Human fetal medial striate artery or artery of Heubner

Laboratory investigation

LJILJANA VASOVIC, M.D., PH.D., SLADJANA UGRENOVIC, M.D., PH.D., AND IVAN JOVANOVIC, M.D., PH.D.

Department of Anatomy, Faculty of Medicine, University of Nis, Serbia

Object. The authors describe some of the features of the medial striate branch or recurrent artery of Heubner (RAH). This structure has indisputable functional, neurological, and neurosurgical significance, and originates from the A1 and/or A2 segments of the anterior cerebral artery.

Methods. Microdissection of 94 human fetal specimens was performed. The RAH was observed in 97.3% (single in 71.6%, double in 25.1%, and triple in 3.3%) of the cases. Its origin was from A2 in 42.3% of specimens, from the A1–A2 junction in 25.7%, and from A1 in 20%.

Results. Five types and 14 subtypes of the RAH were identified, determined based on vessel origin and number. In its course, the RAH gave 1–12 branches, and the terminal part most frequently penetrated into the brain through the anterior perforated substance at the level of the sphenoid segment of the middle cerebral artery. The specimens with a single RAH fenestration, abnormal double RAH anastomosis, and unusual RAH origin and relationship to the surrounding vessels represented new data.

Conclusions. The authors' observations of common anatomical variations in the number and origin of the RAH, as well as its abnormalities, may assist neuroradiologists in the interpretation of diagnostic test results and neurosurgeons in performing procedures in the anterior cerebral circulation. (DOI: 10.3171/2008.12.PEDS08258)

Key Words • anterior cerebral artery • artery of Heubner • human fetal brain • vascular patterns

Cerebral aneurysms frequently occur in the arterial complex composed of the ACA, ACoA, and medial striate artery (the RAH). This arterial complex is also characterized by numerous diverse anatomical variations that complicate the planning and performance of surgery, and often lead to postoperative complications.

German pediatrician Johann Otto Leonhard Heubner was the first to describe the RAH in 1872. Since then many others have also described it, calling it the centralis longa artery or (proximal/distal) medial striate artery. Many of these authors observed that the RAH is usually present and that it exists as single or numerous trunks originating from the lateral or dorsolateral surface of the ACA. The course of the artery of Heubner is (reverse) recurrent. The first part of the artery is in the immediate vicinity of the ACA trunk, and then it runs postero-laterally, extending over the level of the ICA bifurcation and straight gyrus. The RAH most frequently penetrates into the brain parenchyma at the level of the lateral part of the APS or the medial portion of the sylvian fissure. It gives off numerous branches including those that supply the olfactory tract and triangle, the paraterminal gyrus, straight gyrus, subcallosal area, and orbitofrontal cortex. The branches of the RAH also supply the anterior part of the caudate nucleus, the anterior third of the putamen, and the apical part of the lateral segment of the globus pallidus and the anterior limb of the internal capsule.

Surgical interventions in the anterior circle of Willis can be complicated by obstruction of or vascular damage to the RAH, usually caused by irregular clip placement, the structure's location in the immediate vicinity of the ACA trunk, or insufficient knowledge about its anatomical variations. A decrease in or total obstruction of blood flow through the RAH can lead to complications such as hemiparesis of the facial and upper limb muscles on the opposite side, aphasia, and cognitive disorders.

The aim of our research was to compile and present more data about the normal morphological characteristics of the RAH trunk, from its origin to the level where it penetrates into the brain parenchyma.
Methods

Dissections were performed in 94 human fetal brains (188 hemispheres) that had been injected with water-soluble Micropaque or latex solution via the left common carotid artery or left ventricle of the heart. Microdissection of the cerebral blood vessels was performed with an operative microscope (Olympus) in the Department of Anatomy at the Faculty of Medicine in Niš. All fetuses were obtained legally from the Clinic of Gynecology and Obstetrics. All clinics and departments within our medical faculty participate in integrated professional cooperation and internal ethical control efforts. Documentation for the obtained fetuses did not include the restricted information concerning the reasons for abortion. Macroscopic examination did not reveal any congenital malformations. The gestational age of the fetuses was established in accordance with the Patten scale,13 and ranged from 13 to 24 weeks.

The presence of the RAH, its origin from different parts of the ACA, its course and branches, as well as the site of brain parenchyma penetration were recorded. The outer diameters of the RAH and ACA were measured using the eyepiece micrometer at 10 x lens magnification.

Statistical analysis was performed with commercially available software (NCSS-PASS 2004–2005), which accompanied the textbook of Dawson and Trapp,3 and the Statistics Calculator (http://www.statpac.com/statistics-calculator). The significance of differences between the morphometric parameters obtained in the brains was established with the Student t-test and t-test between percentages. In cases where the data did not have normal distribution, the Mann-Whitney U-test was used.

