Normal Variants of Circle of Willis in MR Angiography among Puducherry Population

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Abstract

Introduction: Circle of Willis is the great arterial anastomotic ring at the base of the brain and is an important pathway to maintain adequate blood supply to the brain. In case of arterial occlusion, it is the important source of collaterals to the occluded territory. A detailed knowledge of the normal anatomy of circle of Willis, its anomalies and clinical significance helps the neurosurgeon for planning and keeps away from vascular trauma during surgeries.

Materials and Methods: A retrospective study was conducted on 312 patients (188 men and 124 women). 3 dimensional time of flight Magnetic resonance angiogram technique was used. Variations in the Circle of Willis were evaluated.

Results: The findings show that majority of circle showed anomalies. Percentage of complete circle was slightly higher in males and young subjects. Normal variants are more common in anterior part of the circle and the most common normal variant is the absent anterior communicating artery (34%).

Conclusion: Magnetic resonance angiogram is the sensitive technique for detecting the anatomy of Circle of Willis. Variations in anterior circulation may be asymptomatic and may reduce complications. Knowledge of the presence of Circle of Willis and its variants plays an important role in planning of neurological procedures or may be mistaken for pathologies.

Keywords: Anomalies, absent anterior communicating artery, 3-dimensional time of flight.

Introduction

The human brain represents 2% of body weight. It is supplied by two major arteries, paired internal carotid arteries and vertebral arteries. These vessels form an anastomosis among their branches to supply the various parts of brain and its coverings which is commonly called circle of Willis named after Dr. Thomas Willis who first described the function of arterial anastomosis in 1966. Arteries forming the circle are Internal Carotid Artery, Anterior cerebral and Anterior communicating arteries, Posterior cerebral and Posterior communicating arteries.

Based on recent anatomical and radiological studies it has been proved that normal variations in Circle of Willis are more common in healthy individuals. These variations occur during the process of vasculogenesis. Many studies have been carried out to assess the different variants using various methods including autopsy, Angiography and Magnetic resonance imaging. Knowledge of the presence of normal variants such as fenestrations, duplications, and persistent fetal arteries plays an important role in the diagnosis of arterial malformations and helps in surgical planning.
MR angiography is used in various institutions for initial evaluation of the cerebral circulation. It is also used in assessment of patients with acute stroke and subarachnoid haemorrhage. It is a non-invasive procedure and does not require any contrast injection. The aim of this study was to assess the normal variants of the Circle of Willis in patients who underwent MRI Brain for various reasons.

Materials and Methods
A retrospective study was undertaken in the Department of Radiodiagnosis of SMVMCH, Puducherry. Patients who were included in the study were those who underwent MRI Brain as a part of their health check-up was included in this study. Clearance from Institutional Ethical committee was obtained for this study. Patients with clinical manifestations of cerebrovascular accidents, metallic aneurysm clips, cardiac pacemakers and other metallic implants were excluded. The study included subjects of all age and gender in Puducherry. The 3-dimensional time of flight MR angiograms of Circle of Willis of 312 patients at random were considered for the study. They were aged between 12 and 75 years.

Scan technique
All the patients were examined with 3-dimensional time of flight Magnetic resonance angiography. The study was performed with 1.5 tesla MR machine (Intera, Philips medical systems). A standard head coil was used for angiography. The Magnetic resonance angiography protocol consisted of non-contrast 3-dimensional time of flight transaxial acquisition which was used for examination of all patients with the following parameters (TR /TE /FA (25 /6.91ms /20). Rectangular field of view (FOV) 200 mm, matrix size 560 with slice thickness of 0.8 mm and 160 partitions with the total imaged volume (effective slab thickness) 72 mm. To obtain the best resolution in the section selection direction, the smallest possible slice thickness was used using matrix size 192 x 256; this resulted in an anisotropic voxel size of 0.503 x 0.88x 0.5 mm³ in plane resolution and 0.8 mm slice thickness. The post-processing algorithm, maximum intensity projection (MIP) was used to produce angiographic-like images at 5 degree increments generating 12 MIP projections. The study participants were divided into two groups based on their age, i.e. those who were < 40 in one group and ≥ 40 as another. The variants were analysed based on the following criteria:
- Normal – presence of complete circle
- Absent anterior communicating artery
- Hypoplastic A1 segment – under development of A1 segment
- Absent A1 segment
- Others - variants like azygous anterior cerebral artery, unilateral fetal type PCA, bilateral fetal type PCA and combination of variants.

Figure 1 Three dimensional time-of-flight magnetic resonance (MR) angiogram of the normal CW

Figure 2: Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Absent anterior communicating artery
**Figure 3:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Hypoplasia of A1 segment

**Figure 4:** Three dimensional time of flight magnetic resonance (MR) angiogram of the Absent A1 segment:

**Figure 5:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Azygous anterior cerebral artery:

**Figure 6:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Trifurcation of anterior cerebral artery:

**Figure 7:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Fenestration of A1 segment

**Figure 8:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Bilateral fetal type Posterior cerebral artery
Results

In this present study we have studied retrospectively angiographic findings of Circle of Willis in 312 cases of which 188 (60.25%) were males and 124(39.75%) were females. Among the cases studied anatomical variations in anterior cerebral circulation was detected in 178 cases, posterior cerebral circulation in 28 cases and normal classical pattern in rest 106 cases. In present study we found absent anterior communicating artery in 110 cases (34%), absent A1 segment in 33 cases (10.9%), hypoplastic A1 segment in 31 cases (9.7%), and other anomalies (fenestrations, duplications, azygous anterior cerebral artery, Trifurcation of anterior cerebral artery, Bilateral fetal type Posterior cerebral artery, Anterior cerebral artery forms a common trunk and split distally into two communicating segments, Unilateral fetal type Posterior cerebral artery).

