Non-Linear Interpretations of ECG

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ABSTRACT

The medical world has been somewhat tardy in accepting ‘chaos’ science as a possibly effective and dependent tool for diagnostics and therapeutic interventions. In this brief paper we discuss the far reaching and somewhat astounding results of a study done to test the reliability of the routine ECG test to monitor cardiac health. Our observations show that the readings, which are in effect the recordings of the electrical SA node voltage per impulse are largely conjectural and unreliable when the scales used in recording graphs is altered.

Key words: Chaos, non-linear systems, ECG, PQRST spike

INTRODUCTION

This overview outlines a few salient areas in medicine that have successfully applied the principles of the ‘chaos theory’. Chaotic systems have been shown to operate in quite a few physiological processes. The impact and implications of the new science on the future course of medical diagnostics and health science systems as a whole cannot be overstressed. Exclusive and total dependence on scalar models have compartmentalized patient profiles into rigid cocoons such as age, sex, weight, height, physiological and biochemical evaluations making interventional therapeutic regimens solely dictated by our over-riding choice to use scales of convenience for every single one of our evaluation, assessment and treatment criteria.

The new field of theoretical biology, spawned by the advent and ready acceptance of the 'chaos' model has lead to an explosion in nascent schools of thought that challenge hitherto entrenched linear mathematical Newtonian and Euclidian principles in natural sciences. Fractal configurations and such other non-linear systems have made the need for a second look at physio-dynamic processes of the human biology,
mandatory. Despite rapid strides in the alternate chaotic and randomness applications, the world of medicine is still loathe to modify its dependence and confidence in pharmacokinetic therapeutic solutions based on cause-effect and Euclidean extrapolation linear systems, both in diagnosis and treatment. The human heart also has a chaotic pattern. It has been shown conclusively by many that even the heart rate is chaotic. Even the time between beats does not remain constant; it depends on the individual’s activity, among other things. Under certain conditions, the heartbeat can speed up. Under different conditions, the heart beats erratically. The analysis of a heartbeat can help medical researchers find ways to put an abnormal heartbeat back into a steady state, instead of uncontrolled chaos. Interestingly tachycardia is less chaotic when studied than the so-called normal rate. So too could be fibrillation or flutter – the graphical plots of functioning within a cycle or between cycles could demonstrate a reduction in range of fluctuation – or less chaotic.

EXPERIMENT
Using normal ECG recordings and measuring the just the QR spike height wide fluctuations it was observed at 100 times scale, demonstrates the absolute randomness in the electrical activity of the heart even within a single cardiac cycle. The erratic heights, representing the milli-volt electrical impulse from the sinu-atrial node clearly demonstrate that randomness or chaotic behaviour is norm and signifies good cardiac health. Indeed, by analogy, the ECGs should be 'most' regular in only when static, as in death - a fact well demonstrated in the absolute flat ECG record of the dead human heart. The paradoxical and skewed results in seemingly normal. The paradoxical and skewed results in seemingly normal processes, when viewed through 'chaos' systems, show how wrong our total reliance on scale and linear applications are! Simplistic interpretations such as this throw up more dilemmas. Research has demonstrated that a reduced standard deviation of heartbeat intervals can predict increased mortality in a group of cardiac subjects, each of which has a reduced standard deviation, but it cannot specify which of the individuals will not manifest lethal arrhythmogenesis.

DISCUSSION
In a report, observations identical to that from an earlier work (Kumar 1998) analyzed of electrocardiograms from healthy subjects and those with severe congestive heart failure show short-term variations of beat-to-beat interval exhibited strongly and a consistently chaotic behaviour in all healthy subjects, but were frequently interrupted by periods of seemingly non-chaotic fluctuations in patients with congestive heart failure. Chaotic dynamics in the data collated, exhibited a high degree of random variability over time, suggesting a weaker form of chaos. These findings suggest that cardiac chaos is prevalent in healthy heart, and a decrease in such chaos may be indicative of Congestive Heart failure.
However, more sensitive instruments reveal that normal heart rhythm shows small variability in the interval between beat. Our hearts rarely beat the same way twice. Varying opinions on role of randomness and chaos have been proposed, among which one standing ground is that heart function is non chaotic when healthy and turns erratic, with creation of spatial chaos. Kumar however reports that even in the healthy state, heart physiology exhibits ‘random’ behaviour. Research has also proved operation of fractal systems in the blood flow through portal and hepatic veins.

