



Surgical Anatomy of the Vertebrobasilar Territory and Posterior Circle of Willis

Anatomie chirurgicale du territoire vertébrobasilaire et Circle postérieure de Willis

O. E. Idowu*, A. O. Malomo†, E. E. U. Akang‡

ABSTRACT

BACKGROUND: In the present era of microscopic and neuroendoscopic procedures, the surgical anatomy of the skull base vessels has gained increased significance. The pattern of the vertebrobasilar arterial complex and the posterior circle of Willis (COW) in Nigerians has not been previously reported despite various variants of these complexes existing in different populations.

OBJECTIVE: To review and document the size, distribution and anomalies of the vertebrobasilar territory and posterior COW pattern in a Nigerian set of brains.

Methods: The target population for this study was a group of Nigerian adults 18 years and above. Specimens from patients with an ante-mortem or post-mortem evidence of meningitis or atherosclerosis were excluded. The size, distribution and anomalies of the vertebrobasilar artery, its branches, and the posterior COW were defined in 50 brains.

RESULTS: The male: female ratio was 1.9:1 and a mean age of 44 years. Statistical analysis showed significant differences between the sizes of posterior inferior cerebellar arteries and anterior inferior cerebellar arteries (Student's $t = -30.189$; p -value = 0.000). Fifty-six percent of the brains had no anomalies. Thirty anomalies were noted in posterior COW compared with six in the vertebrobasilar territory. There were no aneurysms in all the specimens studied.

CONCLUSION: Anomalies in the region of the posterior COW are commoner than the vertebrobasilar territory and the region of the posterior communicating artery is the most common site of anomalies in the posterior COW territory. These variations should be taken into account during skull base and carotid surgeries, and cerebral angiography. *WAJM* 2010; 29(4): 230–234.

Keywords: Anomalies; posterior circulation of Willis; vertebro-basilar arterial complex.

RÉSUMÉ

CONTEXTE: À l'ère actuelle des procédures microscopiques et neuroendoscopiques, l'anatomie chirurgicale des vaisseaux base du crâne a acquis une importance accrue. Le modèle du complexe vertébrobasilaire artérielle et le cercle de Willis postérieure (CP) dans les Nigériens n'a pas déjà été signalés en dépit de diverses variantes de ces complexes dans diverses populations.

OBJECTIF: Revoir et documenter la taille, la distribution et les anomalies du territoire vertébro-basilaire et postérieure motif vache dans un jeu nigérian des cerveaux.

Méthodes: La population cible de cette étude était un groupe d'adultes nigériens 18 ans et plus. Les échantillons provenant de patients avec un ante-mortem ou post mortem des preuves de la méningite ou l'athérosclérose ont été exclus. La taille, la distribution et les anomalies de l'artère vertébro-basilaire, ses branches, et la partie arrière GC ont été définis dans 50 cerveaux.

RÉSULTATS: Le ratio hommes / femmes a été 1,9:1 et un âge moyen de 44 ans. L'analyse statistique a montré des différences significatives entre la taille des artères cérébelleuses postérieures inférieures et antéro-inférieur artères cérébelleuses (t de Student = -30,189, p -value = 0,000). Cinquante-six pour cent des cerveaux avait aucune anomalie. Trente anomalies ont été constatées dans postérieure COW comparativement à six sur le territoire vertébro-basilaire. Il n'y avait pas un anévrisme dans tous les spécimens étudiés.

CONCLUSION: Des anomalies dans la région postérieure de la vache sont plus fréquents que le territoire vertébro-basilaire et de la région de l'artère communicante postérieure est le site le plus fréquent d'anomalies dans le territoire postérieur COW. Ces écarts doivent être pris en compte lors de la base du crâne et les chirurgies de la carotide, et l'angiographie cérébrale. *WAJM* 2010; 29 (4): 230-234.

Mots-clés: Anomalies; circulation postérieure de Willis; vertébro-basilaire complexes artérielle.

