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Morphometry and geometry of the formation of basilar artery

Sinem Akkasoglu[1], M.Mustafa Aldur[2], Mustafa F Sargon[3], Emre Can Celebioglu[4], Selma Caliskan[1]

[1]*Ankara Yildirim Beyazit University, Faculty of Medicine, Department of Anatomy, Ankara, Turkey*
[2]*Hacettepe University, Faculty of Medicine, Department of Anatomy, Ankara, Turkey*
[3]*Atilim University, Faculty of Medicine, Department of Anatomy, Ankara, Turkey*
[4]*Ankara University, Faculty of Medicine,Department of Radiology, Ankara, Turkey*

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Abstract

The morphometric studies on pathological changes observed in vertebral and basilar arteries are valuable in the diagnosis of many pathological disorders. The purpose of this study was to detect the morphometry and geometry of the intracranial part of vertebral and basilar arteries according to age, sex, and dominance parameters in huge series to contribute to the literature. In the study, the morphometric analysis was performed on 250 healthy patients (133 males, 117 females) by using Computed Tomography (CT) angiography. In 86 cases (34.4%) (47 males, 39 females), the basilar artery coursed straight to the right side. One hundred forty-five patients (58%) had left vertebral artery dominance. The diameters of the vessels were higher in males than in females, and there was no relationship between this finding and age. The diameter of the basilar artery at the vertebrobasilar junction was statistically significantly higher than its diameter in the terminal part of the pons. By the aid of vertical axis drawn from the formation point of basilar artery by the union of vertebral arteries, the angles of the right and left vertebral arteries were examined separately. These data will penlight future studies. This is the first study in measuring the angle of basilar artery along its course. The aim this study was to determine the changes that might occur in this angle due to the aging. To our knowledge there is no study examining the morphometry and geometry of the vertebral and basilar arteries together with these detailed parameters separately in the literature.

Keywords: Vertebral artery, basilar artery, angiography, sex, age, morphometry

Introduction

The brain is supplied by vertebral artery, internal carotid artery and their branches [1,2]. Knowledge of neural and vascular anatomy of the base of the cranium is critically necessary for surgical procedure [3]. Hemodynamic changes in the vertebral artery may cause significant pathological findings in the spinal cord, brainstem, cerebellum and inner ear. Therefore, the morphometry of vertebral artery is clinically essential [4-6]. Besides, the angle of the vertebrobasilar junction at the point where the vertebral artery merges to form the basilar artery is clinically significant in the diagnosis of aneurysms [7]. The large diameter of the basilar artery is a predisposing factor for many neurological diseases [8].

The purpose of this study was to detect the morphometry and geometry of the intracranial part of vertebral and basilar arteries according to age, sex, and dominance parameters in huge series to contribute to the literature. Additionally, the measurements of the angulations of the basilar artery were performed in a large set for adding some new morphometric data to the literature. These data will help to the neurosurgeons during surgical procedures.

Materials and Methods

A total of 250 patients (133 males, 117 females) were included to the study and were evaluated retrospectively between January 2015 and January 2016 in Karabük University Training and Research Hospital Radiology Clinic by CT angiography. The ages of the patients ranged between 20-89 years (mean: 62.2±15.5 years). In the study, the measurements were performed on healthy individuals who did not have any anatomical, pathological changes observed in CT angiographies. Patients who had head and neck surgery were not included in the present study.

All the procedures of our study were approved by the Ethical Committee of Hacettepe University Faculty of Medicine on April 19, 2016 (Number: GO 16 / 69-04). In terms of medical ethics, the study was found to be under ethical standards.

***Coresponding Author:** Sinem Akkasoglu, Ankara Yildirim Beyazit University, Faculty of Medicine, Department of Anatomy, Ankara, Turkey
E-mail: snm222@hotmail.com

Computed tomography angiography
The CT angiography images of the cases were obtained from the archive system of Karabük University Training and Research Hospital Radiology Department. CT angiography was performed on a 16-slice Toshiba Alexion Computed Tomography scan machine (0.5 mm slice thickness; pitch value 1.5-300 mg / 100 ml iodine contrast material; ray dosage adjustment is automatically performed by the device; matrix pathological morphometric as 512X512; fov: 240 mm; tube rotation speed: 0.75 sec). Shots were performed from arcus aortae level to cranium ceiling.

