

The Prediction of a Potentially Fatal Cardiac Event in the Next 2 to 24 Hours and The Prediction of a Myocardial Infarction Related Death or Sudden Death

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Abstract

Eleven predictive markers have been developed based on the empirical examination of RR intervals (RR) of Holter files from patients who were normal, Post-MI (Myocardial Infarction), and who had expired due to Sudden Death (SD). Combinations of these markers predict the onset of a potentially fatal cardiac event such as a MI related death or SD in the next 2 to 24 hours.

A potentially lethal variability can be a decreased or an increased variability. In a retrospective learning study of 83 Holter files comprised of 39 patients who expired of a MI related death or SD, and 44 Post-MI patients, the results were 3% false negative and 7% false positive. In a retrospective testing study of 156 Holter files comprised of 61 MI related death or SD patients and 95 Post-MI patients, the results were 7% false negative and 13% false positive. There appears to be a direct relationship between decreased variability and a MI related death, and increased variability and SD.

1. Introduction

In the Soviet Union during the early 1960's, Rhythmography, a methodology now termed Heart Rate Variability (HRV), which is the study of normal and abnormal variations in heart rhythm, was used primarily to determine the stress state of cosmonauts.

The two basic Soviet predictive markers are Amplitude of the Mode (AMo), defined as the largest number of identical intervals in a collection of heart beats, later defined as a Time Segment, and Delta X (ΔX), defined as the difference between the longest interval and the shortest interval in a collection of heart beats.[1]

The triangulation index (TINN) first appeared in western medical literature in 1989. Y is the height of the triangle formed by a histogram of a collection of heart beats, and is equivalent to AMo. M-N is equal to the base of the triangle and is equivalent to ΔX . [2,5] ΔX is also similar to Standard Deviation Average Normal to Normal (SDANN) in successive five minute periods.

GWS is developing a wristwatch device whose transducer detects pulse wave intervals from the radial artery, which intervals are the equivalent of ECG RR intervals. The software described below predicts a potentially fatal cardiac event, such as a MI related death or SD in the next 2 to 24 hours. This is ample time for the patient to seek medical intervention at a hospital emergency room.

2. Methods

The 11 GWS predictive markers used in the wristwatch device, including AMo & ΔX , are comprised of six markers which measure decreased variability, four markers which measure increased variability, and one marker which measures a group of intervals comprised of premature ventricular contractions and atrial fibrillation known collectively as Abnormal Cardiac RR (ACRR). An ACRR is an RR 25% shorter or longer than the previous RR, and includes the recovery RR following the abnormal RR.[3] The current NN Time Segment stores NN intervals and transfers ACRR intervals, if any, to a concurrent ACRR Time Segment until the NN Time Segment has stored 101 NN intervals. Then the three longest and three shortest intervals are discarded. The software analyzes both Time Segments and then repeats the process of storing NN & ACRR intervals and analyzing successive Time Segments 24/7. An ACRR Time Segment stores between zero and several hundred ACRR.

Different points are assigned to each of the 11 predictive markers based on the stress level the markers record, and then the points are totaled for each Time Segment. Decreased variability markers are assigned positive points and increased variability markers are assigned negative points.[4] Should a positive or negative total point score for a Time Segment equal or exceed a certain value, then an ALARM is triggered predicting a

cardiac event. Point scores for two patients are shown on the HRV Status graphs, Figures 1 and 2.

One of the definitions of a decreased variability Time Segment occurs when ΔX is equal to or less than 60 milliseconds. One of the definitions of an increased variability Time Segment occurs when ΔX is equal to or greater than 500 milliseconds.[5]

3. Results

3.1. Retrospective learning study

The learning study was composed of 83 Holter files comprised of 38 Holter files where the patient expired and 44 Post-MI Holter files which comprised the control group where the age and gender were known. The Post-MI Holter files were obtained from the patients one month after their MI. The results were 3% false negative and 7% false positive in the prediction of a potentially fatal cardiac event in the next 2 to 24 hours. Note: The longest warning time might be longer, but is presently limited by the 24 hour length of a standard Holter file.