Results

The distribution of fetal RAHs in our specimens is summarized in Table 1. We found no statistically significant difference between side and single, double, or triple RAHs. The origin of the RAH was evaluated in 241 vessels, and is summarized in Fig. 1. The RAH most frequently originated from the A1 segment (42.3% of cases). The RAH had a common trunk with the mFBA or frontopolar artery in only a very few cases. The differences among RAH had a common trunk with the mFBA or frontopolar artery or left ventricle of the heart. The RAH had a common trunk with the mFBA or frontopolar artery or left ventricle of the heart.

TABLE 1: Distribution of fetal RAHs

<table>
<thead>
<tr>
<th>RAH</th>
<th>Left</th>
<th>Right</th>
<th>Total No. of Hemispheres (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>present</td>
<td>91</td>
<td>92</td>
<td>183 (97.3)</td>
</tr>
<tr>
<td>absent</td>
<td>3</td>
<td>2</td>
<td>5 (2.7)</td>
</tr>
<tr>
<td>single</td>
<td>60</td>
<td>71</td>
<td>131 (71.6)</td>
</tr>
<tr>
<td>double</td>
<td>27</td>
<td>19</td>
<td>46 (25.1)</td>
</tr>
<tr>
<td>triple</td>
<td>4</td>
<td>2</td>
<td>6 (3.3)</td>
</tr>
</tbody>
</table>

or double RAHs on the other side were classified as Type IV (6.4%), and specimens with unilateral absence of the RAH were described as Type V (5.3%).

Type I RAHs were further classified into 4 subtypes: H1, bilaterally single RAH originating from the A1 segment; H2, bilaterally single RAHs originating from the A1-A2 junction; H3, bilaterally single RAHs originating from the A2 segment; and H4, bilaterally single RAHs of other origins.

Type II RAHs were subclassified as follows: H5, bilateral double RAHs originating from the corresponding A1 segment; H6, bilaterally double RAHs originating from the A2-A3 junction; and H7, bilateral double RAHs of asymmetrical origin.

Type III RAHs had 2 subtypes: H8, presence of single RAH on the left and double RAHs on the right, and H9, double RAHs on the left and a single RAH on the right.

Type IV also had 2 subtypes: H10, triple RAHs on the left and a single RAH on the right, and H11, triple RAHs on the left and double RAHs in the right hemisphere.

Type V included 3 subtypes: H12, a single RAH on the left and none on the right; H13, single RAH on the right and none on the left; and H14, double right RAHs and no left RAH.

Among these subtypes, H1–H3, H5, and H6 were characterized by symmetrical vascular patterns, and were found in 33 specimens (35%) with the same RAH origin and number on both sides. Furthermore, specimens classified as H1 were the most numerous of these vascular patterns. However, 61 specimens (65%) specimens had asymmetrical RAH vascular patterns (t = 3.049, df = 93, p = 0.0030). Subtypes H4, H7, and H9 were the most common among the specimens with asymmetrical vascular patterns.

The number of sides and terminal branches of the RAHs ranged from 1 to 12. In specimens with single RAHs, side and terminal branches were not observed in 48.33% on the left, and 44% of right RAHs. In the rest of the cases, the number of branches ranged from 1 to 6, and most frequently from 2 to 4 on both sides. In cases of double RAHs, branches were observed in 67% of the cases (range 1–12, but most frequently 2–3) only on the left, while RAH branches were not observed on the right side. In specimens with triple RAHs, branches were observed in 50% of cases, and were most frequent on the left. In 1 case 8 branches were observed on the right side.

The RAHs typically followed their vascular sources and traveled posterolaterally. The terminal part was at the level of the anterior or middle or posterior third of A1 and/or at the level M1 (sphenoid) or M2 (insular) segment of the MCA, where it penetrated into the brain parenchyma. Figure 4 shows that the RAH most frequently (53.53%) terminated at the level of the anterior third of M1, where it penetrated the APS. The RAH was less frequently (27.39%) found to terminate at the level of the anterior third of A1; other RAH terminations were found with less frequency.

There was no relationship between fetal ACA and RAH diameters. Left and right ACAs were equal in 41 of 94 examined fetuses, and the left RAH diameter was equal to the right in 17 (41.4%) of 41 cases. The left ACA was larger than the right in 38 cases, and the left RAH was larger than the right in 11 (28.9%) of these 38 cases. The left ACA was smaller than the right ACA in 15 cases, and the left RAH was smaller than the right in 5 (33.3%) of these 15 cases.

