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Analysis of the symmetric configuration of the circle of Willis in a series of autopsied corpses

Analiza simetričnosti konfiguracije Willis-ovog prstena na seriji obdukovanih tela umrlih osoba

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Abstract

Introduction. The forming of the blood vessels network configuration at the base of the brain and interconnecting of blood vessels during the embryogenesis is directly related to the phylogenetic development of the brain and brain structures. A blood vessel configuration at the brain base, in the form of a ring or a hexagon, stands in direct relation to the perfusion needs of certain parts of the brain during its primary differentiation. The aim of this paper was to determine the incidence of certain blood vessel configurations at the base of the brain and understanding their symmetry or asymmetry. **Methods.** Analysis of the blood vessels at the base of the brain was performed on the autopsied subjects. The object of observation was the anterior segment of the circle of Willis consisting of C1- *a. carotis interna* (ICA), above *a. communicaus posterior* (PcoA), the segment A1 *a. cerebri anterior* (ACA) from *a. carotis interna* bifurcation to the *a. communicans anterior* (AcoA) and *a. communicans anterior* itself, as well as the posterior segment consisting of PcoA and the segment P1 – *a. cerebri posterior* (PCA) from the *a. basilaris* bifurcation to the PcoA. For the purpose of grouping the findings, the four basic configuration types of the circle of Willis were identified based on its symmetry or asymmetry. Type-A (symmetric circle of Willis), type-B (asymmetric circle of Willis' due to the unilateral hypoplastic A1-ACA); type-C (symmetric circle of Willis with bilateral symmetric changes on PcoA) and type-D (asymmetric circle of Willis due to the asymmetric changes on PcoA). **Results.** Autopsy was performed on 56 corpses. A total of 41 (73.2%) subjects were recorded with a symmetric configuration of the circle of Willis', of which 27 (48.2%) subjects had type A and 14 (25%) type C. The asymmetric configuration was present in 15 (26.8%) subjects, of whom 9 (16%) had type B and 6 (10.8%) type D. The symmetric Willis group (73.2%) did not have a homogeneous finding that would fit into the schematic presentation of the symmetric type A and type C. A total of 17 (30.4%) findings were classified in this group of the so-called conditionally symmetric configurations. In all the cases, type B (16%) had unilaterally reduced diameter A1 and hyperplastic AcoA. **Conclusion.** The presence of asymmetric Willis configuration in 26.8% of the cases, which makes up more than one fourth, indicates that the asymmetric configurations do not represent a pathological form of connecting the blood vessels at the base of the brain, but rather one aspect of its adaptation. The forming of the basic types of configurations of the circle of Willis is associated with a tendency toward certain types of hemodynamic disorders and more frequent pathological changes in places of reduced resistance.

Key words:
circle of willis; cerebrovascular circulation; neuroanatomy.

Apstrakt

Uvod/Cilj. Formiranje konfiguracije mreže krvnih sudova u bazi mozga i međusobno povezivanje krvnih sudova tokom embriogeneze direktno je povezano sa poligenetskim razvojem mozga i njegovih struktura. Konfiguracija krvnog suda u bazi mozga u obliku prstena ili šestougla ima direktnu vezu sa potrebama perfuzije određenih delova mozga tokom njegove primarne diferencijacije. Cilj rada bio je utvrđivanje učestalosti odgovarajućih konfiguracija krvnih sudova na bazi mozga i sagledavanje prisustva njihove simetričnosti ili asimetričnosti. **Metode.** Analiza krvnih sudova na bazi mozga vršena je na obdukovanim ispitanicima. Posmatran je prednji segment Willis-ovog prstena koji su činili *a. carotis interna* (ICA) (C1-ICA) iznad *a. communicans posterior* (PcoA), A1-ACA (ACA/*a. cerebri ant.*/ od račve *a. carotis interna* do *a. communicans anterior*) i sama *a. communicans interna* (AcoA), i zadnji segment koji su činile *a. communicans posterior* (PcoA) (PCA)/ *a. cererbi posterior*/ i (P1-PCA) od račve *a. basilaris* (AB) do *a. communicans posterior* (PcoA). Radi grupisanja dobijenih nalaza, formirano je četiri osnovna tipa konfiguracija Willis-ovog prstena, na osnovu prisustva njegove simetričnosti ili asimetričnosti: tip A – simetričan Willis-ov prsten, tip B – asimetričan Willis-ov prsten zbog hipoplazije A1-ACA jedne strane; tip C – simetričan

