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Detection of cerebral artery fenestrations by computed tomography angiography

Fenestracje tętnic mózgowych w angiografii tomografii komputerowej

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Abstract

Background and purpose: Cerebral artery fenestrations (CAF) are rare congenital variations usually diagnosed by digital subtraction angiography (DSA). The aim of this study was to examine the frequency of occurrence of fenestrations in cerebral arteries and their coexistence with cerebral aneurysms in computed tomography angiography (CTA).
Material and methods: All reports of cerebral CTA (1140) performed in one institution from March 2005 to December 2007 were analysed. We found 40 patients with single fenestrations of the intracranial arteries. All 40 examinations were retrospectively reviewed for location of vascular malformations and presence of aneurysms or subarachnoid haemorrhage (SAH). Medical histories of those patients were then analysed for evidence of SAH and referral reasons for CTA.
Results: Forty fenestrated arteries were found in CTA: 18 basilar arteries (45%), 16 anterior cerebral arteries (40%), 4 anterior communicating arteries (10%) and one middle cerebral artery (2.5%). Only one vertebral artery fenestration was found due to the technique of the examination. Six patients (15%) with fenestrated arteries had a total of 8 aneurysms, although only one aneurysm was ipsilateral to the fenestration. In 8 cases of SAH, two were with no evidence of vascular malformation. The coexistence of CAF and aneurysms in CTA amounted to 15% (6/40), but the incidence of ipsilateral aneurysm was only 2.5% (1/40) and it affected the anterior cerebral artery.

Streszczenie

Wstęp i cel pracy: Fenestracje tętnic mózgowych są rzadkimi wrodzonymi wariantami anatomicznymi diagnozowanymi najczęściej przy użyciu angiografii subtrakcyjnej (DSA). Kliniczne znaczenie tych malformacji nie zostało do końca poznane, a ich obecność jest często łączona ze współwystępowaniem krwawienia podpajęczynówkowego (SAH) lub innych malformacji tętniczych. Celem badania była ocena częstości występowania fenestracji w obrębie tętnic mózgowych oraz współistnienia tej anomalii z tętniakami w badaniach angiografii tomografii komputerowej (angio-TK).
Materiał i metody: Retrospektywnej analizie poddano 1140 opisów wszystkich badań angio-TK głowy wykonanych w jednej jednostce w okresie od marca 2005 r. do grudnia 2007 r. Dokumentację medyczną oraz badania angio-TK 40 pacjentów, u których opisano fenestrację, oceniono powtórnie pod kątem: potwierdzenia lokalizacji malformacji tętniczej, współwystępowania tętniaków tętnic mózgowych i SAH. Historie chorób pacjentów analizowano w celu określenia przyczyn skierowania na badanie oraz wystąpienia SAH w późniejszym terminie niż wykonane badanie.
Wyniki: Wśród 1140 analizowanych wyników badań angio-TK wykryto 40 fenestracji tętnic mózgowych, w tym: 18 (45%) zlokalizowanych na tętnicy podstawnej, 16 (40%) tętnicy przedniej mózgu, 4 (10%) tętnicy łączącej przedniej i po 1 (2,5%) na tętnicy środkowej mózgu oraz tętnicy kręgowej. U 6 (15%) pacjentów z fenestracją wykryto 8 tętniaków, w tym w jednym

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Conclusions: Basilar artery fenestration is the most frequent observed fenestration in CTA, followed by anterior cerebral artery and anterior communicating artery fenestrations. Coexistence of fenestration and aneurysm is uncommon in CTA examination.

Key words: computed tomography angiography, artery fenestration, cerebral aneurysm, vascular malformations.

przypadku tętniak położony był po tej samej stronie co fenestracja. U 8 chorych fenestracja współwystępowała z SAH, w tym w 2 przypadkach była jedyną wykrytą malformacją tętniczą.

Wnioski: Najczęstszą lokalizacją fenestracji w badaniach angio-TK głowy jest tętnica podstawna, a w dalszej kolejności: tętnica przednia mózgu i tętnica łącząca przednia. Współwystępowanie fenestracji i tętniaków rzadko obserwuje się w badaniach angio-TK głowy.

Słowa kluczowe: angiografia tomografii komputerowej, fenestracja, tętniak, malformacje naczyniowe.

Introduction

Cerebral artery fenestrations are rare congenital variations usually diagnosed by digital subtraction angiography (DSA). Recent developments in technology allow diagnosis by magnetic resonance (MR) angiography [1] or computed tomography (CT) angiography (CTA) [2,3]. The reports of incidence of cerebral artery fenestrations differ and depend on the cerebral artery location and the method of examination [4]. The relationship between fenestration, cerebral aneurysm and other vascular malformations still remains unclear.

