A STUDY OF CIRCLE OF WILLIS BY MR ANGIOGRAPHY

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ABSTRACT

Introduction: The arterial Circle of Willis at the base of the brain serves as a potential collateral pathway, which will maintain adequate cerebral perfusion in the case of diminished afferent blood supply through internal carotid and basilar arteries.

Aim: 1. The present study aims to assess the normal mean diameter of the vessels forming Circle of Willis. 2. To compare the normal mean diameter of the vessels forming Circle of Willis in age and gender.

Material and Methods: Circle of Willis of 100 healthy persons were examined with the help of 3D-TOF MR Angiography of brain. 74 individuals were aged 18-60 years and 26 individuals were aged above 60 years of either sex. All component vessels of the circle were assessed by measuring the diameter. Sections of the vessels that were visualized as continuous segment for at least 0.8mm in diameter were considered to be normal, those smaller than 0.8mm in diameter were considered hypoplastic.

Result: The normal mean diameter of the anterior and posterior cerebral arteries was more or less equal i.e.1.32mm. Internal carotid artery was found to be large i.e.2.70mm and communicating artery was 0.97mm. The diameters of the blood vessels forming circle of Willis were larger in males than in females.

The diameters of the centripetal arteries i.e. Internal carotid artery are larger in older age group while those of centrifugal arteries is smaller.

Conclusion: The present study is an observational study; the data of this study can be helpful to the neurosurgeon in the selection of patient as well as assessing the feasibility of shunt operation.

KEY WORDS: Circle of Willis, 3D TOF MR Angiography, Centripetal Arteries, Centrifugal Arteries, Shunt Operation.

INTRODUCTION

Brain is highly metabolic organ; it requires constant supply of blood. The major arteries supplying the cerebrum are joined to one another at the base of the brain in the form of an arterial circle or circle of Willis. The arteries which form the circle of Willis are the branches of internal carotid artery and the basilar artery. The cerebral arterial circle is an arterial wreath encircling the optic chiasma, the tuber cinerium in the cistern interpeduncularis. The arterial circle is formed by Anteriorly anterior communicating artery, Anterolaterally right and left anterior cerebral arteries, Laterally
proximal segment of right and left internal carotid arteries, Posterolaterally - right and left posterior communicating arteries, Posteriorly proximal segment of right and left posterior cerebral arteries, which are derived from the bifurcating terminals of the basilar artery.

The cerebral arterial circle is set to equalize the blood flow to various parts of the brain, but normally there is little exchange of blood between right and left sides of arterial circles because of the equality of blood pressure [1,2].

Magnetic Resonance Angiography (MRA) has been evaluated into an attractive and non radiation dependant alternative for imaging of the intracranial vasculature [3,4]. Though many workers have reported abnormalities in the diameter of vessels of Circle of Willis, the normal diameter of these vessels have not been reported. The vessels have been described as narrow, thread like etc, but the actual diameters have rarely been measured. The knowledge of size of these vessels is helpful to the surgeon in selection of patients as well as assessing the feasibility of shunt operation. An attempt has been made to study the normal anatomy of Circle of Willis by MR Angiography.

MATERIALS AND METHODS

Material used for the study is MR Angiography machine “PHILIPS MR ACHIEVA (1.5T)”. Analysis of image: As MR Angiography was being performed, all the images were transferred to a dedicated workstation.

All component vessels of the circle were assessed by measuring their diameter. The section of vessels that were visualized as continuous segment for at least 0.8mm in diameter were considered normal, those smaller than 0.8mm in diameter were considered hypoplastic and those segments, which were not visualized, were considered as absent [5].

The measurements were done with help of Dicomworks software installed in the computer.

The diameters of the vessels were measured where they formed part of the circle of Willis, internal carotid arteries were measured 1mm before origin of posterior communicating arteries. Anterior cerebral and posterior cerebral arteries were measured 2mm away from their origin. Posterior communicating arteries were measured 3mm away from their origin and anterior communicating artery measured midway between the two anterior cerebral arteries [5].

Fig. 1: Complete Circle of Willis.

