MERIT RESEARCH JOURNALS
www.meritresearchjournals.org

Merit Research Journal of Medicine and Medical Sciences (ISSN: 2354-323X) Vol. 3(5) pp. 191-195, May, 2015
Available online http://www.meritresearchjournals.org/mms/index.htm

Original Research Article

Separating Internal Biological Effects from External Environmental Effects

Dennis Ridley[1*] and Pierre Ngnepieba[2]

[1]Florida A&M University and Florida State University, Tallahassee, Florida, USA

[2] Department of Mathematics, Florida A&M University, Florida, USA

***Corresponding Author's E-mail: dridley@fsu.edu**

Abstract

Single charts of Heart Rate (HR) contain internal biological effects and external environmental effects. These effects are confounded, making Heart Rate Variability (HRV) difficult to analyse. A dual chart system is proposed for classifying and separating these effects into common correlated causes and special uncorrelated causes. The dual chart system sharpens heart rate variability analysis.

Keywords: Arrhythmia, Atrial flutter, Heart Rate, Myocardial Infarction, Tachycardia

INTRODUCTION

Heart Rate Variability (HRV) analysis is a methodology for both research and clinical studies. Modern technology and the wide-spread availability of portable computers have reduced the cost and raised the level of convenience of HRV monitors (Malik, 1996). So much so that they are now suitable for personal use at home, while performing normal activities, exercising or while traveling. Gone are the days of the house call. Or, are they? Remote monitoring via wireless telemetry enhances the ability to deliver health care, anywhere. A physician can view HRV charts periodically or upon receipt of a text based alarm when triggered by abnormal conditions. Does wireless telemetry mean that the days of the house call are back?

HRV is comprised of two components. One component is due to internal biological effects. These effects are related to each other. They have a common source. Correlation† is a mathematical measure of the degree to which two sets of numbers vary in like or opposite manner. The numbers can be used to represent two variables. Two variables that vary together are said to be positively correlated. Two variables that vary in opposite directions are negatively correlated. We expect internal biological effects to be highly correlated, arising from common causes. We will refer to these as common cause effects. In addition, there is HRV that is due to random external environmental effects. These effects do not vary in any systematic way, either positively or negatively. They are unrelated, and have zero correlation. We will refer to these as special cause effects. These two effects are confounded†. The confounding of common cause effects and special cause effects makes them difficult to analyse. That is, we cannot tell their causes apart. This makes it difficult for a physician to analyse, isolate and treat or otherwise correct their causes. The purpose of this article is to discuss the separation of HRV into common cause internal biological effects and special cause external environment effects (MyPulse®, Smart Monitors, Inc., Version 2014.5, 2014; Ridley and Duke, 2000). This leads to the replacement of the single chart of heart rates with two charts, one of common cause effects and one of special cause effects. This becomes a dual chart system in which each chart can provide a basis for separate inference and different health care actions.

METHODS

Standard single chart system

It is a simple matter to construct a single chart of heart rate measurements. The chart can be marked with upper and a lower limit, within which HR is considered to indicate normal conditions. If the HR follows a normal probability distribution†, then the upper limit and lower

