ORIGINAL ARTICLE

Prevalence of Variations in the Anterior Communicating Artery Complex of the Circle of Willis: A CT Angiography Study in Malaysia

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ABSTRACT

INTRODUCTION: The anterior communicating artery complex (ACoA complex) within the circle of Willis, contributing to communicating arterial supply to the brain, exhibits significant anatomical diversity. Given the vulnerability of brain tissues to cell death resulting from poor blood supply, knowledge on this variability becomes crucial for diagnosing and managing diseases affecting the arterial supply to the brain. **MATERIALS AND METHODS:** A cross-sectional study was conducted to determine the prevalence and to give a description of these variations based on reconstructed CT angiographic (CTA) images. We included all individuals who underwent head CT angiography at a hospital in Kuantan, Pahang, Malaysia for various reasons between January 2009 and August 2015. A total of 81 CT angiographic images were analyzed for different variations, encompassing hypoplasia, aplasia, and duplication of the anterior communicating artery, as well as hypoplasia and aplasia of the A1 and A2 segments of the anterior cerebral artery, the A2 segments arising from a common trunk, and the third A2 segment. **RESULTS:** Ten distinct variation types were identified, with the typical pattern observed in 35.8% of cases. Vascular variations accounted for 64.2%, signifying a higher prevalence compared to previous studies. The cases presenting variations in the anterior communicating artery constituted 43.2%, with the aplasia being the most prevalent anatomical variation at 28.4%. **CONCLUSION:** The study highlights a higher prevalence of anatomical variations in the ACoA complex than the typical pattern.

Keywords
Anterior communicating artery complex, Circle of Willis, Computed tomography angiogram, Anatomical Variations, Cerebral circulation.

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INTRODUCTION

The brain relies on a continuous supply of blood to ensure a consistent supply of oxygen and nutrients.[1] Brain cells are highly dependent on a constant supply of oxygen and glucose due to their high metabolic rate and their lack of capacity to store oxygen or glucose. They are exceptionally vulnerable to insufficient oxygen, and the absence thereof can lead to rapid death of brain tissue within minutes. In situations where blood supply to one side of the brain is compromised, the establishment of an effective collateral blood supply from the contralateral side becomes essential. The Circle of Willis serves as a mechanism to facilitate this collateral supply.

Stroke is the second leading cause of death, with 1 in 4 people estimated to have a stroke in their lifetime.[1] Variations of intracranial vessels is one of the non-modifiable risk factors of stroke,[2] and are common in patients with ischaemic or haemorrhagic strokes.[3]

The anterior communicating artery complex consists of two anterior cerebral arteries (ACA), and an anterior communicating artery (ACoA). The ACA is divided into two parts. The proximal part is called the A1 segment, which is the pre-communicating segment, the part between its origin and ACoA, which usually passes over the optic nerve. The A2 segment of the ACA is the distal part of the anterior cerebral artery, starting from the anterior communicating artery to the junction between the rostrum and the genu of the corpus callosum.

ACoA complex is an area of high anatomical variability. The vessels in the circle of Willis showed high anatomical variability in both postmortem studies[4,5] and imaging studies.[6] Variations in cerebral arteries can be effectively detected by multi-detector CT angiographic study.[7] The anterior communicating artery is regarded as a common location of aneurysms.[8] There is a significant association between the incidence of aneurysms and the circle of Willis anatomical variations in some studies.[9,10] This study aimed to determine the prevalence and to give a description of these variations based on reconstructed CT angiographic (CTA) images.

MATERIALS AND METHODS

This is a retrospective study observing the arterial variations of the anterior communicating artery complex in reconstructed CT angiographic images. The International Islamic University Malaysia Research Ethics Committee (IREC) approved the study and the National Medical Research Registry registration number is (NMRR ID: NMRR-15-2101-27218).