Division of Neurological Surgery, Department of Surgery*, Lagos State University College of Medicine and Teaching Hospital, Ikeja, Lagos. Departments of †Surgery, ‡Pathology, University College Hospital and College of Medicine, University of Ibadan, Ibadan, Nigeria.

Correspondence: Dr. O. E. Idowu, Division of Neurological Surgery, Department of Surgery, Lagos State University College of Medicine, Ikeja, Lagos. E-mail: oeidowu412@yahoo.com

Abbreviation: COW, Circle of Willis.

INTRODUCTION

Since the English neuroanatomist, Sir Thomas Willis, described the circle (named after him), in his *Cerebri Anatome* in 1664 and its rendering by Sir Christopher Wren, many studies have shown the role of the Circle of Willis (COW) as a collateral channel that compensates for the occlusion and tight stenosis of the extracranial arteries.¹⁻⁴ It is officially named as the *circulus arteriosus cerebri (Willisii)*.⁵⁻⁷

The classical description of the 'textbook' type of circle of Willis configuration illustrates a symmetrical arterial circle, with a single anterior communicating artery and bilateral posterior communicating arteries which typically have smaller diameters than the pre-communicating segments of the posterior cerebral artery (P-1 segments) on the corresponding side.^{8,9}

The function of the COW depends on the continuity of its roughly circular configuration. This configuration is known to vary. The variants that occur include hypoplastic, absent, or duplicated vessels. Atypical configuration of the COW resulting from hypoplasia of one or more of the component stem is quite common (35-84%).⁸⁻¹¹ The diameter of the posterior communicating may exceed that of the corresponding first segment of the posterior cerebral artery: a variation known as a foetal-type posterior cerebral artery.¹²

The endoscopic endonasal approach to the skull base is a technique, which has established itself in the recent years and demands a thorough knowledge of the surgical anatomy and variations of the vital skull base vessels during surgery for sellar/suprasellar tumours, cerebellopontine angle tumours and vertebrobasilar vascular malformations (including aneurysms).

The available information on the morphology of the vertebro-basilar system and the posterior circle of Willis of the African is scanty. The purpose of this study was to define and document the sizes, distribution and anomalies of the vertebrobasilar territory and posterior COW pattern in our Nigerian environment.

SUBJECTS, MATERIALS, AND METHODS

The target population for this study were Nigerian adults 18 years and above who had consecutive postmortem examination at the Pathology Department of University College Hospital (UCH), Ibadan, Nigeria.

Specimens from patients with an ante-mortem or post-mortem evidence of meningitis or atherosclerosis were excluded. The size, distribution and anomalies of the vertebro-basilar artery, its branches, and the posterior COW were defined in 50 brains (Figure 1).

The origin (vessels of origin, relation to the midline/olive/pontomedullary junction, shape) course, diameter at origin, branches, anomaly, and length of the basilar artery prior to bifurcation including the posterior communicating artery were studied and recorded by free-hand line drawing and photography, after adequately dissecting off the arachnoid membrane. The diameter of origin and the length before division were measured with a graduated scale with 0.1mm precision.

The posterior cerebral artery P-1 segment is the portion of the posterior cerebral artery between the basilar bifurcation and the posterior communicating artery junction with the posterior cerebral artery. A normal posterior circulation is defined as one in which the P-1 segment has a diameter larger than the corresponding ipsilateral communicating artery.

Descriptive statistics including mean, median, ranges, standard error of mean, frequency, and Student's t-test were used to compare means. The level of significance was fixed at less than 5% probability for chance.

RESULTS

The male: female ratio was 1.9:1 with a mean age of 44 years. Summary of the dimensions of the vessels are shown in Tables 1 to 3.

Basilar Artery

The basilar artery was formed by the union of two equal sized vertebral arteries in the midline in 41(92%) cases with an average length of 31.42(3.82)mm. Hypoplastic vertebral artery was noted in 2 (2%) vessels.