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Willis-ov prsten sa bilateralnim simetričnim promenama na PcoA i tip D – asimetrični Willis-ov prsten zbog asimetričnih promena na PcoA. **Rezultati.** Obdukcija je izvršena na 56 umrlih osoba. Kod 41 (73,2%) ustanovljena je simetrična konfiguracija Willis-ovog prstena, od toga tip A bio je zastuljen kod 27(48,2%), a tip C kod 14 (25%) umrlih osoba. Zastupljenost asimetrične konfiguracije ustanovljena je kod 15 (26,8%) umrlih, od toga tip B bio je zastupljen kod 9 (16%), a tip D kod 6 (10,8%) umrlih osoba. Grupa sa simetričnim Wills-ovim prstenom (73,2%) nije bila sa homogenim nalazom koji bi se uklopio u šematski prikaz simetričnih Willis-ovih prstenova tipa A i tipa C. U tu grupu, takozvane uslovno simetrične konfiguracije, bilo je svrstano 17 (30,4%) nalaza. Tip B (16%) u svim slučajevima bio je sa jednostrano smanjenim prečnikom A1 i hiperlazijom AcoA. **Zaključak.** Prisustvo 26,8% asimetričnih konfiguracija Willis-ovog prstena, što je više od jedne četvrtine, ukazuje da asimetrične konfiguracije ne predstavljaju patološku formu povezivanja krvnih sudova na bazi mozga, već jedan vid njene adaptacije. Formiranjem osnovnih tipova konfiguracije Willis-ovog prstena, možemo uočiti sklonost odgovarajućeg tipa ka hemodinamskim poremećajima i češćem formiranju patoloških promena na mestima smanjene rezistencije.

Ključne reči:
vilisov arterijski prsten; cerebrovaskularna cirkulacija; neouroanatomija.

Introduction

The forming of the blood vessel network configuration at the base of the brain and interconnecting of blood vessels during the embryogenesis is directly related to the phylogenetic development of the brain and brain structures. A blood vessel configuration at the brain base, in the form of a ring or a hexagon, stands in direct relation to the perfusion needs of certain parts of the brain during its primary differentiation [1–4].

The aim of this paper was to determine the incidence of certain blood vessel configurations at the base of the brain and understanding their symmetry or asymmetry. The potential perfusion potential of the brain could be assumed from the corresponding vessel configuration types present at its base [5, 6].

Methods

Analysis of blood vessels of the brain base was performed on the autopsied subjects randomly selected.

During autopsy, the brain was extracted from the cranial fossa using a precise technique, together with blood vessels of the skull base which were resected at the entrance of the cranial cavity (Figure 1).

All the blood vessels of the brain base were separated from it by accurate dissection and arranged on a homogeneous flat surface so as to form the typical configuration of the circle of Willis. These preparations were photographed with a digital camera (Canon PowerShot A1200 12.1 mega pixels) and analyzed on a computer (the use of Adobe Photoshop CS2).

The elements of observation were parts of the blood vessels comprising the circle of Willis. The object of observation was the anterior segment of the circle of Willis, consisting of part of the *a. carotis interna* (ICA)/(C1-ICA), above the *a. communicans posterior* (PcoA) to its bifurcation, part of *a. cerebri anterior* (ACA)/(A1-ACA) from the *a. carotis interna* bifurcation to the junction with *a. communicans anterior* (AcoA) and *a. communicans anterior* (AcoA), as well as the posterior segment consisting of *a. communicans posterior* (PcoA) and part of *a. cerebri posterior* (PCA)/(P1-PCA) from the *a. basilaris bifurcation* to the junction with *a. communicans posterior* (PcoA).

Each preparation was observed separately and its symmetry was determined by comparing the thickness of the same blood vessels on the opposite sides of the circle of Willis. Comparisons were made regarding the thickness of A1-ACA, the thickness of PCoA and P1-PCA. The narrowing of the outer diameter of the vessel, as compared to the contralateral one, by one third or more was classified as hypoplasia. No absolute values of the thickness of blood vessels were measured, but only the differences in the thickness of the observed blood vessels of the opposite sides of the circle of Willis, in order to determine its symmetry.

