

## Editorial

### Ballistocardiography: Predictor of Coronary Heart Disease

FROM THE early ballistocardiographic (BCG) studies of Starr there developed much hope that the technique would fill an important need in clinical cardiology. Unfortunately the technical deficiencies of certain early methods, their indiscriminate use, and thoughtless interpretation soon caused the method to become clinically discredited in the minds of many people. In spite of this, careful hemodynamic, biophysical and clinical studies continued and recent results of these should go far to reestablish ballistocardiography as a technique which can provide unique information.<sup>1, 2</sup>

The purpose of this editorial is to call attention to recent clinical observations which strongly correlate abnormality of the BCG wave form with the onset of coronary heart disease and to discuss the implications of this finding.<sup>3</sup> For years it has been known that the BCGs of healthy youths are monotonously similar, so much so that they have become accepted as the standard of normal wave form. Deviations from this wave form are seen in most but by no means all whose circulations are known to be abnormal. Between these extremes, there is a third group com-

posed of those whose circulations are normal by conventional criteria but whose BCG wave forms clearly deviate from those typical of healthy youths.

Intrigued by these findings, many years ago Starr began a prospective study of them. Over the years he has found that BCG abnormality in previously healthy persons often foretells not only the development of one of a number of unrelated circulatory abnormalities but it also carries with it a considerably greater death rate in those already afflicted with circulatory disease.<sup>4</sup>

Starr's preliminary observations led Baker, Scarborough, and their associates to focus their BCG studies specifically upon coronary heart disease. As a result two important impressions were soon established as fact: that patients with coronary heart disease more frequently have BCG abnormality than do comparable controls and that BCG abnormality is excessively rare in young controls.<sup>5</sup> It was further observed that with advancing years both patients and controls acquire increasing BCG abnormality so that it is as common in aged controls as it is rare in the young. These findings were regarded at the time as possibly meaning that BCG abnormality when seen in controls indicated the presence of coronary artery disease which had not yet become clinically overt as coronary heart disease, and when seen in patients, that collateral circulation was not as abundant as in those with normal records. To test this hypothesis,

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it was decided to find out whether the development of primary, as well as recurrent, episodes of coronary heart disease over a period of years correlated significantly with the BCG wave form shown by controls and patients when they were initially studied.

A 9-year follow-up study has now been completed and the results seem worthy of presentation and comment inasmuch as they indicate that BCG wave form has impressive power to predict the development of coronary heart disease.<sup>3</sup>

The normal control group consisted of 265 men and women divided about equally by decades. None had symptoms or physical findings of cardiovascular disease and their electrocardiograms, blood pressures, and tele-roentgenograms were normal. Before the follow-up procedure began, the BCGs were interpreted by a single observer who classified them as normal or abnormal on the basis of wave form inspection. Myocardial infarction, angina pectoris, and sudden death, attributable to coronary artery obstruction, were construed as events. Follow-up was complete upon all but three of the control subjects. Controls whose BCGs were abnormal at the outset developed events five to six times as frequently as did those with normal ones. There were over 300 patients with well-documented evidence of coronary heart disease and they too could be similarly subdivided on the basis of BCG wave form; those with abnormal wave forms developed twice the number of recurrences that those with normal ones did.

Interpretation of these results is not easy. The development of coronary heart disease and the incidence of BCG wave form abnormality in controls are both strongly age dependent. Therefore, one cannot relate these differences in development of coronary heart disease directly to BCG wave form until one has acceptably eliminated the confounding effect of age. When one attempted to do this by subdividing the groups finely enough to compare those of similar age, the numbers became too small for the differences to be significant.

Fortunately the multivariate logistic function is peculiarly suited to the analysis of this problem and in large measure resolved the difficulty. Its use demonstrates that the risk of development of coronary heart disease in the control group is strongly dependent upon age but equally strongly and independently dependent upon the wave form of the BCG. For example, the risk that a 40-year-old male control will suffer an event attributable to coronary heart disease in the next year is found to be 0.0046 if the BCG is normal (Framingham risk is 0.01), but 0.023 if it is abnormal, almost a sixfold difference. Put another way, a 40-year-old male control with an abnormal BCG has approximately the risk of a 70-year-old male control with a normal BCG.

Appropriate multiple regression analyses disclose that in a third group of control subjects with a minor abnormality in blood pressure, heart size, or electrocardiogram, or even in all three, BCG wave form retains its rank as a superior predictor of events.

BCG wave form predicts the likelihood of recurrence of an event in those who entered the study as patients with coronary heart disease, significantly but less impressively than it did with initial events in the control group. The conspicuous age dependence of initial events found to be characteristic of the controls is absent in the patients. The singular fact is that once the manifestations of coronary heart disease have appeared, the wave form of the BCG provides strong evidence as to the likelihood of recurrences, regardless of the patient's age.

One can say from these studies that ballistocardiography provides a kind of information fundamentally related to the appearance or recurrence of myocardial ischemia. Although there are interesting preliminary studies, one cannot say precisely what the BCG is recording hemodynamically in man that accounts for this predictive power. These relationships should do much to stimulate intensified efforts to clarify further those he-

modynamic variables responsible for differences in ballistocardiograms.

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