Evaluating the circle of Willis aneurysms location and relationship with its variations by multi detector CT angiography

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Abstract: Computed tomography angiography (CTA) is increasingly used for non-invasive imaging of the cerebrovascular diseases. This study aimed at evaluating the circle of Willis location and relationship with its variations by multi detector CT angiography. This descriptive analytical study was conducted on 240 healthy participants who underwent 64-section CTA All participants underwent cranial CTA with a 64-section multidetector CT scanner All component vessels at the circle of Willis were assessed in each individual. In interpretation of the CT angiograms, the observer assessed the presence or absence of each arterial segment in the circle of Willis. A complete circle of Willis was seen in 68 (28.3%) of 240 subjects. An incomplete anterior and posterior circle of Willis was found in 36 (15%) of 240 subjects. The remaining 136 (56.6%) subjects had partially complete circle of Willis configuration. The most common type of circle of Willis in a single subject was anterior variant A and posterior variant E. A higher prevalence of compromised posterior collaterals was observed in this Iranian population compared to western populations.

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1. Introduction

The Circle of Willis is a circulatory anastomosis that supplies blood to the brain and surrounding structures. The arrangement of the brain's arteries into the Circle of Willis creates redundancies or collaterals in the cerebral circulation.(Hamidi et al. 2013; Willis et al. 2013) If one part of the circle becomes blocked or narrowed or one of the arteries supplying the circle is blocked or narrowed, blood flow from the other blood vessels can often preserve the cerebral perfusion well enough to avoid the symptoms of ischemia.(Zamir et al. 2012; Kuyumcian et al. 2012; Goldust et al. 2012) The circle of Willis encircles the stalk of the pituitary gland and provides important communications between the blood supply of the forebrain and hindbrain.(Wang et al. 2012; Willis and Morris 2013) A complete circle of Willis is present in most individuals, although a well-developed communication between each of its parts is identified in less than half of the population.(Khandanpour et al. 2013; Hansen et al. 2012) Considerable anatomic variation exists in the Circle of Willis. Based on a previous study, the classic anatomy of the circle is only seen in 34.5% of cases.(Best et al. 2012) In one common variation the proximal part of the posterior cerebral artery is narrow and its ipsilateral posterior communicating artery is large, so the internal carotid artery supplies the posterior cerebrum.(Hijjawi et al. 2012; Di and Humphrey 2012) In another variation the anterior communicating artery is a large vessel, such that a single internal carotid supplies both anterior cerebral arteries.(Castro et al. 2012; Dreizin and Munera 2012) Multidetector computed tomographic (CT) angiography is used at many institutions for initial evaluations of the cerebral circulation in the settings of acute stroke and subarachnoid hemorrhage.(Bautista 2012; Takeyama et al. 2012) Variations of the cerebral circulation, in particular of the circle of Willis, are common. When assessing CT angiograms of the cerebral circulation, it is important to understand the appearance of these normal variants, their prevalence, and their clinical relevance, particularly with respect to the risk of aneurysm formation.(Liubchenko et al. 2012; Barlinn et al. 2012) The aim of this study was to evaluate the circle of Willis location and relationship with its variations by multi detector CT angiography.

2. Material and Methods

This descriptive analytical study was conducted on 240 healthy participants (128 men, 112 women; mean age, 44.22 ± 8.74 years) who underwent 64-section CTA at Emam Reza hospital, Tabriz were retrospectively reviewed for evaluation of the circle of Willis configurations from March 2011 to March 2012. This study was approved by the Ethics Committee of Tabriz university of medical sciences. Informed consent was obtained from all participants. Inclusion criteria were as follows: no past history of transient ischemic attack, acute ischemic stroke or hemorrhagic stroke; no disabling neurological

