Intracranial arterial fenestration: frequency on CT angiography in patients with and without aneurysm

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Purpose

The frequency of intracranial fenestration is reported as lower than 1% in previous studies with conventional angiography. In this study, we aim to determine the frequency of fenestration by CT angiography and also search presence of any association with aneurysm and other vascular variations.

Methods and Materials

The study included 145 consecutive patients that underwent CT-angiography between September 2007 and May 2008. Subarachnoid hemorrhage, cerebro-vascular attack, unexplained severe headache and preoperative evaluation of vascular anatomy of patients with intracranial tumors were main indications for the imaging.

CT angiography was performed with Philips Brilliance CT scanner (Philips Medical Systems, Cleveland, Ohio). Scanning was performed with the following parameters: detector rows, 64; collimation, 0.625 mm; feed/rotation, 12.0 mm; and gantry rotation time, 0.75 sec. A volume of 75 mL of non-ionic contrast medium was injected at 4.0 mL/s through an antecubital vein with an automatic power injector. The quantity of contrast material was re-calculated according to body weight (1 ml/kg) for pediatric cases (n=4). The scan delay time was a 5-6-second determined by an automatic bolus-tracking program with a region of interest at the left common carotid artery. The scanning time was 3.1 s. The effective reconstructed section width was 0.75 mm, with a reconstruction index of 0.5 mm. The reconstructed data sets were sent to a workstation for postprocessing to create multiplanar reconstructions (MPR) and maximum intensity projections (MIP). Rotation center MPR was also used to see all length and all borders of the fenestrated segment and aneurysm, respectively. We did not routinely use volume rendering display algorithms, which typically require more time.

The exclusion criterion of the study was technically suboptimal CT-angiographies that hindered proper visualization of intracranial arteries. Nine patients with technically suboptimal CT angiography (movement artifacts, inadequate filling with contrast material, too long pre-scan delay). The remaining patients were included.

In all, the records of the 136 patients (72 female, 64 male, mean 49.3±18, range: 4-96 years) were retrospectively reviewed for aneurysm, fenestration and associated vascular variation.

The rate of overall fenestration rate, the rate of fenestration in patients who had and did not have aneurysms and the rate of aneurysm in patients who had and did not have fenestrations were investigated. Chi-square test was used for statistical evaluation. A value of p less than 0.05 was considered as significant.

Results
A total of 14 fenestrations were identified in 13 patients of the 136 cases (9.6%), the most common localization (4.4%) was the anterior communicating region. The localizations of fenestration sites are briefly listed in table 1 on page . In 1 patient, fenestration of BA and anterior communicating region co-existed. An example of anterior communicating region of fenestration and of basilar artery fenestration is shown in figure 1 on page and figure 2 on page , respectively. Sixty aneurysms were determined in 45 patients, 8 of whom had multiple aneurysms. The frequent localizations of aneurysm were anterior communicating artery (n=21), middle cerebral artery bifurcation (n=14) and posterior communicating artery orifice (n=10) with decreasing frequency. Aneurysms were present at the fenestration site in two patients and remote from the fenestration site in nine. The fenestrated segments with associated aneurysms were at the A1-A2 segments of anterior cerebral artery (ACA), and the proximal half of the BA (Fig. 3). on page

Fenestration was determined in 6 (13.6%) of the 44 patients with aneurysm, and in 7 (7.6%) of the 92 patients without aneurysm. Aneurysm was determined in 6 (46.1%) of the 13 patients with fenestration and in 39 (31.7%) of the 123 patients without fenestration. The rate of fenestration was not significantly different in patients who had and did not have aneurysms (13.6 and 7.6%, respectively), and conversely the rate of aneurysms was not significantly different in patients who had and did not have fenestrations (46.1 and 31.7%, respectively).

Whether having multiple aneurysms also did not seem to increase the frequency of fenestration either. Only one patient with multiple aneurysm had fenestration, whereas others (n=7) did not have.

We observed vascular variation in only posterior circulation. Common origin of posterior cerebral artery and superior cerebellar artery in 2 patients and absence of posterior inferior cerebellar artery in one patient with vertebrobasilar fenestration, duplicated superior cerebellar artery with fenestration of contralateral P1 segment fenestrations were determined. Any variation in anterior circulation co-existed with fenestration was not observed.
Table 1. Distribution of fenestrated segments in the study

<table>
<thead>
<tr>
<th>Localization</th>
<th>Number (n)</th>
<th>Overall rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior communicating region</td>
<td>6</td>
<td>4.4</td>
</tr>
<tr>
<td>Basilar artery</td>
<td>3</td>
<td>2.2</td>
</tr>
<tr>
<td>Superior cerebellar artery</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Middle cerebral artery</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>Posterior cerebral artery</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>Vertebral artery</td>
<td>1</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**Fig.:** Distribution of fenestrated segments in the study.
**Fig.** Axial oblique view. Fenestrated segment of distal A1 (black arrows) and anterior communicating artery (white arrowhead) are seen.
**Fig.**: Coronal view. Fenestration at the proximal segment of basilar artery with bridging artery (asteriks)
**Fig.**: Coronal oblique view. Fenestration at the proximal basilar artery. Also notice the saccular aneurysm located at proximal portion the fenestrated segment (arrow).
Conclusion

Fenestrations are rare congenital anomalies related to abnormal development of primitive embryologic vessels. Fenestration of anterior and posterior circulation have different underlying embryologic basis. It is reported that fenestrations of the basilar system are due to partial failure-of-fusion of the paired longitudinal neural arteries of the 5-7 mm embryo (14), whereas in the anterior circulation, although not well understood, it may be a result of residual anastomoses between the primitive vascular network formed between the anterior and middle cerebral arteries in the 4-5 mm embryo (4).