Data evaluation method
In the study, the following parameters were evaluated in 0.5 mm thick sections of 250 cases from different ages and sexes: Between the cerebral peduncles, the vertical axis passing through the basilar groove and anterior median fissure was accepted as the reference Y-axis in the study. Additionally, the transverse axis passing through the two most lateral points of the bulbo-pontine groove was named as the reference X-axis.

In the study, the diameters of right and left vertebral arteries were measured 0.5 cm distal to the formation point of the basilar artery. The side dominance of the vertebral arteries was determined according to the diameter of the vessel where the vertebral arteries were forming the basilar artery. The basilar artery diameter was measured 0.5 cm distal to its formation point and in the terminal part of the pons. Additionally, a vertical axis was drawn from the point where the basilar artery was formed by the junction of vertebral arteries and then, the angulations of right and left vertebral arteries from this axis were measured. In the morphometric measurements of the basilar artery, the angulation of the basilar artery with the Y-axis in the geometric plane was measured and the course of the basilar artery was evaluated. The morphometric measurements related to all these parameters were performed by two independent researchers. The obtained CT angiography images were evaluated quantitatively and transferred to the image evaluation program named Horos Free Medical Viewer GNU Lesser General Public License Version 3 (LGPL-3.0).

In the present study, no pathological conditions were radiologically observed at the levels where the measures were taken. All these CT images were measured by using a circular 0.01-0.02 cm2 region of interest intraluminal contrast Hounsfield unit (HU) values. After measuring Hu values, the formula described by Saba et al. [9] was used for the evaluation of the vascular structure. During the analyses of CT images, 300% magnification values were used for every morphometric measurement.

Analysis of the obtained data was performed using SPSS 21 and STATISTICA package programs. Descriptive statistics of the variables in the data set consisted of number and percentage for qualitative (categorical) variables and mean ± standard deviation statistics for continuous variables. The Kolmogorov Smirnov or Shapiro-Wilk normality tests were applied to assess whether the continuous variables corresponded to the normal distribution. Also, 95% confidence intervals of the mean for the measurement variables were calculated. In the study, to assess age, gender, dominance and the course of the basilar artery, the covariance analysis was used. Considering the information in the literature and to be able to include it in the subsequent investigation as a qualitative variable, the age variable was divided into three groups (20-39 years, 40-59 years, and 60 and over). To assess the difference in diameter measurements according to age groups and sex, two-way ANOVA was used.

Relations between the variables were examined by Pearson correlation coefficient. In terms of qualitative variables, Chi-square was assessed by the Likelihood Ratio test.

For all of the statistical analyses, the p-value less than 0.05 was considered as the statistical significance level.

Results

The mean right vertebral artery diameter for both sexes was measured 2.4±0.71 mm. While it was 2.49±0.7 mm in males, 2.29±0.71 mm in females. The mean left vertebral artery diameter for both sexes was found to be 2.5±0.7 mm. While it was measured 2.54±0.7 mm in males, it was found to be 2.47±0.69 mm in females (Figure 1). The mean basilar artery diameter measured 0.5 cm proximal to its formation point was 3.2±0.69 mm in both sexes. It was 3.31±0.66 mm in males and 3.08±0.7 mm in females (Figure 2). The mean basilar artery diameter measured in the terminal part of the pons was 2.36±0.61 mm. It was 2.46±0.63 mm in males and 2.26±0.57 mm in females. The mean value of the angulation of the right vertebral artery from the vertical axis was 48.95°±12.67° for both sexes. It was 48.84°±13° in males and 49.07°±12.32° in females (Figure 3). The mean value of the angulation between the left vertebral artery and the vertical axis was 52.2°±14.24° for both sexes. It was found to be 50.56°±13.67° in males and 54.10°±14.7 ° in females. The mean value of the angle between basilar artery and the Y-axis was found to be 31.9°±12.15° for both sexes. It was 31.58°±13.12° in males and 32.27°±10.99° in females (Figure 4 and Table 1).

Diameters of vertebral and basilar arteries were found to be increased by aging. Besides, the number of straight coursed of the basilar artery decreased in the older age group. Among the age groups, the incidence was 58.3% in the young age group (20-39 years), 30% in the middle age group (40-59 years) and 19.9% in the older age group (60 and over) (Table 2). In the present study, the basilar artery was found to have straight course in 66 cases (26.4%) (37 males and 29 females). In 86 cases (34.4%) (47 males, 39 females), the artery coursed straight to the right side. In 30 patients (12%) (19 males, 11 females), the artery had a rightward curvature. Also, in 47 patients (18.8%), the artery had a straight course to the left (20 males, 27 females) and in 21 patients (8.4%), the artery had a leftward curvature (10 males and 11 females) (Figure 5).