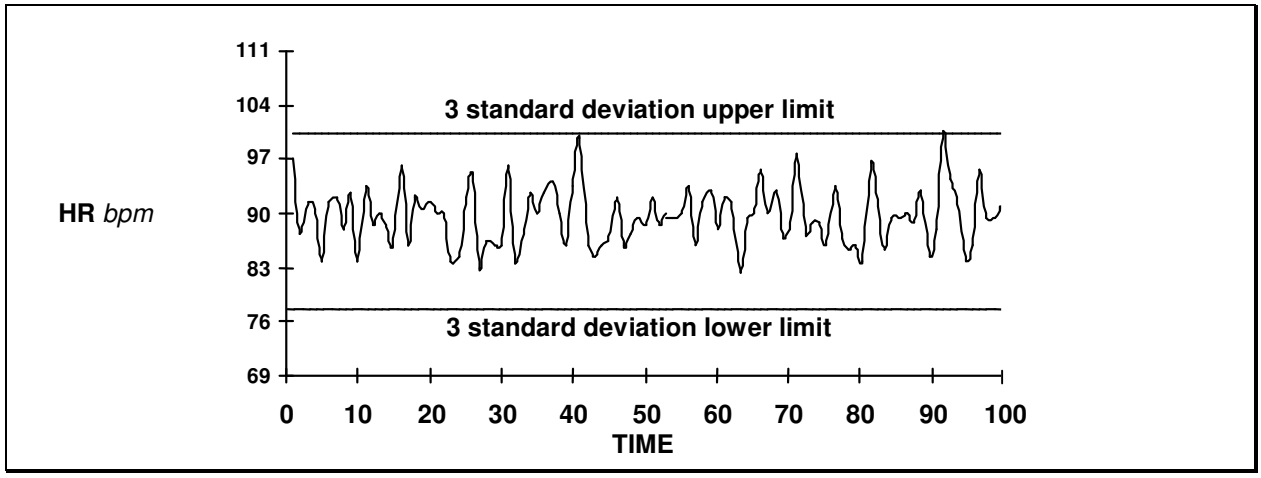

Figure 1. Single chart of total HR.

limit can be specified as an equal number of standards deviations above and below the mean value of HR. Values of HR that fall above the upper limit or below the lower limit are considered abnormal. The choice of the number of standard deviations† is based on the assumption that the HR measurements are independent of each other, and are normally and identically distributed. However, HR values depend very much on previous HR and many other immediate past conditions. Therefore, HR measurements are not independent. They are serially correlated (Ridley and Ngnepieba, 2014). Furthermore, HR can temporarily trend up or down, and HRV can increase or decrease. Therefore, HR values are not identically distributed.These factors invalidate the traditional single chart upper and lower limits. This in turn leads to an increased rate of false positive and false negative indications. Various researchers have suggested alternative statistical process control charts for serially correlated measurements (Box and Jenkins, 1963; Crowder, 1987; Hunter, 1986; Lucas and Saccucci, 1990; Montgomery and Mastrangelo, 1991; (MyPulse®, Smart Monitors, Inc., Version 2014.5, 2014; Ridley and Duke, 2000; Roberts, 1959; Wardell et al., 1992; Wardell et al., 1994; Yashchin, 1987). Still, in addition to serial correlation and changing variability, the single chart will contain confounded internal biological effects and external environmental effects.

The following is an example of a single HR time chart on which a sample of total HR values is plotted in Figure 1. In this example, the average HR is 90 beats per minute (bpm). The upper and lower limits are set at +3 and -3 standard deviations respectively, above and below the average. For normally distributed independent HR values, these limits include 99.7% of HR. Therefore, there is only a 0.3% (three tenths of one percent) chance of HR rising above the upper limit or falling below the lower limit. If HR values between these limits indicated normal conditions, then all appears to be normal.

What is considered normal for HR varies from person to person, male and female, young and old (Malasonas et al., 1981). Someone with a sedentary life style is expected to have a higher resting HR than someone who exercises frequently, ceteris paribus. So, it is not meaningful to specify the upper and lower limits in terms of HR. It is more useful to express the limits in terms of standard deviations. Since the standard deviation is calculated from the data for a particular individual, it personalizes the limits. At first, this may seem paradoxical. One might wonder how the standard deviation can be a standard if it is different in each case. What is meant is that it forms a standard for judging the HRV of the individual.

The Dual Chart Biomedical Monitoring System

The dual chart system is comprised of a common cause chart of internal biological effects on HR and a special cause chart of external environmental effects on HR. The common cause chart contains the component of the data that is systematic (correlated). The special cause chart contains the component of the data that is random (independent). Splitting the data into these two components is accomplished by fitting a time series† mathematical model to the data (MyPulse®, Smart Monitors, Inc., Version 2014.5, 2014. http://mypulsemonitor.com/). The common cause chart is constructed from the model fitted values. The special cause chart is constructed from the residual values.

The flow chart in Figure 2 shows the scheme for splitting the HR data. The data are continuously updated regardless of the size of the pulse measurement. Breaches of the special cause chart are attributed to one-of-a-kind external environmental special causes, impacting the human body, and that are to be removed if harmful. For example the effects of a one of a kind loud noise that is startling, raises heart rate temporarily but does not repeat in

