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Running title: Analysis of posterior circulation diameter

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Abstract

Background: Posterior circulation of brain is important because of vital organs’ blood supply provided by them. In this study, we evaluate the relationship of posterior circulation measurements with age, gender and side by using computed tomography angiography (CTA) images.

Materials and methods: A total 199 brain CTA examinations were retrospectively analyzed for all posterior circulation arteries (vertebral artery (VA), basilar artery, posterior cerebral artery
(PCA), superior cerebellar artery (SCA), anterior inferior cerebellar artery (AICA) and posterior inferior cerebellar artery (PICA)) to compare the difference based on age, gender and side.

**Results:** There is no correlation between age and the mean diameters of all vessels (p>0.05). The mean diameter left vertebral artery was higher than right vertebral artery in all genders (p:0.004 for males and p<0.001 for females). The mean diameter left SCA and PICA were higher than right SCA and PICA in females (p:0.032 and p:0.027, respectively). The mean diameters of basilar, left PCA, left SCA, left vertebral, right PCA, right SCA, right PICA and right vertebral artery were higher in males and that differences were statistically significant (p<0.001, p:0.002, p:0.006, p:0.004, p:0.001, p:0.003, p:0.002 and p:0.006, respectively).

**Conclusions:** The posterior circulation vessel diameter is not affected by aging. The mean diameters of basilar artery, both PCAs, both SCAs, right PICA, both vertebral arteries were higher in males. The mean diameters left vertebral artery is higher than right in all genders.

**Key words:** cerebral arteries, cerebellar arteries, posterior circulation, morphometric measurements, computed tomography

**INTRODUCTION**

Posterior circulation consists of vertebral, basilar, posterior cerebral, superior cerebellar, anterior inferior cerebellar and posterior inferior cerebellar arteries, as well as their branches. It is very variable and sometimes complex. Posterior circulation vascularizes the posterior part of the brain, in which many vital structures, such as the cerebellum, thalamus, and brainstem are located. Although digital subtraction angiography (DSA) is the gold standard in vascular imaging, it has been shown that computed tomography angiography (CTA) has become as effective as DSA with the advances in technology(1). A brain CTA examination is a non-invasive evaluation method. There are several morphologic studies which evaluate the brain arterial system (1-4). There are several studies investigating the variations in the posterior circulation system(1, 2, 5); however, those involving the measurement of arterial diameter are limited in number (4, 6). To our knowledge, the current study is the first in English language literature that
explored the relationship between posterior circulation arteries and age, gender, and side simultaneously.

MATERIAL AND METHODS

This retrospective study included the data from the patient files gathered from the local picture archiving and communication systems between January 2019 and January 2020. A total of 256 brain CTA examinations were included. CTA examinations were performed on a 320-row detector CT (Aquillion ONE Vision; Toshiba Medical Systems Corporation, Otawara, Japan), or a 256-row detector CT (Somatom® Definition Flash, Siemens Healthcare, Forchheim, Germany). The CT acquisition protocol also performed with the following parameters: 0.5-s gantry rotation time, 0.5mm slice thickness, 128 x 0.6-mm or 192x0.6-mm collimation using a z-flying focal spot, 200 mAs tube current at 120 kVp tube voltage. For optimal intraluminal contrast enhancement, the delay time between start of contrast material administration and start of scanning was determined for each patient individually by using a bolus-tracking technique. A total of 60–75 mL iopromide (Ultravist 370 mg/ml, Bayer Schering Pharma, Berlin, Germany), an automatic injector was used (MCT Plus; Medrad, Pittsburgh, PA) over 15 seconds through an 18-gauge intravenous line placed into the right antecubital vein at a rate of 4-5 ml/sec. The contrast produced a sensation of “hot flash” Immediately following the injection of the iodinated contrast, 50 ml saline was infused by the same injector via the same route.