The dynamics of fluid flow and turbulence are areas that have engaged medical researchers applying 'chaotic systems' to study cardiovascular physiology and the biophysics of blood flow. In fact, this area has much potential for research in the world of medicine. Blood pressure and the heamo-dynamics of vascular biomechanisms throw up challenges that defy conventional physics and linear mathematical analyses. Fractal configurations and such other non-linear systems have made the need for a second look at physiodynamic processes of the human biology, mandatory. Despite rapid strides in the alternate chaotic and randomness applications, the world of medicine is still loathe to modify its dependence and confidence in pharmacokinetic therapeutic solutions based on cause-effect and Euclidean transcription linear systems, both in diagnosis and treatment. This paper very briefly, illustrates the fallacy in such approaches, using the record of the electrophysiological function of the heart (ECG) as a parameter for diagnosing cardiac health. The paradox in ECG interpretation as clue to functional status of the heart, is demonstrated here when the principles of ‘chaos’ are applied as diagnostic tool. (1)

Electrocardiographic recordings of three adult, normal males, applying Lead II (bipolar) were made. Twenty contractions of the heart and its record were studied from each volunteer. The ventricular depolarisation wave, QR, was isolated from the PQRST complex from every cardiac cycle. The QR spike was next projected onto a giant wall mounted screen to magnification of 100 (1cm to 1 meter). The projected on-screen spike height was then measured to the nearest mm.

When measured in its projected magnified form, each and every QR spike of a typical PQRST segment of the ECG record had its own individual and distinct height; the heights varied randomly and erratically even in tandem recordings within a single record-strip of the same individual. No two heights were identical. The characteristic, randomness and erraticity of variations in heights appeared to be obvious features in any ECG taken in same lead in normal individuals (see Figure)
Fig: Graph showing fluctuating random electrical discharge voltages in normal ECG

Electrocardiography, is based on Einthoven's principles, quantify the electrical activity of the heart. The recordings of electrical discharges are from the nodal pacemaker of cardiac tissue are made through different leads. The milli-volts of the depolarisation process of the generation and conduction of electrical impulses form the characteristic PQRST segments of a typical ECG. (2, 3)

In observations made from this study, the seemingly regular milli-volt strengths recorded as ECG in normal individuals, are altered when scales are modified or magnified. The wide fluctuations in spike heights observed at 100 times scale, demonstrates the absolute randomness in the electrical activity of the heart even within a single cardiac cycle. The chaotic behaviour, according to nonlinear chaos theory, is normal and signifies good health. Electrocardiography, is based on Einthoven's principles, quantify the electrical activity of the heart. The magnified spike measures clearly show that our long held historic view of the order and pattern of electrocardiographs and their interpretations could well be based on assumptions and presumptions that may well be fallacious. Our dependence on convenience of scale adopted by the ECG instrumentation processes, rather than accuracy and correctness, are dictated primarily by the ease of the facility and simplicity of its usage.

The science of chaos states that irregularity denotes wellbeing of physiological functions. Regularity forebodes ill health. Randomness and unpredictability are natural and innately normal processes: Disturbances and disruptions in erratic activity and behaviours patterns leads to disease and dysfunction. The simple rhythms and conventional periodic patterns induced by phase mode locking in physiological activities in man, maybe is not be as sacrosanct as held till now. Every function has inherent randomness directly and increasingly proportional to robustness. The oscillation of Poincare (butterfly) graph between health and ill health attractors are said to show regularity in records as outcome of the diseased states.
Indeed, by analogy, the ECGs should be 'most' regular in only when static, as in death - a fact well demonstrated in the absolute flat ECG record of the dead human heart. By interpolation malfunctioning heart, fibrillating or fluttering should produce ECG records, that when magnified, show less erraticity in the entire PQRST.

Though we have, for purpose of demonstration of nonlinear chaotic system application, chosen only a single lead, part of the ECG wave and strip and used only three volunteers with normal hearts, it is our view that, even from the limited data studied, it is obvious that inherent randomness indeed is characteristic in normal cycles of the cardiovascular system and that electrical discharge from the pacemaker is as a norm, fluctuant and erratic. Medicine, both diagnostic, clinical and treatment both pharmacological and therapeutic, could well reassess its stress on normal ranges and standardization's, averages and means and statistical reliance on convenience derived parameters and instrumentations such as electrocardiography.

REFERENCES

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