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Investigation of the Golden Ratio in Human Heart Anatomically by Cardiac Magnetic Resonance Imaging Method

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ABSTRACT

***Objective:** The aim of this study was to determine the existence of golden ratio in the human heart anatomically by using the data obtained from cardiac magnetic resonance imaging.*

***Materials and Methods:** In this study, cardiac magnetic resonance imaging data required for various indications from 54 healthy individuals without any pathological findings were evaluated. In the images of these individuals, the existence of golden ratio was investigated by evaluating the measurements obtained from four-chamber, short axis and three-chamber steady-state free precession (SSFP) sequences of images of the heart, ventricles, and atria, respectively on the workstation.*

***Results:** The median age of the subjects included in the study was 31.5 and 61% of them were male. While the ratio of horizontal and vertical diameters obtained from the four-chamber images of the heart was 1.238, this ratio was 1.823 for the left ventricle, and it was 1.714 for right ventricle in male patients and 1.625 in female patients.*

***Conclusion:** The data obtained from cardiac MRI did not show the presence of the golden ratio in human heart anatomically.*

Keywords: *Golden Ratio, Heart, Cardiac Magnetic Resonance Imaging*

INTRODUCTION

The golden ratio is a geometric and numerical relation which is believed to reflect the most aesthetic harmony between the parts of a whole, used mainly in different fields of life during history, especially in biology, fine arts, mathematics and architecture.[1,2] Knowledge about the use of this mysterious ratio in art and architecture goes back to the ancient Egyptian pyramids.[3] This numerical relation, which was described by Luca Pacioli in De Divina Proportione (Divine Ratio) in 1509, was named Sectio Aurea (Golden Ratio) by Leonardo da Vinci, who prepared drawings for the same book.[2,3] Being defined as the proportion of the eye, the golden ratio is an irrational number, and is written in the decimal system as 1.618033988749894…[2] When any line segment is divided into two pieces according to the golden ratio, the ratio of the large piece to the smaller one is equal to the ratio of the whole to the large part (If a is the large piece and b is the small piece, a/b= a+b/a= Golden Ratio=1.618).[3] The symbol used for the golden ratio is Phi (Φ), which is the 21st letter of the Greek alphabet. This symbol, which refers to the number 1.618 in mathematics, comes from the first two letters of the name of Greek sculptor Phidias because of his frequent application of the golden ratio in his works.[4]

Research on the association of the structures in the human body with the golden ratio, which is believed to provide the best harmony in the form or structure of many living or non- living things in nature, has often been demonstrated in facial structures and extremities.[2, 5-7] There are few clinical studies on the existence of the golden ratio in the human heart, which contains many mysteries that cannot be elucidated in both structural and functional aspects. In these studies, the data on the existence of golden ratio in the heart is based on electrocardiographic (ECG) and echocardiographic (ECHO) examinations in healthy individuals.[4,8-10,13] The aim of this study was to anatomically investigate

the existence of golden ratio in the heart by evaluating the cardiac magnetic resonance imaging (MRI) data performed with various preliminary diagnoses of healthy individuals with no pathology.

MATERIALS AND METHOD

The data of 134 patients for whom cardiac MRI examination was requested with various indications in the cardiology clinic between August 2017-2018 were analyzed retrospectively. 54 patients with no coronary artery disease, heart valve disease, heart failure, pulmonary hypertension, congenital heart disease, diabetes mellitus, hypertension and no pathological findings detected in cardiac MRI were included in the study. While patients were examined with a 1.5 Tesla MRI unit (Magnetom Aera, Siemens, Erlangen, Germany) and retrospective electrocardiographic triggering, 8-channel cardiac coils were used for image acquisition. After acquiring the serial thoracic reference images, the position and orientation of the heart in the thorax were determined. Steady-state free precession (SSFP) sequences were used to capture the left ventricular two-chamber image during 10-15 seconds of end-expiratory breath-hold (imaging parameters: repetition time 3.6 ms; echo time 1.6 ms; 350-mm imaging area; 6-mm section thickness; with 2-mm gap; 45° flip angle; 14 VPS; matrix 224 × 160). Then, 4-chamber, short axis and 3-chamber steady-state free precession (SSFP) sequences were obtained in order. Images were evaluated on the workstation (Sectra IDS7, Linköping, Sweden). The diameters of both ventricles and atria were measured in 4-chamber SSFP cine images. The vertical diameter of the right ventricle was measured by combining the tricuspid annulus midpoint and the right ventricular apex in the end-diastolic image. The horizontal diameter of the right ventricle was measured between the right ventricular endocardium and the interventricular septum, parallel to the tricuspid valve and 1 cm distal from the valve.[11] The vertical diameter of the left ventricle was measured by combining the mitral annulus midpoint and the left ventricular apex in the end-diastolic image. The horizontal diameter of the left ventricle was measured between right ventricular endocardium and the interventricular septum, parallel to the mitral valve and 1 cm distal from the valve. The mediolateral diameter of the right atrium was measured in the mid-section of the atrium between the right atrial free wall and the interatrial septum, parallel to the tricuspid valve. The apicobasal diameter of the right atrium was measured by combining the atrium baseline with the tricuspid annulus midpoint.[11] The left atrial mediolateral diameter was measured in the mid-section of the atrium between the left atrium free wall and the interatrial septum, parallel to the mitral valve. The apicobasal diameter of the left atrium was measured by the vertical line between the atrium baseline and the midpoint of the mitral annulus.[12]