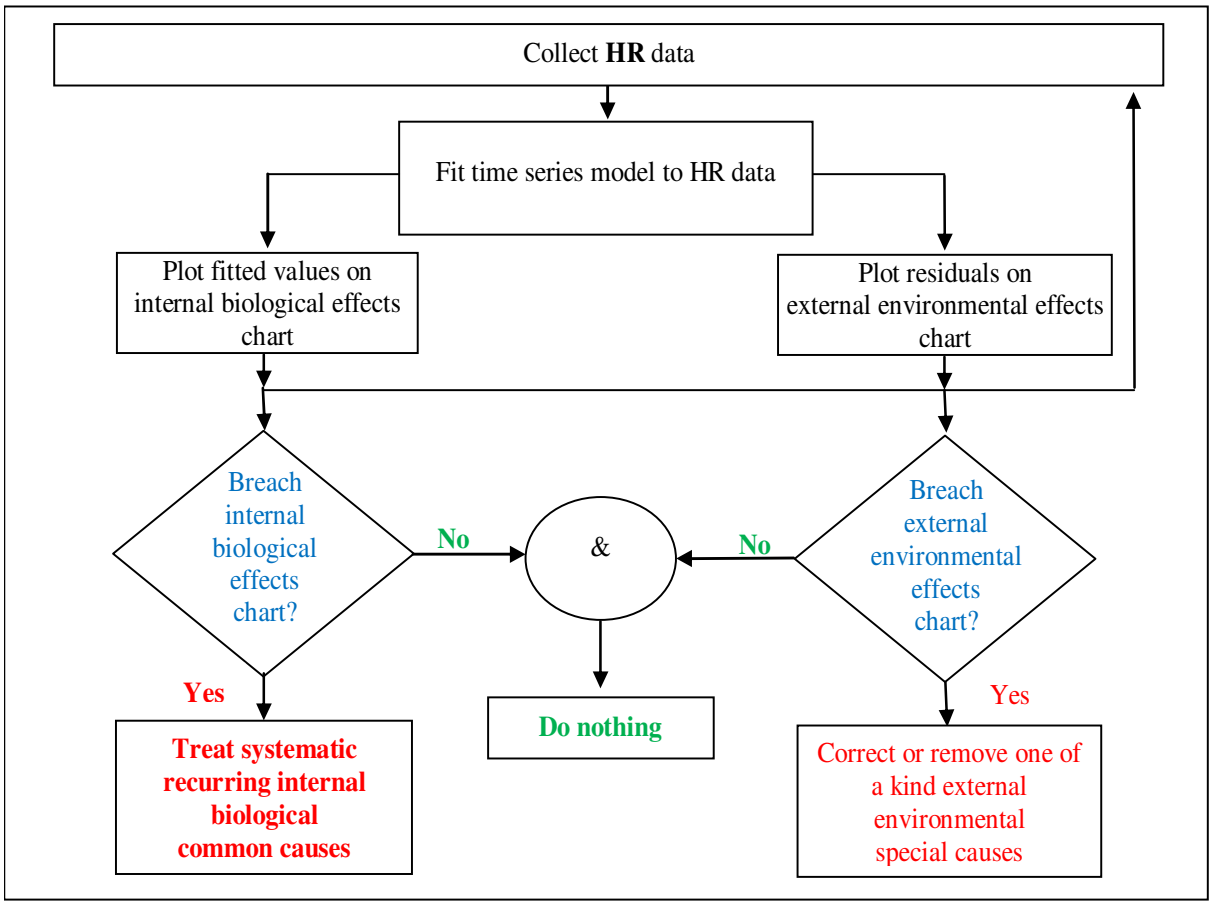

Figure 2. Scheme for splitting the HR data.

a systematic way. They may also be the effect of a one-time application of a medication, the effect of which will eventually work its way from the special cause chart to the common cause chart.

Variations on the common cause chart are attributed to systematic recurring internal biological common causes that are to be treated accordingly. For example, the appropriate treatment may be with medication. The common cause chart identifies what is systematically occurring, internally, inside the body, due either to normal health, healing or failing health.

Dual charts permit and facilitate proper analysis and diagnosis of the human biological condition as far as can be determined from the data. The dual chart system also reduces the number of false positives (false alarms) that distract the attention of valuable medical personnel away from real and important problems, and reduces the number of false negatives when real and important problems go unnoticed. These features are greatly needed. The computer programme (MyPulse®, Smart Monitors, Inc., Version 2014.5, 2014. http://mypulsemonitor.com/) is designed expressly for the purpose of separating systematic internal biological effects from random external environmental effects in biomedical data. Splitting the HR chart increases its diagnostic value.