The learning study started with six predictive markers, and then based on empirical results was expanded to 11 predictive markers, nine of which are directly or indirectly related to markers published in the peer reviewed literature.

3.2. Retrospective testing study

The software settings used in the learning study were used in the definitive study to analyze 153 new Holter files comprised of 58 cardiac death files where the age and gender were not known and 95 Post-MI Holter files where age and gender were known. The Post-MI Holter files were obtained from the patients six months after their MI. The results were 7% false negative and 13% false positive in predicting a potentially fatal cardiac event in the next 2 to 24 hours.

The age group 55 & older settings were used for all cardiac death patients in the definitive study since the age of the patients was unknown. Among the Post-MI patients are patients with an underlying heart problem such as congestive heart failure and/or who experienced a MI with Killip Class III or IV heart failure, which problems contributed to the 13% false positive rate. Also, a false positive could be attributed to an unanticipated ischemic episode.

Approximately half of this high risk group can use a desensitized version of the software and reduce the false positives rate, however false negatives rate will tend to increase.

4. MI related death or sudden death

An examination of seven Holter files from the learning/definitive studies and three from a study of patients who underwent non-cardiac vascular surgery (NCVS) indicated that the 11 predictive markers also predict if the potentially fatal cardiac event will be a MI related death or an SD. The four increased variability markers combined with the ACRR predictive marker indicate an SD, Figure 1, and the six decreased variability markers indicate a MI related death, Figure 2. One 12 lead ECG report, Figure 3, charted ST elevations, were present in Figure 2 confirming an indication of MI in addition to decreased variability. Three NCVS patients who expired triggered a decreased variability ALARM, which an attending physician confirmed as a clinical MI. Further study is required to expand this anecdotal data, using ECG and blood enzyme tests to help confirm or rule out a predicted decreased variability ALARM indicating a MI related death.

5. Conclusions - Other HRV software vs GWS HRV software

It appears that other HRV software are general predictors of a cardiac event that could occur anywhere from six months to two years in the future. The GWS HRV software, as previously noted, predicts a potentially fatal cardiac event will occur in the next 2 to 24 hours.

Other HRV software, does not appear to distinguish between a MI related death and SD. Based on anecdotal evidence the GWS HRV software distinguishes between a MI related death and SD.

Other HRV software use one, perhaps two predictive markers, while the GWS HRV software uses 11 predictive markers, which helps insure the accurate prediction of a potentially fatal cardiac event without increasing the incidence of false positives.

The GWS HRV software is unique because it is designed to be imbedded in a non-invasive wristwatch style device for the continuous monitoring of cardiac patients.

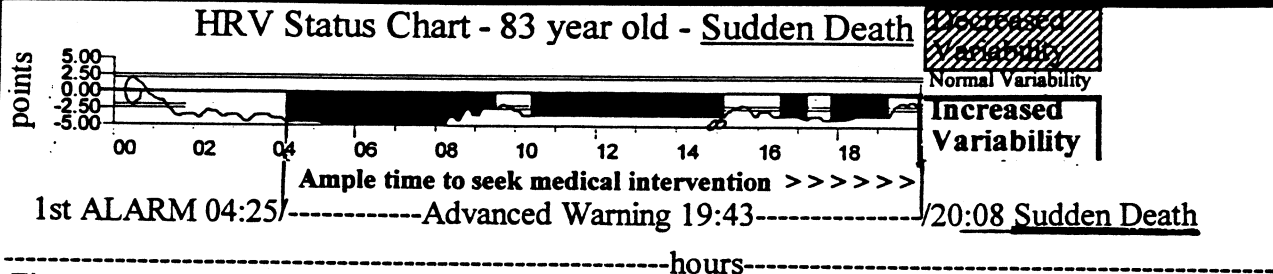


Figure 1 ALARM triggered at 04:25 hours. At 20:08 hours patient expires of an increased variability Sudden Death. The advance warning time was 19 hours and 43 minutes.

