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MAGNETIC RESONANCE ANGIOGRAPHIC EVALUATION OF CIRCLE OF WILLIS: A MORPHOLOGIC STUDY

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ABSTRACT

The circle of Willis (CoW) is considered as an important potential collateral pathway in maintaining adequate cerebral blood flow in patients with internal carotid artery (ICA) obstruction. A total of 300 healthy participants (198 men, 102 women; mean age, 55 years) who underwent three-dimensional time-of-flight (3D-TOF) MR angiograms of the circle of Willis (CoW) were obtained with the sequence of spoiled gradient-recalled acquisition (SPGR) using a 1.5-tesla MR scanner. Among the subjects studied, 184 subjects had partially complete circle of Willis, which is the commonest. Among partially complete circle of Willis, men (65.1%) are common. The commonest anterior circle variant is type A (normal anterior configuration) with a prevalence of 66%.

INTRODUCTION

The brain, though representing only 2% of the total body weight, receives one fifth of the resting cardiac output. This blood supply is carried by the two internal carotid arteries (ICA) and the two vertebral arteries that anastomose at the base of the brain to form the circle of Willis. The carotid arteries and their branches (referred to as the anterior circulation) supply the anterior portion of the brain while the vertebrobasilar system (referred to as the posterior circulation) supplies the posterior portion of the brain. Therefore, the haemodynamics in the circle of Willis is anatomically significantly different from the haemodynamics in normal branching situations addressed by the optimality principle. Accordingly, the normal physiology of flow and the likely impact of deviation from normality in the circle of Willis are not fully understood [1]. Variations in the circle of Willis significantly correlate with the relative contributions of the flow rates of proximal arteries [2].

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The development of such detour routes depends on individual morphological and hemodynamic factors. The anterior communicating artery (AComA) and (bilateral) posterior communicating arteries (PComAs) are component vessels of the CoW and are designated the primary collateral pathways. Other pathways, known as the secondary collateral pathways, may also be recruited: flow reversal through the ophthalmic arteries, reversed flow through the anterior choroidal artery, and anastomoses between the cortical branches of the intracerebral arteries (leptomeningeal collaterals), which may provide (retrograde) collateral flow to any deprived area. The collateral potential of the CoW is believed to be dependent on the presence and size of its component vessels [3,4], which vary among normal individuals [5].

Some anatomical variants might pose different hemodynamic challenges to cerebral blood flow and might thus evoke some clinical importance related to the cerebral vascular diseases [6,7]. The circle of Willis (CoW) is considered as an important potential collateral pathway in maintaining adequate cerebral blood flow in patients with internal carotid artery (ICA) obstruction. With the advances in microneurosurgery and the more effective

ability to tackle diseases of the intracranial arteries at the base of the brain (often referred to as the Circle of Willis) surgically, the accurate knowledge of the intracranial vascular anatomy is becoming increasingly important. The major arteries supplying the brain, paired internal carotid and vertebral arteries, form a unique anastomosis, the "Circle of Willis" named after Dr. Thomas Willis who first accurately described it and provided its physiological significance in 1664 [8]. Anteriorly, the anterior cerebral arteries (from internal carotids) are joined by the anterior communicating artery. Posteriorly, the basilar artery divides into two posterior cerebral arteries each joined to the ipsilateral internal carotid artery by a posterior communicating artery.

Its ability to redistribute blood flow depends on its morphology, the presence and size of the component vessels. In the embryonic period, several developmental anomalies of the cerebral arteries can occur. The knowledge of these anatomic variations in the cerebral arteries is important for the safe performance of interventional radiologic or neurosurgical procedures. Many variations have been reported [9]. There is normally no mixing of the opposing streams of blood which meet in the posterior communicating arteries at points where the pressures of the two are equal. The same applies in the middle of the anterior communicating artery. Its importance is seen in two clinical circumstances, i.e. incidental detection of occlusion of major arteries in asymptomatic cases and when surgical occlusion of a major vessel is contemplated. Fields, et al [10] have summarized these studies.

METHODOLOGY

Participants: This study was approved by the ethical committee of Narayana Hrudayalaya Institute of Medical Sciences, Bangalore. Informed consent was obtained from all participants. 300 patients who referred for, as part of health check up or neuroischemic study protocol from February 2010 to July 2011, were included in the analysis.

It is a prospective and retrospective study. A total of 300 healthy participants (198 men, 102 women; mean age, 55 years) who underwent three-dimensional time-of-flight (3D-TOF) MR angiograms of the circle of Willis (CoW) were obtained with the sequence of spoiled gradient-recalled acquisition (SPGR) using a 1.5-tesla MR scanner (Achieva; Philips Medical Systems) at the Department of Radiodiagnosis in Narayana Hrudayalaya Hospital were reviewed for evaluation of the circle of Willis configurations.

Inclusion criteria

All those patients who referred for, as part of health checkup or neuroischemic protocol in our hospital (Narayana Hrudayalaya Institute of Medical Sciences), Bangalore, from February 2010 to July 2011.

Exclusion criteria

- Patients with pacemaker, intracerebral aneurysmal clips or other metallic implants.
- Patients with severe claustrophobia.
- Severely ill, uncooperative patients who are not able to remain stable for study duration time

RESULTS

Table 1. Gender and age distribution

Age	Male	Female	Total
0-10	0	1	1
11-20	4	2	6
21-30	3	9	12
31-40	18	17	35
41-50	35	20	55
51-60	50	20	70
61-70	53	20	73
71-80	32	11	43
Total	198	102	300

Most of the patients were men 198 of 300 (66%) and female were 102 of 300 (34%).

