Association Between Basilar Artery Hypoplasia and Undetermined or Lacunar Posterior Circulation Ischemic Stroke

Stephane Olindo, MD; Saad Khaddam, MD; Jonathan Bocquet, MD; Nicolas Chausson, MD; Mathieu Aveillan, MD; Philippe Cabre, MD; Didier Smadja, MD

Background and Purpose—The aim of the current study was to determine the prevalence of basilar artery hypoplasia (BAH) and to evaluate whether BAH is a possible risk factor for posterior circulation stroke (PCS).

Methods—Basilar artery diameter was assessed by MRI in 685 consecutive ischemic stroke patients. BAH frequency, defined as a diameter <2 mm, was measured and compared between anterior circulation stroke and PCS groups.

Results—Thirty-seven patients had BAH (5.2%): 15 of 195 (7.7%) in PCS and 22 of 490 (4.5%) in anterior circulation stroke (P=0.2). In undetermined or lacunar stroke patients, BAH frequency was higher in PCS than in anterior circulation stroke (14/97, 14.4% vs 10/216, 4.6%; P=0.005). National Institutes of Health Stroke Scale score was ≤4 in 65%. Localization of stroke was predominant in pons or cerebellar territories (71.4%). Half of PCS and BAH patients showed small pontic-penetrating arteries infarcts.

Conclusions—Our study suggests that BAH is associated with PCS in lacunar or undetermined stroke. Patients often had minor stroke and infarctions that were usually small and frequently located in pontine-penetrating artery territories. (Stroke. 2010; 41:2371-2374.)

Key Words: basilar artery ▪ hypoplasia ▪ posterior circulation stroke

Congenital variations in the size and arrangement of cerebral arteries are well-recognized. Vertebral artery hypoplasia or asymmetry is frequently described and significant association with posterior circulation stroke (PCS) has been shown in 2 studies.

Few observations have reported an association between basilar artery hypoplasia (BAH) and PCS. Although 2 case series have described PCS in patients with hypoplasia or small verteobasilar arteries, no data are available for BAH frequency or for its clinical relevance.

MRI is now widely used in the evaluation of acute stroke. Time-of-flight (TOF) MRA is a sensitive and easy technique for evaluating the circle of Willis.

High-resolution CT and TOF-MRA studies determined a mean basilar artery (BA) diameter at the pons level at ~3 mm. In fact, there is no consensus defining BAH, and we considered in the present work a diameter calculated at mid-pons level of <2 mm.

The aim of the current study was to determine, on MRI sequences, the prevalence of BAH in our hospitalized ischemic stroke population and to evaluate whether BAH is a possible risk factor for PCS.

Patients and Methods

From June 2006 to June 2009, 788 consecutive patients admitted for an acute ischemic stroke (AIS) to our stroke unit department were identified from our prospective database. Patients who did not undergo brain MRI (n=103) were excluded. Thus, 685 patients (285 women, 400 men; mean age, 66.91±13.85 years) were included.

Anterior circulation stroke was diagnosed in 490 (71.5%) patients and 195 (28.5%) had PCS. AIS diagnosis was made on clinical examination and brain MRI by 5 board-certified neurologists (S.O., S.K., N.C., P.C. and D.S.).

All imaging was performed in the horizontal plane using a 1-T MRI Scanner (Philips Intera) and recorded on Centricity Picture Archiving and Communications System (Centricity Enterprise Web V3.0; General Electric).

The routine MRI protocol included diffusion-weighted images, fluid-attenuated inversion recovery, gradient echo, and TOF-MRA on Willis circle sequences. Presence and localization of acute ischemic lesion were determined on diffusion-weighted image sequences. TOF images in a maximum intensity projection of the luminal flow detected artery abnormality on Willis circle.

We focused on BA, upper segment of vertebral artery (V4), and precommunicating segment of the posterior cerebral artery. MRA images were evaluated separately by 2 neuroradiologists who were blind to the diffusion-weighted image sequences results (M.A. and J.B.). BAH was retained when the 2 examiners agreed. BA diameter was calculated on TOF source images at the...
mid-pons level, whereas V4 diameter was considered at 10 mm of basilar junction. The selected TOF source images were zoomed and artery diameters were measured with a precision of 0.01 mm using Centricity software tools.

The mean BA diameter in all AIS was 3.33 ± 0.66 mm. A diameter less than mean minus 2 SD (2 mm) defined hypoplasia. The same cut-off value was considered for V4 artery hypoplasia. Fetal-type posterior circle of Willis configuration defined precommunicating

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### Table 1. Clinical and Radiological Characteristics of Patients With and Without Basilar Artery Hypoplasia