Splitting the HR data

The correlation structure of HR can be quite complex. The process variable may contain many auto-regressions and numerous periodicities. For the purpose of explaining the concept, let us consider the simplest autoregressive model in which HR values are related as follows: $\mathrm{HR_t} = \phi \mathrm{HR_{t-1}} + \mathrm{e_t}, \mathrm{t} = 2,3,..,\mathrm{n}$, where ϕ is a parameter of unknown value and e_t are unobservable random errors, t represents time and there are n values in the record to be analysed. This model describes a process in which the current HR value is determined from its last value multiplied a constant plus a random error. The first step in splitting the data is to fit a mathematical model to the data by calculating an estimate for the value of ϕ that minimizes the sum of squares of the errors e_t. Let us denote the estimate of ϕ as $\hat{\phi}$. Then, the values of HR that best fit the model are $\widehat{\mathrm{HR}}_t = \hat{\phi}\mathrm{HR}_{t-1}$. These $\widehat{\mathrm{HR}}_t$ values change systematically and represent the common cause internal biological effects in HR. The estimate of

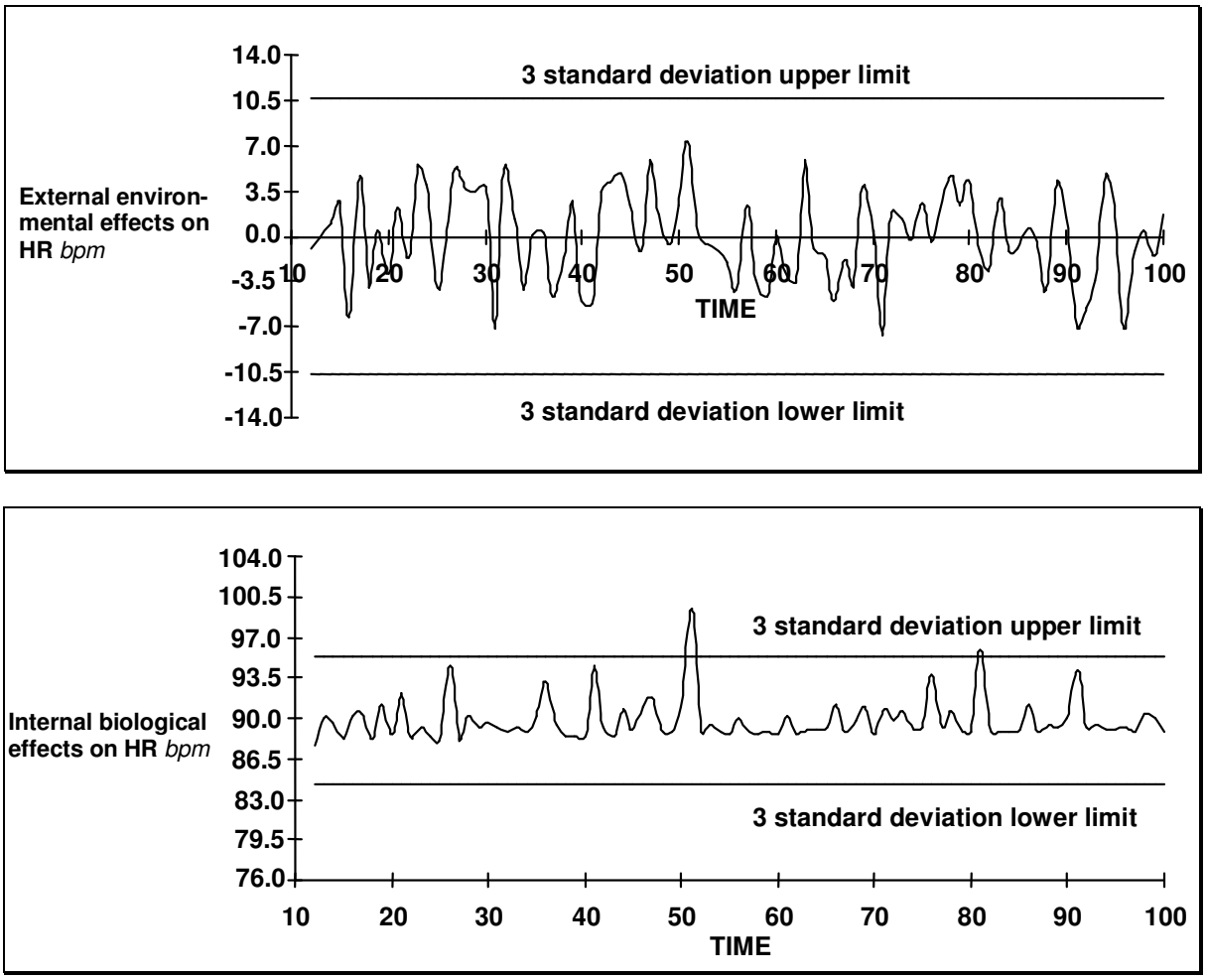

Figure 3. Dual chart system of internal biological and external environmental effects on HR.