The origin of the basilar artery was commonly at the pontomedullary junction in 34 (68%) brains, above the pontomedullary junction in 11(22%) of cases and below it in 5 (10%) of cases. It extended from the lower to the upper border of the cisterna pontis in most 49 (98%) brains; and early bifurcation at the mid-pontine region was noted in one vessel (2%). It laid in a median shallow groove on the ventral pontine surface,

Table 1: Distribution of Basilar Arteries by Diameter

Diameter (mm)	Number	Percentage	Cumulative percentage
2.5-2.9	1	2	2
3.0-3.4	6	12	14
3.5-3.9	20	40	54
4.0-4.4	11	22	76
4.5-4.9	9	18	94
5.0-5.4	1	2	96
5.5-5.9	2	4	100
Total	50	100	

Table 2: Distribution of Basilar Arteries by Length

Length (mm)	Number	Percentage	Cumulative percentage
25-27	9	18	18
28-30	12	24	42
31-33	15	30	72
34-36	8	16	88
37-39	5	10	98
40-42	1	2	100
Total	50	100	

Table 3: Diameters of Brain Arteries in 50 Nigerians

Artery	Diameter (mm)
Vertebral artery	2.98(0.64)
Basilar artery	3.82(0.63)
PICA	1.26(0.39)
AICA	1.49(0.34)
Superior cerebellar artery	2.06(0.34)
Posterior cerebral artery	2.45(0.53)
PCoMA	1.62(0.58)

Values are mean (SD) in mm
 *AICA, Anterior inferior cerebellar artery;
 PCoMA, Posterior communicating artery;
 PICA, Posterior inferior cerebellar artery.

between the abducent nerves at the lower pontine border and the oculomotor nerves at the upper pontine border, where it divided terminally into two posterior cerebral arteries. Its termination was at the pontomesencephalic junction by running a straight course in 30 (60%) of cases, convex to the right in 9 (18%), convex to the left in 9 (18%) cases and forming a loop in two vessels (4%). The length ranged between 20.0mm and 40.0mm (mean, 31.42mm). The diameter was

relatively constant throughout its course except for the widening at the bifurcation. Its mean diameter was 3.82mm minimum–maximum : (2.5–5.5mm).

Paramedian perforating arteries arose solely from the posterior and lateral surfaces of the vessel to supply the pons and adjacent arteries. It also gave long circumferential arteries namely the anterior inferior cerebellar, superior cerebellar and posterior cerebral arteries, and occasionally two short circumferential arteries, the internal auditory arteries.

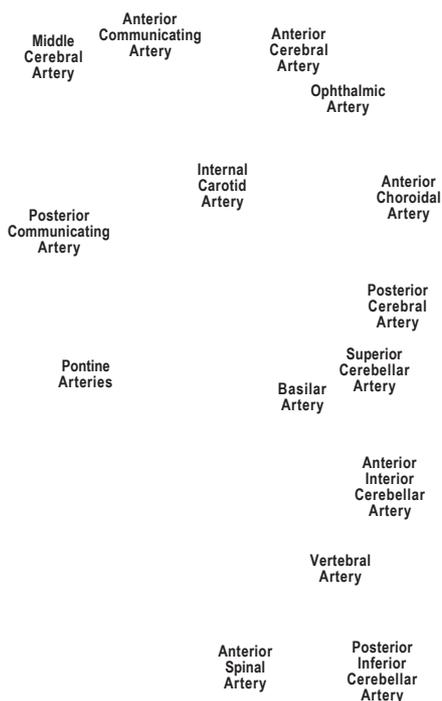


Figure 1: Typical Anatomy of the Circle of Willis

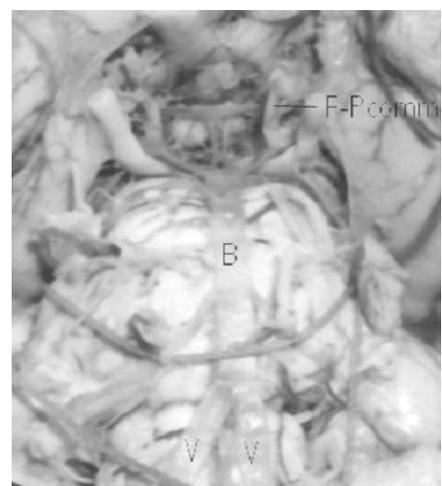


Figure 2: A Unilateral Foetal-type Posterior Communicating Artery (F-PcomA)