Despite the studies indicating equal vertebral arteries in the literature [10,11], we found one-sided dominant vertebral artery in each of our cases (Table 2).

Statistical analysis
Regardless of age, diameter of the vessels was higher in males than in females. A strong and statistically significant correlation was found between the right vertebral artery dominance, diameter and angle formation ($p<0.05$). Secondly, a statistically significant difference was found between the age, the right vertebral artery angle, and the basilar artery angle ($p=0.042$). Another statistically significant difference was determined between the left vertebral

artery's diameter, dominance, gender and the course of the basilar artery (p<0.05).

In the statistical analysis of the parameters, significant difference, and positive correlation were found between the diameter of the basilar artery at the vertebrobasilar junction and age (r=0.13 and p=0.04). There were statistically significant positive correlation and significant difference between the diameter of basilar artery measured at the vertebrobasilar junction and the diameter measured at the terminal part of the pons (r=0.46 p=0). The measured diameter of basilar artery at the vertebrobasilar junction and the right vertebral artery's diameter showed a statistically significant positive correlation and difference (r=0.46 p=0). Also, the diameter of basilar artery at the vertebrobasilar junction and the diameter of left vertebral artery showed statistically positive correlation and significant difference (r=0.34 p=0). There were positive correlation and statistically difference between the diameter of basilar artery measured at the terminal part of pons and the angle formed by basilar artery (r=0.13 p=0.04). There were statistically significant positive correlation and significant difference between the diameter of basilar artery at the terminal part of pons and the diameter of right vertebral artery (r=0.42 p=0), and the diameter of left vertebral artery (r=0.36 p=0). There were statistically positive correlation and significant difference between the angle of right vertebral artery and the angle formed by the left vertebral artery (r=0.28 p=0), and the angle formed by the basilar artery (r=0.19 p=0). Statistically positive correlation and significant difference were also found between the angle formed by the basilar artery and the diameter of left vertebral artery (r= 0.16 p=0.01). The last statistically positive correlation and significant difference were detected between the diameters of right and left vertebral arteries (r=0.13 p=0.04).

Table 1. Averages of variables (VA-Vertebral Artery, BA- Basilar Artery)

Variables	Mean ± Standard DeviatioN (mm, °)	95% Confidence Intervals		Minimum-Maximum (Mm, °)
		Lower Limit (Mm, °)	Upper Limit (Mm, °)	
Diameter of Right VA	2.4±0.71 mm	2.31mm	2.49mm	1.1-5.24 mm
Diameter of Left VA	2.5±0.7 mm	2.42mm	2.59mm	1.03-5.11 mm
Diameter of BA	3.2±0.69 mm	3.12mm	3.29mm	1.42-5.39 mm
Terminal Part of Pons BA Diameter	2.36±0.61 mm	2.29mm	2.44mm	1.26-6.79 mm
Angle of Right VA	48.95°±12.67°	47.37°	50.53°	17.28°-100.45°
Angle of Left VA	52.22°±14.24°	50.45°	53.99°	19.61°-107.66°
Angle of BA	31.9°±12.15°	30.39	33.42°	0°-93.45°

Table 2. Gender, the dominance of the vertebral artery (VA) and course of the basilar artery

Gender	Dominance	Course of The Basilar Artery					Total
		Straight	Right straight	Right curved	Left straight	Left curved	
Diameter of Right VA	Right VA	18	16	7	12	8	61
Diameter of Left VA	LEFT VA	19	31	12	8	2	72
Diameter of BA	Right VA	16	10	4	7	7	44
Terminal Part of Pons BA Diameter	LeftVA	13	29	7	20	4	73
Total		66	86	30	47	21	250

