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A study on age- and gender-dependent differences in distance and angle between the internal carotid artery and basilar artery

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Abstract.
BACKGROUND: Variations or malformation of the internal carotid artery (ICA) and basilar artery (BA) can be risk factors during simple surgery. So medically the focus has been on information about the positional relationship between the blood vessels based on the distance and angle between the ICA and BA.
OBJECTIVE: This study measured the distance and angle between the ICA and BA in 188 healthy Korean male and female subjects in their 20s and 40s and analyzed the differences in terms of age and gender.
METHODS: Magnetic resonance images were obtained; the distance between the right ICA and BA was defined as R1 [cm], the distance between the left ICA and BA was defined as L2 [cm], and the distance between the right ICA and left ICA was defined as M3 [cm]. The angles between the right and left ICA and BA were defined as AR1 [degree] and AR2 [degree], respectively.
RESULTS: With increasing age, R1 and M3 became shorter in both men and women, and L2 became shorter only in women.
CONCLUSION: The results of this study provide data on the average distance and angle between the ICA and BA of healthy Korean men and women in their 20s and 40s, which may later be used to support the diagnosis of relevant brain diseases and simple routine surgical procedures.

Keywords: Internal carotid artery (ICA), basilar artery (BA), distance and angle, age and gender

1. Introduction

The vertebral artery and internal carotid artery (ICA) are two major blood vessels that meet at the base of the brain and supply it with blood. These two blood vessels are connected by the posterior communicating artery and due to the blood vessels meeting at the posterior communicating artery from either side, it is a common site for aneurysms. The two vertebral arteries and the basilar artery (BA) are sometimes also known together as the vertebrobasilar system, which supplies blood to the posterior part of the circle of Willis and joins with blood that is being supplied to the anterior part of the circle of Willis by the internal carotid arteries. Major blood vessels of the brain, such as the ICA and BA, have been reported to play an important role in diagnosing stroke patients and high-risk patients [1,2].

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Table 1
The characteristics of the subjects

	Men	Women	Total
20s	51 men (mean age = 22.4 ± 2.5 years old)	54 women (mean age = 20.6 ± 2.1 years old)	105 subjects (mean age = 21.5 ± 2.5 years old)
40s	37 men (mean age = 49.3 ± 3.6 years old)	46 women (mean age = 47.0 ± 3.4 years old)	83 subjects (mean age = 48.0 ± 3.7 years old)

In the patient group, abnormal blood vessel patterns (curving and looping) of the ICA and BA have been classified using imaging systems such as magnetic resonance imaging, computed tomography, and digital radiography, and the results have been used to diagnose brain diseases [1,3]. In addition, the results of morphological variations such as the length and diameter of each blood vessel have been classified according to age and gender. Moreover, studies have predicted stenosis using data such as blood flow volume (BFV) of the ICA and BA and velocities of the ICA [4,5].

However, since variations or malformation of the ICA and BA can be risk factors during simple surgery, medically, the focus has been on information about the positional relationship between the blood vessels based on the distance and angle between the ICA and BA [6–8]. Furthermore, this positional information can be used to predict cerebrovascular-related diseases. However, little research has been carried out on these results. In particular, no studies have shown information on the distance and angle, which are one of the criteria for predicting the positional relationship between the ICA and BA in patients as well as healthy subjects, and no studies have compared these differences according to age and gender.

Therefore, this study aimed to measure the distance and angle between the ICA and BA in healthy men and women in their 20s and 40s to obtain standard average data for healthy subjects. We also analyzed the differences in the distance and angle between the ICA and BA in terms of age and gender, which are some of the variables that have the greatest impact on anatomical information.

2. Methods

One hundred and eighty-eight healthy adults in their 20s and 40s, without any history of mental or neurological disease, were selected as subjects. The number of subjects in their 20s and 40s and their characteristics are presented in Table 1. All experimental procedures were performed in accordance with the regulations of our Institutional Review Committee.

MRI measurements were conducted using a 3.0-T FORTE machine equipped with whole-body gradients and a quadrature head coil (ISOL Technology, Korea). T1-weighted brain images were obtained with a three-dimensional, magnetization-prepared, and rapid-gradient echo sequence. The sequence information is TR/TE/TI = 10/4/100 ms, slice thickness = 1.5 mm, field of view = 220 mm × 192 mm × 192 mm, number of slices = 128, slice gap = 0, matrix size = 256 × 224 × 128, and number of excitations (NEX) = 2.

With the help of anatomists, as shown in Fig. 1, one transverse plane slice was selected from each subject's obtained images, in which the ICA and BA could be seen clearly. The distance between the right ICA and BA was defined as R1 [cm], the distance between the left ICA and BA was defined as L2 [cm], and the distance between the right ICA and left ICA was defined as M3 [cm]. The angles between the right and left ICA and BA were defined as AR1 [degree] and AR2 [degree], respectively (Fig. 1). The distance and angle between the ICA and BA were measured using PicPick S/W (Korea).