Our aim was to assess the incidence of fenestration in various cerebral artery locations in CTA studies. We also examined the incidence of the coexistence of cerebral artery fenestrations with cerebral aneurysms in CTA.

Material and methods

All written reports of CTA performed from March 2005 to December 2007 in HELIMED Diagnostic Imaging Center in Katowice, Central Clinical Hospital of the Medical University of Silesia (1140 patients), were retrospectively reviewed. The examinations were performed using the GE Medical System 16-row CT scanner LightSpeed in the same protocol of examination. The images were obtained with minimum collimation of 1.25 mm after the intravenous administration of 100-120 mL of contrast media injected at the rate of 4-4.5 mL/s. All 1140 CTA reports were prepared by one of five radiologists with more than 10 years of experience. We found 40 patients with cerebral fenestrations. Their CT angiograms were re-assessed by one experienced radiologist using the Advantage Workstation 4.4 (AW, General Electric) and the multiplanar (MPR), maximum intensity (MIP) and 3D volume rendering (VR) protocols of reconstruction. We confirmed the location of fenestration, the presence of aneurysms, subarachnoid haemorrhage (SAH) and other vascular malformations. There were no significant differences between the retrospectively reviewed reports and visualized pathologies. We checked the history of hospitalization of the patients in the Hospital Information System and the reasons for which they were referred for CTA.

Results

Among 1140 CTA reports, we found and confirmed cerebral artery fenestrations in 40 patients (3.51%, 28 women and 12 men) the mean age of whom was 42 years (ranging from 9 to 76 years) (Table 1). Six out of 40 patients (15%) had a total of 8 aneurysms but only in one case (2.5%) was the aneurysm ipsilateral to the fenestrated artery (anterior cerebral artery, ACA). Eight of 40 patients (20%) with fenestration had SAH – no evidence of vascular malformations was found in two of them (Table 2).

Eighteen patients (11 women and 7 men) had fenestration of the basilar artery (BA), in one case coexisting with SAH and aneurysms of the basilar (BA), internal carotid artery (ICA) and the middle cerebral artery (MCA) (Fig. 1). Another patient had SAH with middle cerebral artery (MCA) aneurysm. We observed one case of fenestrated BA coexisting with SAH without clear evidence of an aneurysm.

In 16 cases (13 women and 3 men), fenestrations were associated with ACA among which 3 cases of SAH and aneurysms of the internal carotid artery (ICA), vertebral artery (VA) or anterior cerebral artery (ACA) were noted. In one case of fenestrated ACA, the patient after SAH presented no evidence of vascular malformations.

We found 4 patients (3 women and 1 man) to have a fenestration of the anterior communicating artery (AComA) (Fig. 2), in one case after SAH with MCA aneurysm. Only one woman had an MCA fenestration.

Table 1. The location of cerebral artery fenestration

Location of fenestration	Number of cases	Male to female ratio	Percent of cases (%)	Proportion of fenestration in all CTA reports (%)	Aneurysm	Patients with aneurysm	Patients with SAH
ACA	16	1 : 4.3	40.0	1.40	3	3	4
MCA	1	0 : 1	2.5	0.08	0	0	0
AComA	4	1 : 3	10.0	0.35	1	1	1
BA	18	1 : 1.6	45.0	1.58	4	2	3
VA	1	1 : 0	2.5	0.08	0	0	0
Total	40	1 : 2.3	–	3.51	8	6	8

CTA – computed tomography angiography, SAH – subarachnoid haemorrhage, ACA – anterior cerebral artery, BA – basilar artery, AComA – anterior communicating artery, ICA – internal carotid artery, MCA – middle cerebral artery, VA – vertebral artery

Table 2. Subarachnoid haemorrhage and cerebral artery fenestration

Case	Sex	Age (years)	Presentation	Location of fenestration	Aneurysm	Location of aneurysm
1	F	15	SAH	ACA	1	ICA
2	F	62	SAH	ACA	–	–
3	F	63	SAH	BA	3	BA, ICA, MCA
4	F	74	SAH	AComA	1	MCA
5	F	42	SAH	BA	1	MCA
6	M	51	SAH	ACA	1	ACA
7	F	38	SAH	ACA	1	VA
8	F	45	SAH	BA	–	–

F – female, M – male, SAH – subarachnoid haemorrhage, ACA – anterior cerebral artery, BA – basilar artery, AComA – anterior communicating artery, ICA – internal carotid artery, MCA – middle cerebral artery, VA – vertebral artery

We also found a single case of vertebral artery (VA) fenestration.

