Incidence of Normal variants of the cerebral circulation at 128 slice computed tomography angiography

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ABSTRACT

Introduction : Normal variants of the cerebral circulation are common, and most such variants can be identified at 128 slice CT angiography.

Materials & Methods: An observational study to find out the normal variants of cerebral circulation in 120 patients who underwent CT cerebral angiogram for various causes during the period of January 2014 to July 2015.

Results: Out of 120 patients, 0.8% had fenestrations of anterior cerebral artery, 0.8% had fenestrations of anterior communicating artery, 26.7% had hypoplasia of A1 segment of anterior cerebral artery, 0.8 % had absent anterior communicating artery, 17.5% had early branching of middle cerebral artery,17.5% had fetal origin of the posterior cerebral artery , 1.7 % had hypoplasia of the internal carotid artery. Out of all variants, hypoplasia of A1 segment was most common and other common variants were Early branching of middle cerebral artery and Fetal origin of the posterior cerebral artery .

Conclusion: Accurate detection and characterization of variation of cerebral circulation is an essential prerequisite for surgical treatment planning. The introduction of 128 slice CT scanner has greatly advanced the role of CTA in three dimensional analysis variation of cerebral circulation of particularly in places where digital subtraction angiography (DSA) is not available. CTA is highly sensitive and specific and can replace DSA for diagnostic purposes.

Keywords: CT angiography, fenestration, variations of circle of willis, persistent carotid and basilar artery anastomoses.

INTRODUCTION

The circle of Willis, whose function is to protect the brain from ischemia, is the main structure that provides a constant and regular blood flow to the brain. The circle of Willis is an arterial polygon and is a vascular ring composed of branches of arteria (a) carotis interna and a. basilaris. This circle is composed of bilateral A1 segments of anterior cerebral arteries (ACAs), anterior communicating artery (AComA) that links these 2 arteries, bilateral P1 segments of posterior cerebral arteries (ACPs), and posterior communicating arteries (AComP) which links a. carotis interna (ACI) to ACP. This communicating pathway allows equalization of the blood flow between the 2 sides of the brain and permits anastomotic circulation, if a part of the circulation becomes occluded. In recent years, detailed knowledge about the circle of Willis has generally been based on cadaver studies [1–5].

Digital subtraction angiography (DSA) remains the reference standard for detection of intracranial vascular anomalies. However, the sensitivity and specificity of multidetector CT angiography are reported to be high (81%–90% and 93%, respectively)[6]. The high spatial resolution of three-dimensional (3D) multidetector CT angiography facilitates understanding of the anatomic relationships between bone and blood vessels[7]. A comprehensive CT examination of the intra- and extra cranial arteries entails a review of 3D images, maximum intensity projection (MIP) images, and axial images of the skull base that are obtained with bone window settings. Normal variants include fenestrations and duplications, variants of the circle of Willis, persistent carotid-basilar anastomoses, and other vascular anomalies identified in the skull base. The article reviews the most important and clinically relevant normal variants in these four categories.

MATERIALS & METHODS

The study was approved by our institutional ethics committee; written informed consent was obtained in all instances either from the patient or a close family member. The present study was conducted on 120 patients from January 2014 to July 2015, who underwent CT angiography for various cause at the institution . Pregnant women , patients having a history of contrast allergy and patients with renal insufficiency as assessed by serum creatinine level more than 1.5 mg/dl were excluded from the study. Patients who had already undergone placement of a clip or coil for an aneurysm were also excluded.

Imaging Protocol

All CT angiography studies were performed by using a 128 slice CT scanner (Ingenuity; Philips Healthcare). The patient's head were immobilized by using a head holder during the examination to minimize motion artifacts. Imaging parameters included the following: pitch 0.6; section thickness 0.9 mm with 0.45-mm interval; section collimation 0.6 mm; reconstruction interval 0.625 mm; matrix 512 x 512; field of view 180–240 mm; tube voltage 120 kV; and tube current, 250 mAs/slice. The scanning coverage extended from the bottom of the anterior arch of the first cervical vertebra to the top of the cranial vault. After a starting point was set, the automatic bolus tracking method was employed to trigger scan, 60 ml of contrast agent (Omnipaque 350; Iohexol 350mg iodine/ml) was intravenously injected through an 18 or 20- gauge needle via the antecubital vein at a rate of 5 ml/sec followed by 25 ml of saline chase at the rate of 4ml/second using double piston power injector (MEDRAD). A test dose was given before the scan. All CT angiography data were transferred to a workstation (Philips Extended Brilliance Workspace) for post-processing. The source images were reformatted in the coronal and sagittal planes as well as maximum intensity projection (MIP) and volume-rendered images.

