Venous Drainage in Perimesencephalic Hemorrhage

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Background and Purpose—In perimesencephalic nonaneurysmal hemorrhage (PMH), subarachnoid blood accumulates around the midbrain. Clinical and radiological characteristics suggest a venous origin of PMH. We compared the venous drainage of the midbrain between patients with PMH and aneurysmal subarachnoid hemorrhage (aSAH) by means of computed tomography angiography (CTA).

Methods—CTAs of 55 PMH patients and 42 aSAH patients with a posterior circulation aneurysm were reviewed. Venous drainage was classified into: (1) normal continuous: the basal vein of Rosenthal is continuous with the deep middle cerebral vein and drains mainly to the vein of Galen (VG); (2) normal discontinuous: drainage anterior to uncal veins and posterior to VG; and (3) primitive variant: drainage to other veins than VG. Additionally, we compared in PMH patients the side of the primitive variant and side of the bleeding.

Results—A primitive variant was present on one or both hemispheres in 53% of PMH patients with PMH (95% CI, 40% to 65%) and in 19% of aSAH patients (95% CI, 10% to 33%). In all 16 PMH patients with a unilateral primitive drainage, blood was seen on the side of the primitive drainage (100%; 95% CI, 81% to 100%); blood was never found mainly on the side with normal drainage.

Conclusions—Patients with PMH have a primitive venous drainage directly into dural sinuses instead of via the vein of Galen more often than do controls. Moreover, the side of the perimesencephalic hemorrhage relates to the side of the primitive drainage. These results further support a venous origin of PMH. (Stroke. 2004;35:1614-1618.)

Key Words: perimesencephalic hemorrhage • subarachnoid hemorrhage • computed tomography • angiography

Perimesencephalic nonaneurysmal hemorrhage (PMH), first described by van Gijn et al in 1985, is characterized by accumulation of subarachnoid blood predominantly around the midbrain and absence of an aneurysm or other source of bleeding on angiography.2,3 Perimesencephalic hemorrhage constitutes ≈10% of all episodes of spontaneous subarachnoid hemorrhage (SAH) and two thirds of those with a normal angiogram.1,4–6 Typically, the clinical course is uneventful, rebleeding and ischemia do not occur, and patients have an excellent outcome.7,8

The cause of PMH has not yet been determined. The normal arteriograms, the limited extension of the hemorrhage, and the invariably mild clinical features at onset all suggest a small leakage of venous blood rather than a rupture under arterial pressure. Abnormalities of the perimesencephalic and deep internal veins have been suggested as well as cryptic brain stem arteriovenous malformations, but studies reviewing the venous phase of digital subtraction angiography (DSA) and magnetic resonance imaging (MRI) modalities of the veins included only few patients or did not show consistent structural abnormalities.9–13 Computed tomography (CT) venography is another way of depicting cerebral venous structures and yields detailed images of the intracranial venous circulation comparable to DSA and better than MR venography.14–16 An advantage of CTA over DSA in retrospective studies is that for CTA, the complete data set remains available in digital form whereas for DSA, although also digital, often only hard copies of past examinations are available.

We studied the venous drainage of the midbrain with CT angiography (CTA) to determine if there were structural differences between patients with PMH and patients with subarachnoid hemorrhage from a ruptured aneurysm (aSAH).

Materials and Methods

Patients

Since July 1995, all patients with SAH undergo CTA as part of the diagnostic work-up. We selected all patients since July 1995 with a PMH and all patients with a SAH from a posterior circulation aneurysm and a CTA of good quality and retrospectively assessed the perimesencephalic and deep cerebral veins on the CT angiograms. We assessed the clinical condition on admission by means of the World Federation on Neurological Surgeons (WFNS) scale.17 The quality of the CTA was assessed before evaluation of the venous vessels. The quality was considered good if there was enough contrast to evaluate the vessels and no artifact from patient movements or other artifact was impeding the evaluation of the cerebral vessels.

The majority of the patients in this study were scanned on the single slice CT scanner. Since November 2002, we screen patients with clipped aneurysms using multislice CTA (MS-CTA) as part of an ongoing study and since May 2003, we also patients with acute SAH.
CT Angiographic Acquisition: Single-Slice CTA

CTA was performed on a spiral CT scanner (Tomoscan SR 7000; Philips Medical Systems) with the following protocol: 40 to 60 1-second rotations of 1- to 1.5-mm collimation and pitch 1, reconstruction interval 1 mm, 140 kV/125 mA, and 16-cm field of view. The gantry was angled to the orbitomeatal line starting just above the posterior arch of C1. Scan delay was determined using a test bolus of 15 mL nonionic contrast (Iopromide, Ultravist, 300 mg iodine/mL; Schering) injected at a rate of 3 mL/sec using a power injector (CT 9000 Digital Injector System; Liebel-Flarsheim). For the CTA, 130 mL of the same contrast material was injected at a rate of 3 mL/sec.