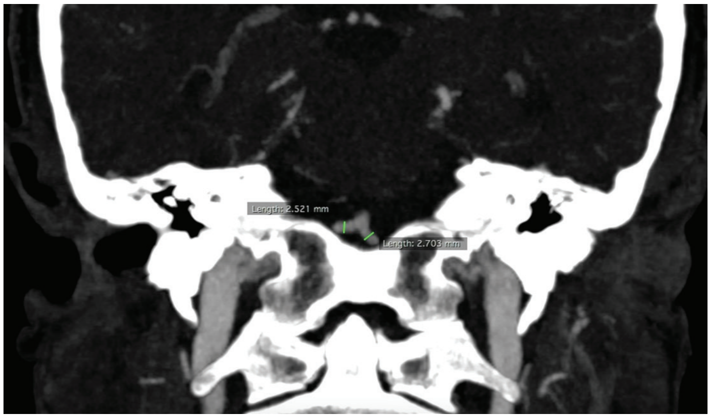

Figure 1 CT Angiography image of right and left vertebral arteries diameters

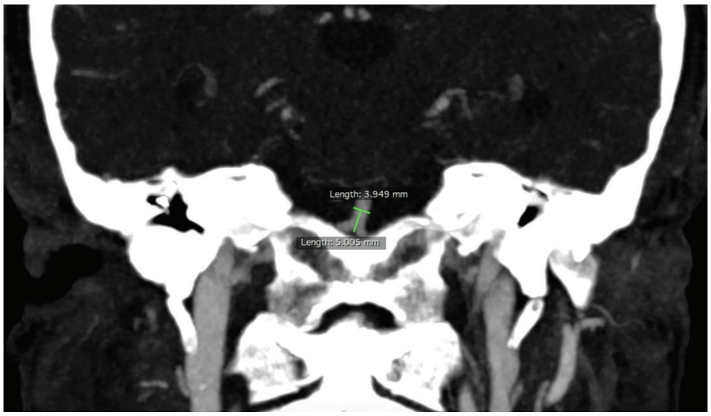

Figure 2. CT Angiography image of basilar artery diameter (above the vertebrobasilar junction)

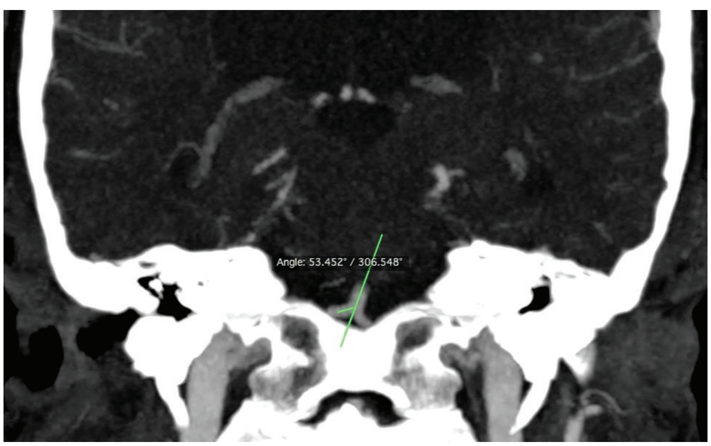

Figure 3 Vertical axis drawn from the formation point of the basilar artery by the union of right vertebral artery angle

