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The Human Heart: Deviating from the Golden Ratio and Diagnosing Disease

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Abstract

The golden ratio (golden section, golden mean, divine proportion) is an irrational number whose value is approximately $\Phi = 1.618$. The golden ratio has imposed itself throughout history as a kind of principle of unison and harmony that is so subtly and fascinatingly repeated in nature, science, art, and even in the structure and function of the human body. What is typical for the golden ratio is that it places the larger segment in relation to the smaller segment, uniting them into a single whole, which again place it in the same relationship with its larger part. If we consider the cardiac cycle as one such whole, its "larger segment" would refer to the diastolic phase, while the "smaller segment" would refer to the systolic phase of one cardiac cycle. In this article, the mathematical processing of 100 ECG records included the measurement of intervals representing the systolic and diastolic phases of the cardiac cycle, where the ratio of diastolic and systolic phases, and the ratio of one cardiac cycle and diastolic phase was obtained. The study has shown that people with normal ECG records have a ratio of the diastolic and systolic phases of the cardiac cycle, and the cardiac cycle and the diastolic phase, which are very close to the golden ratio. On the other hand, persons whose ECG records indicate certain pathological conditions in the heart muscle have ratios of diastolic and systolic phase, and of the total cardiac cycle and diastolic phase, which deviate to varying degrees from the value of the golden ratio. It has been shown that for a certain pathological condition there is a characteristic deviation of the diastole/systole and cardiac cycle/diastole ratio from the number Φ, which opens the possibility of applying this method as a potential diagnostic or screening method in rapid analysis of ECG records.

Keywords: golden ratio; number Φ ; electrocardiogram; cardiac cycle; golden ratio in cardiac cycle.

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1. Introduction

The golden ratio is a number that, with its ubiquity and unusual aesthetic appeal, has for centuries attracted the attention of experts in absolutely all fields of human activity: artists, philosophers, mathematicians, biologists, and, more recently, researchers in the medical sciences. Mario Livio says *„it is probably fair to say that the Golden Ratio has inspired thinkers of all disciplines like no other number in the history of mathematics"* [1]. The golden ratio is a mathematical constant whose value is approximately Φ = 1.618 [2]. The first clear definition of the ratio, which would only later be known as the golden ratio, was given by the ancient Greek mathematician Euclid, around 300 BC. Euclid derived the definition of this ratio from a simple division of the line into, as he called it, „extreme and medium ratio". According to him, a straight line is divided into an extreme and a medium ratio when the ratio of the larger part to the smaller is equal to the ratio of the whole line to the larger part. It is hard to think that such a simply divided line hides many mysteries that so subtly and captivatingly permeate the entire universe, and even the human body, from the smallest parts of the cell structure, through the structure and function of almost the entire human body [1,3]. The heart as a vital and one of the most important organs in the human body is the subject of numerous researches and studies whose basic motive is to prove how fascinating regularity in the functioning and structure of the heart muscle manifests the very existence of the number Φ = 1.618 [4]. One in a series of these studies is a study conducted by Turkish scientists in 2013, which is symbolically called „*Golden Ratio is beating in our heart* " [5,6]. Namely, the aim of this study was to prove that a healthy heart muscle really beats in the rhythm of a golden ratio, or that the ratio of diastolic and systolic phase of one heart cycle in healthy individuals with normal heart muscle function gravitate to number Φ. The study included subjects who did not have any systemic infection, malignant disease, or valvular heart disease. Subjects who used any drug therapy were also excluded from the study. So, the goal was to get individuals with the best possible health condition and completely normal function of the heart muscle. Analogous to the previously described study, the aim of our research is to show through mathematical analysis of 100 ECG records, and by determining the *diastole/systole* and *cardiac cycle/diastole* ratio, that proper heart muscle function in healthy individuals, without pathological conditions, is consistent with the golden ratio. The systolic phase was defined as the time between the peak of the R-wave and the end of the T-wave on the ECG record, while the diastolic phase was calculated as the difference between the R-R interval and the systolic phase [6,7,8]. The *diastole/systole* ratio and *R-R interval/diastole* were determined for each patient. In healthy individuals, with a physiological ECG, we found that the mean value of the first ratio was equal to 1.61; while for the mean value of the *R-R interval/diastole* ratio we obtained a value of 1.62. We see that these are values that are approximate values of the number Φ, which is a confirmation that the human heart really *„beats in the rhythm of the golden ratio"*, and that the number Φ *„can be viewed as a kind of regulator of the human body and cardiovascular system"* [2,5,9,10]. In addition, we tried to prove the existence of a correlation between the type of pathological condition of the heart muscle and the size of the deviation of the observed ratios (*diastole/systole, cardiac cycle/diastole*) from the number Φ through the analysis of pathological ECG records. In other words, the aim is to show that a certain pathological condition is characterized by a precise deviation of the mentioned parameters from the value of the number Φ, and that there is a possibility of applying this correlation as a potential diagnostic or screening method in quickly determining the type of pathological muscle condition.

