Blood Pressure Deviation from the Golden Ratio φ and All-cause Mortality: A Pythagorean View of the Arterial Pulse

Abstract

Introduction: There is one mathematical element with strong historical and philosophical background that exhibits remarkable properties and applications; the golden ratio (phi). Mathematically, the golden ratio equals approximately 1.61803. A rather provocative geometrical analysis of the arterial pulse according to the golden ratio was recently described, and herein, we aim to set out the hypothesis that individuals with blood pressure (BP) values that follow the golden ratio may have different prognosis than those whose BPs deviate from the divine proportions. **Materials and Methods:** We used published data from the National Health and Nutrition Examination Survey during 1999–2010. **Results:** We found that the deviation of the BP values from the golden ratio is independently associated with all-cause mortality. **Conclusions:** This observation stimulates further research of the potential utility of the golden ratio of B*P* values on the diagnosis and prediction of BP-related abnormalities and risk.

Keywords: *Aorta, arterial pulse, blood pressure, brachial artery, hemodynamics, pulse wave analysis*

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Introduction

A rather provocative geometrical analysis of the arterial pulse according to the golden ratio (phi) was recently described.[1] This ratio, otherwise known as divine proportion, extreme and mean ratio, or golden number, is defined as the ratio of two quantities (a and b) where the ratio of the larger quantity (a) to the smaller one (b) is equal to the ratio of the sum of the quantities (a + b) to the larger quantity (a). The golden ratio is symbolized by the Greek letter *φ* (phi), and its value is approximately 1.618. While the Egyptians seem to have employed *φ* in the design of the Great Pyramids (2560 BC), most evidence designates that its mathematical concept was theoretically described by the mathematician and philosopher Pythagoras of Samos (CA 580BC-500BC) and his school.[2]

The golden ratio is observed in several places in nature, and it is believed that fulfill conditions of ultimate esthetics and harmony. *Phi* has been used historically in architecture and art. For example, it can be found in the famous painting the Mona Lisa, in Parthenon and other places like the pyramids of Egypt. This ratio is symbolized by the Greek letter *φ* (phi), the first Greek letter of the name of the Greek architect and sculptor Phidias (480BC-430BC) since he used it broadly in his sculptures including those of Parthenon.

The hypothesis

Among other biological phenotypes, the arterial pulse may also exhibit characteristics following the divine proportion.[1,3,4] In terms of rhythm (in time domain), the cardiac pulse has been thought to follow a harmonic and perhaps "divine" pattern as recently speculated and described.[5] Furthermore, the ratio of systolic blood pressure (SBP) to diastolic blood pressure (DBP) may equal to 1.618 according to the equation: DBP/PP = SBP/DBP $\overset{\text{def}}{=}$ φ, where PP the pulse pressure.[1] Although this geometrical approach has no proven physical-hemodynamic rationale yet, it is intriguing to examine whether participants with SBP/DBP (or DBP/pulse pressure [PP]) ratio close to 1.618 [Figure 1] have different prognosis compared to those whose ratio deviates from *φ*. To test this hypothesis, we

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analyzed the data from the National Health and Nutrition Examination Survey (NHANES) during 1999–2010.

Materials and Methods

NHANES is a multistage, stratified probability sample of noninstitutionalized individuals at the US, conducted by the National Center for Health Statistics (NCHS).[6] Methodological and research details concerning the NHANES study have been described elsewhere.[7-9] The following data were extracted and used in our analysis: age, gender, smoking status, history of diabetes, hypercholesterolemia, hypertension, heart attack, angina, congestive heart failure, coronary heart disease, and stroke. Mortality status was extracted from the Public-use Linked Mortality Files of the NCHS which includes a limited set of mortality variables for adult participants only that correspond to the period from the date of survey participation through December 31, 2011.

At each participant, after resting quietly in a sitting position for 5 min, three consecutive BP readings were obtained by certified examiners. The deviation of the arterial pulse from the golden ratio was quantified using the absolute difference between the two BP ratios;[1] absolute Δ-BPratios = abs ([DBP/PP]−[SBP/DBP]). Values close to zero indicate that BP ratios are close to the golden number 1.618, whereas larger values imply that the ratios deviate from φ.

Statistical analysis

Distribution normality of continuous variables was evaluated graphically by histograms and statistically using Kolmogorov–Smirnov test. Multiple logistic regression analysis was performed to assess the independent predictors of all-cause mortality. Collinearity between continuous variables was assessed by bivariate correlation coefficients and by the variance inflation factor (VIF) determined by multiple regression models. Statistical significance was accepted for *P* values lower than 0.05. Statistical analysis was performed by IBM SPSS for windows (IBM Corp., Armonk, NY, USA) and STATA (StataCorp LP, College Station, Texas, USA).
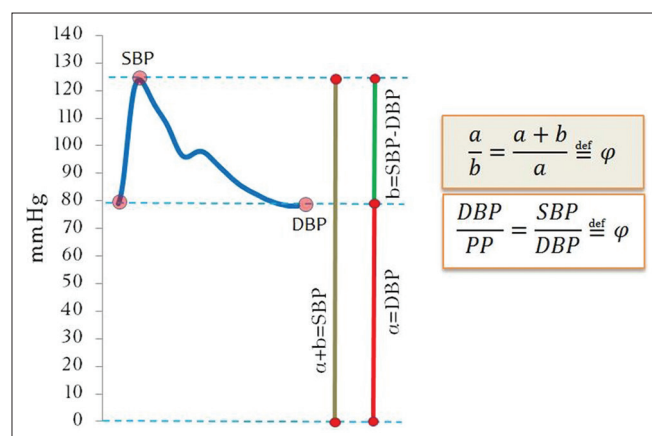

$$\frac{a}{b} = \frac{a+b}{a} \stackrel{\text{def}}{=} \varphi$$

$$\frac{DBP}{PP} = \frac{SBP}{DBP} \stackrel{\text{def}}{=} \varphi$$

Figure 1: Illustration of blood pressure ratios according to the golden ratio φ (phi)