**Unusual Cases**

Although the RAHs commonly originated from the anterior wall of A1, or from the A1–A2 junction and/or A2 segment lateral wall, we found some exceptions to this rule (Fig. 5). In 1 instance the RAH originated from the ipsilateral A1–A2 junction medial wall (Fig. 5A). In another, the RAH originated from the medial wall of the contralateral A2 segment (Fig. 5B), and in yet another (Fig. 5C) there was a fusion of A2 segments or an azygos pericallosal artery and bilaterally double RAHs. Three originated from the mFBA (2 on the left and 1 on the right), and 1 RAH, with a significantly smaller external diameter, originated from the right A1 segment. Four spe-
Recurrent artery of Heubner

cial cases with unusual morphological characteristics and relationships with the surrounding arteries are shown in Fig. 6 and described in depth in the legend.

Discussion

The neurosurgeon’s ability to detect and identify anatomical variations in the RAH should significantly decrease surgical complications near the anterior circle of Willis. Injury to this area frequently causes postoperative complications such as neurological disorders, memory loss, impairment of cognitive functions, and psychological changes. Although there are abundant data in the literature concerning the origin, course, caliber, length, and place at which the RAH penetrates into the brain parenchyma, the significant differences between the data presented by different authors can complicate our understanding of the anatomy of this perforating artery.

The first part of our research presents the incidence of RAH and the number of cases in which it was detected as single, double, triple, or multiple vessels. According to the results reported in the majority of studies (> 90%), it can be concluded that ≥ 1 RAH is almost always present.7,11,12,17 The incidence of single and double RAHs in the literature was 55–88% and 12–33%, respectively.1,4,7,11,12,19 Our results are in agreement with those of other authors (single RAH in 71.6% and double RAHs in 25.1%).1,4,7,11,12,19 Although there were studies in which the presence of double RAHs was not observed, Gomes et al.7 reported the presence of double RAHs in 1–20% of their cases. Only Rosner et al.10 and Gorczyca and Mohr4 obtained significantly different results, reporting single RAHs in 28%, double in 48%, and triple or multiple RAHs in 24% of their cases. Musso and colleagues14 reported a slightly higher frequency of double RAHs, 49.6%. We found triple RAHs in 3.3% of examined brains, an incidence similar to that reported by Marinkovic et al.12 (3%), then by Avci et al.1 (1.6%), and Tao et al.19 (5.6%). The authors of other studies did not report the presence of triple RAHs. Loukas and associates11 noted bilaterally single RAHs in 68% of their cases, bilaterally double RAHs in 7%, and a combination of a single RAH on 1 side and double RAHs on the opposite side in 25% of their cases. These incidences are very similar to our results concerning RAH vascular patterns—53, 11, and 24.5%, respectively. According to the recommendation of Loukas et al.11 we believe that although the anterior circle of Willis displays anatomical variations, the RAH should be identified according to its recurrent course, the site of its penetration into the brain parenchyma, and thus the region of the brain it supplies. The FPA or mFBA thus cannot be confused with the RAH and such cases cannot be misinterpreted as having triple or double RAHs. The fact that the RAH, mFBA, and FPA frequently all originate from the A1–A2 junction, sometimes even from a common arterial trunk, and have similar external diameters additionally complicates their differentiation. In contrast to FPA and mFBA, there is no possibility for intentional RAH sacrifice during ACoA aneurysm clipping.1 Furthermore, the presence of double RAHs is often associated with other variations or malformations, which may later cause complications.12

In attempting to classify RAH origin data, we discovered large discrepancies in the literature. The A1 segment is reported as the origin in 7–14% of the cases.1,7,11,12,17,19 Marinkovic and colleagues12 report this origin in 17% of their cases, and Rosner et al.10 report it in one-third of theirs. We detected A1 segment RAH origination in 20% of our cases. In the literature, the RAH originates as a branch of the A1–A2 junction in 8–63% cases.1,7,11,12,17,18,19 We found this origin in 25.7% of samples, similar to the results of Marinkovic.
et al.,\(^1\) of 21%, and Avci et al.,\(^1\) of 29%. Most authors agree that the most frequent origin, found in 35–78% of cases, is the A\(_2\) segment.\(^1,4,7,11,12,17,18,21\) We also observed the highest incidence of A\(_2\) segment RAH origin (42.3%). Loukas and colleagues\(^1\) reported an A\(_2\)-segment origin in 23.3%, and Rosner et al.\(^1\) did not observe such an RAH origin at all. The RAH may originate together with the FPA or mFBA from the common arterial trunk, a side branch of the MCA or olfactory artery.\(^19\)