To observe the differences of distance and angle between the ICA and BA in terms of age, gender, and the interaction of age and gender, multivariate two-way analysis of variance (ANOVA; PASW,

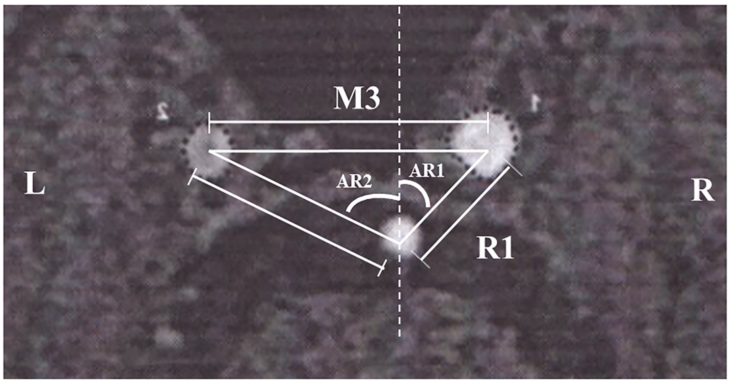

Fig. 1. A slice in the transverse plane where the ICA and BA can be clearly distinguished (M3: distance between the right ICA and left ICA [cm], R1: distance between the right ICA and BA [cm], L2: distance between the left ICA and BA [cm], AR1: angle between the right ICA and BA [degree], AR2: angle between the left ICA and BA [degree]).

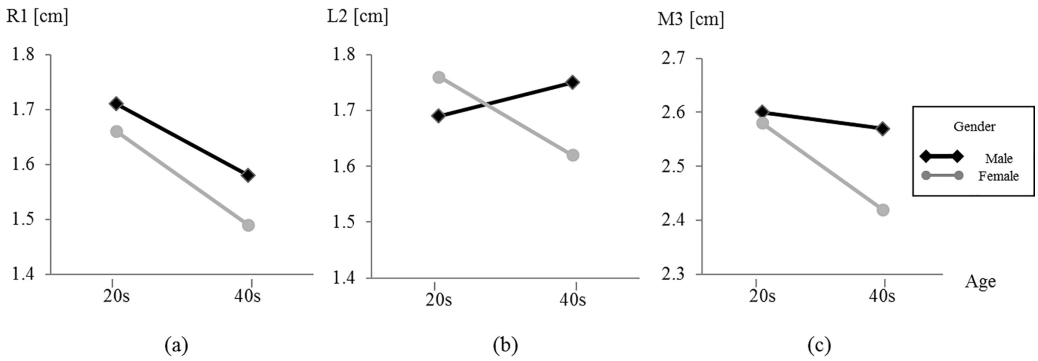

Fig. 2. Age- and gender-specific graphs for (a) R1 [cm], the distance between the right ICA and BA, (b) L2 [cm], the distance between the left ICA and BA, and (c) M3 [cm], the distance between the right ICA and left ICA.

ver.18.0) was performed with age (level 2) and gender (level 2) as independent variables. In the event of an interaction effect between the two independent variables, simple main effect analysis was conducted using one-way ANOVA.

3. Results

The average values of R1, L2, M3, AR1, and AR2 in the subjects are shown in Table 2. Using multivariate two-way ANOVA, R1 showed a significant difference only for age ($p < 0.001$) (Table 3). Specifically, the distance between the right ICA and BA was shorter in those in their 40s than in those in their 20s (Fig. 2a). M3 differed significantly in terms of age ($p = 0.011$) and gender ($p = 0.020$) (Table 3), where the distance between the right ICA and left ICA was shorter in subjects in their 40s than in those in their 20s, and in women but not in men (Fig. 2c). L2 showed an interaction effect between age and gender ($p = 0.016$), indicating significant differences between men and women depending on age (Table 3). Specifically, the distance between the left ICA and BA was shorter in women in their 40s than in women in their 20s; this distance was longer for men in their 40s than for men in their 20s (Fig. 2b). A simple main effect analysis was performed on L2, which showed an interaction effect. One-way ANOVA was

Table 2
Means and standard deviations of R1, L2, M3, AR1, and AR2 in the subjects

	20s		40s	
	Men	Women	Men	Women
R1 [cm]	1.71 ± 0.26	1.66 ± 0.22	1.58 ± 0.27	1.49 ± 0.31
L2 [cm]	1.69 ± 0.24	1.76 ± 0.28	1.75 ± 0.28	1.62 ± 0.32
M3 [cm]	2.60 ± 0.27	2.58 ± 0.24	2.57 ± 0.21	2.42 ± 0.22
AR1 [degree]	49.58 ± 7.81	45.76 ± 10.46	48.63 ± 9.61	50.00 ± 12.21
AR2 [degree]	51.29 ± 8.05	52.39 ± 6.56	52.93 ± 9.61	54.72 ± 11.51