Multislice CTA

CT scanning was performed on a 16-slice spiral CT scanner (Philips Mx8000 LDT, workstation MXView) with the following protocol: 16-row collimation at 0.75 mm, pitch 0.3, slice thickness 1 mm, reconstruction interval 0.5 mm, 120kV/200 mAs, and field of view 160 mm.

Scanning was performed in caudal-cranial direction, covering the volume from C1 to the vertex. A test bolus of 16 mL nonionic contrast (Iopromide, Ultravist, 300 mg iodine/mL; Schering) was given to determine the scan delay. With the use of a power injector (Stellant, Medrad), 70 mL contrast was injected into the cubital vein (18-gauge needle): 50 mL at a rate of 5 mL/s and 20 mL at a rate of 3 mL/s. A 30-mL saline flush was given at a rate of 3 mL/s. The MS-CTA was performed with low pitch in patients with PMH to visualize the venous system and in clipped patients to reduce clip artifacts.

CTA Evaluation

CTAs were reviewed in consensus by 2 observers. The evaluation could not be performed blinded for type of bleeding (PMH or aSAH) because either the aneurysm or the clip was visible on the CTA in patients with SAH. To avoid intense and operator-dependent post-processing with the risk of removing vasculature as well as bone, the venous system was evaluated on the axial source images in cine mode without any postprocessing. The MS-CT angiograms could also be viewed with a slab-viewer using multiplanar reconstruction (MPR) and maximum-intensity projection.

CTAs were reviewed for venous drainage and structural abnormalities of the deep cerebral and perimesencephalic veins (eg, malformations or varicose veins). Venous drainage was classified according to Watanabe et al:11 in normal continuous (type A), the basal vein of Rosenthal is continuous with the deep middle cerebral vein and drains mainly to the vein of Galen (arrow). C and D, Normal discontinuous venous drainage on the right side (type B), anterior to the uncal vein (black arrow), posterior to the vein of Galen. Discontinuous segmented venous drainage (type C) on the left side, anterior to the uncal vein (black arrow), posterior to the vein of Galen, and perimesencephalic to the superior petrosal sinus (open arrow). E and F, Discontinuous venous drainage (type B) in the right hemisphere and venous drainage directly into the straight sinus (open arrowhead) instead of via the vein of Galen (type C) in the left hemisphere. F and G, Impression of the tentorial margin on the basal vein of Rosenthal (arrowhead) draining into the straight sinus.

Types of venous drainage of the midbrain. A to F, Axial maximum intensity projection (MIP) slab images. G, Sagittal maximum intensity projection (MIP) slab images. A and B, Normal continuous drainage on both sides (type A). The basal vein of Rosenthal is continuous with the deep middle cerebral vein and drains mainly to the vein of Galen (arrow). C and D, Normal discontinuous venous drainage on the right side (type B), anterior to the uncal vein (black arrow), posterior to the vein of Galen. Discontinuous segmented venous drainage (type C) on the left side, anterior to the uncal vein (black arrow), posterior to the vein of Galen, and perimesencephalic to the superior petrosal sinus (open arrow). E and F, Discontinuous venous drainage (type B) in the right hemisphere and venous drainage directly into the straight sinus (open arrowhead) instead of via the vein of Galen (type C) in the left hemisphere. F and G, Impression of the tentorial margin on the basal vein of Rosenthal (arrowhead) draining into the straight sinus.

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Additionally, we assessed on noncontrast CT (NCCT) scans of PMH patients if the pattern of hemorrhage was symmetrical or asymmetrical. We defined asymmetrical as unequal amount of blood in the ambient cisterns. From 6 patients, the NCCT could not be retrieved for reviewing.