The cases with trauma, tumor or vascular pathologies, pediatric cases, and repetitive examinations were excluded (Figure 1). As a result, a total of 199 brain CTA examinations were evaluated on axial, coronal, or sagittal images by two radiologists with three and 10 years of neuroradiology experience. The diameter of the vertebral artery (VA) was measured on the intracranial segment (V4), 1 cm before the confluence. The diameters of the posterior cerebral artery (PCA) were measured on the P1 segment. If there was no P1 or V4 segment, the measurement was not performed. The diameter of the basilar artery (BA) was measured from the mid-part. The diameters of the superior cerebellar artery (SCA), anterior inferior cerebellar artery (AICA), and posterior inferior cerebellar artery (PICA) were measured from the proximal part (Figure 2). The measurements and patients’ demographic data were recorded.

Statistical analyses were performed using SPSS v. 22.0 (SPSS Inc., Chicago IL, USA). The suitability of the data for normal distribution was evaluated by the single-sample
Kolmogorov-Smirnov test. Levene’s statistics were used for the homogeneity analysis of group variances. The independent-samples t-test was conducted to determine the differences between male and female biometric measurements, and the paired-samples t-test was utilized to determine those between the left and right measurements of men and women. The significance level was accepted as $p < 0.05$.

RESULTS

The mean age of the patients was $48.55 \pm 15.82$ (range 18-91) years. Of the patients, 105 (52.76%) were female. The mean diameters were calculated as $3.34 \pm 0.59$ (range 1.35-5.3) mm for BA, was $1.79 \pm 0.47$ (range 0.52-3.50) mm for the left PCA, was $1.12 \pm 0.33$ (range 0.40-2.18) mm for the left SCA, was $1.02 \pm 0.34$ (range 0.33-1.98) mm for the left AICA, $1.26 \pm 0.36$ (range 0.40-2.20) mm for the left PICA, 2.99 $\pm$ 0.70 (range 0.95-5.13) mm for the left VA, was $1.76 \pm 0.47$ (range 0.80-2.94) mm the right PCA, $1.06 \pm 0.31$ (range 0.36-2.10) mm for the right SCA, $0.95 \pm 0.31$ (range 0.30 -1.76) mm for the right AICA, $1.18 \pm 0.36$ (range 0.43-2.56) mm for the right PICA, and $2.68 \pm 0.71$ (range 0.94-4.52) mm for the right VA. There was no correlation between age and the mean diameters of any of the arteries ($p > 0.05$).

The mean diameters of BA, left PCA, left SCA, left VA, right PCA, right SCA, right PICA, and right VA were statistically significantly higher in males than in females (Table 1). Left fetal-type PCA was observed in four males and five females. Right fetal-type PCA was detected in two males and two females. There was no statistically significant difference in fetal-type PCA variations between the genders ($p = 0.95$). The left SCA could not be visualized in one male, the right SCA in one female, the left AICA in 34 males and 39 females, the right AICA in 30 males and 33 females, the left PICA in two males and five females, the right PICA in two males and eight females, and the V4 segment of the right VA in two females.

The mean diameters of SCA, PICA, and VA were statistically significantly higher on the left side compared to the right side (Table 2). However, in gender-based subgroup analyses, a statistically significant result was observed in only one artery (VA) in both genders (Table 3). The mean diameters of SCA and PICA were higher on the left side in both males and females but
the differences were not statistically significant in males (Table 3). The mean diameter of the left VA was higher than that of the right VA in both genders.

**DISCUSSION**

In this study, a total of 13 fetal-type PCA variations (6.53%) were observed, which is a lower percentage than reported in the literature (2, 5). Han et al. showed that CTA with 1-mm slice thickness underestimated cerebral arteries compared to DSA (1). In the current study, we used 0.5-mm slice thickness for CTA. Thus, we consider that our different results were due to our CT device being able to show smaller vessels. This is supported by similar results obtained from cadaver studies (6, 7). Another explanation may be that there is a difference in the rate of variation in different societies. Further thin-slice CTA and cadaver studies on this subject can provide a better explanation.

In this study, the diameters of VA, BA, PCA, PICA and AICA were similar to the ranges in the literature (2.8 mm versus 2.2-2.8 mm, 3.3 mm versus 2.7-3.6 mm, 1.8 mm versus 1.6-2.2 mm, 1.2 mm versus 1.2-1.7 mm, and 1 mm versus 1 mm, respectively) (3, 4, 6, 8-10). However, the SCA diameter was lower than the literature range (1.1 mm versus 1.3-1.4 mm) (9, 11, 12). This could be related to the differences in the method (cadaver versus CTA), technique (1 mm versus 0.5 mm slice thickness), or patient selection (inclusion and exclusion criteria).