Patients with fenestrated arteries were referred for CTA mostly due to headaches (14 out of 40) or suspicion of vascular malformations other than aneurysm (8 out of 40). Eight patients had SAH symptoms. The other reasons for referral were suspicion of aneurysm (3 patients), metastases or other intracranial tumours (5 patients) and an ischaemic event of the central or peripheral nervous system (2 patients).

Discussion

Fenestrations of cerebral arteries are congenital variations mostly related to abnormal development of the primary cerebral vessel system during the embryonic period. Fenestrations of intracranial vessels are caused by the incomplete fusion of primary neural arteries (BA) in the embryo of 5 weeks [4-6] or most likely are remnants of the plexiform anastomosis (MCA, ACA) formed in the fourth to sixth fetal week [2,4]. Although the embryological basis of those anomalies has been described, the aetiology of fenestration still remains unclear.

Despite the differences between them, the terms 'fenestration' and 'duplication' are sometimes used interchangeably in the literature. The word 'fenestration' refers to the localized duplication of a vessel split into two channels with separated lumens that have a common origin and rejoin distally. The term 'duplication' refers only to such variations which have a duplicated origin.

The incidence of fenestrations differs among studies and depends highly on the location and method used in the study (Table 3). DSA is "the gold standard" in diagnosis of cerebral artery anomalies, but recent developments in technology allow diagnosis by CTA or MR angiography. Moreover, small fenestrations are not detectable by conventional 2D angiography [4,7] and the frequency of fenestration reported in those studies (0.7%) was much

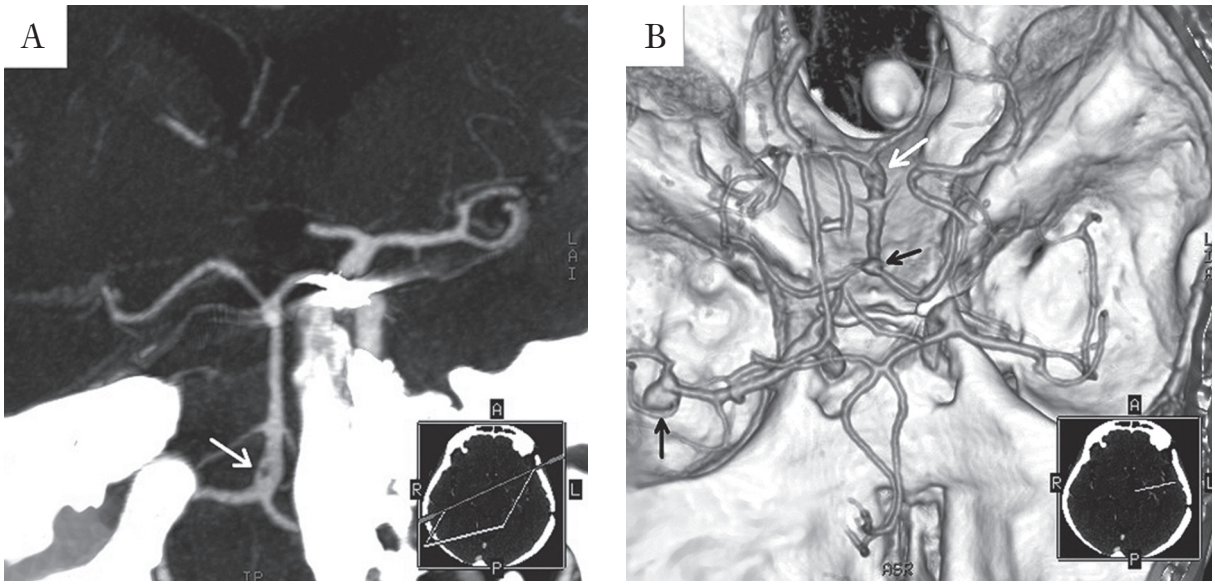

Fig. 1. CT angiography – MIP (A) and 3D volume rendering reformats (B). Basilar artery fenestration (white arrow) with coexistence of right middle cerebral artery and basilar artery aneurysm (black arrows). Artifacts after surgical treatment of internal carotid artery aneurysm

lower than in a single review of CTA (11%) and in our study (3.5%) [6]. On the other hand, small fenestrations of the AComA or ACA can be mistaken for AComA aneurysm in MR angiography [4]. Recent studies confirm that this type of small fenestration can be detected by 3D reconstruction images from rotational DSA (3D DSA) and report occurrence of fenestration in as many as 28% of patients [8].