To investigate if the quality of the SS-CTA or MS-CTA affects the readings, we compared the venous systems on SS-CTA and the MS-CTA for patients who were scanned on both scanners and used the kappa statistics to calculate the agreement for the venous systems. For 11 patients, both SS-CTA and MS-CTA were assessed for the type of venous drainage. All 22 venous systems were equally categorized except for 2; 2 venous systems were scored as normal discontinuous (type B) on the SS-CTA and as normal continuous (type A) on the MS-CTA. Cohens kappa was 0.83 (95% CI, 0.61 to 1), which indicates good agreement.
Data Analysis
We calculated proportions with corresponding 95% CI to analyze differences in the type of venous drainage between patients with PMH and patients with aSAH and for the relationship between side of the primitive variant (type C) venous drainage and side of the bleeding on NCCT scan.

Results

Venous Drainage
We assessed the perimesencephalic and deep internal veins of 55 patients with a PMH and 42 patients with an aSAH from a posterior circulation aneurysm.

Seven patients (6 with aSAH and 1 with PMH) were excluded because the CTA could not be evaluated because of insufficient quality of the scan. This was because of technical error (1 aSAH patient), movement artifacts (1 aSAH patient), or suboptimal contrast enhancement (3 aSAH and 1 PMH patient). All patients with a PMH were in perfect clinical condition on admission (WFNS 1). Of the patients with aSAH, 14 were in perfect condition (WFNS 1), 19 were in good condition (WFNS 2 or 3), and 12 were in poor condition (WFNS 4 or 5) on admission.

Table 1 shows the distribution of type of venous drainage in PMH and aSAH patients. A primitive variant of venous drainage (type C) was present at least in 1 hemisphere in 29 patients with PMH (53%; 95% CI, 40% to 65%) and in 8 patients with aSAH (19%; 95% CI, 10% to 33%). A bilateral normal continuous drainage was present in 15 of the aSAH patients (36%; 95% CI, 23% to 51%) and in 4 of the PMH patients (7.3%; 95% CI, 2.9% to 17%). We did not find any vascular malformation or varicose veins.

Asymmetry of Hemorrhage and Side of Primitive Drainage (Type C)
Table 2 shows the relation between the primitive variant of venous drainage (type C) and distribution of blood. In all 16 patients with a unilateral primitive drainage from whom the NCCT scan was available, blood had extravasated on the side of the primitive drainage or symmetrically (100%; 95% CI, 81% to 100%); there were no patients with unilateral primitive drainage and extravasated blood distributed mainly to the contralateral side.

Discussion
In patients with PMH, the venous drainage is often directly into dural sinuses instead of via the vein of Galen. This primitive variant of venous drainage is much more frequent in patients with PMH than in patients with an aSAH. Moreover, in patients with a unilateral primitive variant, blood was always found on the side of the primitive drainage.

We did not find structural abnormalities of the perimesencephalic or deep internal veins. This is in accordance with other studies on structural abnormalities underlying PMH. In the original article, in PMH a tear in the basal vein of Rosenthal or one of its tributaries was posited as the most likely source. Other authors have proposed alternative sources, such as the anterior longitudinal pontine or interpeduncular and posterior communicating veins, ventriculostriate or thalamo-perforating arteries, and cryptic brain stem arteriovenous malformations. However, careful examinations of venograms revealed no consistent abnormalities in all these articles.

The categorization of the venous system in normal continuous (type A), normal discontinuous (type B), and primitive variant (type C) is based on the embryological development of the venous system and has recently been outlined. The basal vein of Rosenthal is a secondary vessel formed by longitudinal anastomosis of three primitive veins. These primitive veins drain initially into the tentorial sinuses; however, during development, these draining veins generally obliterate and drainage becomes mainly into the Galenic system. Because failure of anastomosis is most frequent between the first and second segment, type B is a common variant of type A.

<table>
<thead>
<tr>
<th>Type of Venous Drainage</th>
<th>PMH, n (%)</th>
<th>95% CI</th>
<th>aSAH, n (%)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (type A)</td>
<td>21 (19%; 13%–27%)</td>
<td></td>
<td>40 (58%; 48%–68%)</td>
<td></td>
</tr>
<tr>
<td>Bilateral normal (A)</td>
<td>4 (7.3%; 2.9%–17%)</td>
<td></td>
<td>15 (36%; 23%–51%)</td>
<td></td>
</tr>
<tr>
<td>Discontinuous (type B)</td>
<td>48 (43%; 35%–53%)</td>
<td></td>
<td>26 (31%; 22%–42%)</td>
<td></td>
</tr>
<tr>
<td>Primitive (type C)</td>
<td>29 (53%; 40%–65%)*</td>
<td></td>
<td>8 (19%; 10%–33%)*</td>
<td></td>
</tr>
</tbody>
</table>

*Score per patient: at least 1 type C venous drainage gives a positive score.