Image Interpretation

The CT angiograms were interpreted by two experienced radiologists. All readers were informed of the findings on the unenhanced CT scans. Image interpretation of CT angiograms included initial examination of source images as well as multiplanar three dimensional volume-rendered and MIP images. The readers evaluated for the normal variants for fenestrations in Anterior communicating artery, Anterior cerebral artery, Middle cerebral artery, Basilar artery and vertebral artery, Posterior cerebral artery,Internal carotid artery,Azygous anterior cerbral artery,Anterior cerebral artery trifurcation, Bihemispheric anterior cerebral artery, A1 segment absence or hypoplasia, Absent anterior communicating artery , Accessory middle cerebral artery , Early branching of middle cerebral artery , Hyperplasic anterior choroidal artery, Fetal origin of the posterior cerebral artery , Posterior communicating artery infundibulum , Common posterior cerebral and superior cerebellar artery trunk , Persistent trigeminal artery variants , Primitive hypoglossal artery , Protlantal intersegmental artery , Persistant otic artery , Perisistent dorsal ophthamic artery,Peristant primitive olfactory artery , Persistant stapedial artery , Aberrant internal carotid artery, Internal carotid artery agenesis , Hypoplasia of the internal carotid artery .

RESULTS

Out of 120 patients, 0.8% had fenestrations of anterior cerebral artery , 0.8% had fenestrations of anterior communicating artery, 26.7% had hypoplasia of A1 segment of anterior cerebral artery ,0.8 % had absent anterior communicating artery, 17.5% had early branching of middle cerebral artery ,17.5% had fetal origin of the posterior cerebral artery, 1.7 % had hypoplasia of the internal carotid artery [Table 1 & 2].

Results showed that out of all variants hypoplasia of A1 segment was most common and other common variants were Early branching of middle cerebral artery and Fetal origin of the posterior cerebral artery .

There were no complications or technical failures during CT Angiography examination. One CT angiogram had artifacts produced by severe head motion during scanning. However, the artifacts did not interfere with the interpretation of the causative aneurysm. A total of 9 patients had two aneurysms each and 19 patients had no aneurysm. Of these 19, six had negative findings, eleven had perimesencephalic haemorrhage, and two had arteriovenous malformation.

In most cases, CT angiography helped find one or more projections that may clearly depict the aneurysm neck from the parent artery and adjacent vascular structures. Therapeutic decision could be made in all the patients based on the information provided by CT angiography. The patients were then referred for placement of surgical clip. Incidence of Normal variants of arteries of skull base are shown in[Table 3].

Table 1: Percentage of fenestration in cerebral vasculature

ARTERY	PERCENTAGE
Anterior communicating artery	**0.8**
Anterior cerebral artery	**0.8**
Middle cerebral artery	**0**
Basilar artery and vertebral artery	**0**
Posterior cerebral artery	**0**
Internal carotid artery	**0**

Table 2: Percentage of variations in cerebral vasculature

ARTERY	PERCENTAGE
Azygous anterior cerbral artery	**0**
Anterior cerebral artery trifurcation	**0**
Bihemispheric anterior cerebral artery	**0**
A1 segment absence or hypoplasia	**26.7**
Absent anterior communicating artery	**0.8**
Accessory middle cerebral artery	**0**

ARTERY	PERCENTAGE
Early branching of middle cerebral artery	17.5
Hyperplastic anterior choroidal artery	0
Fetal origin of the posterior cerebral artery	17.5
Posterior communicating artery infundibulum	0
Common posterior cerebral and superior cerebellar artery trunk	0

Table 3: Incidence of Normal variants of arteries of skull base

ARTERY	PERCENTAGE
Persistent stapedial artery	0
Aberrant internal carotid arteries	0
Internal carotid artery agenesis	0
Hypoplasia of the internal carotid artery	1.7

Fig 1: Early branching MCA

Fig 2: Fetal origin of left PCA

Fig 3 :Absent left A1 segment

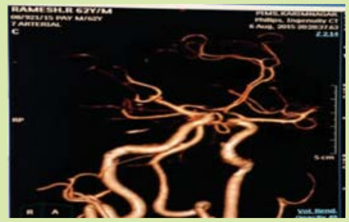

Fig 4: Fenestration

DISCUSSION

Accurate detection and characterisation of variations of circle of willis is an essential prerequisite for surgical treatment planning. The introduction of 128 slice CT scanner has greatly advanced the role of CT angiography in the three dimensional analysis of variations of circle of willis .

Fenestration, by contrast, is defined as a division of the arterial lumen into distinctly separate channels, each with its own endothelial and muscularis layers, while adventitia may be shared[8].

Anterior Communicating Artery : Fenestration of the anterior communicating artery is present in 12%–21% of the population[9]. Fenestration of the anterior communicating artery is seen more frequently in anatomic imaging studies than in angiographic evaluations (5.3% of cases)[10] .