2. Materials and methods

Following the example of a study conducted by doctor Yetkin and his colleagues, in our study we analyzed 100 ECG records, of which 20 were physiological findings, and the remaining 80 were found to have a certain pathological condition. ECG records originate from the Department of Pathophysiology, Faculty of Medicine, University of Sarajevo. The mean age of patients whose ECG records were considered was 35±12 years. ECG records were recorded at a sensitivity of 10mm/1mV, and a paper speed of 25mm/s. Mathematical analysis of ECG records involved measuring distances on ECG records corresponding to one cardiac cycle, and its systolic and diastolic phases. The measurement was performed with a ruler with a millimeter division and an accuracy of up to 0.5 mm.

The following measurements were performed on each ECG record:

1. the duration of the R-R interval, which corresponds to the duration of one cardiac cycle,
2. the distance between the peak of the R-wave and the end of the T-wave, which corresponds to the systolic phase of the cardiac cycle,
3. the difference between the corresponding R-R interval and the corresponding R-T interval, which corresponds to the diastolic phase of the cardiac cycle.

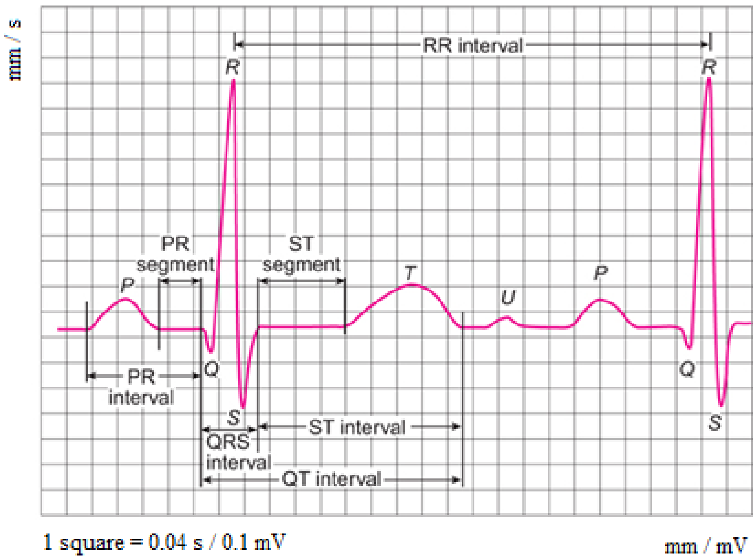

Figure: Schematic representation of the systolic and diastolic phases of one cardiac cycle

(*drawing: http://www.msd-prirucnici.placebo.hr/msd-prirucnik/kardiologija/kardioloske-dijagnosticke-pretrage/elektrokardiografija*)

Measurements of RR and RT intervals were performed in 3 consecutive cardiac cycles, and their mean values were taken into account (RR_{sr}, RT_{sr}) while diastolic phases were determined as the difference between the mean values of RR and RT intervals ($RR_{sr} - RT_{sr}$).