SAMPLES

The study population comprised patients who underwent CTA (head) for various reasons in Hospital Tengku Ampuan Afzan (HTAA) from January, 2009 to August, 2015. The nonionic iodinated contrast materials used were Iopamiro [(Iopamidol, 300); Bracco Dexxon Ltd, Ferentino, Italy] injected at a rate of 3 mL/s (for cases done before 2014) and Omnipaque, [(Iohexol 370); GE Healthcare Inc., Princeton, NJ] injected at a rate of 5 mL/s (for cases done in 2014 onwards) with the use of a power injector (Medrad, Pittsburgh, PA) and an 18- or 20- gauge needle inserted in the antecubital vein. The volume of iodinated contrast material in each case was typically 90 to 100 mL. According to literature, the prevalence of anatomical variants in the anterior communicating artery complex ranges from 26-95.2%.[11,12,13,14] Assuming the expected prevalence of 30%, and the confidence limit (the precision) of 10%, by using the formula for sample size, $n = [DEFF*Np(1-p)]/ [(d^2/Z^2_{1-\alpha/2}*(N-1)+p*(1-p)]$ from OpenEpi, version 3,[15] (p: the expected prevalence, d: the precision, alpha: the type 1 error and DEFF (design effect) as 1, with infinite population, and 95% confidence level), the sample size calculated was 81. Anticipating the rejection rate of images as 20%, the number of samples required was 97 (81+16).

DATA COLLECTION

A total of 112 cases for CT angiography of the cerebral vessels performed in HTAA from 1st January 2009 to 31st December 2015 were traced from Radiology Information System (RIS). The images were retrieved from Picture Archiving and Communication System (PACS), saved in Digital Imaging and Communication in Medicine (DICOM) format and transferred to iMAc for reconstruction using OsiriX software by using preset volume-rendered and maximum intensity projection display algorithms. Subsequently, the images were manipulated in any projections with varying amounts of time needed for review. Images degraded by motion or metallic artefacts, and images from diseases that obscure or significantly distorted the vascular anatomy were excluded from the study (Fig. 1). The number of images which could be retrieved for assessment was 81.

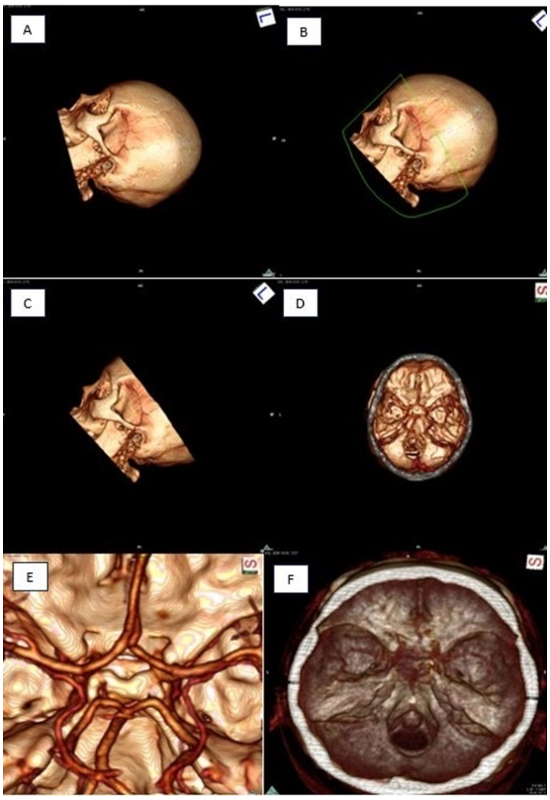

Figure (1). A: The 3D image after reconstruction. B: The direction of cutting the image. C: The image obtained after cutting. D: The image rotated to visualize the circle of Willis. E: An example of the zoomed image. F: An example of excluded images of the suboptimal CTA due to poor contrast.

CT Scanners

Multi-section CT angiograms were obtained with two different CT scanners. The cases before 2014 were performed using a 4-slice CT scanner (Somatom Volume Zoom CT scanner, Siemens Medical Systems, Forchheim, Germany). The cases done in 2014 onward used a 256 multi-row detector CT scanner (Somatom Definition Flash, dual source CT scanner; Siemens Medical Systems, Forchheim, Germany).