The vertical diameters of the right and left heart cavities were obtained from the sum of the ventricular vertical diameter and atrial apicobasal measurements. The horizontal diameter of the heart was obtained from the sum of the interventricular septal thickness with the right and left ventricular horizontal diameters (Figure 1A-D). The horizontal diameters of the main pulmonary artery, right and left pulmonary arteries in 4-chamber SSFP cine images were measured. In order to conduct the study, ethical approval was obtained from the Scientific Research Ethics Committee of the Faculty of Medicine of Trakya University (TUTF-BAEK 2018/308).

STATISTICAL ANALYSIS

The normal distribution assumption was tested using the Shapiro-Wilk test before comparison for the quantitative variables. Group comparisons for variables with normal distribution assumption were performed with independent two sample t-test and Mann-Whitney U test was used for variables without normal distribution assumption. For qualitative variables, a chi-square test was used for comparison. Mean and standard deviation are given for the quantitative variables that conform to the normal distribution, while the median and quartiles (1st quartile - 3rd quartile) are given for the quantitative variables that do not comply with the normal distribution. For qualitative variables, descriptive statistics were given as frequency and percentage.

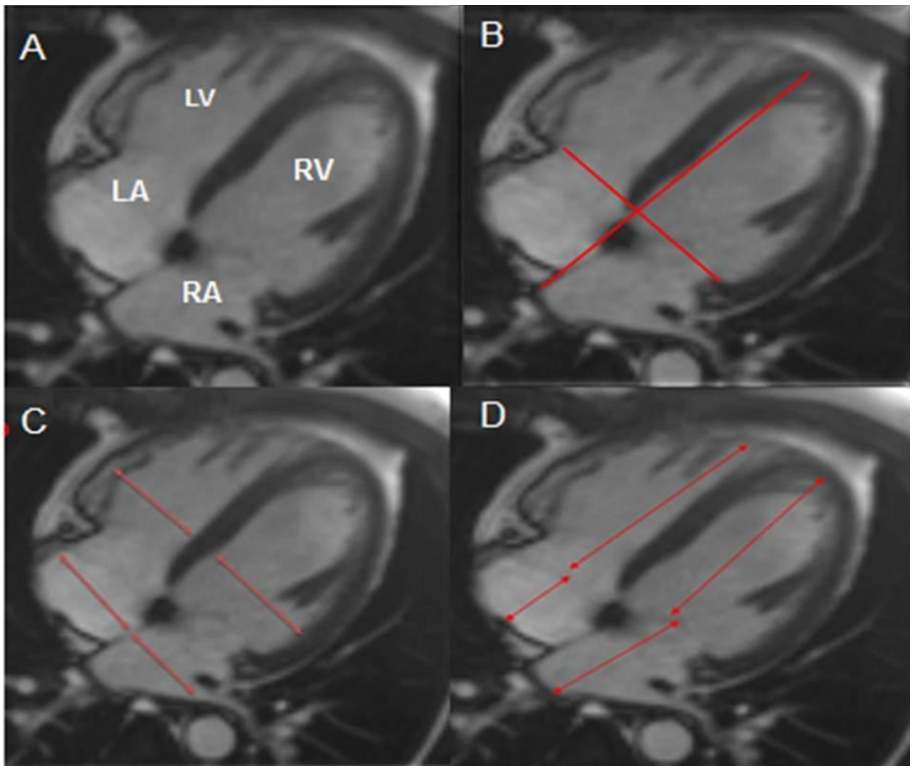

Figure1 A-*D:* *Measurement of the longitudinal and transverse diameters of the heart cavities in 4 chamber SSFP images obtained at the end of diastole of cardiac cycle in cardiac MRI. V: Ventricular A: Atrium*

RESULTS

A total of 54 healthy individuals (61% male, 39% female) who met the inclusion criteria were included in the study. Demographic characteristics of individuals and cardiac MRI measurements are summarized in Table 1. According to this table, the mean age of the study group was 31.5 years, the mean height was 170.71 cm and the mean weight was 76.88±7.8 kg. The mean vertical cardiac diameter obtained from the cardiac MRI 4-chamber image was 13.51±1.15 cm, and the mean horizontal cardiac diameter was 10.930.94 cm. The cardiac ratio obtained from these diameters was calculated as 1.230.07. The ratio of vertical and horizontal diameters was found to be 1.823±0.206 for the left ventricle and it was 1.694±0.279 for the right ventricle. The ratios of the left atrium and right atrial apicobasal and mediolateral diameters were found as 1.343±0.193 and 1.022±0.179, respectively, while the ratios of the main pulmonary artery to the right and left pulmonary artery was 1.38±0.17 and 1.35±0.14, respectively.