Table 3
Results of multivariate two-way ANOVA with age (level 2) and gender (level 2) as independent variables. The differences in the measured distance and angle between the ICA and BA in terms of age, gender, and the interaction between age and gender were analyzed

Source	Dependent variable	Type III sum of squares	df	Mean square	F	Sig.
Age	R1	0.950	1	0.950	13.844	0.000
	L2	0.103	1	0.103	1.298	0.256
	M3	0.382	1	0.382	6.679	0.011
	AR1	124.699	1	124.699	1.215	0.272
	AR2	181.036	1	181.036	2.250	0.135
Gender	R1	0.191	1	0.191	2.780	0.097
	L2	0.045	1	0.045	0.564	0.454
	M3	0.313	1	0.313	5.464	0.020
	AR1	69.452	1	69.452	0.677	0.412
	AR2	95.780	1	95.780	1.190	0.277
Age $\times$ gender	R1	0.023	1	0.023	0.336	0.563
	L2	0.466	1	0.466	5.868	0.016
	M3	0.185	1	0.185	3.241	0.073
	AR1	310.978	1	311.978	3.031	0.083
	AR2	5.409	1	5.409	0.067	0.796

conducted on the differences according to age in each gender. The results showed a significant difference between women in their 20s and 40s ($p = 0.015$), but there was no difference in terms age in men ($p > 0.05$). In addition, one-way ANOVA for differences in terms of gender in each age group showed no significant differences according to gender in either age group ($p > 0.05$). In conclusion, the distance between the left ICA and BA was shorter in those in their 40s than in those in their 20s and only in women. AR1 and AR2 showed no difference in terms of gender and age.

4. Discussion

For the diagnosis of brain diseases, information about the volume of the cerebral blood vessels, the direction of the blood flow, the difference in the relative blood flow velocity, the distance that the blood vessel is traced, and the relative positional relationship between blood vessels is essential. In particular, information on the positional relationships such as distance and angle between the ICA and BA, which are two major blood vessels for the treatment of brain diseases and brain surgery, has attracted attention as important data [6,7]. However, previous studies have only classified abnormal blood vessel patterns (curving and looping) of the ICA and BA in patients [1,3], measured the length and diameter of blood vessels [9–11], analyzed morphological variations according to age and gender [9–11], or measured BFV and blood flow velocity [4,5].

ICA morphological variations are associated with gender and age, and Sacco et al. [9] particularly reported that ICA morphological variations are more common among women, as opposed to men, and among older adults, as opposed to younger adults. The etiology of ICA morphological variations still remains a controversial topic with multiple hypotheses. Further, some surmise that ICA morphological variations are associated with shorter neck lengths [12], and ICA morphological variations have been reported to be more common on the left side as opposed to the right [9]. However, these results vary across research institutions, and the exact cause is yet unknown. Moreover, a previous study that measured the diameter of BA to assess vessel volume, but there have been no reports on the standard measurements of BA in terms of gender and age. Most previous studies have been conducted on patient populations, with no study comparing the standard measures of distance and angle, which are two of the parameters used to accurately assess ICA and BA in terms of gender and age in the general population.

Most previous studies on ICA involved morphological variations according to sex and age in patient populations, so our findings cannot be directly compared with them. This study measured the distance and angle between the ICA and BA, obtained standard average data that can predict the positional relationship between these blood vessels, and examined the differences in terms of age and gender. The results provided mean data for the distance and angle between the ICA and BA in Koreans in their 20s and 40s. In the future, it will be necessary to improve the reliability and utility of the data by obtaining additional DB in terms of race, age, and gender. The results of the present study showed a shorter distance between the right ICA and BA (R1) in subjects in their 40s than in those in their 20s. The distance between the right ICA and left ICA (M3) was shorter in subjects in their 40s than in those in their 20s and in women than in men. The distance between the left ICA and BA (L2) was shorter in subjects in their 40s than in those in their 20s only in women. In other words, with increasing age, R1 and M3 became shorter in both men and women, and L2 became shorter only in women. It is known that, in healthy subjects, as age increases, brain volume decreases due to brain atrophy [13], which may explain the results of this study. In general, it has been reported that the brain of a woman is smaller than that of a man [14]. Even though there was no difference between men and women in R1 and L2, this may explain the shorter distance for M3 in women than in men in this study. Three distances were affected by age and gender. It is also necessary to verify this result based on additional DB on various races, gender and ages in the future. Furthermore, follow-up studies should measure the distance and angle between the ICA and BA in patients with cerebrovascular diseases and compare them with the data of healthy subjects.

The results of this study provided the information on the average distance and angle between the ICA and BA of healthy Korean men and women in their 20s and 40s. The results may be used to help the diagnosis of relevant brain diseases (arteriosclerotic pathology, fibromuscular dysplasia, cerebral emboli, intermittent stenosis, atherosclerotic stenotic lesions) and simple routine surgical procedures for otorhinolaryngologists (adenoidectomy, tonsillectomy, and uvulopalatopharyngoplasty).

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Conflict of interest

The authors declare that there is no conflict of interest.

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