On analysing the parameters the commonest variant reported was absent anterior communicating artery. This finding was observed more in the age group ≥ 40 years. No significant difference was noted with regard to gender (the percentage of variants other than the normal were 65.34% in males and 65.17 % in females). The percentage of normal variants was 69.56 % (34.66% in males and 36.9 % in females) which is in agreement with the other studies.

Gender Distribution

It was found that there was mild increase in the normal variants in male when compared to females. Out of the 312 patients taken up for this study, male were found to be 188 (60.25%) and female were found to be 124 (39.74 %)

Male

Table 1 shows the percentage of normal variations in male population

<table>
<thead>
<tr>
<th>Variants</th>
<th>&lt;40 years</th>
<th>≥40 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>34 (40.47%)</td>
<td>30 (28.84%)</td>
</tr>
<tr>
<td>Absent anterior</td>
<td>23 (27.38%)</td>
<td>45 (43.26%)</td>
</tr>
<tr>
<td>communicating A1 segment</td>
<td>06 (7.14%)</td>
<td>12 (11.53%)</td>
</tr>
<tr>
<td>Hypoplastic A1 segment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absent A1 segment</td>
<td>09 (10.71%)</td>
<td>07 (6.73%)</td>
</tr>
<tr>
<td>Others</td>
<td>12 (14.28%)</td>
<td>10 (9.61%)</td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
<td>104</td>
</tr>
</tbody>
</table>

Female

Table 2 shows the percentage of normal variations in female population

<table>
<thead>
<tr>
<th>Variants</th>
<th>&lt;40 years</th>
<th>≥40 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>18 (39.13%)</td>
<td>24 (30.76%)</td>
</tr>
<tr>
<td>Absent anterior</td>
<td>13 (28.26%)</td>
<td>29 (37.17%)</td>
</tr>
<tr>
<td>communicating A1 segment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypoplastic A1 segment</td>
<td>04 (8.69%)</td>
<td>09 (11.53%)</td>
</tr>
<tr>
<td>Absent A1 segment</td>
<td>05 (10.86%)</td>
<td>12 (15.38%)</td>
</tr>
<tr>
<td>Others</td>
<td>06 (13.04%)</td>
<td>04 (5.12%)</td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>78</td>
</tr>
</tbody>
</table>
Discussion

Thomas Willis (1621-1675) in his book Cerebri Anatome in 1664, the history of the arterial Circle of Willis goes back to Hetrophilus, who discovered a structure which he called as 'retemirabile'; later on, Galen mentioned that the carotid arteries run in the neck and enter the cranium and gives of two cerebral arteries to supply the brain. The first reasonable and correct description of basal arterial ramification was given by Fallopius (1523–62) except for the posterior communicating artery which he thought to be indirectly connected with the internal carotid artery through a network of small arteries. Later this mistake was rectified by Casserius (1561–1616) unilaterall. Since first described by Thomas Willis, the cerebral arterial circle has been the subject of multiple investigations[17,18].

Anatomical variations of circle of Willis in the inter peduncular at the base of the brain are very common incidental finding on MR angiographic studies. Vascular imaging with MRA or CT angiography coupled with perfusion imaging provides complementary information that is used to diagnose and make treatment decisions in acute stroke. Usually patients are asymptomatic but recognition of these variants is important for planning surgery and endovascular treatment planning. Even though they are clinically insignificant some may predispose the patient to development of aneurysms or ischemic events.

In this study, it is demonstrated that the percentage of entire complete circle of Willis was seen in 34.8%, this results cope with the results of published studies by krabbe et al [4] and Hafez KA[8] et al which showed complete circle in 36% and 45%. The anterior circle configurations were complete in 30.12 % of cases in this study, and results reported by other studies shows 68–78%. Several factors influence the variations in the results. First, the study populations differ (studies performed in normal brain versus those performed in patients with CVA). Second the different methods and technique used such as anatomic dissection at autopsy versus conventional catheter angiography, versus phase contrast or TOF MR Angiography. Third, the variations in the age and gender distributions in the selected study population. In our study, complete circle of Willis was higher in age group of <40 yrs than in the age group >40yrs which has been in line with other studies. The percentage of the complete circle >40yrs in our study was higher in females (30.76%) than males (28.84%) these results cope with the results of published studies by Hafez et al, Chen et al, and Hartkamp et al[8,7,4]. All of these studies used 3-dimensional time of flight Magnetic resonance angiography in examination of the circle of Willis. There are some limitations in displaying small collateral channels because of the turbulent flow, saturation effect of slow flow or long in-plane flow, or slower velocity of blood adjacent to the wall due to laminar flow[15]. Since an increase in flow velocity improves signal intensity which increases the sensitivity of 3-dimensional time of flight Magnetic resonance angiography in detection of small communicating vessels. Negligible or slow flow within a patent vessel or vessel aplasia are not visualized on a time of flight Magnetic resonance angiography. The lower limit of normal vessel diameters is arbitrary and affects the number of vessel segments classified as hypoplastic, which also affects the prevalence of circles, defined as complete[4,16].

Conclusion

The study shows that variants are not uncommon. Anterior communicating artery complex is the most frequent site of intracranial aneurysms frequently present with subarachnoid haemorrhage. Due to its angio architecture and flow dynamics of the anterior communicating artery region, frequent anatomical variations, deep inter hemispheric location, and danger of severing the perforators with ensuing deficits. Knowledge of the presence of normal variants plays an important role in the diagnosis of arterial malformations and helps in surgical planning.
References