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Normal Variants of the Circle of Willis in patients undergoing CT Angiography

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ABSTRACT

Background & Objectives: The Circle of Willis represents the important anastomotic cerebral vessels at the base of the brain. Variation in the Circle of Willis is common. A complete or normal Circle of Willis varies widely in the literature. As no prior data on the variations of Circle of Willis is available on Nepalese population, this study was undertaken in patients undergoing CT Angiography. **Materials & Methods:** During the period July 2016 till Dec 2016, 65 patients who were referred for brain CT Angiography (Toshiba Aquilion Prime 160 slice Multi Detector CT scanner) from medicine, neurology and neuro-surgery were included in the study. CT scans were taken from the base of skull to the vertex. In addition to the axial source data, post-processed multiplanar reformatted (MPR), maximum-intensity projection (MIP), and 3D volume-rendering (VR) images were evaluated. **Results:** Of the 65 patients who underwent CT Angiography a normal or complete Circle of Willis was seen in only 35.4 % (23 patients). The most common variant of the Circle of Willis was a hypoplastic Pcom seen in 26.2 % (17 patients). This was followed by fetal origin of PCA seen in 13.8 % (9 patients). An absent Pcom and hypoplastic / absent Acom was in 12.3 % each (8 patients each). **Conclusion:** Variation in the Circle of Willis is common. Variations in the posterior portion of the Circle of Willis are more common than the anterior portion.

Key words: Circle of Willis; CT Angiography; Variants

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INTRODUCTION

The brain, though representing only 2% of the total body weight, receives one fifth of the resting cardiac output. 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 in 1664.[1]

One of the structures among many parts of human body that is known to exhibit considerable anatomical variability is the Circle of Willis. A complete Circle of Willis consists of pre-communicating segments of right and left anterior cerebral arteries (ACA), joined by the anterior communicating artery (Acom); posteriorly, pre-communicating segments of right and left posterior cerebral arteries (PCA) which are connected to the corresponding internal carotid arteries by posterior communicating arteries (Pcom). The prevalence of this 'typical or classic circle', the "normal" textbook polygon ranges from 4.6% to 72.2%. 2

The variations of Circle of Willis are of paramount clinical importance. For instance, a narrower carotid siphon or the presence of a fetal-type Pcom may alter hemodynamic stress and con-sequently influence the formation of both Pcom and Acom aneurysms in susceptible individuals.[3] The Circle of Willis is also the main route for collateral blood flow in severe occlusive diseases of the internal carotid artery. Those patients with variants of the circle with efficient collateral circulation have a lower risk of transient ischemic attack and stroke than that of patients without such collaterals.[4, 5]

CT angiography (CTA) allows reliable non-invasive evaluation of the intracranial arteries. Moreover, CTA provides useful information about anatomical variations of cerebral circulation, with reported high

sensitivity and specificity (81–90% and 93%, respectively), approaching the diagnostic accuracy of digital subtraction angiography.[6]

This study was undertaken in College of Medical Sciences-Teaching Hospital as no data or study is available in Nepalese population regarding the normal variants of Circle of Willis. The data from this study was then compared to the reported incidence of normal variants in other population studies.

MATERIALS AND METHODS

During the period July 2016 till Dec 2016, 65 patients who were referred to the Department of Radiodiagnosis, College of Medical Sciences-Teaching Hospital for brain CTA from medicine, neurology and neuro-surgery were included. Patients who were excluded from the study were patients with skull base tumors, brain vascular malformations and congenital brain abnormalities.

Prior to CT, patient was preferably advised for NPO for at least four to six hours. CTA examinations were performed by using 160-detector scanner (Toshiba Aquilion Prime). In our standard CT protocol for brain examinations, a scanogram area from the skull base to the vertex level in a supine position was adopted as field of view (FOV). During examination, an 18 to 20 gauge angiocath in the antecubital vein was used to inject 70 to 100 mL of nonionic iodinated contrast media (370 mg/ml) using bolus-tracking method with an automatic injector at a rate of 5 mL/sec. The region of interest was positioned at the aortic arch, and the threshold for CT angiography was set as 150 HU. When the threshold was surpassed, helical scanning was automatically initiated. The obtained axial images from CT were transferred to a workstation for analysis. In addition to the axial source data, post-processed multiplanar reformatted (MPR), maximum-intensity projection (MIP), and 3D volume-rendering (VR) images were evaluated.