Anatomical variations in RAH origins can be challenging to the neurosurgeon and require additional preoperative diagnostic procedures.\(^9,10,19\) Our classification of RAHs into different subtypes, and the observation of incidence of detected vascular patterns, might prove useful in this regard. Our results demonstrated that asymmetric vascular patterns were more common than symmetric ones. The subtype H4, in which the RAH is bilaterally single and originates from the A\(_2\) segment on the left side and on the A\(_1\)–A\(_2\) junction on the right, had the highest incidence (21.2%). The subtype H1, with a bilaterally symmetric RAH origin from the A\(_2\) segment, had a lower incidence (19.1%). We found a slightly lower frequency for the H9 subtype (16%), in which the left RAH was double (1 originating from the A\(_2\) and the other originating from the A\(_1\) segment), while the right RAH was single and most frequently originated from the A\(_2\) segment. The other 11 subtypes we observed had significantly lower incidences, but could nonetheless be encountered by neurosurgeons during the inspection of the anterior part of the circle of Willis.

The caliber of the RAH was measured in most of the

---

**Fig. 5.** Photographs demonstrating the origin of the right RAH (asterisks) from the medial wall of the ipsilateral A\(_1\)–A\(_2\) junction (A), the medial wall of the contralateral A\(_2\) segment (B), and bilaterally from the mFBAs (C). Dashed arrows mark the beginning and course of the right RAH in B. In panel C, arrow marks the right mFBA and dashed arrow marks the left mFBA. APA = azygous pericallosal artery.

**Fig. 6.** Photographs depicting unusual RAH morphological features and topographical relationships with surrounding arteries in 4 cases. A: An anastomotic loop (arrow) between 2 left RAHs. B: Fenestration of the single left RAH, simultaneous with fenestration of the right posterior communicating artery (PCoA). C: Pseudofenestration of the right A\(_1\) segment caused by an ipsilateral RAH. D: The left mFBA and right RAH are shown crossing at the level of the inferior surface of the right A\(_1\).
cases immediately after its beginning and ranged from 0.6–1 mm. In the majority of our cases, the external caliber of the fetal RAH did not differ significantly between single, double or triple RAHs, nor was it dependent on the origin. A significant difference in caliber was not found by other authors either. On its way to the site at which the RAH penetrates into the brain parenchyma, we observed that it gave off 1–12 branches (most frequently 2–4 branches). Similar results were obtained by Perlmutter and colleagues (4.2 branches on average) and by Tao et al., who observed 3–12 branches. Rosner et al. reported higher numbers of branches (1–28).

The RAH usually penetrates the brain parenchyma at the level of the APS or the medial part of the sylvian fissure. Most studies have confirmed that the RAH terminates by penetrating brain parenchyma at the level of the medial or lateral APS in > 80% of cases. In our study of human fetal hemispheres, we classified RAH termination in relation to the ACA or MCA segments (Fig. 4). In half of our cases, we observed that the RAH terminated in penetration of the brain parenchyma at the level of the anterior third of M_1 segments. If we consider the anterior continuation of the posterior communicating artery as the dividing line separating the APS into medial and lateral parts, then we can conclude that in more than half of cases (57%), the RAH terminated at the level of the lateral APS, and in 43% of cases at the level of the APS medial portion.

Our results also demonstrate some specific and very rare cases of RAH morphology and topography. The cases of single RAH fenestration and abnormal anastomosis of double RAH are unique and are probably the consequence of the persistence of a primitive olfactory artery. A case in which the mFBA crossed opposite to the RAH confirms the assumption that not only A_2, but also A_1 segment branches could be bihemispheric. Our cases illustrate the anatomical and morphological diversity of the RAH, of which neurosurgeons must be aware.

Our opinion is that comparative analysis of fetal and adult cases is justified by the fact that cerebral arteries are completely developed by Day 52 of gestation with all variations and abnormalities. We also believe that prenatal artery variations and abnormalities may remain in later life because of constant interaction between primitive arterial remnants and cerebral arteries in postnatal life, unless lesions arise.

Conclusions

The RAH was present in 97.3% of 188 evaluated hemispheres, and absent in 2.7% of the cases. Five types of RAHs were observed during morphological analysis. There were significantly more asymmetric subtypes (present in 65% of evaluated fetal brains) than symmetric subtypes. We hope that our results will be useful to neurosurgeons in planning and performing surgeries in this region of the brain so that unintentional injuries to the RAH and consequent postoperative complications can be avoided.

Disclaimer

The authors report no conflict of interest concerning the materials and methods used in this study or the findings specified in this paper.

References


301

Accepted December 18, 2008.
Address correspondence to: Ljiljana Vasović, M.D., Ph.D., Faculty of Medicine, Department of Anatomy, Boulevard Dr Zoran Đinđić 81, 18000 Niš, Serbia. email: wassa@ptt.yu or likica@medfak.ni.ac.yu.