ASSESSMENT

Two independent radiologists validated and finalized the assessment of types of variations for every step. The source images and multi-planar reformations also were reviewed on the workstations by the radiologist. The selected images were reviewed for any type of variation in the anterior communicating artery complex and no interobserver difference was noted.

The 3D images generated by 3D reconstruction were cut, and orientated to get a view of the intracranial fossa of the skull, and zoomed in to visualize the circle of Willis (Fig. 1). The contrast was adjusted to get the best reconstructed image. The presence or absence of the anterior communicating artery, the common trunk of anterior cerebral arteries with the absence of the anterior communicating artery, the second anterior communicating artery, the A1 and A2 segments of right and left anterior cerebral arteries, and the presence of the third A2 segment of the anterior cerebral artery were observed in each case. The minimum and maximum diameters of each found artery in the anterior communicating artery complex were measured. A vessel with a maximal diameter of less than 1mm was regarded as hypoplasia. The radiologists reviewed the source images and multi-planar reformations on the workstations. A biostatistician analysed the outcomes by descriptive statistics. The types of variations were classified as illustrated in Fig. 2 (A).

RESULTS

The age of the subjects ranged from 11 to 87 years old of which the majority (78%) were 31 to 70 years old and 42% of the total cases were male. No statistical significance was noted in comparing the percentages of having variations in male and female subjects (Table I). The typical pattern, type 1 (Fig. 2B), of the anterior communicating artery complex was seen in 29 out of 81 cases, accounting for 35.8% (Fig.3). The prevalence of variations is shown in Table II. Among the variations, ACoA aplasia is the commonest type (Fig. 2C), while A1 segment aplasia is the second commonest (Fig. 2D). The third commonest variant which was found in 10 cases, accounting for 12.3%, is the duplication of ACoA (Fig. 2E). The MACC or the third A2 segment was found in 1 case (Fig. 2F).

Table I: Proportion of cases with the typical pattern in male and female subjects

	Male		Female		P value
	N	%	N	%	
Type 1	11	32.4	18	38.3	0.582[a]
Other Types	23	67.6	29	61.7	
Total	34	100	47	100	

Note. a = Pearson Chi-Square

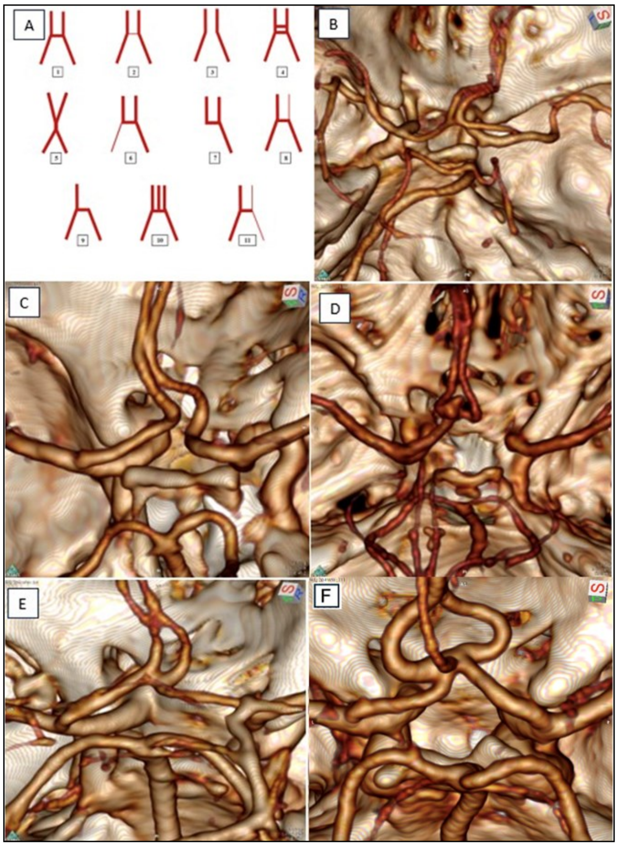

Figure (2). The anterior communicating artery complex (ACoA complex) of the circle of Willis. A. Variations in the anterior communicating artery complex. B. The typical pattern of the anterior communicating artery complex. C. Aplasia of the anterior communicating artery. D. Aplasia of the A1 segment E. Duplication of the anterior communicating artery F. Median artery of the corpus callosum or 3rd A2 segment.

