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Fenestrations of Intracranial Arteries Detected with 3D Rotational Angiography

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BACKGROUND AND PURPOSE: Fenestrations of intracranial arteries are variants resulting from incomplete fusion of primitive vessels. An association with aneurysms is suggested in many studies. On conventional angiography, fenestrations are rarely visible. 3D rotational angiography (3DRA) provides improved visualization of cerebral vessels from any desired angle. We used 3DRA to assess the frequency and location of fenestrations of intracranial arteries and a possible relationship with aneurysms.

MATERIALS AND METHODS: In 208 patients with suspected intracranial aneurysms, 3DRA of 1, 2, or 3 cerebral vessels (in 143, 16, and 49 patients) was reviewed for the presence and location of fenestrations and aneurysms. When fenestrations were present in combination with aneurysms, we noted the relationship of the locations.

RESULTS: In 59 of 208 patients, 61 fenestrations were detected (28%). Fenestrations were more frequent in the anterior than in the posterior circulation (23% versus 7%). The frequency of fenestrations in 185 patients with aneurysms was not different from the frequency in 23 patients without aneurysms. Of 220 aneurysms present in 208 patients, 10 aneurysms (4.5%) were located on a fenestration. Of 61 fenestrations, 51 (84%) were not associated with an aneurysm.

CONCLUSIONS: With 3DRA, fenestrations were found in 28% of patients. In our study, fenestrations occurred more often in the anterior than in the posterior circulation, and the most common location was the AcomA. A definite relationship between fenestrations and aneurysms cannot be concluded from our data.
In patients with both aneurysms and fenestrations, we classified the relation of the location of the fenestration with the location of the aneurysms as remote from the fenestration, adjacent but unrelated to the fenestration, or on the fenestration itself (Fig 1). In addition, we assessed whether detected fenestrations were visible in retrospect on standard projections of 2D angiographic images.

**Data Analysis**

We compared sex distribution in patients with and without fenestrations. In patients with and without intracranial aneurysms, we compared the proportion of patients with a fenestration with those without a fenestration. In patients with fenestrations, we compared the proportion of fenestrations in the anterior circulation with the proportion of fenestrations in the posterior circulation. For comparison of proportions, the $\chi^2$ test was used.

**Results**

**Patients**

Of 208 patients with re-evaluated 3DRA datasets, 71 (34%) were men and 137 (66%) were women, with a mean age of 52.8 years (range, 14–84 years). Of 208 patients, 49 had 3DRA of 3 vessels (both carotid arteries and a vertebral artery), 16 had 3DRA of 2 vessels (14 patients with both carotid arteries and 2 patients with a carotid and a vertebral artery), and 143 patients had 3DRA of 1 vessel (carotid artery in 122 patients and vertebral artery in 21 patients). Altogether, 248 carotid arteries and 72 vertebral arteries were imaged with 3DRA.

In 23 patients, no aneurysm was detected. The remaining 185 patients had 218 aneurysms with the following locations: AcomA, 62 (28%); middle cerebral artery, 49 (22%); posterior communicating artery, 40 (18%); basilar artery, 13 (6%); cavernous sinus, 11 (5%); carotid tip, 11 (5%); anterior choroidal artery, 9 (4%); ophthalmic artery, 8 (4%); posterior inferior cerebellar artery, 6 (3%); superior cerebellar artery, 4 (2%); vertebral artery, 3 (1%); P1 segment of the posterior cerebral artery, 1 (1%); and anterior inferior cerebellar artery, 1 (1%).

**Fenestrations**

Results are summarized in Fig 2. Sixty-one fenestrations were present in 59 of 208 patients (28%, 2 patients had 2 fenestrations) with the following locations: AcomA in 43 (70%), middle cerebral artery in 12 (20%), posterior cerebral artery in 2 (3%), carotid artery in 1 (2%), vertebral artery in 1 (2%), superior cerebellar artery in 1 (2%), and basilar artery in 1 (2%). Of 59 patients with fenestrations, 22 (37%) were men and 37 (63%) were women. Sex distribution did not differ between patients with and without fenestrations. Of 61 fenestrations, 56 were located in the anterior circulation, diagnosed on 248 carotid artery 3DRAs, (23%), and 5 were located in the posterior circulation, diagnosed on 72 vertebral artery 3DRAs (7%). This difference was significant ($P = .0043$).

