41 cases, a ballistocardiographic study was done during the first week of the illness; all but 1 of these 41 ballistocardiograms were graded II or worse in degree of abnormality. (The one subject with a normal ballistocardiogram eight days after a myocardial infarction was a young man of 36 who made a rapid, uneventful recovery from an epicardial infarction.) Serial ballistocardiographic studies for all the patients in this study group were begun at approximately four weeks after the onset of the infarction, when the patient had begun ambulation. The electrocardiogram indicated a stable electrical pattern and the erythrocyte sedimentation rate was normal in almost all instances. Serial ballistocardiograms were taken at two week intervals during the first three months of the study, and at monthly intervals thereafter, and indicated that ballistocardiographic reversion toward normal may continue from four weeks to eight months after a normal erythrocyte sedimentation rate had been attained. In a large majority of cases, the ballistocardiogram had improved to the greatest extent possible within six months.
after the initial myocardial infarction. Gradual increase in the patient's activity was permitted during the period of ballistocardiographic recovery, but it did not seem wise to consider a patient well and ready for full activity until his ballistocardiogram, recording the force of cardiac ejection, had improved to the greatest degree possible, both at rest and after the exercise test. (A grade II abnormality after the initial myocardial infarction. Eighth week, and was then permitted to return to work. The 36 year old man referred to in the preceding paragraph, whose ballistocardiogram was normal eight days after the occurrence of his infarct, was also at work at the eighth week. There were seven others, three over 50 years of age, whose ballistocardiograms returned to normal, at rest and after exercise, within 3 to 12 months after the myocardial

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* Maximal degree of ballistocardiographic recovery attainable by each subject during the observation period, with the exception of 4 subjects with grade III tracings who had shown grade II patterns for varying intervals before regressing to grade III.

† Wagener-Keith classification.

at rest or after exercise was arbitrarily chosen as the greatest degree of ballistocardiographic abnormality with which we would permit a patient to undertake full activity.)

There were 65 patients in whom ballistocardiographic recovery to grade II or better was found. Subjects under the age of 42 demonstrated a more prompt ballistocardiographic recovery. A 34 year old man, who had suffered a posterior wall myocardial infarction, showed a normal ballistocardiogram at the end of the infarction. All of these have returned to full activity and are without complaints. In 22 patients, ballistocardiographic recovery to grade I, at rest or after exercise was found; all of these were without restriction of activity before the end of the first year of observation. Four of the 22 complained of occasional angina pectoris on extended effort. In the 34 remaining of these 65 patients, the ballistocardiograms never became better than grade II. Two of this group have suffered another
myocardial infarction; one died 14 months after the initial myocardial infarct; the other is suffering from angina on slight effort, and his ballistocardiogram is now grade III. Twenty-four returned to their former occupations (household or gainful), and of these, seven have angina pectoris after unusual effort. The remaining eight are disabled by recurrent congestive heart failure or severe angina of effort.

In this group of 65 cases with ballistocardiographic recovery to grade II or better, 10 did poorly. In none of these 10 had the ballistocardiogram improved to better than grade II. One died after a second myocardial infarct. Nine were incapacitated by angina or repeated episodes of congestive heart failure.

There were 35 patients in whom marked abnormalities (grade III or IV) of the ballistocardiogram were found. In 19, the ballistocardiogram was grade III; four had temporarily attained a grade II pattern. Two of the 19 died in a subsequent attack of myocardial infarction: one 10 months, the other 17 months after the initial episode. Nine were totally disabled by congestive heart failure or severe angina pectoris, or both. Five are engaged in sedentary work but have angina pectoris on effort. Three have no complaints and have returned to their former occupations after nine months of convalescence; in two of these patients, the ballistocardiograms improved to grade II in the twenty-fifth and twenty-sixth month of observation, respectively, after more than a year of uninterrupted work. In 16 subjects, serial ballistocardiograms showed a persistence of a grade IV pattern. Nine of these patients have died: one seven months, another nine months, and the remainder within 18 months following the initial myocardial infarction. Seven patients were incapacitated by recurrent episodes of congestive heart failure, or angina of effort.