Based on the described measurements, the following 2 parameters were followed:

- The relationship between the diastolic and systolic phases of the cardiac cycle, or $\frac{RR_{sr}-RT_{sr}}{RT_{sr}}$
- The ratio of the total cardiac cycle and the diastolic phase, or $\frac{RR_{sr}}{RR_{sr}-RT_{sr}}$

3. Results

The first group of ECG records referred to physiological cases where no deviation from normal heart muscle function was noted. The measurement results are shown in Table 1.

The measurement results led us to the following conclusions:

- The ratio of the duration of the diastolic and systolic phases of the cardiac cycle ($\frac{RR_{sr}-RT_{sr}}{RT_{sr}}$) varies in the range from 1.48 to 1.67, with a mean value of 1.61, which is a deviation of 0.6% from the number Φ,
- The average ratio of the duration of the total cardiac cycle and the diastolic phase ($\frac{RR_{sr}}{RR_{sr}-RT_{sr}}$) is 1.62, which is very close to the ideal ratio (Φ = 1.618 ...).

Table 1: Normal ECG records

	RR1	RT1	RR2	RT2	RR3	RT3	RRsr	RTsr	RRsr-RTsr	$\frac{RR_{sr}-RT_{sr}}{RT_{sr}}$	$\frac{RR_{sr}}{RR_{sr}-RT_{sr}}$
1.	21	8.5	22.5	8	22	8	22.17	8.33	13.87	1.67	1.60
2.	18	7	18	6.5	18	7	18	6.83	11.17	1.63	1.61
3.	22	8.5	21	8.5	22	8	21.67	8.33	13.34	1.60	1.62
4.	17	6.5	17	6.5			17	6.5	10.5	1.62	1.62
5.	18.5	7	18.5	7	18.5	7	18.5	7	11.5	1.64	1.61
...	...	...	...	...	...	...	...	...	...	...	...
16.	17.5	7	17.5	7	17	7	17.33	7	10.33	1.48	1.68
17.	18	6.5	17	6.5	17	7	17.33	6.67	10.66	1.60	1.63
18.	18	7	18	7	18	7	18	7	11	1.57	1.64
19.	17.5	6.5	17	6.5	17.5	6.5	17.33	6.5	10.83	1.67	1.60
20.	18	6.5	18	7	18	7	18	6.83	11.17	1.63	1.61
Mean	18.55	7.1	18.45	7.05	18.67	7.17	18.53	7.10	11.44	1.61	1.62

After the analysis of physiological ECG records, followed an analysis of ECG records on which certain pathological conditions were registered, and they were mostly heart rhythm disorders or disorders in the normal conduction of electrical impulses through the conduction system of the heart. For each of these conditions, mean values of *diastole/systole* and *cardiac cycle/diastole* were determined, as well as the degree of deviation from the average physiological finding that is consistent with the number Φ. Eleven different pathological conditions were considered, namely: LV hypertrophy, right and left branch block, complete AV block, paroxysmal supraventricular tachycardia, WPW syndrome, sinus tachycardia and sinus bradycardia, ventricular tachycardia, ventricular atrial fibrillation and ventricular atrial fibrillation.