Results

We analyzed the data from 31,622 individuals (above 17 years old) with valid BP measurements and known mortality status. A total of 2820 individuals were deceased (8.9%). In the analyzed dataset, the estimated date of death was not available.

Table 1 reports the strongest, independent predictors of all-cause mortality, using multiple logistic regression analysis. SBP, DBP, and absolute Δ-BPratios did not exhibit collinearity (*r* <0.5 and VIF <1.3). By this preliminary analysis, it was found that participants with SBP/DBP values that deviate from the golden ratio have a significantly higher risk of death, regardless from other

Table 1: Multivariate logistic regression analysis for the identification of independent parameters associated with all-cause mortality

Independent variable	*P*	OR	95% CI	
			Lower	Upper
Model-1§				
Age (years)	<0.001	1.088	1.077	1.098
Gender (male)	<0.001	1.548	1.256	1.907
BMI (kg/m²)	0.047	0.981	0.963	1.000
Mexican American	0.196	1.632	0.777	3.428
Other Hispanic	0.228	1.728	0.711	4.199
Nonhispanic white	0.145	1.694	0.834	3.439
Nonhispanic black	0.083	1.914	0.919	3.983
Smoking status (yes)	0.326	0.904	0.740	1.105
Diabetes mellitus (yes)	0.003	1.507	1.154	1.968
Hypercholesterolemia (yes)	0.001	0.709	0.577	0.871
Congestive heart failure (yes)	<0.001	3.167	2.117	4.740
Coronary heart disease (yes)	0.085	1.392	0.956	2.029
Angina (yes)	0.139	1.352	0.907	2.018
Heart attack (yes)	0.473	1.153	0.782	1.699
Stroke (yes)	<0.001	2.113	1.467	3.043
Heart rate (bpm)	<0.001	1.021	1.013	1.029
SBP (mmHg)	0.063	1.006	1.000	1.013
DBP (mmHg)	0.448	1.005	0.992	1.018
Absolute Δ-BPratios	0.026	1.238	1.025	1.494
Model-2*				
Age (years)	<0.001	1.088	1.079	1.098
Gender (male)	<0.001	1.583	1.289	1.945
Diabetes mellitus (yes)	0.005	1.439	1.116	1.855
Hypercholesterolemia (yes)	0.001	0.710	0.579	0.871
Congestive heart failure (yes)	<0.001	3.334	2.282	4.870
Coronary heart disease (yes)	0.006	1.591	1.144	2.212
Stroke (yes)	<0.001	2.118	1.474	3.043
Heart rate (bpm)	<0.001	1.021	1.012	1.029
SBP (mmHg)	0.001	1.008	1.003	1.013
Absolute Δ-BPratios	0.011	1.168	1.036	1.317

§Enter method (forced entry of all variables), *Stepwise-backward (only the strongest, independent variables remained in the model). CI: Confidence interval; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; Absolute Δ-BPratios: Absolute difference between DBP/PP and SBP/DBP; PP: Pulse pressure; OR: Odds ratio

established risk factors in comparison to individuals whose BP values fulfill the golden proportion.

Discussion

Current evidence supports that traditional assessment of BP at the brachial artery (and its corresponding systolic and diastolic values), which is still based on the same main methodological-measurement principles during the last decades,[10] does not always predict accurately cardiovascular (CV) risk and target organs' damage. For example, there is plenty of evidence indicating that in older persons, SBP is no longer associated with mortality under specific circumstances.[11-14] Moreover, a debate exists concerning the comparative relevance of SBP and DBP on CV risk prediction of specific populations and which value can provide optimal management of the hypertension burden.[15] Despite the huge number of currently available epidemiological data, recommendations for optimal BP values (SBP and DBP) are continuously being modified and recently reconsidered.[16] These limitations in the prognostic value of SBP and DBP seem to be overcome in some cases if a combined index such as the PP is used.[17,18] A step forward might be made by considering an alternative BP-related index such as the ratio of SBP/DBP or DBP/PP. In our current hypothesis, a challenging geometrical concept of the "golden arterial pulse"[1] based on historical and philosophical theories on harmony and balance (expressed by the golden ratio) was applied on existing epidemiological data. The deviation of the arterial pulse from the divine proportion between SBP and DBP (~1.618) was quantified and found to be a strong and independent predictor of all-cause mortality in the NHANES population.

Conclusions

The hypothesis stated in this article expands the application of the golden ratio in respect to the morphology of the arterial pressure wave. Are these statistical findings a matter of alchemy, a statistical "illusion" or the results of real biological and physical principles? Further evidence-based research and experiments will give us the answer.

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Conflicts of interest

There are no conflicts of interest.

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