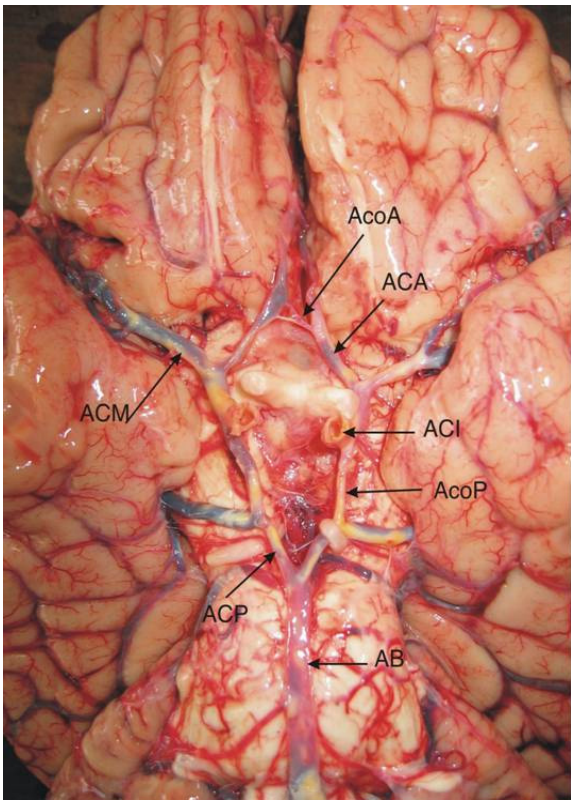

Fig. 1 – Brain preparation after the extraction from the scull AB – *a. basilaris;* ACP – *a. cerebri posterior*; AcoP – *a. communicans posterior*; ACI – *a. carotis interna*; ACA – *a. cerebri anterior*; AcoA – *a. communicans anterior*; ACM – *a. cerebri media*.

For the purpose of grouping the findings, the four basic configuration types of the circle of Willis were identified based on its symmetry or asymmetry (Figures 2 and 3).

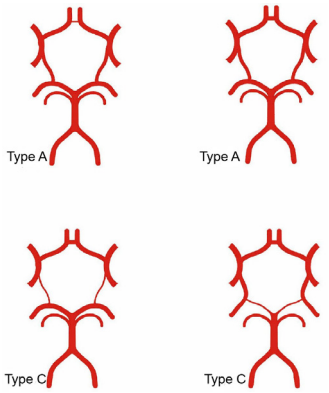

Fig. 2 – Symmetric types of the circle of Willis.

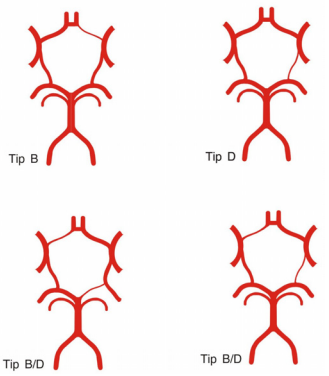

Fig. 3 – Asymmetric types of the circle of Willis.

The first configuration type (type A), is a symmetric circle of Willis. No significant differences in the thickness of the contralateral blood vessels were detected, except for possible variations of the AcoA.

The second configuration type (type B), represents an asymmetric type of the circle of Willis presenting with a narrower A1-ACA diameter unilaterally.

The third configuration type (type C), is a symmetric circle of Willis presenting with varying degrees of bilateral changes present on PCoA according to the type of hypoplasia, or the presence of a bilateral fetal-type PCoA.

The fourth configuration type (type D), is an asymmetric Willis circle because of the observed presence of unilateral hypoplastic PCoA or unilateral fetal-type PCoA. Combinations are possible with changes to the posterior and the anterior segment with the formation of asymmetric (Subtype B/D).

Types A and C belong in the group of symmetric circle of Willis, whereas types B and D are classified as asymmetric circle of Willis.

Results

In the group of 56 autopsied bodies, 36 were male and 20 female. Most of the subjects (48.2%) were above 60 years of age. The average age with regard to gender was of no significant difference. In 32 subjects a violent death occurred, whereas in 24 subjects death was the result of illness.