Posterior Inferior Cerebellar Artery

These vessel arose from the intracranial segment of the vertebral artery in 88(88%) of cases and two(2%) vessels originated from the basilar artery; the others were from the extracranial part of the vertebral artery. Its mean diameter was 1.26(0.39)mm. It usually curved backwards near the lower end of the olive (86 vessels, 86%) and above it in 14%. Curving backwards around the Olive it ascends behind the IX and X cranial nerve roots to the inferior border of the pons, where it curved and descended along the inferior border of the 4th ventricle. It finally turned laterally into the cerebellar vallecula, dividing into medial and lateral rami.

Anterior Inferior Cerebellar Artery

This arose from the lower third of the basilar artery in 67 (67%) cases, and in 13% of cases it arose from the middle third of the BA. It arose as an anomalous vessel having two origins from the lower third of the right side of the basilar and upper third of the right vertebral artery in on one side of a brain studied. The anterior inferior cerebellar artery originated at the same level on both sides of the BA in 16 brains. They arose higher on the right and left in 19 and 15 brains respectively.

The mean diameter of the anterior inferior cerebellar artery was 1.49 (0.34)mm. It ran posterolaterally usually ventral to the abducent, facial and vestibulo-cochlear nerves.

Superior Cerebellar Artery

This vessel arose as the penultimate branch of the basilar artery near its end in 97 (97%) of the vessels studied. In three instances, the superior cerebellar artery

arose from a common trunk from the terminal end of the basilar artery that later divided to give rise to the posterior cerebral and the superior cerebellar artery. Its mean diameter was 2.06(0.34)mm. It passed laterally below the oculomotor nerve which separated it from the posterior cerebral artery and curved round the cerebral peduncle below the trochlear nerve; before its destination on the superior cerebellar surface.

Posterior Cerebral Artery

This was larger than the superior cerebellar artery except in 5 (5%) of cases. It was separated from the superior cerebellar artery near its origin by the oculomotor nerve and, lateral to the midbrain, by the trochlear nerve. Its mean length (prior to joining the posterior communicating artery) and diameter was 7.57(1.7)mm and 2.45(0.53)mm respectively. It passed laterally, and parallel with the superior cerebellar artery, it received the posterior communicating artery, winds round the cerebral peduncle and reached the tentorial cerebral surface, where it supplied the temporal and occipital lobes.

Posterior Communicating Artery

This forms the lateral boundary of the circle of Willis. It arose from the posterior medial surface of the internal carotid artery and swept backward and slightly medially above the third cranial nerve to join the posterior cerebral artery. Its mean length and diameter was 1.62 (0.58)mm while its length was 13.02 (2.1)mm. Hypoplastic posterior communicating arteries were noted in 24 vessels. The posterior surface of this vessel gave several small central branches which pierced the posterior perforated substance with similar other vessels from the posterior cerebral artery.

There was no gender or side difference between the diameters of the vertebral, posterior cerebral, superior cerebellar, posterior inferior cerebellar and anterior inferior cerebellar arteries. Statistical analysis did show significant difference between the sizes of posterior inferior cerebellar arteries and anterior inferior cerebellar arteries (Student’s t = -30.189; p-value = 0.000). Similar difference was also noted between

superior cerebellar and posterior cerebral arteries.