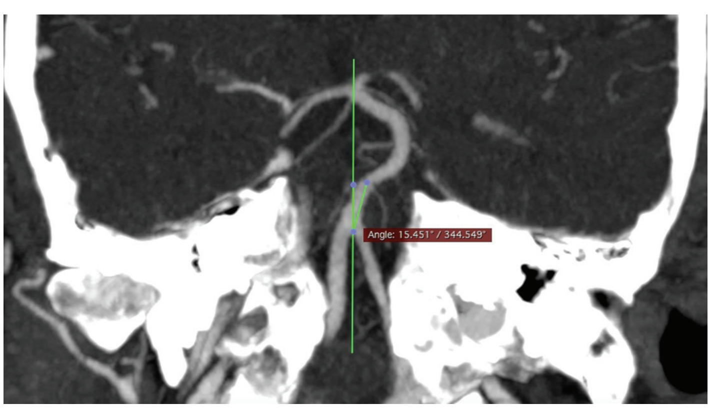

Figure 4. CT Angiography image of basilar artery angle

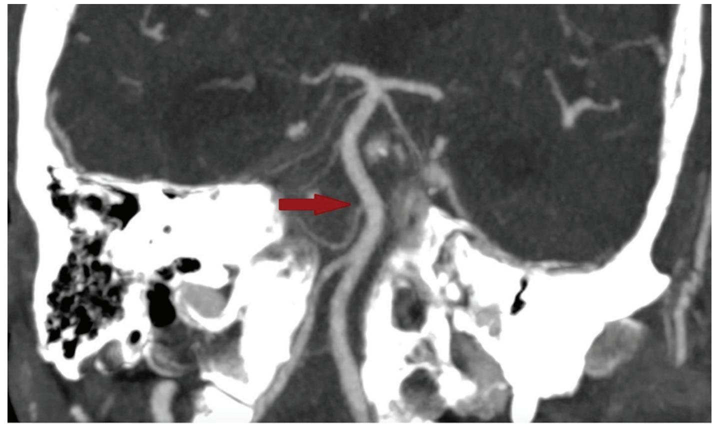

Figure 5 CT Angiography image of the course of the basilar artery: left S curved

Discussion

In this study, the morphometric measurements of the basilar artery and intracranial vertebral arteries were performed on CT angiography images of 250 healthy adults. As a result of these measurements, the mean diameter of the right vertebral artery was found to be 2.4±0.71 mm and for this parameter, 95% confidence interval was 2.31-2.49 mm. The mean diameter of left vertebral artery was 2.5±0.7 mm, and the 95% confidence interval was 2.42-2.49 mm. Yang et al. found that the diameter of the left vertebral artery was 4.37±1.21 mm, and the diameter of the right vertebral artery was 3.22±1.64 mm [12]. Pai et al. reported the diameter of the left vertebral artery as 3.4 mm and the diameter of right vertebral artery as 2.9 mm [13]. Songur et al. measured the diameter of left vertebral artery 3.02±0.81 mm and the diameter of the right vertebral artery2.85±0.99 mm on 109 autopsy materials and one cadaver [7]. Deng et al. measured the right vertebral artery diameter 1.5-3.5 mm and left vertebral artery diameter 1.7-3.7 mm in males on MR images with a 95% confidence interval. In the same study, in females, the diameter of the right vertebral artery was found 1.1-3.1 mm and on the left side 1.4-3.4 mm [14]. In the present study, with a 95% confidence interval, the right vertebral artery diameter was measured 2.2-2.4 mm and the left vertebral artery diameter 2.3-2.6 mm in females. In males, the right vertebral artery diameter was 2.4-2.6 mm, and the left vertebral artery diameter was 2.4-2.7 mm with a 95% confidence interval. Another parameter of our study was the diameter of the basilar artery at the vertebrobasilar junction, and it was measured 3.2±0.69 mm with a minimum-maximum value of 1.42-5.39 mm. Additionally, the diameter of basilar artery in the terminal part of pons was measured 2.36±0.61 mm with a minimum-maximum value of 1.26-6.79 mm. However, in the study of Mehinovic et al., the diameter of the basilar artery at the vertebrobasilar junction was found 2-4 mm, and in the terminal part of the pons, the basilar artery diameter was measured 3-5 mm in MR images [15]. Yang et al. found the basilar artery diameter in the terminal part of pons 4.45±1.28 mm [12]. There are studies in the literature measuring diameter of basilar artery without indicated level. Celebioglu et al. found this diameter 3.2 mm [16], Smoker et al. 3.17 mm [17], Busch et al. 4.1 mm [18], Wollschloger et al. 3.2 mm [19], Pai et al. 4.3 mm [13], Pico et al. 2.6±0.6 mm [20], and Songur et al. 3.97±0.96 mm [7]. In the previous MR Angiography studies, it has been reported that vertebrobasilar dolichoectasia occurs in cases where the diameter of the basilar artery is greater than 4.5 mm and the diameter of the intracranial vertebral artery is greater than

4 mm [21, 22]. In the present study, we determined the diameter of the basilar artery at the vertebrobasilar junction 3.2 mm, the diameter of the right intracranial vertebral artery 2.4 mm and the diameter of the left vertebral artery 2.5 mm.