Table 1. Incidence of the normal variants of Circle of Willis

Variants of circle of Willis	No. of patients (n=65) (%)
Complete Circle	23 (35.4 %)
Hypoplastic Pcom	17 (26.2 %)
Fetal origin PCA	09 (13.8 %)
Absent Pcom	08 (12.3 %)
Hypoplastic / absent Acom	08 (12.3 %)

RESULTS

A total of 65 patients (35 males and 30 females) were referred for CTA. The age ranged from 18 to 75 years. Most of the patients indicated for CTA were due to spontaneous intracranial / subarachnoid hemorrhage or incidental discovery of aneurysm on brain CT.

As shown in Table 1, out of the 65 patients who underwent CTA, a normal or complete Circle of Willis was seen in 35.4 % (23 patients).

The most common variant of the circle of Willis was a hypoplastic Pcom seen in 26.2 % (17 patients). This was followed by fetal origin of PCA seen in 13.8 % (9 patients).

An absent P com and hypoplastic / absent Acom was in 12.3 % each (8 patients each). Because it was sometimes difficult to evaluate whether Acom is hypoplastic or absent on CTA, both this variant was grouped together.

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 'rete mirabile'; later on, Galen mentioned that the carotid arteries run in the neck and enter the cranium forming 'rete mirabile' (wonderful net), giving two cerebral arteries to supply the brain. Fallopius (1523–62) gave the first reasonably correct description of basal arterial ramifications except for the posterior communicating artery which he thought to be indirectly connected with the internal carotid artery through a network of small arteries. Casserius (1561– 1616) corrected this mistake unilaterally.[7,8]

Since first described by Thomas Willis, the cerebral arterial circle has been the subject of multiple investigations.

In this present study, a complete or normal Circle of Willis was seen in 23 of the 65 patients (35.4 %). In a study of 200 patients by Hashemi et al, 69 (34.5%) had a typical anatomy of the Circle of Willis which was almost similar to our findings. In the remaining 65.5%, there were variations in the Circle of Willis.[9]

In contrast, in a study by Klimek-Piotrowska et al[10] in 250 subjects, the prevalence of a normal Circle of Willis constituted only a minority of cases in a healthy population (16.80%). In an autopsy study of the human brain by Sinha et al[11] in India, 62 out of total 80 specimens (77.5%), the classic form of Circle of Willis that was complete, symmetrical and

normal caliber was found. The rest 18 specimens (22.5%) of human brain were stamped as variant. Thus the incidence of a complete or normal Circle of Willis varied among different studies.

The most common variant of the circle of Willis in this present study was a hypoplastic Pcom which was seen in 26.2 % (17 patients). An absent Pcom was seen in 12 .3 % (8 patients). Thus the posterior circulation of the Circle of Willis was deficient in 38.5% (25 patients).

Similarly, Sinha et al[11] also noted that the most common variation in their autopsy series was seen in the Pcom (10%), most common type of variation being hypoplasia (6.25 %) and absent or aplastic in 3.75 %.

Pcom was seen to exhibit maximum instances of abnormalities resulting in anomalous circle. These observations corroborate with those of Windle BCA and Romanes CJ who emphasized that the majority of anomalies occur in the posterior
portion of the Circle of Willis, particularly in the Pcom.[12,13]

An anatomic variant of the PCA, known as fetal-type or fetal PCA, has been detected by anatomic and angiographic studies in 11% to 46% of adult humans, either unilaterally or bilaterally.[14] In our study, fetal origin of PCA was the second most common variant seen in 13.8 % (nine patients).

Noninvasive imaging studies often fail to visualize the Acom, but it does not mean that this artery is absent. Based on examination during surgical procedures reported incidence of this variant (Acom hypoplasia / absent) is estimated at 5%.15 Hypoplastic / absent Acom was seen in eight patients (12.3 %) in this study. Sinha et al noted absent Acom in 1.25 % in autopsy study of the human brain.[11]

CONCLUSION

Variation in the Circle of Willis is common and varies among different studies. Variations in the posterior portion of the Circle of Willis are more common than the anterior portion in most patients.

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