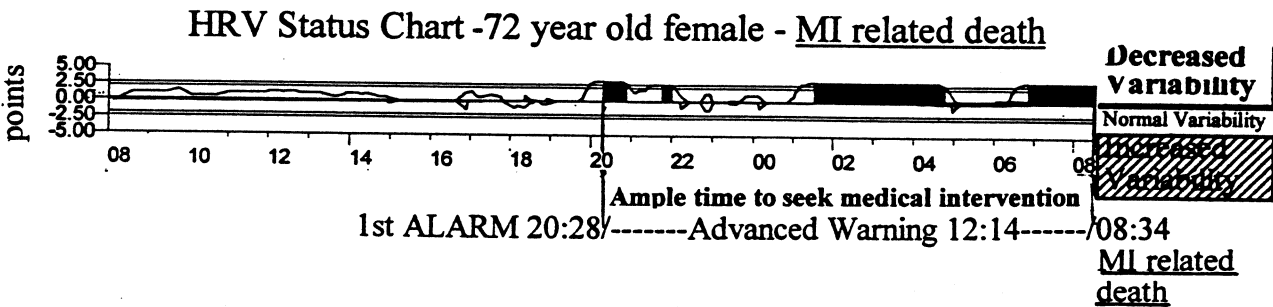


Figure 2 1st ALARM triggered at 20:28 hours. At 08:34 hours patient expires of a decreased variability MI related death. The advanced warning time was 12 hours and 14 minutes.

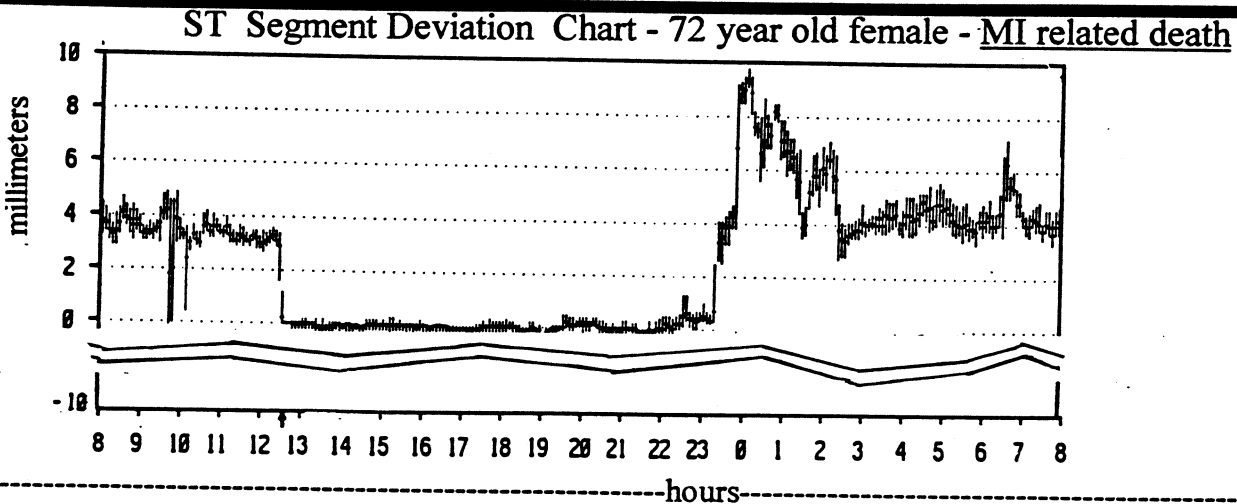


Figure 3 The ECG report charts ST elevations as high as 10mm (1mV), an indication of a possible decreased variability MI related death.

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