The right vertebral artery dominance was found in 105 (61 males, 44 females) (42%) of 250 patients and the left vertebral artery dominance was found in 145 (72 males, 73 females) (58%) cases. Zhu et al. found the right vertebral artery dominance 43.6% and the left vertebral artery dominance 56.4% [23]. Cloud and Markus found the left vertebral artery dominance 50% and the right vertebral artery dominance 25% by using MR images. They also suggested that dominance was found to be very close to each other in 25% of the cases [10]. All the individuals in our study were found to have absolute dominance in accordance with the results of Zhu et al. [23]. In the present study, it was determined that the left vertebral artery diameter was higher than of the right vertebral artery. The left vertebral artery dominance was found to be higher in our series. According to these findings, the diameter of the vertebral artery and dominance were directly related to each other. Tütüncü et al. examined the angle of the vertebrobasilar junction in 3-D MR images of patients with and without aneurysm. The researchers found this angle 146.7°±20.5° in the patients with aneurysm and 95.3°±20.2° in the healthy population [24]. However, in our study, this angle was measured by drawing a vertical axis from the point of the formation of the basilar artery. Then, the angles of the right and left vertebral arteries from this vertical axis were measured separately. In the present study, while the angle formed by the right vertebral artery was measured 48.95°±12.67°, the angle formed by the left vertebral artery was measured 52.22°±14.24°. In the study of Tütüncü et al. [24], did not measure the right and left vertebral artery angles separately; therefore, in the determination of aneurysms, our measurements seem much more sensitive.

In the present study, the angle between the Y-axis and the basilar artery was measured at 31.9°±12.15° for both sexes. Additionally, with a 95% confidence interval, this angle was measured 30.39°-33.42° (min-max: 0°- 93.45°). To our knowledge, no study measuring this angle parameter was found in the literature.

In the literature, the course of the basilar artery was described as straight, curved, S-shaped [11] or straight, right curved, and left curved [23]. In the dissection of 52-brains, Nishijima observed 34.6% S-shaped, 55.8% curved, and 9.6% straight basilar artery [11]. In the examination of MR images, Zhu et al. found 50% straight, 19.2% leftward curved and 30.8% rightward curved basilar arteries [23]. In the studies of Wollschlaeger et al. and Nishijima et al. [11,19], the morphometric measurements were done on the external diameters of the vessels. However, in the other morphometric studies [7,12-15,17,18,20-24], scientists measured the internal diameters of the vessels. In the present study, we performed the measurements on the inner diameters of the vessels. In our opinion, the inner diameter measurements of the vessels seem much more useful for the researchers and surgeons. In this study, we classified the patients in five groups according to the course of the basilar artery; straight, right straight, left straight, right curved and left curved groups. We studied these parameters both in males and females separately. To our knowledge, a comparative study using these findings in terms of males and females is not available in the literature.

Vertebral artery dominance leads asymmetrical blood flow from vertebral arteries to the basilar artery. Asymmetrical flow pattern provides a mechanical force in the origin of basilar artery and induces curving of arterial wall. The curved course of the basilar artery is a predisposing factor of atherosclerosis. Chronic process due atherosclerosis ends in insufficient blood flow in the vertebrobasilar system. Posterior inferior cerebellar artery (PICA) is a branch basilar artery and has no collateral circulation. The morphologic changes in this system may lead infarction in the distribution area of these vessels. Zhu et al. concluded that there is a direct link between stroke and vertebral artery dominance [23]. In this study we analyzed morphometric changes in the vertebrobasilar system due to vertebral artery dominance.

Conclusion

In conclusion, it can be said that this is the first study measuring the angle of the basilar artery along its' course. To our knowledge, in the literature, there is no study to evaluate the morphometry and geometry of the vertebral and basilar arteries with these detailed parameters separately. The data obtained in this study are essential for the determination of pathological disorders in the intracranial part of the vertebral and basilar arteries. We think that there is a link between vertebral artery dominance and the basilar artery morphometry. Changes in morphometry and geometry of vertebrobasilar system may lead inadequate blood supply in the territory of these vessels. Patients with these pathological changes are more likely to have stroke due to aneurysm and atherosclerosis.

Conflict of interest
The authors declare that there are no conflicts of interest.

Financial Disclosure
All authors declare no financial support.

Ethical approval
All the procedures of our study were approved by the Ethical Committee of Hacettepe University Faculty of Medicine in April 19, 2016 (Number: 16969557-422). In terms of medical ethics, the study was found to be in accordance with GO 16 / 69-04 decision number.

Sinem Akkasoglu ORCID:0000-0002-3371-4734
M.Mustafa Aldur ORCID:0000-0002-5530-4234
Mustafa F. Sargon ORCID:0000-0001-6360-6008
Emre Can Celebioglu ORCID:0000-0002-1580-7064
Selma Calikan ORCID:0000-0002-5839-3172

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