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Incomplete Circle of Willis: A risk factor for mesial temporal sclerosis?

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ABSTRACT

Objective: The aim of this study was to investigate whether there may be a correlation between the anatomical variants of Circle of Willis (CoW) and presence/laterality of mesial temporal sclerosis (MTS).
Methods: We retrospectively identified the CoW variants on Wada angiograms in 71 patients with pathologically proven MTS. Angiograms were interpreted by two radiologists independently and blinded to clinical data. We divided the anterior and posterior components of the CoW into functionally complete and functionally incomplete groups. We then sought its correlation with the presence and laterality of MTS.
Results: No statistically significant relationship was found between the functional status of the anterior circulation and the laterality of the MTS ($p = 0.657$). Relationship of the posterior incomplete circle to MTS was statistically significant on both sides ($p = 0.023$ for the left, $p = 0.04$ for the right), with an effect size moderate to large for the left side and moderate for the right side. Although the fetal variant appeared to be related to the ipsilateral MTS, it did not reach to a level of statistical significance ($p = 0.15$).
Significance: The study demonstrates a statistically significant association of the incomplete posterior circulation of the CoW to the presence of ipsilateral MTS. Further studies in larger patient populations may be needed to seek whether an incomplete circulation may facilitate development of MTS, especially affecting the watershed zones.

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1. Introduction

The Circle of Willis (CoW), situated at the base of the brain, is an anastomotic channel uniting the internal carotid and vertebrobasilar systems. The organization of the CoW is such that, even in the case of occlusion or stenosis of one of its member arteries, a relatively constant blood flow is maintained to different brain areas (Gunnal et al., 2014; Li et al., 2011; Liebeskind, 2003). CoW variants with an incomplete circle were reported in the literature at 20%–50% depending on the methods used to identify these, such as magnetic resonance angiography (MRA), computed tomographic angiography (CTA), and postmortem studies, as well as the varying criteria used to identify the hypoplasia and absence of a vessel (Gunnal et al., 2014; Kapoor et al., 2008; Krabbe-Hartkamp et al., 1998; Li et al., 2011; Stock et al., 1996). Recent studies using a magnetic resonance imaging (MRI) perfusion technique showed that the cerebral blood flow delivered to different areas of the brain varied depending on the type of CoW variant (Tanaka et al., 2006). Incomplete CoW was noted to cause decreased cerebral perfusion, and the watershed areas are inherently more prone to such low volume insults (Li et al., 2011; Schomer et al., 1994).

The medial temporal lobe and hippocampus appear to be a watershed area between the anterior and posterior cerebral circulation (Fig. 1) (Duvernoy, 2004; Kiernan, 2012). Hippocampal ischemia was demonstrated in two cases of carotid artery dissection with ipsilateral fetal posterior cerebral artery (PCA) as well as a case of global hypoperfusion due to cardiac arrest (Walha et al., 2013). Selective vulnerability to ischemia of some sectors of the hippocampus (De Reuck et al., 1979; Schmidt-Kastner and Freund, 1991) may play at least a partial role in this process. An ischemic-

Abbreviations: ACA, anterior cerebral artery; ACoA, anterior communicating artery; CoW, Circle of Willis; CTA, computer tomographic angiography; DSA, digital subtraction angiography; FLAIR, fluid attenuated inversion recovery; ICA, internal carotid atery; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging; MTS, mesial temporal sclerosis; PCA, posterior cerebral artery; PCoA, posterior communicating artery.

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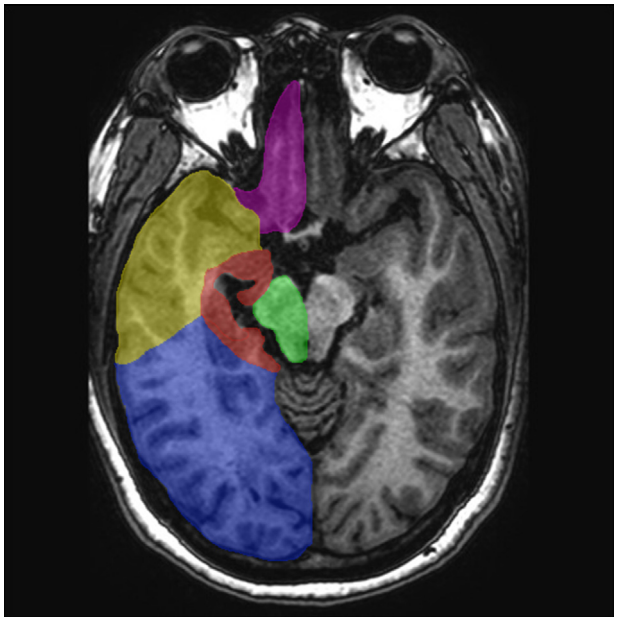

Fig. 1. Color-coded cerebral vascular territories showing watershed area between anterior choroidal artery and posterior cerebral artery irrigation area at medial temporal lobes coded respectively by red and blue colors. Red: Anterior Choroidal arteries, Blue: Posterior Cerebral Arteries, Purple: Anterior Cerebral Artery, Yellow: Middle Cerebral Artery, Green: Posterior Cerebral Artery.

hypoxic mechanism was also offered leading to the development of hippocampal sclerosis (Lucchi et al., 2015).