<table>
<thead>
<tr>
<th></th>
<th>Whole Stroke Cohort</th>
<th>Unetermined and Lacunar Stroke Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BAH + N=37</td>
<td>BAH – N=648</td>
</tr>
<tr>
<td>Age, mean ± SD, y</td>
<td>68.8 ± 14</td>
<td>66.8 ± 14</td>
</tr>
<tr>
<td>Men</td>
<td>21 (56.7)</td>
<td>379 (58.5)</td>
</tr>
<tr>
<td>PCS</td>
<td>15 (40.5)</td>
<td>180 (27.8)</td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td>18 (48.6)</td>
<td>448 (69.1)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>9 (24.3)</td>
<td>141 (21.8)</td>
</tr>
<tr>
<td>Smoking</td>
<td>1 (2.7)</td>
<td>96 (14.8)</td>
</tr>
<tr>
<td>Unilateral V4AH</td>
<td>26 (70)</td>
<td>181 (28)</td>
</tr>
<tr>
<td>Bilateral V4AH</td>
<td>18 (48.6)</td>
<td>8 (1.2)</td>
</tr>
<tr>
<td>Unilateral FTP</td>
<td>21 (56.7)</td>
<td>93 (14.3)</td>
</tr>
<tr>
<td>Bilateral FTP</td>
<td>19 (51.3)</td>
<td>16 (2.5)</td>
</tr>
<tr>
<td>Bilateral V4AH and FTP</td>
<td>18 (48.6)</td>
<td>2 (0.3)</td>
</tr>
</tbody>
</table>

All values are expressed as n (%) except for age.

BAH indicates basilar artery hypoplasia; FTP, fetal-type posterior circle of Willis; PCS, posterior circulation stroke; V4AH, upper-segment vertebral artery hypoplasia.

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### Table 2. Clinical and Radiological Characteristics of Undetermined or Lacunar Posterior Circulation Stroke Patients With Basilar Artery Hypoplasia

<table>
<thead>
<tr>
<th>Patient</th>
<th>Gender</th>
<th>Age (y)</th>
<th>NIHSS Score at Admission</th>
<th>Neurological Symptoms</th>
<th>mRS Score at Discharge</th>
<th>BAH Diameter (mm)</th>
<th>Associated Artery Hypoplasia</th>
<th>Stroke Territory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>51</td>
<td>1</td>
<td>Left hemi-hypoesthesia</td>
<td>0</td>
<td>1.67</td>
<td>Bilateral V4AH and bilateral FTP</td>
<td>Right thalamus</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>62</td>
<td>8</td>
<td>Left hemiparesis + dysarthria</td>
<td>1</td>
<td>1.80</td>
<td>Right V4AH and bilateral FTP</td>
<td>Right pons (AMA)</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>77</td>
<td>1</td>
<td>Right ataxia</td>
<td>1</td>
<td>1.95</td>
<td>Left V4AH and bilateral FTP</td>
<td>Left cerebellum (SCA)</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>51</td>
<td>1</td>
<td>Internuclear ophthalmoplegia</td>
<td>1</td>
<td>1.60</td>
<td>Bilateral V4AH and bilateral FTP</td>
<td>Right pons (PA)</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>83</td>
<td>12</td>
<td>Tetraparesis + dysarthria + internuclear ophthalmoplegia</td>
<td>6</td>
<td>1.81</td>
<td>Bilateral FTP</td>
<td>Bilateral pons (AMA + ALA)</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>83</td>
<td>9</td>
<td>Right hemiparesis + hemi-hypoesthesia + dysarthria</td>
<td>4</td>
<td>1.05</td>
<td>Bilateral V4AH and bilateral FTP</td>
<td>Left pons (AMA)</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>74</td>
<td>2</td>
<td>Left cerebellar ataxia</td>
<td>3</td>
<td>1.92</td>
<td>Bilateral V4AH and bilateral FTP</td>
<td>Left cerebellum (ACA)</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>38</td>
<td>3</td>
<td>Right hemiparesis + dysarthria</td>
<td>1</td>
<td>1.65</td>
<td>Bilateral V4AH and bilateral FTP</td>
<td>Left pons (AMA + ALA)</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>56</td>
<td>1</td>
<td>Right hemi-hypoesthesia</td>
<td>1</td>
<td>1.54</td>
<td>Left V4AH and bilateral FTP</td>
<td>Left thalamus</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>77</td>
<td>20</td>
<td>Tetraparesis + cerebral blindness + dysarthria</td>
<td>6</td>
<td>1.91</td>
<td>Bilateral V4AH</td>
<td>Bilateral occipital, pons (ALA), and cerebellum (SCA)</td>
</tr>
<tr>
<td>11</td>
<td>F</td>
<td>30</td>
<td>2</td>
<td>Left cerebellar ataxia + dysarthria</td>
<td>0</td>
<td>1.62</td>
<td>Bilateral V4AH and bilateral FTP</td>
<td>Right pons (AMA)</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>75</td>
<td>1</td>
<td>Right hemi-hypoesthesia</td>
<td>1</td>
<td>1.16</td>
<td>Bilateral V4AH and bilateral FTP</td>
<td>Left anterior medulla</td>
</tr>
<tr>
<td>13</td>
<td>F</td>
<td>65</td>
<td>1</td>
<td>Dysarthria</td>
<td>1</td>
<td>1.96</td>
<td>Bilateral V4AH and right unilateral FTP</td>
<td>Right cerebellum (SCA and ACA)</td>
</tr>
<tr>
<td>14</td>
<td>F</td>
<td>44</td>
<td>2</td>
<td>Right hemi-hypoesthesia</td>
<td>0</td>
<td>1.75</td>
<td>Left V4AH and bilateral FTP</td>
<td>Left thalamus</td>
</tr>
</tbody>
</table>