Rai et al. revealed that the vessel caliber was affected by age (4). However, Ichikawa et al. found no correlation between age and vessel caliber (13). Furthermore Vitosevic et al. showed that the caliber of BA was higher in the elderly but those of VA and PCA were similar (3). In the current study, we observed no correlation between age and vessel caliber.

In this study, the mean diameters of BA, left PCA, right PCA, left SCA, right SCA, right PICA, left VA and right VA were higher in males. Rai et al. and Ichikawa et al. revealed similar results in that the mean diameters of BA and VA were higher in males (4, 13). On the other hand, Vitosevic et al. showed no diameter difference in BA by gender (3). However, the authors did not evaluate SCA, AICA, and PICA; therefore, we could not compare our results.

In this study, the mean diameters of SCA, PICA and VA were higher on the left side. Vitosevic et al. showed no statistically significant diameter difference in VA and PCA depending
on the side (3). However, several studies including the current study showed that the left VA diameter was higher than the right VA diameter (4, 6, 8-10). Shrontz et al. revealed that there was no diameter difference between the left and right sides for PCA, PICA, and AICA (10). Pai et al. reported that the diameters of the left AICA and SCA were higher than those of the right side while two other studies showed no side-based diameter differences in SCA (11, 12). The current study has both similarities and differences compared to the literature, which can be attributed to the differences in the technique used, number of patients evaluated, and the anatomical variations between the samples.

There are several limitations of this study. First, a CTA study cannot provide as comprehensive data as a cadaveric study. Second, we used the slice thickness as 0.5 mm; thus, we were not able to evaluate vessels that were smaller than 0.5 mm in diameter; however, 0.5 mm is the lowest available cross-sectional thickness of devices in current medical use. Another limitation concerns the small sample size. Finally, we excluded patients with vascular diseases, which may have affected our age-related evaluation.

CONCLUSIONS

A CTA examination is a valuable technique for vascular evaluation even in small vessels, such as PICA and AICA. The posterior circulation vessel diameter was not affected by normal aging. The mean diameters of the left VA were found to be higher than those of the right. Lastly, the mean diameters of BA, left PCA, right PCA, left SCA, right SCA, right PICA, left VA and right VA were higher in males compared to females.

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Table I. The intergroup comparison of the posterior circulation arteries measurements by gender

| Artery       | Gender | N  | Mean | Standart Deviation | t    | df  | p    |
|--------------|--------|----|------|--------------------|------|-----|------|
| Basilar      | Male   | 94 | 3,52 | .61                | 4,033| 197 | .000 |
|              | Female | 105| 3,18 | .58                |      |     |      |
| Left PCA     | Male   | 90 | 1,91 | .47                | 3,195| 188 | .002 |
|              | Female | 100| 1,68 | .48                |      |     |      |
| Left SCA     | Male   | 93 | 1,18 | .35                | 2,768| 196 | .006 |
|              | Female | 105| 1,06 | .29                |      |     |      |
| Left AICA    | Male   | 60 | 1,01 | .37                | -1,55| 124 | .877 |
|              | Female | 66 | 1,02 | .3                |      |     |      |
| Left PICA    | Male   | 92 | 1,30 | .37                | 1,520| 190 | .130 |
|              | Female | 100| 1,22 | .35                |      |     |      |
| Left Vertebral| Male | 94 | 3,14 | .75                | 2,924| 197 | .004 |
|               | Female | 105| 2,85 | .62                |      |     |      |
| Right PCA    | Male   | 92 | 1,88 | .49                | 3,514| 193 | .001 |
|              | Female | 103| 1,65 | .43                |      |     |      |
| Right SCA    | Male   | 94 | 1,13 | .35                | 2,965| 167 | .003 |
|              | Female | 104| .99  | .25                |      |     |      |
| Right AICA   | Male   | 64 | .95  | .31                | -137 | 134 | .892 |
|              | Female | 72 | .96  | .31                |      |     |      |
| Right PICA   | Male   | 92 | 1,26 | .38                | 3,065| 187 | .002 |
|              | Female | 97 | 1,10 | .32                |      |     |      |
| Right Vertebral | Male | 94 | 2,82 | .7                 | 2,765| 195 | .006 |
|               | Female | 103| 2,55 | .69                |      |     |      |
**PCA**: Posterior cerebral artery, **SCA**: Superior cerebellar artery, **AICA**: Anterior inferior cerebellar artery, **PICA**: Posterior inferior cerebellar artery