The highest incidence was the circle of Willis type A configuration, which was present in 27 (48.2%) subjects (Figure 4), followed by type C identified in 14 (25%) subjects (Figure 5). The asymmetric type B configuration was found in 9 (16%) subjects (Figure 6) (Table 1); the asymmetric type D

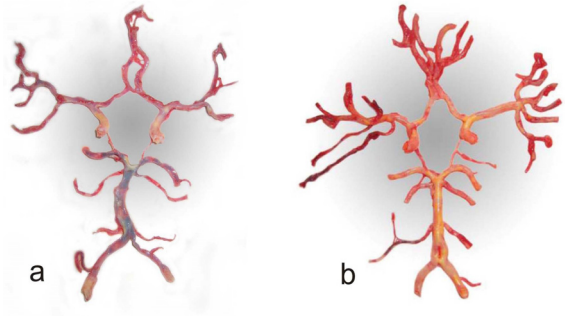

Fig. 4 – Type A of the circle of Willis.

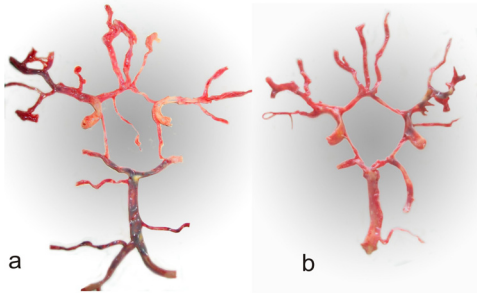

Fig. 5 – Type C of the circle of Willis.

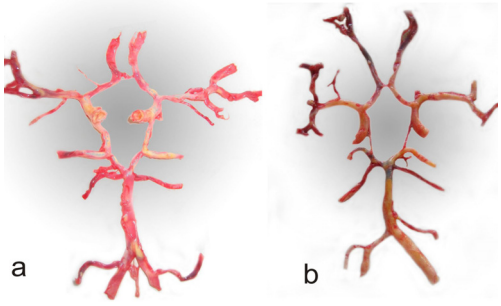

Fig. 6 – Type B of the circle of Willis.

Table 1

Type B circle of Willis changes

Change on A1	Associated changes	n	Subjects, n (%)
Hypoplasia of A1 *sin.*	Dilated ACoA	3	4
	Dilated AcoA with *a. mediana corpori callosi*	1	
Hypoplasia of A1 *dex.*	Dilated ACoA	3	5
	Dilated AcoA with *a. mediana corpori callosi*	1	
	Fenestrated ACoA	1	
Total, n (%)			9 (16)

ACoA – *a. communicans anterior.*

configuration was present in 6 (10.8%) subjects, of which 3 (5.4%) cases had mixed asymmetric subtype – B/D configuration (5.4%) (Figure 7) (Table 2). The symmetric Willis configuration was recorded in 41 (73.2%) subjects and 15 (26.8%) subjects with asymmetric Willis configuration.

Table 2

Type D – circle of Willis changes

Changes on PCoA	Associated changes	n	Subjects, n (%)
Fetal PcoA *dex*.	Hypoplasia of A1 *dex*.	2	3
Fetal PcoA *sin*.		1	
	Hypolasia of A1 *dex*.	1	
Hypolasia of PcoA *dex*.	Hypolasia *a. mediani corporis callosi*	1	3
Hypolasia of PcoA *sin*.	Hypolasia of A1 *dex*.	1	
Total n (%)			6 (10.8)

PCoA – *a. communicans posterior*; A1 – a part of *arteria cerebri inferior*.

Table 3

Symmetric circle of Willis changes

Circle of Wills	Changes of the circle of Wills	n	Subjects, n (%)
Symmetric			24 (42.8)
	Hypoplasia of PcoA bill.	9	
	Hypoplasia of PcoA bill. – *a. mediana corporis callosi*	1	
Conditionally symetric	Hypoplasia of PcoA bill – hypoplasia of ACoA	3	17 (30.4)
	Fetal PcoA bill. – *a. mediana corporis callosi*	2	
	Lnger A1 *sin*. – *a. medina corporis callosi*	1	
	Longer A1 *sin*.	1	
Total, n (%)			41 (73.2)

PCoA – *a. communicans posterior*; A1 – a part of *arteria cerebri inferior*.