AICA indicates anterior inferior cerebellar artery; ALA, pontine anterolateral artery; AMA, pontine anteromedial artery; BAH, basilar artery hypoplasia; F, female; FTP, fetal-type posterior circle of Willis; M, male; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; PA, pontine posterior artery; SCA, superior cerebellar artery; V4AH, upper-segment vertebral artery hypoplasia.
segment of the posterior cerebral artery hypoplasia. Focal stenosis at the calculated level and irregular or occluded arteries were not considered as hypoplastic. Hypoplasia was defined as a continuous diameter reduction all over the artery.

Patients were assessed regarding the cause of the cerebral infarction. AIS etiologic diagnosis was determined according to TOAST classification.\(^{13}\) We focused on the undetermined and lacunar etiologic stroke subgroup to exclude patients with clear determined cause. Patients with negative evaluation results were considered as undetermined. Patients were classified and analyzed according to presence or absence of BAH, stroke location, and etiologic diagnosis.

### Results

#### Analysis of BAH Patients

BAH was found in 37 of 685 (5.2%) patients; AIS was found in 15 (7.7%) PCS patients and 22 (4.5%) anterior circulation stroke patients (\(P=0.2\)). Demographic characteristics and prevalence of conventional vascular risk factors did not differ between the 2 groups except for a higher arterial hypertension frequency in BAH-negative patients than in BAH-positive patients (Table 1). V4 artery hypoplasia and fetal-type posterior circle of Willis were significantly associated with BAH and 18 of 37 patients (48.7%) had an association of bilateral V4 artery hypoplasia, BAH, and fetal-type posterior circle of Willis.

In the undetermined (\(N=245\)) or lacunar (\(N=68\)) etiologic stroke subgroup (\(N=313\)), BAH frequency in PCS patients reached 14.4% (14/97) as opposed to 4.6% (10/216) in anterior circulation stroke patients (\(P=0.005\)).

#### Analysis of BAH Patients in Undetermined or Lacunar PCS

Neurological and MRI characteristics of the 14 BAH patients with undetermined or lacunar-PCS are described in Table 2. National Institutes of Health Stroke Scale score at admission was \(<4\) in 65% and modified Rankin score at discharge was \(<3\) in 79%. The mean BA diameter was 1.76±0.22 mm. Localization of stroke was predominant in pons or cerebellar territories (10/14; 71.4%). Seven (50%) patients experienced an infarction in the territories of pontine-penetrating arteries. Pontine infarctions tended toward a higher prevalence in BAH-positive patients than in BAH-negative patients (50% vs 23%; \(P=0.07\)). Brain MRI findings in patients with BAH associated with undetermined or lacunar-PCS are showed in the Figure.

#### Discussion

We found that BAH is significantly associated with undetermined or lacunar-PCS in a consecutive and prospective stroke database analysis based on diffusion-weighted images and TOF-MRA sequences. BAH frequency is relatively high in our Afro-Caribbean cohort (5.4%). Although no other study is available, BAH is usually considered as anecdotic.\(^{8}\) BAH prevalence does not differ significantly between all PCS and anterior circulation stroke patients. To exclude patients with demonstrated causes of stroke, we focused on patients with undetermined etiologic stroke defined as negative evaluation and lacunar size infarction. In this subgroup, BAH frequency was 3-fold higher in PCS than in anterior circulation stroke (14.4% vs 4.6%; \(P=0.005\)). The most prevalent pattern of Willis circle variation was the association of bilateral V4 artery hypoplasia, BAH, and bilateral fetal-type posterior circle of Willis. The high proportion of artery anatomic variation associated with regular BA narrowing argues for an embryonic developmental cause rather than an atherosclerosis-acquired cause.
Symptoms at admission were generally minor and functional prognosis was often good at discharge in BAH and PCS patients. Infarctions were usually small, and our findings support the study by Park et al. that demonstrated that congenital arteries hypoplasia was associated with small scattered infarction. The lesion was located in pontine-penetrating artery in half of our patients. These lesions are supposed to be caused by blocking of vessels because of luminal plaque of BA. The blood flow volume and velocity might be decreased in BAH, resulting in a higher susceptibility to prothrombotic or atherosclerosis processes than arteries of normal size.

It must be noted that our study cohort is likely not representative of the worldwide general population of AIS subjects in the frequency of BAH because our data are limited to a single center and to a homogenous ethnic Afro-Caribbean group.

**Conclusion**

In conclusion, our study constitutes the first large-scale frequency analysis of BAH in AIS patients. It suggests that BAH is related to undetermined or lacunar-PCS. These patients present homogenous clinical and MRI patterns. They are quite similar to other ischemic patients in terms of risk factors, they often had minor strokes, and infarctions are usually small and located in the territory of pontine-penetrating arteries. Further epidemiological studies in other populations are requested to confirm the association between BAH and PCS.

**Disclosure**

None.

**References**


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