Fig. 2: Complete Circle of Willis with Diameters of Anterior Communicating Artery (Acom), Left Anterior Cerebral Artery (LAC), Right Internal Carotid Artery (RIC), And Right Posterior Cerebral Artery (RPC).
The diameters of the blood vessels forming circle of Willis is larger in males than in females except posterior communicating arteries.

**Table 3:** Comparison of mean diameter of vessels which form Circle of Willis in less than 60yrs and more than 60yrs age group.

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Age group</th>
<th>No.</th>
<th>Mean diameter (mm)</th>
<th>Std. Dev</th>
<th>S E of Mean</th>
<th>Unpaired t test</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACA</td>
<td>Less than 60</td>
<td>70</td>
<td>1.33</td>
<td>0.2</td>
<td>0.03</td>
<td>1.45</td>
<td>0.229</td>
</tr>
<tr>
<td>PCA</td>
<td>Less than 60</td>
<td>67</td>
<td>1.32</td>
<td>0.3</td>
<td>0.04</td>
<td>0.471</td>
<td>0.642</td>
</tr>
<tr>
<td>ICA</td>
<td>Less than 60</td>
<td>74</td>
<td>2.66</td>
<td>0.4</td>
<td>0.059</td>
<td>1.431</td>
<td>0.194</td>
</tr>
<tr>
<td>Acom</td>
<td>Less than 60</td>
<td>26</td>
<td>2.81</td>
<td>0.5</td>
<td>0.11</td>
<td>Difference is not significant</td>
<td></td>
</tr>
<tr>
<td>RAC</td>
<td>More than 60</td>
<td>26</td>
<td>0.98</td>
<td>0.2</td>
<td>0.007</td>
<td>0.296</td>
<td>0.772</td>
</tr>
<tr>
<td>LPC</td>
<td>More than 60</td>
<td>8</td>
<td>0.95</td>
<td>0.1</td>
<td>0.072</td>
<td>Difference is not significant</td>
<td></td>
</tr>
<tr>
<td>LRCom</td>
<td>More than 60</td>
<td>48</td>
<td>0.99</td>
<td>0.2</td>
<td>1</td>
<td>1.429</td>
<td>0.158</td>
</tr>
<tr>
<td>LPCom</td>
<td>More than 60</td>
<td>16</td>
<td>0.93</td>
<td>0.03</td>
<td>0.95</td>
<td>Difference is not significant</td>
<td></td>
</tr>
</tbody>
</table>

The diameters of the centripetal arteries i.e. Internal carotid artery is larger in older age group while those of centrifugal arteries (i.e. anterior cerebral artery, posterior cerebral artery and communicating artery) is smaller except posterior cerebral artery which is larger in older age group.

**DISCUSSION**

**Table 4:** Comparison of diameter of blood vessels forming circle of Willis with previous studies. (Diameter in mm).

<table>
<thead>
<tr>
<th>Author and year</th>
<th>ACA</th>
<th>PCA</th>
<th>ICA</th>
<th>Acom</th>
<th>PCom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kamath S (1981)</td>
<td>2.3</td>
<td>2.1</td>
<td>4.2</td>
<td>1.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Krabbe-Hartkamp MJ et al (1998)</td>
<td>1.9</td>
<td>1.9</td>
<td>3.7</td>
<td>1.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Hartkamp MJ et al (2000)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.1</td>
<td>1.3</td>
</tr>
<tr>
<td>Present study</td>
<td>1.31</td>
<td>1.32</td>
<td>2.69</td>
<td>0.98</td>
<td>0.96</td>
</tr>
</tbody>
</table>

The diameter of the anterior cerebral artery studied by Kamath S [6] by dissection method is greater by 0.99mm and by Krabbe-Hartkamp MJ et al [5] by MR A angiography is greater by 0.59mm than the present study. The diameter of the posterior cerebral artery studied by Kamath S [6] by dissection method is greater by 0.68mm and by Krabbe-Hartkamp MJ et al [5] by MRA study is greater by 0.99mm than the present study.
The diameter of the internal carotid artery studied by Kamath S [6] by dissection method is greater by 1.51mm and by Krabbe-Hartkamp MJ et al5 by MRA study is greater by 0.42mm and by Hartkamp MJ et al [3] by MRA study is greater by 0.12mm than the present study. The diameter of the posterior communicating artery studied by Kamath S [6] by dissection method is greater by 0.44mm, by Krabbe-Hartkamp MJ et al5 by MRA study is greater by 0.24mm and by Hartkamp MJ et al [3] by MRA study is greater by 0.34mm than the present study.