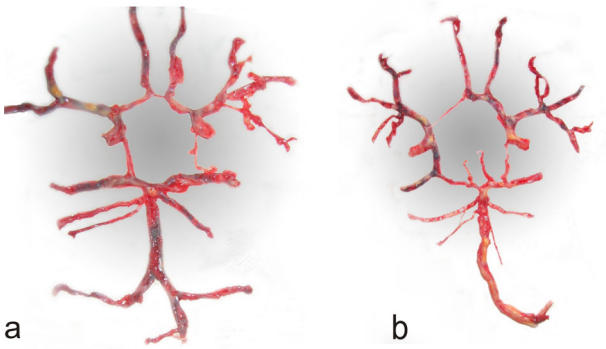

Fig. 7 – Type D and Type B/D of the circle of Willis.

The symmetric Willis group (73.2%) did not have a homogeneous finding that would fit into the schematic presentation of the symmetric Willis of type A and type C. There was a considerable deviation from the schematic presentation but this did not change the basic configuration display, 17 (30.4%) findings were classified in this group of the so-called conditionally symmetric configurations (Table 3).

The asymmetric type B configuration (16%) had in all cases a reduced A1 diameter and hyperplastic AcoA. Of this total, hypoplastic A1 *dex*. was found in 5 cases, whereas hypoplastic A1 *sin*. was detected in 4 subjects. The analysis of the asymmetric D type showed asymmetry in two cases because of the presence of unilateral fetal PCoA (one left and right), and in 4 cases because of the presence of a hypoplastic PcoA (two left and right).

Discussion

The embryological development of the cerebral blood vessels and their task to follow the development and growth of the brain parenchyma directly condition various modalities of differentiation and development of the circle of Willis [2, 7]. This leads us to conclude that we cannot talk about the normal definition of the circle of Willis, but rather about certain types of its configuration [8–11].

The presence of 26.8% of asymmetric configurations of the circle of Willis, which makes up more than one fourth of the total number of cases observed, indicates that the asymmetric configurations do not represent a pathological form of blood vessel configurations at the base of the brain, but one aspect of its adaptation (Table 4) [1, 12, 13].

Table 4

Incidence of the basic types of Willis' configuration [12–14]

Willis' configuration	Subjects, n (%)
Type A	27 (48.2)
Type B	9 (16)
Type C	14 (25)
Type D	6 (10.8)
Total, n (%)	56 (100)

In all asymmetric type B (16%) cases, hyperplasia of the AcoA was present as the adaptive process to ensure adequate perfusion because of the hypoplasia of one A1 ACA [14–16]. All this can lead to hemodynamic load and segmental dilatation of AcoA with subsequent formation of aneurysmal changes [2, 17, 18]. In addition, on the side of the Willis with the hypoplastic A1-ACA, there is a direct perfusion rush from ICA to *a. cerebri media* (ACM), ipsilaterally, which may lead to increased hemodynamic rush in the middle cerebral artery (MCA)

bifurcation area. All this suggests that type B has decreased hemodynamic reserve so, in the event of increased perfusion needs, some parts may be subjected to greater stress [19].

The asymmetric type D is without significant hemodynamic load since the asymmetric posterior segment does not result in significant hemodynamic load. However, due to the presence of asymmetry of the anterior segment as well, the asymmetric B/D type (5.4%) becomes hemodynamically loaded.

The symmetric type A was recorded in 41 (73.2%) subjects. Within this group, 17 (30,4%) subjects were found to have some kind of deviation presenting as changes to the AcoA or PCoA, or different lengths of A1-ACA, PCoA or P1-PCA. Nevertheless, these changes did not lead to deviation from the basic type of symmetric type A configuration.

The forming of the basic types of configurations of the circle of Willis is associated with a tendency toward certain types of hemodynamic disorders and more frequent pathological changes in places of reduced resistance.

Places of reduced resistance are characteristic for specific types of the circle of Willis, carrying a greater tendency towards the formation of aneurysmal changes. Symmetry or asymmetry of certain types of the circle of Willis reflect their hemodynamic characteristics in the sense of higher or lower hemodynamic reserve, which is directly related to the functionality of the collaterals and certain segments of the circle of Willis [20, 21].

Conclusion

The presence of asymmetric Willis configuration in 26.8% of the cases, which makes up more than one fourth, indicates that the asymmetric configurations do not represent a pathological form of connecting the blood vessels at the base of the brain, but rather one aspect of its adaptation. The forming of the basic types of configurations of the circle Willis is associated with a tendency toward certain types of hemodynamic disorders and more frequent pathological changes in places of reduced resistance.

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