Table 2. Gender distribution of completeness of circle of Willis

Gender	Complete	Partially complete	Incomplete
Male	21	129	48
Female	29	55	18
Total	50	184	66

Gender and age distribution of subjects studied: Among the subjects studied, Most of the patients were men 198 of 300 (66%) and female were 102 of 300 (34%). Common age groups is 51-60 yrs and 61-70 yrs with 70 and 73 in number respectively. The least in 0-10 yr with one patient aged 9 yrs. The oldest patient is aged 90 yr.

Table 3. Age distribution of anterior and posterior parts of circle of Willis

Both complete	Male	21
	Female	29
	Total	50
Anterior circulation	Male	148
	Female	84
	Total	232
Posterior circulation	Male	22
	Female	29
	Total	51

Gender distribution of complete, partially complete and incomplete distribution of circle of Willis was studied. Among the subjects studied, 184 subjects had partially complete circle of Willis, which is the commonest. Among partially complete circle of Willis, men (65.1%) are common. Complete and incomplete circle of Willis are less common, 16.6 % and 22 % respectively.

DISCUSSION

Magnetic resonance angiography (MRA) has demonstrated high sensitivity in evaluation of component vessels in the circle of Willis [11]. 3D time-of-flight MRA allows real-life visualization and measurement of collateral flow in the circle of Willis, the technique is not without limitations. Because the sensitivity of 3D time-of-flight MRA depends on the blood flow velocity of the vessel, the technique may have difficulties in visualizing small vessels in the circle of Willis with slow or turbulent flow [12]. The configuration of the circle of Willis in patients has been investigated in many studies. However, there are only a few studies that have systematically investigated the configuration of the circle of Willis in a general population.

The present study focuses on the presence of normal anatomical variants of the Circle of Willis by analyzing the magnetic resonance angiographies of 300 subjects (males n=198, females n=102). The results were compared with some published studies. Most of the studies considered the following vessels forming part of the circle of Willis: the Anterior communicating Artery (AcomA), the precommunicating segment (A1) of the Anterior Cerebral Artery (ACA), the precommunicating segment (P1) of the Posterior Cerebral Arteries (PCA), the posterior communicating arteries (PcomA) and the Internal Carotid Artery (ICA) because they are the most commonly affected vessels. Out of the 300 cases 198 were males and 102 were females.

In previous studies, the prevalence of a complete anterior circle varied from 74% to 90% in different ethnic groups. Alpers and Berry [13] reported that only 33% of autopsy brains demonstrated a normal configuration of the CoW. Riggs and Rupp [14] investigated autopsy brains taken from adults classified only 21% of the arterial circles as normal. In Monique J. Krabbe-Hartkamp study, 63 (42%) demonstrated an entirely complete circle of Willis (complete anterior and posterior parts of the circle combined). Jeroen van der Grond; patients demonstrated a significantly higher percentage of entirely complete CW configurations (55% versus 36%, p=0.02). Hsin Wen Chen study, 89 (21.30%) cases demonstrate entire configuration of the Circle. Higher prevalence of complete circle of Willis was found in younger group (36.04% of younger subjects versus 17.17% of older subjects) and in females (26.69% of women versus 15.35% of men). Mohamed and co worker study, entirely complete CoW was seen in 46.7%. In the present study, the prevalence of entirely complete CoW was higher in females than males (28.4% and 10.6% respectively) and young than older subjects (33.9% and 6.8% respectively).

Kanchan Kapoor study, out of 1000 subjects examined, 452 (45.2%) conformed to the typical pattern. In the rest of the specimens (54.8%) there were variations in the circle of Willis. In Qi Li and co-worker, a complete circle of Willis was seen in 43 of 160 participants (27%). In Suemoto and co-worker, the frequency of normal circulation of CoW varies from 11% to 58%. In the study the entire complete circle of Willis is seen in 29.6%. The major difference is the percentage of a complete-configured CoW, which ranges from 21%[5] to 52% [13] in autopsy studies. Several reasons could account for this variation. First, the objects selection difference; healthy volunteers are included in some studies with normal brains or brains without vascular disorders or even from those with neurological disease were used in other autopsy studies [15]. Second, different observation method; Phase-contrasted MR angiography also has been used [16]. Third, the criteria for a complete-circled configuration difference. We applied the criterion of the vessel diameter less than 0.8 mm as absence in determining the prevalence of various anatomical variants. Some autopsy studies used 1 mm as their lower limit [13,15]. Although TOF-MRA demonstrates high sensitivity in detecting intracranial arteries, this technique does have its disadvantages. Slow or turbulent flow may not be demonstrated in the TOF-MRA images, even though the vessels are patent. Therefore, the prevalence of the complete-configured circle may be underestimated. The incidence of incomplete configuration of the circle is 22%. In these variations, a single major artery such as the internal carotid artery supplying several cerebral arterial territories, with little collateral flow provided by other arteries,

should be noteworthy. Such variation, called isolated circulation, is important to be noted for preoperative surgical planning, especially when temporary or permanent occlusion of the parent artery is anticipated. For example, temporary occlusion of the internal carotid artery during carotid endarterectomy would take the risk of ischemic insult in the watershed area between these separately perfused territories.

CONCLUSION

The morphological variations demonstrated in our study providing an important reference value for the 3D-TOF MR angiography. Our findings show that the configuration of the CoW may vary largely in general population.

The prevalence of complete configuration of the circle is 16.6% and is slightly higher in females than males and younger (below 50 yrs) than older subjects. In the present study the complete anterior circle of Willis is common with 77.3% of all the subjects.

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CONFLICT OF INTEREST:

The authors declare that they have no conflict of interest.

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