Table1. *Data on Demographic and Cardiac MRI measurements*

Variable	Descriptive statistics*
Gender (male n,%)	33(%61,11)
Age, (years)	31.5 (23.0–48.50)
Height, (cm)	170 (160.25–175.0)
Weight (kg)	76.889±7.806
Cardiac Vertical Diameter	135.111±11.529
Cardiac Horizontal Diameter	109.354±9.473
Cardiac Rate	1.238±0.072
Left ventricle horizontal diameter	48.9±5.66
Left ventricular vertical diameter	88.65 (80.65–92.40)
Left ventricular ratio	1.823±0.206
Right ventricle horizontal diameter	36.731±4.878
Right ventricular vertical diameter	61 (56.80–64.975)
Right ventricular ratio	1.666 (1.504–1.82)
Left atrium apicobasal diameter	44.23±8.1
Left atrial mediolateral diameter	32 (29.3–35.90)
Ratio of left atrium	1.343±0.193

Right atrium apicobasal.	38.95±6.55
Right atrial mediolateral	38.15 (34.22 –40.57)
Ratio of right atrium	1.022±0.179
Aortik annulus	21.1 (19.55–23.0)
Sinus valsalva	28.83±4.07
Sinotubular junction	23.124±3.598
Proximal ascending aorta	31.022±4.371
Mitral annulus	32.6 (31.20–33.77)
Tricuspid annulus	29.73±3.87
Pulmonerannulus	26.16±2.49
Main pulmonary artery	23.38±2.68
Right pulmonary artery	17.08±2.62
Left pulmonary artery	17.41±2.46
Main PA / Right PA ratio	1.38±0.17
Main PA / Left PA ratio	1.35±0.14

** Descriptive statistics are presented as mean ± standard deviation, median (25th percentile-75th percentile), frequency (percentage).*

DISCUSSION

In this study, we investigated whether there is a golden ratio in human heart anatomically by using cardiac MRI data. It is seen in the literature that the existence of golden ratio in the heart is mostly investigated by the parameters measured in the ECHO.[4,8,9] Henein et al. included two healthy groups differing in terms of ethnicity (Swedish and Chinese) in their study and investigated the existence of golden ratio in the left ventricle using data from ECHO. At the end of their study, it was found that the vertical and horizontal diameters of the left ventricles of the Swedish individuals were higher than the measurements of the Chinese individuals, but the ratio of the vertical diameter of the left ventricle to the horizontal diameter was found to be in accordance with the golden ratio, 1.618.[4] Celik and colleagues reported that in the ECHO examinations of healthy Turkish males, the ratio of the vertical diameter of the right and left ventricles to the horizontal diameter was not consistent with the golden ratio, but the ratio of the vertical and horizontal diameters obtained from the four-chamber view of the heart was 1.618, coincided with the golden ratio.[8] Yetkin et al. investigated the ratio of end-diastolic and end-systolic diameters of the left ventricle by M-mode echocardiography and reported compliance with golden ratio in patients with normal left ventricular ejection fraction.[9]

In our study, the ratio obtained for the left ventricle was 1.823, while the ratio obtained for the right ventricle was 1.714 in male patients and 1.625 in female patients. The ratio of horizontal and vertical diameters obtained from the four-chamber images of the heart was 1.238. Unlike previous studies using ECHO data, in our study, cardiac MRI measurements showed no correlation of the golden ratio with the left and right ventricles and the four-chamber view of the heart. In our study, it was also determined that the diameters of the main pulmonary artery, right and left pulmonary artery were not in compliance with the golden ratio.

LIMITATIONS OF THE STUDY

One of the most important limitations of our study is the retrospective use of data from a single center and the low number of patients. Moreover, due to the lack of ECHO data in addition to cardiac MRI data of the same patient group, the results of the two methods were not compared.

CONCLUSION

Our study is the first in the literature to investigate the presence of the golden ratio in human heart by cardiac MRI. Although the data on the existence of golden ratio in the human heart has been demonstrated by ECHO measurements, no golden ratio was found using the cardiac MRI method in our study.

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