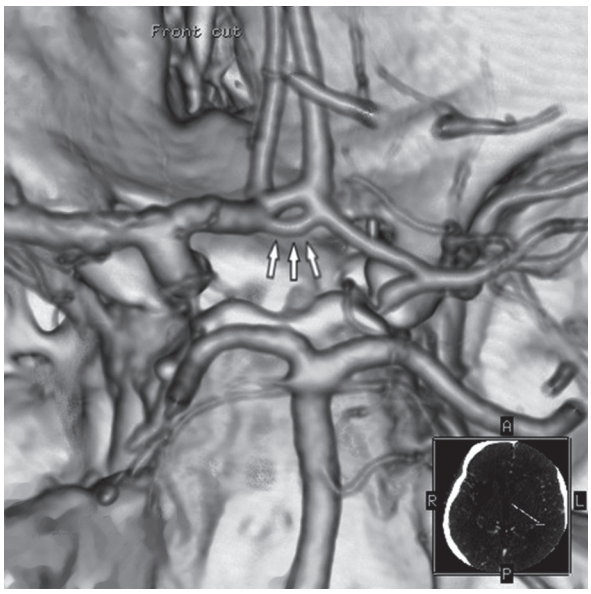

Fig. 2. CT angiography – 3D volume rendering – anterior communicating artery fenestration (white arrows)

The most common location of fenestration is the ACA-AComA complex with the incidence varying from 7 to 40% in autopsy series, 6.9% in CTA, and up to 20.7% in 3D DSA [4,6,8]. Fenestrations not located in anterior communicating system arteries were most frequently found in the BA. The incidence of BA fenestration was reported to be 1-6% based on autopsy series [2,4-6,9] and was similar to that described in 3D DSA studies (2%) [8]. In CTA, the rate of BA fenestration was 2.4% [6] and was much higher than in conventional 2D angiography – 0.31-0.6% [7,10]. To date, there has been only one review of 600 MR angiography examinations, which demonstrated a 1.7% incidence of BA fenestrations [1]. MCA fenestrations are very rare anomalies with similar incidence of coexistence ranging from 0.17-0.43% of cases in cerebral angiograms [3,7,10], 0.4% in CTA series, and up to 0.28% in autopsy series [10].

In our study, the rate of fenestrations detected by CTA was 3.5% among a specific group of patients referred for CTA, not in the population. Anterior communicating system artery fenestration was a more common location (40% of ACA and 10% of AComA) than vertebrobasilar fenestration (45% of BA and 2.5% of VA). The incidence of VA fenestration could be underestimated due to the range of cerebral CTA, which does not cover the entire vertebral artery. This rate is much higher than in previous conventional 2D angiographic studies and similar to MR angiography studies, but much lower than in recently reported CTA and 3D DSA studies. The limitation of

Table 3. Incidence of fenestration in published studies using different methods

	Diagnostic method	Analysis based on	Group of patients	Overall incidence	Localization of fenestration			
					BA	VA	MCA	ACA or AComA
Our study	CTA	retrospective review of reports	referred for CTA – consecutive	3.5% 40/1140	1.6 %	0.08%	0.08%	1.7%
Bharatha *et al*. (2008) [6]	CTA	retrospective review of imaging data	referred for CTA – consecutive	10.5% 53/504	2.4%	0.4%	0.4%	6.9%
Rooij *et al*. (2009) [8]	3D DSA	retrospective review of imaging data	suspected aneurysm – not consecutive	28% 59/208	0.4%	0.4%	5.8%	20.7%
Okahara *et al*. (2002) [4]	Autopsy	review of literature	–	–	1-5%	0.2-2%	–	7.5-40%
Uchino *et al*. (2001) [5]	MRA	retrospective review of imaging data	referred for MRA – consecutive	–	1.7 % 10/600	–	–	–
Sanders *et al*. (1993) [7]	2D angio-graphy	retrospective review of reports	referred for angio-graphy – consecutive	0.7% 38/5190	0.31%	0.19%	0.17%	0.06%

CTA – computed tomography angiography, DSA – digital subtraction angiography, MRA – magnetic resonance angiography, ACA – anterior cerebral artery, BA – basilar artery, AComA – anterior communicating artery, ICA – internal carotid artery, MCA – middle cerebral artery, VA – vertebral artery

our study and of most angiographic series is due to the fact that only written reports, not all of the image data, were reviewed, which could lead to underreporting. In one of the recent CTA studies only 15% of fenestrations were described in the official report [6]. Such artery anomalies can be easily overlooked not only in CTA but also in 2D conventional angiography. Consequently, there can be a tendency to report coexistence of fenestration and other pathologies such as aneurysms while underreporting incidental fenestrations observed in CTA studies.