Fifty-six percent of the brains had no anomalies. Thirty anomalies were noted in posterior COW compared with six in the vertebrobasilar territory. Hypoplastic posterior communicating artery was found in 22 of 100 of these vessels and a foetal type anomaly in five vessels. Hypoplastic vertebral arteries and basilar arterial loop were noted in two vessels each. Of the 50 basilar arteries studied one had early bifurcation. There were no aneurysms in all the specimens studied.

DISCUSSION

Cerebral blood flow is supplied through the left and right internal carotid artery and the basilar artery to the arterial circle of Willis, and thence to the brain. The arterial circle of Willis at the base of the brain serves as a potential collateral pathway, which maintains adequate cerebral perfusion in the case of diminished afferent blood supply through the internal carotid and basilar arteries.

The diameter of the basilar artery ranged from 2.5 to 5.0mm with a mean of 3.82mm, with the superior cerebellar and posterior cerebral arteries being 2.06mm and 2.45mm respectively (Table 3). Noakatsu and Albert recorded a mean diameter of 4.1mm for the basilar artery, 1.9mm for superior cerebellar artery and 2.6 mm for the first segment of the posterior cerebral artery.¹¹ This is similar to our findings. The mean diameter for vertebral, posterior inferior cerebellar, anterior inferior cerebellar, and posterior communicating arteries were 2.98mm, 1.26mm, 1.49mm and 1.62mm respectively. Parametric analysis showed no significant sex or side difference in the diameter of these vessels.

The most frequent origin of the posterior inferior cerebellar artery is from the intracranial segment of the vertebral artery. According to Ahuja, *et al.*¹⁴ this occurs in 61% of cases. We noted a far higher percentage in our series (91 vessels, 91%).

The size of the anastomotic circle varies considerably. The vertebral arteries may differ greatly in diameter or one may be missing likewise the posterior cerebral or posterior communicating arteries.

These anastomotic variations determine the site and extent of infarction in cerebrovascular disease. They also make it difficult to predict whether or not functionally adequate anastomosis will readily occur in any given individual if a major vessel on one side suddenly becomes blocked or damaged during surgery.

About half of the brains studied had at least one anomaly, predominantly in the posterior COW compared with the vertebrobasilar territory. In the series by Macchi *et al*, the circle of Willis showed an entirely complete configuration in 47% of the subjects, a complete configuration of its anterior part in 90% of the subjects, and a complete configuration of its posterior part in 48.5% of the subjects.¹⁵ This is similar to our findings and that of Noakatsu *et al* and Alper's *et al.*; although some authors have noted far higher anomalous rates.^{9,10} Among patients with aneurysms, the COW was normal in 21%, and anomalies occurred in 79%.^{16,17} Kayembe *et al* studied 44 patients with intracranial arterial aneurysms and found only 11 per cent with the "normal" circle of Willis.¹⁸

Embryologically, the posterior cerebral artery arises from the posterior communicating artery. Thus the segment between the basilar artery and terminal posterior communicating artery is the true "communicating" branch. This segment is sometimes called the basilar communicating artery or mesencephalic artery to acknowledge this fact. The wide range of reported incidence of anomalies has resulted from lack of uniform definition of anomaly. However, obvious anomaly would include hypoplastic vessels, foetal-type posterior cerebral artery, abnormal configuration or duplications. Hypoplasia of posterior communicating artery occurred in 22% in our series while Rhoton noted 32 per cent in his own review¹⁹. Ninety percent of the posterior COW anomalies occurred in the region of the posterior communicating artery in our study, 73.3% of this was accounted for by hypoplastic posterior communicating arteries.

We conclude that the dimensions and distribution of the vessels of the vertebro-basilar and the posterior COW territory in Nigerians are similar to that of

Caucasians. Anomalies in the region of the posterior COW are commoner than the vertebrobasilar territory and the region of the posterior communicating artery is the most common site of anomalies in the posterior COW territory. The study reveals significant variations in the posterior COW which should be taken in to account during skull base and carotid surgeries, and cerebral angiography.

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