Anterior Cerebral Artery : Fenestration of the anterior cerebral artery is a rare finding. The prevalence of fenestration of the A1 segment is between 0% and 4% in anatomic imaging studies 10 and 0.058% in angiographic studies [11].

Normal Variants of the Circle of Willis

A1 Segment Absence or Hypoplasia: In the presence of either variant, the contralateral anterior cerebral artery may supply part or all of the territory of the normal anterior cerebral artery via a large anterior communicating artery[12]. In the event of thromboembolic disease, these conditions result in a diminished collateral supply and therefore an increased risk of infarction[13].

Absent Anterior Communicating Artery: The anterior communicating artery often is not depicted at angiography, but this does not necessarily mean that the artery is absent. Definitive absence of the anterior communicating artery has been found in 5% of surgical dissections[14] .

Early Branching of the Middle Cerebral Artery: In this variant, the M1 segment either bifurcates or trifurcates in the region of the insula. Early division of the M1 segment close to its origin at the internal carotid artery is a common finding and may be unilateral or bilateral . Early branching of the middle cerebral artery is not associated with an increased risk of aneurysm formation and therefore is of little clinical significance.

Fetal Origin of the Posterior Cerebral Artery: In the presence of this anomaly, the caliber of the posterior communicating artery may be the same as or greater than that of the ipsilateral P1 segment, and the dominant blood supply to the occipital lobes comes from the internal carotid artery. Fetal origin of the posterior cerebral artery occurs when the embryonic posterior cerebral artery fails to regress. It may occur on the right side (10% of the general population), the left side (10% of the general population), or bilaterally (8% of the general population)[15,16] . The P1 segment may be absent in fetal origin of the posterior cerebral artery, but its absence is an uncommon finding[17].

Normal Variant Arteries in the Skull Base

Hypoplasia of the Internal Carotid Artery: Congenital hypoplasia of the internal carotid artery is associated with a small carotid canal and should not be confused with acquired causes of diffuse narrowing, such as dissecting aneurysm, fibromuscular dysplasia, or segmental stenosis[12]. Congenital hypoplasia of the internal carotid artery may be associated with anencephaly and basal telangiectasia[18].

Kalula N. T Kayembe et al[19] In order to obtain information about the relationship between variations in the circle of Willis and aneurysms, 44 complete circles of Willis with aneurysm were studied macroscopically and concluded that the incidence of variations of circles of Willis in the aneurysm series compared to the control. The incidence of "typical" circles of Willis was significantly lower in the aneurysm series ($p < 0.01$). Variations showing a significantly higher incidence in the aneurysm group were Asym ACA ($p < 0.05$), Asym PComA ($p < 0.01$). Med ACA was shown to have a higher incidence in the aneurysm series than the control but the difference was not significant .

Hina Siddiqi et al[20] conducted a study to identify the anatomical variations in cerebral arterial circle of Willis in patients with hemorrhagic stroke and concluded that , seventeen (31.4%) of fifty four (100%) cerebral arterial circles were complete. Eleven (20.3%) had typical configuration, nine (16.6%) had symmetrical and forty seven subjects (87%) had different types of variations in their component vessels. Variations are most common in posterior communicating artery followed by anterior communicating. Eleven (20.3%) circles were found with aneurysm .

Bishwa jeet Saikia et al[21] conducted a study to observe and compare the morphology of circle of Willis using two entirely different methods; gross dissection (GD) and Magnetic resonance angiography (MRA) and to correlate the variant patterns encountered with the possible underlying developmental events and found out that only 31 cases (22.14%) presented with a complete circle of Willis, out of which 14 (20%) were cadaveric specimen and 17 (24.18%) were in MRA group. Unilateral hypoplastic posterior communicating artery was the most common variation observed in our study (19.28%).

Ayse Karatas et al[22] conducted a study to assess the structural characteristics of the circle of Willis within the Turkish adult population, along with variations and the study revealed 82% adult, 17% fetal, and 1% transitional configurations. A complete polygonal structure was observed in 28% of cases. Variations of the circle of Willis were more common in the posterior portion. Hypoplasia was found to be the most common variation and was observed as a maximum in the posterior communicating artery (AComP).

There were limitations to our study. We did not compare the diagnostic performance of 128 slice CT angiography with DSA.

CONCLUSION

Accurate detection and characterization of variation of cerebral circulation is an essential prerequisite for surgical treatment planning. The introduction of 128 slice CT scanner has greatly advanced the role of CTA in three dimensional analysis variation of cerebral circulation of particularly in places where digital subtraction angiography (DSA) is not available. CTA is highly sensitive and specific and can replace DSA for diagnostic purposes.

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