<table>
<thead>
<tr>
<th>Side of Primitive Drainage</th>
<th>Symmetric</th>
<th>Predominantly Left</th>
<th>Predominantly Right</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Left side</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Right side</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>No primitive drainage</td>
<td>11</td>
<td>6</td>
<td>6</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>16</td>
<td>13</td>
<td>49*</td>
</tr>
</tbody>
</table>

*In 6 patients, no information of lateralization of bleeding pattern was available.
The venous phases of 6 patients with PMH have recently been compared retrospectively on DSA with those of patients with aSAH. In all 6 patients with PMH, the basal vein of Rosenthal drained into various dural sinuses rather than in the Galenic system (type C primitive variant) on 1 or both sides. Similar primitive forms of the venous system were less frequently found in patients with aneurysmal SAH. In our study with a larger series of patients and with the entire data set available for review, many, but not all, patients with a PMH had a primitive drainage.

CTA has some clear advantages over DSA in the evaluation of the venous system. For all patients, the original data set of the CTA was available in digital form, which enables multidirectional visualization of the blood vessels. For DSA, usually only hard copies can be retrieved for retrospective review, because the data set often is not stored in digital form. Retrospective assessment of the venous system by means of CTA is therefore more precise than retrospective assessment by means of DSA. Because of the possibility of retrospective data assessment, we could evaluate a relatively large number of patients with a PMH.

Our study has some weak points. The majority of patients were scanned with SS-CTA. The resolution of SS-CTA is lower than DSA and MS-CTA. Compared with DSA, this allows for clear depiction of the venous pathways, but fine perimesencephalic venous networks are below the perception of the SS-CTA. However, the resolution of SS-CTA is sufficient to categorize the main route of venous drainage as expressed in our study. In a study comparing CTA with DSA for visualization of the venous system, MPR CTA had a 100% sensitivity for depicting the veins of the main route of drainage. Preferably, we would have had a blinded evaluation for type of SAH (PMH or aneurysmal SAH). However, because the presence of an aneurysm or clip depicts the source of hemorrhage, this was not possible. For 6 patients, the pattern of hemorrhage on the initial CT could not be re-assessed because this scan had been made in another hospital and could no longer be retrieved.

Because MS-CTA has a higher resolution than SS-CTA, even better visualization of the intracranial venous structures is to be expected with MS-CT depending on the scan protocol. The higher resolution may enable detection of small vessels that are undetectable on SS-CTA. Diagnostic bias could therefore occur, resulting in more type B instead of type A when evaluated with SS-CTA. The classification of type C drainage is not likely to be influenced by the difference in resolution, because this classification is not dependent on continuity of small vessels but rather on main route of drainage. Despite the differences in resolution, we found a good agreement regarding type of venous drainage for these 2 imaging modalities Therefore, we do not think that the use of these 2 modalities in our study has influenced our results.

Why a type C venous drainage is seen more often in patients with PMH remains unclear. It has been suggested that the direct connection of perimesencephalic veins with the dural sinuses may predispose to sudden increases in venous pressure with engorgement and rupture of the veins as a result. However, this suggestion is not substantiated by clinical findings. In large series of patients with PMH, only a minority reported Valsalva preceding the headache. When a large type C vein drains directly to a dural sinus, a tear might result from torsion or friction, where it crosses the tentorial margin, as suggested by van Gijn et al in 1985. Impression of the tentorial margin on the vein could be demonstrated in 1 of our patients with PMH who had a basal vein of Rosenthal draining directly into the straight sinus (Figure F and G).

In our series, some patients with PMH had a bilateral normal continuous venous drainage (type A). One explanation for PMH in patients with a normal drainage pattern is that the fine capillary perimesencephalic network also drains partly to the superior petrosal sinus, but this is below the resolution of the CTA, especially with the SS-CTA performed in most of our PMH patients. This could be evaluated with MS-CTA in the future. Another, but less likely, explanation is that a primitive venous drainage disrupts after the PMH, and from that time on, venous blood drains into the normal basal vein of Rosenthal route. A venous malformation or variant outside the CTA volume is unlikely because we perform an extensive scan from the posterior arch of C1 up to the vertex.

In conclusion, patients with PMH often have primitive venous drainage directly into dural sinuses instead of via the vein of Galen in comparison to patients with aSAH. Moreover, the side of the perimesencephalic hemorrhage relates to the side of the primitive drainage. These results further support a venous origin of PMH.

Acknowledgments

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References

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