Table 1: Review of all disorders of cardiac muscle function diagnosed on the basis of ECG records and deviations of the ratio of the observed intervals from the number Φ

Pathological condition	Diastole/systole	Deviation from number Φ (%)	Cardiac cycle / diastole	Deviation from number Φ (%)
Left ventricular hypertrophy	1.92	18.5	1.53	5.56
Right branch block	1.25	22.84	1.80	11.11
Left branch block	1.15	29.01	1.87	15.43
Complete AV block	2.79	72.22	1.37	15.43
PSVT	0.52	67.90	2.94	81.48
WPW syndrome	1.95	20.37	1.52	6.17
Sinus tachycardia	0.94	41.98	2.10	29.63
Sinus bradycardia	2.52	55.56	1.41	12.96
Ventricular tachycardia	0.31	80.86	4.6	183.95
Ventricular extrasystole	1.35	16.67	1.76	8.64
Atrial fibrillation	0.85	47.53	2.31	42.59

Table 2 provides a summary of the mean ratios of diastolic and systolic phase, and the total cardiac cycle and diastolic phase in observed disorders of heart muscle function. The percentage of deviation of the calculated ratios from the number Φ is also given.

4. Discussion

In the first group of ECG records in which no deviation from normal heart muscle function was recorded, the average ratio of the diastolic and systolic phases of the cardiac cycle was extremely close to the number Φ, with a value of 1.61. The deviation from the number Φ is only 0.6%. The average ratio of total heart cycle to diastolic phase is 1.62, which is very close to the value of the golden ratio. The results of these measurements only once again confirmed that the perfectly coordinated work of the heart muscle, necessary for maintaining continuous blood circulation, unequivocally testifies to the existence of the number Φ and confirms its role as a subtle indicator of normal functioning of the cardiovascular system. By measuring the diastolic and systolic phases of the cardiac cycle in different pathological conditions shown in Table 2, it was concluded that for each pathological condition there is a characteristic deviation of the observed ratios from the number Φ. Namely, for each group of disorders, the ratio of diastolic and systolic phase, and the ratio of the total cardiac cycle and diastolic phase is approximately the same. Table 2 lists the mean values of the observed ratios, and the magnitude of their deviation from the number Φ. The observation that a certain pathological condition of the heart muscle is characterized by a specific degree of deviation from the golden ratio opens the possibility of using the number Φ as an auxiliary diagnostic method in cardiology, which could determine and differentiate the type of deviation from the golden ratio in the ratio of cardiac cycles, disorders in the structure and function of the heart muscle, and which disorders can be ruled out. For the sake of simplicity of determining the characteristic deviation for individual pathological conditions, it is sufficient to monitor only the ratio of diastolic and systolic phases of the cardiac cycle, ignoring the ratio of cardiac cycle/diastole, or vice versa. What could be an aggravating circumstance is the wide range of disorders in the heart muscle functioning, and the existence of the possibility of overlapping in the size of the deviation from the gold standard in different diagnoses. However, it is important to note that certain pathological conditions are characterized by positive or negative deviations. Thus, it may happen that two different diagnoses have the same magnitude of deviation, except that one has a positive deviation and the other a negative deviation from the number Φ. For example, a complete AV block and a PSVT have approximate deviations of the observed ratios from the number Φ, with the difference that the AV block has a positive deviation, and the PSVT a negative deviation from the number Φ. Analysis of a larger number of ECG findings and a more detailed approach to measurements would certainly lead to new insights into the correlation between the golden ratio and the structure and function of cardiac structures. Such a unique approach to the analysis of ECG records, using the language of comparisons and mathematical relationships, based on the principles of the golden ratio, would lead to a completely new era in cardiovascular diagnostics and it would be very justified to invest additional efforts in research and studies.

5. Conclusion

The function of a healthy heart muscle is based on the proportion of the golden ratio, which is manifested through the ratio of the diastolic and systolic phases of one cardiac cycle, and the ratio of the cardiac cycle and the diastolic phase. In certain pathological conditions in the heart muscle, the legality of the golden ratio is violated, and the observed ratios deviate from the value of the number Φ. Of particular interest is the conclusion that for each pathological condition there is a characteristic deviation of the *diastole/systole* and *cardiac cycle/diastole* ratio from the number Φ, which opens the possibility of applying this correlation as a diagnostic or screening method in rapid determination of the heart muscle pathological condition type.

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