The aim of this study was to investigate whether there may be a correlation between the CoW variants and mesial temporal sclerosis (MTS). For this purpose, two radiologists independently analyzed the digital subtraction angiography (DSA) images of a group of patients with the history of MTS, blinded to the clinical and pathological data. A correlation was then sought between the identified CoW variants and the presence/laterality of MTS.

2. Methods

2.1. Participants

This retrospective study was approved by the Institutional Review Board of the Rush University Medical Center. Patients with pathologically proven MTS who underwent temporal lobectomy with a pre-operative angiography at our institution were included in the study. Seventy-four patients met these criteria. Of these, three were excluded (one with only unilateral injection, and two others due to poor image quality) (%4).

2.2. Analysis

Two independent radiologists blinded to clinical data interpreted carotid angiograms. The same radiologists also reviewed carotid angiograms of ten random patients outside the study group for standardization purposes prior to reviewing study cases. Extra care was taken to differentiate between the anterior choroidal and posterior communicating arteries (PCoA). In cases of disagreement, a consensus result was sought selecting one of the two raters' decisions for final analysis.

CoW was first divided into the functionally complete or functionally incomplete anterior and posterior circulation. Functional completeness of the arteries was based on the angiographic filling disregarding any difference in vessel size.

Functionally complete anterior circulation is the one that shows filling of the A1 segments of the bilateral anterior cerebral arteries (ACA) and anterior communicating artery (ACoA). Functionally complete anterior circulation was then divided into the right dominant, left dominant, and co-dominant subgroups depending on the filling of the contralateral side with the injection of the ipsilateral side. Functionally incomplete anterior circulation was divided into the right or left A1 agenesis or nonfunctional ACoA.

Functionally complete posterior circulation was based on the non-dominant presence of the PCoA (based on the assumption that a P1 segment of the PCA also exists). Functionally incomplete posterior circulation was divided into the fetal PCA and absent PCoA; those cases in which P2 and P3 segments continue directly from PCoA were assigned to this group. Fig. 2 shows the groups and subgroups of CoW variants in this study in detail.

Kappa statistics was used for inter-rater reliability of angiographic interpretation. Unweighted kappa was used to assess dichotomous determination of complete versus incomplete anterior and posterior CoW. Inter-rater reliability showed an overall agreement for 85% of cases with kappa = 0.70. The agreement was 83% with kappa = 0.64 for the anterior circulation, and it was 87% with kappa = 0.73 for the posterior circulation.

2.3. Statistical analysis

Chi-square test was used to show the relationship between the laterality of MTS and the functional status of CoW. Fisher exact and Chi-square tests were used for the analysis of the complete and incomplete CoW sub-groups. Statistical significance level was accepted at 0.05. Patients having functionally complete and incomplete anterior circulation were compared with respect to the side of the MTS. Similarly, the patients with the right and left functionally complete and incomplete posterior circulation were compared with respect to the side of the MTS. All subgroups of complete anterior (right dominant, left dominant, codominant) and incomplete anterior (right A1 agenesis, left A1 agenesis, nonfunctional ACoA) groups were individually crosstabbed. Two subgroups of functionally incomplete posterior circulation (absent PCoA and fetal PCA) were similarly crosstabbed. Fisher's exact test was used in cross tabulations where at least one cell less than or equal to 5 (namely comparisons of all subgroups described above); and chi-square test was used in all other cases.

3. Results

There were 42 functionally complete anterior circulation cases with 29 incomplete anterior circulation cases. Thirty incomplete right posterior circulation cases were identified, 11 of which were fetal posterior cerebral variations. Thirty-one incomplete left posterior circulation cases were identified 15 of which were fetal posterior cerebral variations. The demographic and imaging findings of all patients with the pathologically proven MTS are summarized in Table 1.

There was no statistically significant relationship between the functional status of the anterior circulation and the laterality of the MTS ($p = 0.657$) using chi-square test. Neither complete nor incomplete anterior circulation sub-groups reached a level of statistical significance using Fisher's exact test.

The relationship of the posterior incomplete circle to MTS, evaluated with chi-square test, was found to be statistically significant on both sides ($p = 0.023$ for the left, $p = 0.04$ for the right), and the effect size was moderate-to-large for the left side and moderate for the right (Fig. 3). Subgroups of incomplete posterior circulation such as fetal PCoA or absent PCoA, independently, failed to show a statistically significant relationship with MTS laterality

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