**Table II.** The intergroup comparison of the posterior circulation arteries measurements by side

| Artery | Side | N   | Mean | Standart Deviation | t     | df  | p     |
|--------|------|-----|------|-------------------|-------|-----|-------|
| PCA    | Right  | 186 | 1.76 | .47               | -624  | 185 | .533  |
|        | Left   | 186 | 1.78 | .49               |       |     |       |
| SCA    | Right  | 197 | 1.06 | .31               | -2.692| 196 | .008  |
|        | Left   | 197 | 1.12 | .33               |       |     |       |
| AICA   | Right  | 120 | .95  | .31               | -1.657| 119 | .100  |
|        | Left   | 120 | 1    | .32               |       |     |       |
| PICA   | Right  | 187 | 1.18 | .36               | -2.274| 186 | .024  |
|        | Left   | 187 | 1.25 | .36               |       |     |       |
| Vertebral | Right  | 197 | 2.68 | .71               | -4.816| 196 | .000  |
|        | Left   | 197 | 2.9  | .7                |       |     |       |

**PCA**: Posterior cerebral artery, **SCA**: Superior cerebellar artery, **AICA**: Anterior inferior cerebellar artery, **PICA**: Posterior inferior cerebellar artery
Table III. The subgroup comparison of the posterior circulation arteries measurements by gender

| Gender | Artery  | Gender | N  | Mean | Standard Deviation | t     | df | p      |
|--------|---------|--------|----|------|--------------------|-------|----|--------|
|        | PCA     | Right  | 88 | 1.86 | ,49                | -.672 | 87 | .503   |
|        |         | Left   | 88 | 1.9  | ,47                |        |    |        |
| Male   | SCA     | Right  | 93 | 1.13 | ,35                | -1.619| 92 | .109   |
|        |         | Left   | 93 | 1.18 | ,35                |        |    |        |
|        | AICA    | Right  | 56 | .95  | ,31                | -9.34 | 55 | .354   |
|        |         | Left   | 56 | .99  | ,35                |        |    |        |
|        | PICA    | Right  | 91 | 1.26 | ,38                | -9.39 | 90 | .350   |
|        |         | Left   | 91 | 1.30 | ,37                |        |    |        |
|        | Vertebral | Right  | 94 | 2.82 | ,7                 | -2.973| 93 | .004   |
|        |         | Left   | 94 | 3.14 | ,75                |        |    |        |
| Female | PCA     | Right  | 98 | 1.66 | ,43                | -1.92 | 97 | .848   |
|        |         | Left   | 98 | 1.67 | ,48                |        |    |        |
|        | SCA     | Right  | 104| .99  | ,25                | -2.168| 103| .032   |
|        |         | Left   | 104| 1.06 | ,29                |        |    |        |
|        | AICA    | Right  | 64 | .95  | ,32                | -1.393| 63 | .169   |
|        |         | Left   | 64 | 1    | ,31                |        |    |        |
|        | PICA    | Right  | 96 | 1.1  | ,32                | -2.242| 95 | .027   |
|        |         | Left   | 96 | 1.2  | ,34                |        |    |        |
|        | Vertebral | Right  | 103| 2.55 | ,69                | -3.962| 102| .000   |
|        |         | Left   | 103| 2.86 | ,63                |        |    |        |

PCA: Posterior cerebral artery, SCA: Superior cerebellar artery, AICA: Anterior inferior cerebellar artery, PICA: Posterior inferior cerebellar artery
Figure 1. Study Flow diagram; CTA computed tomography angiography

Figure 2. Axial (A), coronal (B) and 3D volume rendered (C) computed tomography images of 51-year old male. The measurements of right vertebral artery (R Ver) and left vertebral artery (L Ver) are shown on axial image (B). The measurements of right anterior inferior cerebral artery (R AICA) and left anterior inferior cerebral artery (L AICA) are shown on axial image.