In this group of 35 patients with marked ballistocardiographic abnormalities, only eight have been able to return to their work or household duties. Eleven deaths occurred (two in patients with grade III ballistocardiograms; and nine in patients with grade IV ballistocardiograms). Nineteen are cardiac invalids.

**DISCUSSION**

In observing these patients recovering from myocardial infarction, we have come to rely upon progressive improvement toward normal in serial traces as an indication of functional recovery of the heart muscle. The ballistocardiograph thus provides a guide as to when optional recovery from the acute myocardial infarction has been obtained. The degree of ballistocardiographic recovery which each patient attains has proved to be a reliable yardstick upon which to venture a prognosis.

When satisfactory ballistocardiographic recovery following myocardial infarction has finally been reached, the physician may feel secure in encouraging the patient to return to full activity. Ballistocardiographic recovery is especially important in the presence of stabilized marked abnormalities in the electrocardiogram. Starr and Hildreth, who have followed patients for periods as long as 10 years, have arrived at a similar conclusion.

Where the ballistocardiogram showed persistent marked abnormalities, the outlook for functional recovery was not good. A minority of these patients have returned to work. The greater number of deaths and cardiac invalidism occurred in this group.

**SUMMARY**

One hundred patients who survived their first attack of myocardial infarction were studied during the period of recovery and subsequently with serial ballistocardiograms and followed for periods of 18 to 24 months.

In 65 patients, ballistocardiographic improvement to grade II or better was recorded; 55 of these patients have returned to their gainful or household duties. Of the remaining 10, one died of a second myocardial infarct; one showed advance to a grade III ballistocardiographic abnormality after recovering from a second attack of myocardial infarction; and the others were disabled by recurrent attacks of congestive heart failure or severe angina.
In 35 patients, the ballistocardiograms following myocardial infarction, and subsequently, showed advanced abnormalities of pattern. Only five of this group have been able to return to their former duties. Eleven have died and 19 are cardiac invalids.

Case Reports

Case 1. A. M., a 57 year old traveling salesman, developed an acute myocardial infarct on Jan. 18, 1950. His sedimentation rate was normal on the twenty-first day; his electrocardiogram became stabilized with minimal changes after the fifth week. The initial ballistocardiogram was grade III, taken in the fourth week of his convalescence. Improvement in pattern was progressive and in the tenth week following the acute infarction, the ballistocardiograms, figure 1, A and B, showed a grade II pattern. He was permitted progressive increase in his activity.

At the fourteenth week, the ballistocardiograph recorded full recovery to normal (fig. 1, C and D), and he was permitted to return to work. He has had no complaints since.

Case 2. W. K., a 44 year old man employed as a shipping clerk, suffered a posterior wall myocardial infarct March 3, 1950. His sedimentation rate was normal after the sixth week. His electrocardiogram was stabilized after the eleventh week with a pattern characteristic of healed posterior wall myocardial infarction. The initial ballistocardiogram was grade III. Successive ballistocardiograms showed no change in pattern during the first year of his convalescence. He suffered angina on slight effort and did not feel strong enough to return to his work.

Twelve months after the infarction, the clinical examination showed no enlargement of the heart; the blood pressure was 140/80. The trace recorded at this time, figure 2, A and B, was grade III at rest and after exercise.

He made several efforts to return to work after this examination but could not continue because of angina. However, since December, 1951, 21 months after the infarction, he has engaged in full activity and is asymptomatic. The ballistocardiogram, 25 months after infarction, shows some improvement (C and D). This is an exceptional instance where functional recovery was not reflected by major improvement in the ballistocardiogram.

On Oct. 3, 1952, he reported that he has never felt better in his life. The blood pressure was 150/85. The electrocardiogram showed no change. The resting ballistocardiogram (fig. 2E) was grade II. However, the exercise trace was now normal (fig. 2F).

Case 3. J. L., a 47 year old man, suffered an acute myocardial infarct in December, 1949. His condition was critical, with initial shock and subsequent congestive heart failure. Sedimentation rate was

Fig. 1. Ballistocardiograms of case 1.

Ten weeks following myocardial infarction: (A) Basal. Grade II pattern. The third and sixth complexes are normal; the others have low amplitude IJK complexes with prominent H waves. (B) After exercise. Grade II pattern. Slurring and diminution of the IJ stroke is noted in the first, fifth and sixth complexes; the second and third complexes are normal; H is prominent in the fourth and fifth complexes.