deficits on examination; and the CT angiograms were diagnostic for delineation of the circle of Willis. Subjects were excluded from our study if they had brain abnormalities detected on unenhanced CT scan or CT angiograms. All participants underwent cranial CTA with a 64-section multidetector CT scanner (Siemens sensation; Germany). A total of 80 mL of non-ionic contrast medium (iopromide, 370 mg iodine/mL) was injected through an 18-gauge needle via the antecubital vein with an automated injector at a flow rate of 4 mL/s. The scanning delay was automatically adjusted for each individual by a bolus tracking technique. A contrast-enhanced image was obtained with the following parameters: 120 kV, 300 mA, pitch of 0.531, section thickness of 0.5 mm, 0.5 mm increment, 180 mm field-of-view, 512 _ 512 matrix with soft reconstruction kernel. CT angiograms were reviewed by single radiologist. All component vessels at the circle of Willis were assessed in each individual. In interpretation of the CT angiograms, the observer assessed the presence or absence of each arterial segment in the circle of Willis. If an arterial segment was visible, the diameters of bilateral A1, P1 and posterior communicating arteries (PcomA) were measured. Arterial segments that were larger than 1 mm were considered to be normal. Arterial segments that were less than 1 mm were classified as hypoplastic. The posterior collaterals were classified as one of three variants: an adult configuration, a transitional configuration and a fetal configuration. Vessels arising from the internal carotid artery that had diameters larger than P1 and continued as posterior cerebral arteries were regarded as a fetal-type posterior cerebral artery. The transitional configuration was defined as a variant in which the diameters of the PcomA and the P1 segment were the same. In the adult configuration, the PcomA was smaller than the ipsilateral P1.

Statistical Analysis

An independent bio-statistician performed the statistical analysis. All statistical tests were performed by SPSS version 16. The univariate analysis consisted of Student *t* test or Mann-Whitney *U* test for the comparison of mean values between 2 groups or ANOVA test for the comparison between 3 groups and Pearson correlation tests to measure the strength of the association between 2 quantitative variables. Fisher exact test for the comparison between percentages. Logistic regressions were performed by the generalized linear model procedure. The statistical significance threshold was set at $P < .05$.

3. Results

All participants underwent a 64-section CTA examination at our institution. There were no technical failures or complications. Of the 248 participants who underwent CTA examination, eight were excluded because of incidental aneurysms (n = 5), an arteriovenous malformation (n = 2) and moyamoya disease (n = 1) on CT angiograms. Thus, the circle of Willis configurations were evaluated in 240 participants. Consequently, 240 participants (128 men, 112 women; mean age, 44.22 ± 8.74 years) were included in the final analysis.

Anterior circle of Willis variants

In total, the anterior circle of Willis was complete in 182 of 240 participants (75.8%), of whom a normal configuration was seen in 172 subjects. In ten patients, two anterior communicating

arteries were observed. The anterior circle was incomplete in 56 participants who had compromised anterior collateral flow, of whom the anterior communicating artery was invisible (absent) in 20. The remaining 36 subjects had A1 hypoplasia or aplasia. The most common type of anterior collateral was type A (normal), in which all component vessels were competent. There were no statistically significant sex-related differences in the anterior part of the circle.

Posterior circle of Willis variants

No statistically significant sex-related differences were found in the posterior circle of Willis. A significantly higher percentage of incomplete collaterals were observed in the posterior part of the circle compared with the anterior collaterals ($p < 0.05$). The most common type of posterior variation was type E, in which bilateral PcomA were absent. Of the 72 participants with complete posterior circles, an adult configuration was observed in 40 participants, and a very rare transitional variant was observed in 12 participants. A fetal-type posterior circle of Willis was seen in 30 (12.5%) of the 240 subjects. Of the 30 subjects with FTP, 27 (90%) were classified as having partial FTP in which a hypoplastic P1 segment was present, and three (10%) were found to have a full FTP in which a P1 segment was absent. Of the 27 participants with a partial FTP, a unilateral FTP was found in 20 (74.1%) participants and bilateral FTP was seen in seven (25.9%) participants. In our study, a new type of posterior variant was observed in four of 160 participants. In four participants, the PcomA arose directly from the internal carotid artery and did not fuse with the posterior cerebral artery. In the new type of variant, the posterior cerebral artery territory

was supplied by separate collaterals from the ipsilateral posterior cerebral artery and the PComA.

Combined analysis of entire circle

In the combined analysis, a complete circle of Willis was seen in 68 (28.3%) of 240 subjects. An incomplete anterior and posterior circle of Willis was found in 36 (15%) of 240 subjects. The remaining 136 (56.6%) subjects had partially complete circle of Willis configuration. The most common type of circle of Willis in a single subject was anterior variant A and posterior variant E.