the random component is obtained from $\hat{e}_t = \widehat{HR}_t - HR_t$. These $\hat{e}_t$ residual values change unsystematically and represent the special cause external environmental effects in HR. The common cause effects and special cause effects are shown on the pair of dual charts in Figure 3

RESULTS

The chart of external environmental effects on HR shows that all HR values are between the upper and lower limits. Once again all appears to be normal in the environment. However, the chart of internal biological effects on HR shows that there are two HR values above the upper limit. Due to the independence caveat cited earlier, the probability associated with the limits is different from 0.3%. That notwithstanding, the breaches indicate a need for further investigation and possible medical intervention. This tachycardia arrhythmia† may turn out to be a case of atrial fibrillation†. This condition was not revealed by the single chart.

CONCLUSIONS

HRV is a quantitative marker for autonomic† nervous system activity and is high in post myocardial infarction† predictive ability. But, confounded internal biological effects and external environmental effects are difficult to analyse. A dual chart system has many advantages over a single chart when correlated data are to be analysed. How the dual chart system is used depends on the particular application. In biomedical monitoring, the common cause chart can help a physician to focus on the internal biological activity of a patient. One can evaluate the rate of impact and efficacy of an applied medication by studying its appearance on the special cause chart followed by its appearance on the common cause chart. The special cause chart can help a nurse to focus on the environment in which a patient is being cared for. The

†Nomenclature

Arrhythmia	High, low or irregular heart rate.
Atrial fibrillation	Irregular heart rate.
Autonomic nervous system	Involuntary (unconscious) biological control system.
Bradycardia	Low heart rate.
Confounded	Confused due to the indirect mingling of different causes.
Correlation	The degree to which two random variables change together.
Myocardial infarction	Blood flow related heart attack.
Probability distribution.	The fixed pattern of a random variable. Example: Normal, lognormal, uniform.
Standard deviation.	Square root of variance.
Tachycardia	High heart rate.
Time series.	A sequence of numbers that are indexed by time.
Variance.	The amount of change that occurs in a random variable.

dual chart system provides for an optimal collaboration between physician and computer in which both get smarter together.

REFERENCES

Box GEP, Jenkins GM (1963). Further contributions to adaptive quality control: simultaneous estimation of dynamic: Non-zero costs, *Bulletin Internat. Statist. Inst., 34th session*; 943.

Crowder SV (1987). A simple method for studying run-length distributions of exponentially weighted moving average charts. *Technometrics*; 29, 401-407.

Hunter JS (1986). The exponentially weighted moving average. *Journal of Quality Technology;* 18,203-210.

Lucas JM, Saccucci MS (1990). Exponentially weighted moving average control schemes: properties and enhancements. *Technometrics*;32,1-29.

Malasonas L, Barkauskas V, Moss M, Stoltenberg – Allen K (1981). *Health Assessment, 2nd edition,* The C.V. Mosby Co.

Malik M (1996). Heart Rate Variability: standards of measurement, physiological interpretation, and clinical use. Task Force of the European Society of Cardiology and North American Society of Pacing Electrophysiology.1996; *Circulation* 93:1043-1065.

Montgomery DC, Mastrangelo CM (1991). Some statistical process control methods for autocorrelated data. *Journal of Quality Technology*; 23, 179-193.

MyPulse®, Smart Monitors, Inc., Version 2014.5, 2014. http://mypulsemonitor.com/.

Ridley AD, Duke D (2000). Statistical process control: an mws model. *Proceeding of the Industrial Engineering & Management Systems (IEMS) conference;* 363-368.

Ridley AD, Ngnepieba P (2014). Antithetic time series analysis and the CompanyX data. *J. Royal Statistical Soc. (A)*; 177: 83-94.

Roberts SW (1959). Control chart tests based on geometric moving averages. *Technometrics*;1,239-250.

Wardell DG, Moskowitz H, Plante RD (1992). Control charts in the presence of data correlations. *Management Science*; 38, 1084-1105.

Wardell DG, Moskowitz H, Plante RD (1994). Run-length distributions of special-cause control charts for correlated processes. *Technometrics*;36,3-27.

Yashchin E (1987). Some aspects of the theory of statistical control schemes. *IBM J. Res. Develop*;31,199-205.