Table 5: Comparison of sex related differences in the mean diameter of blood vessels forming circle of Willis with previous studies.

<table>
<thead>
<tr>
<th>Author and year</th>
<th>ACA</th>
<th>PCA</th>
<th>ICA</th>
<th>Acom.</th>
<th>PCom.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krabbe-Hartkamp MJ et al [1998] 3D-TOF-MRA</td>
<td>1.95</td>
<td>1.95</td>
<td>1.95</td>
<td>1.95</td>
<td>1.95</td>
</tr>
<tr>
<td>HSIN-WEN CHEN et al [2004] 3D-TOF-MRA</td>
<td>1.95</td>
<td>1.95</td>
<td>1.95</td>
<td>1.95</td>
<td>1.95</td>
</tr>
<tr>
<td>Present study by MR Angiography method</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
</tr>
</tbody>
</table>

The diameter of the anterior cerebral artery studied by Krabbe-Hartkamp MJ et al [5] by MRA method as well as by present study is more in < 60yrs age group than in > 60yrs age group and the difference is statistically significant in both studies. The diameter of the posterior cerebral artery studied by Krabbe-Hartkamp MJ et al5 by MRA method was more in < 60yrs age group than in > 60yrs age group but in the present study it is more in > 60yrs age group than in < 60yrs age group.

The diameter of the internal carotid artery studied by Krabbe-Hartkamp MJ et al [5] (1998) by MRA method as well as by present study is more in > 60yrs age group than in < 60 yrs age group but the difference is statistically significant only in Krabbe-Hartkamp MJ et al [5] study.

The diameter of the anterior communicating artery studied by Krabbe-Hartkamp MJ et al [5] (1998) by MRA method as well as by present study is more in < 60yrs age group than in > 60yrs age group. The diameter of the posterior communicating artery studied by Krabbe-Hartkamp MJ et al [5] by MRA method as well as by present study is more in < 60yrs age group than in > 60yrs age group but the difference between them is statistically significant only in Krabbe-Hartkamp MJ et al [5] study.

Justification: The diameter of centripetal vessels tends to be larger in older individuals, while that of centrifugal vessels tends to be smaller. This
might be explained in terms of compensatory enlargement of centripetal vessels in elderly persons in reaction to decreased cardiac output, decreased wall elasticity or atherosclerosis, of which prevalence is known to increase with age [5].

These factors may also account for the lower velocity of blood flow in the vessels of older individuals. Three dimensional time of flight MR Angiography depends on the blood flow velocity in the vessels. Blood flow rate in centrifugal vessels decrease with age. This is known to cause signal intensity loss at three dimensional time of flight MR Angiography and therefore smaller diameters of centrifugal vessels are measured.

CONCLUSION

The normal mean diameter of the anterior cerebral artery is 1.31mm (SD 0.2) and posterior cerebral artery is 1.32mm (SD 0.3), normal mean diameter of the internal carotid artery is 2.70mm (SD 0.5), normal mean diameter of the posterior communicating artery is 0.96mm (SD 0.2) and anterior communicating artery is 0.98 (SD 0.01). The diameters of the blood vessels forming circle of Willis is larger in males than in females except posterior communicating arteries. Diameters of the centripetal arteries i.e. Internal carotid artery is larger in older age group while those of centrifugal arteries (i.e. anterior cerebral artery, posterior cerebral artery and communicating artery) is smaller except posterior cerebral artery which is larger in older age group.

The present study was an observational study; the data of this study can be helpful to the neurosurgeons in the selection of patient as well as assessing the feasibility of shunt operation.

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REFERENCES


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