Defects of the tunica media in the vessel wall of fenestrated arteries were described which may promote growth of aneurysms and structural degenerative changes in the vessel [2,4,5]. This association of fenestrations with aneurysm was often reported in case studies [2,3,7,10]. However, there are a few angiographic studies [7,8] and

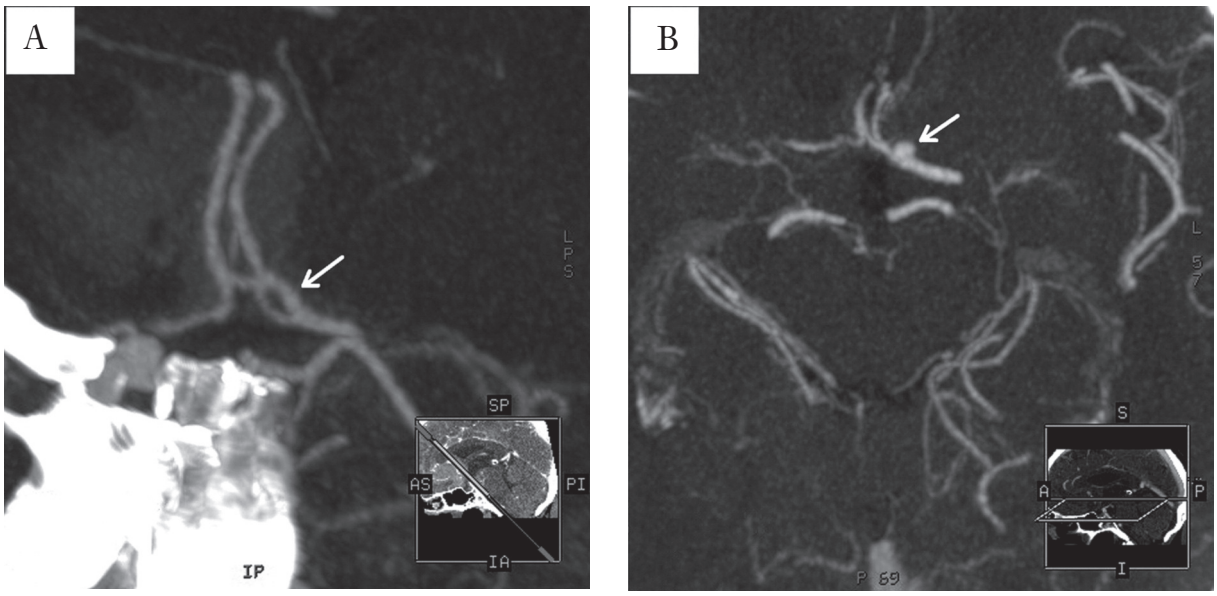

Fig. 3. CT angiography – MIP reconstruction. A) anterior cerebral artery fenestration (arrow) and subarachnoid haemorrhage. B) CT angiography after three weeks shows aneurysm at the place of fenestration (arrow)

single MR angiography [1] and CTA [6] studies which do not confirm this relationship. We also did not notice a strong relationship between fenestrations and aneurysms in our selected group of patients, particularly at the site of the fenestrated artery. In our material 15% of patients (6) with fenestration had aneurysms but only in one case (2.5%) ipsilateral to the fenestrated artery. One patient had three aneurysm (BA, ICA, MCA) and fenestration of BA but not at the exact location of the aneurysm. Generally, multiple cerebral aneurysms comprise about 25% of cases [11] so we do not see an association of fenestration in those cases. The rate of fenestration in the group of patients with aneurysms is not higher than in patients without aneurysms [6,8]. In the clinical history of one patient we observed AComA fenestration in a patient with MCA aneurysm and SAH who developed aneurysm 3 weeks later at the site of the fenestration (Fig. 3). Most diagnosed SAH was due to ruptured aneurysm, but it is noteworthy that the fenestration was the only malformation coexisting with SAH in two cases (Table 2). The small number of cases and limitations of our study do not allow us to assess the association of the fenestration's presence with development of an intracranial aneurysm.

Conclusions

1. The basilar artery is the most common location of cerebral artery fenestration diagnosed in CTA.
2. The anterior cerebral artery is the second most common location of this malformation observed in CTA.
3. Coexistence of fenestration and aneurysm is uncommon in sequential CTA examinations.

Disclosure

Authors report no conflict of interest.

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