Anterior communicating region and vertebro-basilar system are the two more frequent sites of fenestration. ACoA itself is an exception, known to have a complex anatomy at microsurgery with duplicated, fenestrated or plexiform appearance in greater than 40-60% of cases (15). Despite this frequent occurrence in anatomic studies, angiographic demonstration of fenestrations of the ACoA is very uncommon. Sanders et al. (4) revealed the frequency of ACA fenestration as 0.058% in conventional angiography. Incidence of BA fenestration was reported as 5.26% in an autopsy series (2). However, Sanders et al (4) reported only 16 BA fenestrations among 5,190 cerebral angiograms (0.3%). But limitation of the latter study is that only the angiography reports, not the images, were reviewed. Another pitfall of conventional angiography technique that reduces the number of basilar fenestration may be related with possible obscure of laminar flow from the contralateral vertebral artery.

Different angiography techniques other than conventional angiography were used to detect fenestration and other vascular variants. Uchino et al. (13,16) studied both ACA variations including fenestration and also BA fenestrations with MR angiography. Frequency of anterior communicating region and BA fenestrations were reported as 1.2 % and 1.7 %, respectively. But we think that small fenestrations may be missed due to low resolution of 3-dimensional-time-of-flight technique that was used in these studies. Also, exclusion of vertebro-basilar junction from the field of view may be another reason of reduced fenestration number. Bharatha et al. (6) investigated the frequency of fenestration in cerebral vessels with multi-detector CT-angiography, to our knowledge the only study other than ours. They reported that anterior communicating region was the most frequent (6.9%), and BA was the second frequent (2.8%) site of fenestration. In our study, we also found fenestration most frequently in the anterior communicating region (4.4%). The overall rate (10.4%) was also close to their study (10.8%). The fenestrations we detected were relatively large and generally had a lens-like shape in the anterior circulation, whereas small fenestrations with slit-like shape were more commonly observed in the BA. BA fenestrations are most commonly located in the proximal basilar trunk close to the vertebrobasilar junction (17).

The association of fenestrations with aneurysms has been extensively reported in case series (8-12) although the exact relationship is not well defined in studies with large samples (4,6,13). Probable association of fenestration with aneurysm due to presence of focal defects on media layer at proximal and distal end of the fenestrated segments (18) is challenging for neurosurgeons and also especially interventional neuroradiologists. Aneurysms associated with fenestrations are

classically thought to arise at the proximal end due to a combination of hemodynamic stresses and this media defect. A similar risk of aneurysm formation at the circle of Willis branch points which have similar wall defect has been reported (4). The incidence of this association was reported to be 7% with conventional angiography (4). Gast et al (15) focused on only ACoA aneurysms relation with fenestration of the same location and they found 10 of the 12 fenestration out of 305 3-dimensional datasets associated with ACoA aneurysms. This high association ratio is defined neither in our study nor in the study by Bharatha et al (2 of the 14 in ours, 2 of the 53 in Bharatha's). Because of low fenestration rates compared to cadaver series, and lack of data from non-aneurysmatic patients, Gast et al (15) also could not establish a definite relationship. To compare fenestration rates in patients who had and did not have aneurysms (at the fenestration site or remote), we constituted patient groups according to CT findings (whether with aneurysm or not), in contrast to imaging reasons, the way Bharatha et al. did. In our study although overall ratio of aneurysm was higher, significant association was not established, with similar results when compared to their study.

Main limitation of our study is absence of any other techniques, especially conventional angiography, as a gold standard modality to compare the findings. But nowadays, introduction of multi-detector row CT with speed gantry rotation time allows fast data acquisition with high spatial resolution. Also with scopes of multi-planar imaging and post-processing techniques, it has become more important to show details of cerebral vessels in contrast to vascular superposition that limits optimal evaluation in conventional angiography (11). So, the gold-standard position of conventional angiography will probably be questioned in the near-future. Although there are some studies (15,17) and case reports (12,19) with 3-dimensional rotational angiography showing presence of fenestration, we could not use that modality because it is not available in our institution.

As a conclusion, this study reveals the higher frequency of overall fenestration rate other than autopsy series. Fenestration does not seem to be directly associated with aneurysm. Association fenestration with other vascular variations are relatively uncommon especially in anterior circulation. Multi-detector CT angiography with high resolution post-processing techniques such as MPR and MIP, enables correct diagnosis of vascular variations such as fenestration.