Table II: Prevalence of the types of variations in the anterior communicating artery complex

Type	n	%	95% CI
1. (Typical pattern)	29	35.8	25.4, 46.2
2. (ACoA Hypoplasia)	3	3.7	-0.4, 7.8
3. (ACoA Aplasia)	23	28.4	18.6, 38.2
4. (ACoA Duplication)	10	12.3	5.2, 19.5
5. (Common trunk of ACA with no ACoA)	1	1.2	-1.2, 3.6
6. (A1 Hypoplasia)	1	1.2	-1.2, 3.6
7. (A1 Aplasia)	14	17.3	9.1, 25.6
8. (A2 Hypoplasia)	0	0	-
9. (Unilateral Aplasia of A2)	0	0	-
10. (MACC)	1	1.2	-1.2, 3.6
11. (Unilateral hypoplasia of A1 and A2)	0	0	-

Note. ACA = The anterior cerebral artery; MACC = The median artery of the corpus callosum

DISCUSSION

In this study, about two-thirds of the cases showed variations in the anterior communicating artery complex (Fig. 3). The percentage of cases having variations was 64.2%, which is the highest compared to previous different studies in different countries as stated in Table III. Further elaboration such as determining the association between the aneurysm and the variation is needed to discuss why the prevalence in this study was found to be higher than reported in other publications. Each of 62.4% of the cases in this study had one type of variation, and none of the cases had more than one type of variation. Types of variations found and their percentages are shown in Table II.

Table III: Percentages of variations in the anterior communicating artery complex in different studies

Country	Method	Percentage of variations
Serbia[16]	MRA	11.3%
Iran[17]	MRA	19.05%
India[13]	Autopsy	31.3%
Taiwan[18]	MRA	32.74%
Poland[19]	CTA	52.8%
Present study	CTA	62.4%

Note. MRA = Magnetic resonance imaging. 3D TOF MRA = Three-dimensional time-of-flight magnetic resonance angiography. CTA = Computed tomography angiography.

In this study, the most common type of anatomical variation in anterior communicating artery complex, as well as the most common variant of anterior communicating artery (ACoA), was ACoA aplasia (Fig. 2C, Table II). Absence or fenestration of ACoA has also been found to be the commonest variation (12 to 21%) in the anterior communicating artery complex in other studies.[20] The anterior communicating artery plays a crucial role in supplying blood to the side in need. This finding of the high prevalence of ACoA aplasia is important to be noted for surgeons since collateral supply from the other side can be inadequate in cases of anatomical variants such as ACoA aplasia.

CONCLUSION

It is important to note that the types and prevalence of anatomical variations in human as the knowledge of different variants is important for surgeons, physicians, and for radiologists in providing differential diagnosis, and in management of diseases. In addition, variations such as hypoplasia and aplasia can cause reduced blood supply to the supplied area of the brain. The anterior communicating artery complex (ACoA complex) of the circle of Willis is an area with great anatomical diversity, and it forms part of the communicating arterial supply to the brain. As brain tissues are susceptible to cell death due to insufficient blood supply, knowledge on this variability is important in diagnosis and management of any diseases that affect brain circulation, and can be useful to avoid accidental trauma to the vessels during surgeries4.

FUTURE RECOMMENDATION

This study has shown that the prevalence of anatomical variations in the anterior communicating artery complex is high probably because the sample were the CTA images of patients with pathology. There can probably be the difference of this figure in different populations. Studies should be done to define hypoplasia, and to describe if there is any difference in defining hypoplasia between the autopsy and imaging studies.

LIMITATIONS OF THIS STUDY

This research collected and analysed data from patients in whom CTA was done as part of investigation and management. Therefore, if the outcome representing the general population is needed, the healthy subjects have to be included.

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