4. Discussions

The Willisian circle can redistribute the vertebrobasilar flow and the reduction of flow is attributable to orthrostatic presyncope. The circle of Willis provides the principal collateral pathway in the event of internal carotid artery occlusion.(Oshima et al. 2012; Smit et al. 2012) Collateral flow from the vertebrobasilar system is provided by posterior to anterior flow in the PCoA. A very small or absent ipsilateral PCoA increases the risk of a watershed infarction.(Cai et al. 2012; Huddle et al. 2012) Technical innovations in multidetector CT scanners have made CTA an ideal imaging method for evaluation of circle of Willis collaterals.(Kashyap et al. 2011; Scheperjans et al. 2011) In our study, we have investigated the configuration of all component vessels in the circle of Willis with the 64-section CTA. Unlike early autopsy studies, CTA is an accurate imaging method that allows real-life visualization of arterial segments in the circle of Willis. In addition, CTA is not dependent on the flow velocity, thereby allowing accurate documentation of vessel diameters. Although many studies have observed the segmental variations in the circle of Willis, only a few authors have systematically investigated the circle as a whole.(Malaki et al. 2012; Bushett et al. 2011) In previous studies, the prevalence of a complete anterior circle varied from 74% to 90% in different ethic groups.(Stence et al. 2011; Baikoussis et al. 2011) In our study, a complete circle of Willis was seen in 68 (28.3%) of 240 subjects. An incomplete anterior and posterior circle of Willis was found in 36 (15%) of 240 subjects. The remaining 136 (56.6%) subjects had partially complete circle of Willis configuration. In healthy volunteers studied by magnetic resonance angiography, Brown and coworkers reported an entirely complete circle of Willis in 42%, a complete anterior circulation in 74%, and a complete posterior circulation in 52% of cases.(Brown et al. 1997) According to the study by Lell and colleagues, the AcomP may be hypoplastic or absent on one or both sides of the brain in about 25% to 30% of patients and the AcomA in about 10%, and hypoplasia of the anterior cerebral artery segment can be seen in about 25%.(Lell et al. 2002) Consistent with a previous MRA study of a western population, no sex-related difference was found for the prevalence of circle of Willis configurations in the Iranian population. The anterior circle of Willis configurations reported here were in accordance with previous autopsy studies of normal brain specimens or MRA studies of a western population.(Sockrider et al. 2002; Darwin et al. 2002) Nevertheless, it is well established that considerable variation exists in the posterior circle of Willis. In an MRA study of 150 participants, the posterior circle was complete in 52% of subjects.(Gadda et al. 2002) Compared with previous reports, we observed a high incidence of incomplete posterior circles of Willis in our study. We found that the most common types of variants in the posterior circle were types E and F, in which bilateral PcomA were hypoplastic or absent. A higher percentage of hypoplastic or absent PcomA in the posterior circle reported here is probably due to differences in the ethnic background of the participants. The incidence in western countries of aneurysms in the arteries of circle of Willis including PCoA is from 0.25% to 4.9%.(Kotre and Willis 2003; Tateshima et al. 2003) It was also observed to be very low in Iran and in eastern countries. Brains of 1000 medicolegal autopsy subjects were examined by Proust et al. observed only 10 (1%) specimens where aneurysm was present in the arteries of the circle of Willis, of which there was 1 (0.1%) brain where PCoA was involved.(Proust et al. 2002) On the other hand, de Andrade et al. examined 175 dissection hall specimens of brains; they observed Berry aneurysm in 18 instances (10.3%) in the arteries of the circle of Willis, of which in 2 (1.1%) cases, PCA was involved.(de Andrade et al. 2003) This report recorded the incidence to be even much higher than in the western countries. Rajagopal et al. examined the circle of Willis in 126 adult cadavers and observed the incidence of macroaneurysmal dilatations in PCoA to be 39.7% of the brains, which indeed is a very high figure. He did not produce any evidence to show that these dilatations were aneurysms and not artifacts; it is therefore not possible to accept his observations.(Rajagopal et al. 2003).

Conclusion

Normal variants of the cerebral circulation are common, and most such anomalies can be identified at multidetector CT angiography. This article describes the appearances, prevalence, and associations of clinically relevant variants. A substantially higher prevalence of compromised posterior collaterals was observed in a normal Iranian

population compared to reports of Western populations. The anatomical variations of cerebral collaterals reported here may contribute to our understanding of collaterals as well as to various underlying mechanisms of cerebrovascular diseases.

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