Fourteen weeks after myocardial infarction: (C) Basal. Normal. (D) After exercise. Normal.

The upper channel in each figure represents the ballistocardiogram; the lower channel, the concomitant tracing taken from the left radial artery (a pulse tracing). The headward J wave occurs synchronously with the apex of the radial pulse trace; the K wave is the first footward stroke following the apex of the pulse trace.

Grades I, II, III and IV follow Brown's classification.2
PORTABLE ELECTROMAGNETIC BALLISTOCARDIOGRAPH

![Ballistocardiograms](image)

**Fig. 2. Ballistocardiograms of case 2.**

Twelve months after myocardial infarction: (A) Basal. Grade III pattern. Poor amplitude; short IJ waves in inspiration (first, second and third complexes); plateau HJ in expiration, with absent I waves in the fourth and fifth complexes. (B) After exercise. Grade III ballistocardiogram. Bizarre, low amplitude pattern. The occasional tall complexes are due to dyspnea.

Twenty-five months after myocardial infarction: (C) Basal. Grade II pattern. The second and third complexes are definitive but of low amplitude. The first, fourth and fifth complexes are abnormal in configuration; (D) After exercise. Grade II pattern. The complexes are taller but are abnormal; shortening of the IJ stroke is seen in the first, second, fourth and fifth complexes. A low H wave is noted in the third complex.

Thirty-one months after myocardial infarction:

normal after the eighth week. Convalescence was slow; digitalis, sodium restriction and mercurial diuretics were needed to maintain cardiac compensation. Serial ballistocardiograms were never better than grade III. A tracing taken under basal conditions three months after his initial infarct is shown in figure 3A. The electrocardiogram showed evidence of a healed anterior lateral wall myocardial infarction.

He was incapacitated by repeated episodes of congestive heart failure despite adherence to digitalis, sodium restriction and repeated mercurial injections. The ballistocardiogram (fig. 3B), taken

**Fig. 3. Ballistocardiograms of case 3.**

Three months after myocardial infarction: (A) Basal. Grade III pattern. Abnormally low amplitude; the first, second and fifth complexes lack definitiveness. The patient could not exercise because of angina.

Nine months after myocardial infarction: (B) Basal. Grade III pattern. The J waves are of low amplitude and could be identified only because of the accompanying pulse trace. The patient could not exercise because of angina.

**Fig. 4. Ballistocardiogram of case 4.**

Grade IV pattern of low amplitude, with no recognizable complexes. This was obtained at each examination, done every four weeks, until the patient died of a second myocardial infarct 16 months after the onset of the initial coronary occlusion.

(E) Basal. Grade II pattern. The complexes in inspiration are normal; those in expiration, the second and third complexes, are of low amplitude. (F) After exercise. The ballistocardiogram is normal.
nine months after the myocardial infarction, shows persistence of the markedly abnormal pattern. This patient suffered a fatal myocardial infarct one month later.

Case 4. P. B., a 57 year old man, developed a posterior myocardial infarct in April, 1950. The sedimentation rate was normal after the eighth week. The electrocardiogram was stabilized after the third month and showed minimal changes.

Disabling angina prevented him from returning to work. The ballistocardiogram showing a grade IV abnormality was recorded two months after his coronary occlusion (fig. 4). Serial studies, done once a month, showed no change in pattern. He died 16 months after his initial illness of a second occurrence of myocardial infarction.

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SUMARIO ESPAÑOL

Cien pacientes que han sobrevivido el primer episodio de infarto del miocardio fueron estudiados con series de balistocardiogramas que proporcionaron un índice confiable del recobramiento de funcionamiento del miocardio. El grado de reversión balistocardiográfica hacia lo normal ha probado ser signo de valor en el prognóstico, a juzgar por periodos de observación de 18 meses o más.

REFERENCES

11. —, and Hildreth, E. A.: Changes in the ballistocardiograms of healthy persons and of patients in most cases followed for a period of ten years or longer. Tr. A. Am. Physicians 64: 59, 1951.
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