Fifty-six fenestrations were present in 54 of the 185 patients (29%) with aneurysms. Five fenestrations were present in 5 of the 23 patients (22%) without aneurysms. This difference was not significant.
The anatomic relationship of the 56 fenestrations and the aneurysms in 54 patients with aneurysms was as follows: aneurysm located on the fenestration itself in 10 (18%), aneurysm adjacent to the fenestration in 12 (21%), and aneurysm remote from the fenestration in 34 (68%). In 208 patients with 218 aneurysms, 10 aneurysms (4.5%) were located on a fenestration and 210 were not. Of 61 fenestrations, 51 (84%) were not associated with an aneurysm.

Of 61 fenestrations detected on 3DRA, 10 (16%) were in retrospect visible on 2D angiographic images.

Discussion
In this study, we found that fenestrations of intracranial arteries are commonly found with 3DRA imaging. The frequency of 28% for the presence of fenestrations found in this study is an underestimation because most patients had only 1 vessel territory imaged with 3DRA. With complete 3DRA evaluation of all cerebral vessels, a frequency of approximately 40% would probably be a realistic estimate. Although fenestrations can be located anywhere in the intracranial circulation (Fig 3), they occur more often in the anterior circulation than in the posterior circulation. The most common location is the AcomA, followed by the middle cerebral artery (Fig 4). Although most fenestrations are located on or near the circle of Willis, distal cerebral arteries can also be fenestrated (Fig 4C).

The common occurrence of fenestrations of intracranial arteries, especially in the AcomA complex, is well known from anatomic and surgical studies. However, with 2D angiography, fenestrations are rarely found: In 2 studies of 5190 and 4500 cerebral angiograms, fenestrations were reported in 0.7% and 0.07%, respectively. Apparently, with 2D imaging, most fenestrations are overlooked or are invisible because of over-
projecting vessels, preferential flow in 1 limb, or location remote from the region of interest. Many fenestrations are only visible from specific viewing angles that are usually not available on 2D imaging. Also in our study, just a small minority of fenestrations was, in retrospect, visible on standard 2D angiographic projections. With the advanced postprocessing techniques of 3DRA, cerebral vessels can be evaluated from any desired angle, and complex vascular anatomy can be unraveled effectively, allowing detection of many vessel fenestrations.

The advantage of 3D imaging in the detection of fenestrations has recently also been demonstrated in a study using CT angiography (CTA). In this study, fenestrations were reported in 11% of patients. The lower reported frequency of intracranial fenestrations with CTA compared with 3DRA (despite complete imaging of the brain vasculature with CTA) reflects the lower resolution of CTA combined with less-sophisticated postprocessing software. Few data are available on the detection of fenestrations with MR angiography (MRA), but the frequency seems lower as reported with both 3DRA and CTA.

The association of aneurysms with fenestrations has been extensively documented, though the reason for this relationship is not well understood: Vessel wall microstructure at fenestrations is not different from that of normal cerebral vessels. At branching points, medial defects are equally common in fenestrations as in normal vessel branching points. Aneurysms associated with fenestrations are classically thought to arise at the proximal end of a fenestration due to a combination of a medial defect and hemodynamic stresses, similar to aneurysm formation on the circle of Willis. In our study, the frequency of fenestrations was not different in patients with or without aneurysms. Most fenestrations were not associated with an aneurysm on the fenestration itself, and most aneurysms were not located on a fenestration. Our patient group was selected on the suspicion or presence of intracranial aneurysms. These criteria resulted in a maximal bias toward patients with aneurysms. Most of these rare aneurysms are associated with a proximal basilar fenestration. Also, some unusual locations of fenestrations in combination with aneurysms in our patient group might suggest a relationship (Figs 3A and 4A, -B). Although fenestrations might not be related to aneurysms in general, fenestrations on specific locations could, nevertheless, be associated with aneurysms. Without the availability of robust data on the frequency and location of fenestrations in the general population as a control, no definite relationship between fenestrations and aneurysms can be established. Perhaps, specific aneurysms (for example vertebral junction aneurysms) might be associated with a fenestration at that site.

Presently available data indicate that the detection rate of fenestrations with 3DRA is higher than that with CTA or MRA.

Conclusions

With 3DRA, fenestrations were found in 28% of patients. Fenestrations occur more often in the anterior circulation than in the posterior circulation, and the most common location is the AcomA. A definite relationship between fenestrations and aneurysms cannot be concluded from our data.

References