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Vertebrobasilar and internal carotid arteries dissection in 188 patients

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1. Introduction

Arterial dissection mainly represents a tear of the intima coat (the intimal flap) with a consecutive penetration of blood into the arterial wall, due to a disruption of the internal elastic lamina and the media coat, and formation of a false lumen or local intramural (subintimal) hematoma [1–3]. In this case, a luminal stenosis develops which can progress to an occlusion with a subsequent hypoperfusion or ischemia of the cervical spinal cord, brain parenchyma, retina, and certain peripheral nerves, as well as the occasional local thrombosis with a potential distal thromboembolism [1,3–13].

On the other hand, a rupture of the intramural vasa vasorum, or a deeper penetration of blood from the lumen, causes a subadventitial hematoma formation [1,13–17]. Due to the latter, a dissecting aneurysm (pseudoaneurysm) can occur with a consecutive compression of the adjacent structures or with a perivascular hemorrhage [1,4,8,15,16].

Dissection can affect one or, less frequently, both internal carotid (ICAs) or vertebral arteries (VAs) [1,3,8,14,18–21], and exceptionally three or four of the mentioned vessels [22–42]. The cervical or intracranial segments of the mentioned paired arteries can be involved, including their branches, i.e. the main cerebral arteries [1,3,8,36,43–45].

Since the ICA, VA and basilar artery (BA) dissections (ICAD and VBAD) are usually presented as case reports [6,37,38,46–56] or as smaller groups of patients [1,8,27,36,41,43,57–63], we decided to present them in a group of 188 patients. In addition to a detailed examination of each patient, a comparison between the ICAD and VBAD will be presented as well.

2. Materials and methods

2.1. Patients

A total of 188 patients with arterial dissections were enrolled in the period from February 2008 to February 2018. Each patient had his or her history records, as well as laboratory results, cardiologic, neurologic, and radiologic findings, which were analyzed in detail.

2.2. Radiologic examinations

These examinations were mainly related to magnetic resonance imaging (MRI) and angiography (MRA), and rarely to computerized tomography (CT) and angiography (CTA), as well as to digital subtraction angiography (DSA) and Doppler sonography.

As regards MRI examination, the following sequences and procedures were applied. T1-weighted: TR/TE 450/min ms, matrix 320 × 224, FOV 24, slice thickness 5 mm, spacing 0.5 mm. T1-fat saturation: TR/TE 590/min, matrix 256 × 192, FOV 26, slice thickness 3 mm, spacing 1 mm. T2-weighted: TR/TE 4600/108 ms, matrix 384 × 256, FOV 24, slice thickness 5 mm, spacing 0.5 mm, as well as TR/TE (450/min), matrix 256 × 192. T2-fat saturation: TR/TE (4600/102), matrix 384 × 256, FOV 26, slice thickness (3 mm), spacing 1 mm. Diffusion-weighted imaging (DWI): TR/TE (ms) 8000/min, matrix 128 × 128, FOV 24, slice thickness (5 mm), spacing (0.5 mm), b-values, 0 s/mm^2 and 1000 s/mm^2. Fluid-attenuated inversion recovery (FLAIR): TR/TE 8000/120 ms, matrix 256 × 192, FOV 24, slice thickness 5 mm, spacing 0.5 mm, TI (2000 ms).

Brain MRA (3D TOF): TR/TE (23/7), matrix 384 × 224, FOV (22), section thickness 2 mm, overlap lochs 10, lochs per slab 32, FA 20^0, acquisition time 5 min 4 s. Neck MRA (TRICKS): TE minimum, matrix 320 × 192, FOV 36.0, PHASE FOV 0.75, section thickness

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3.2 mm, scan lochs 28, FA 30^0, output temporal phases 15, scan time 1.10 (0.15).

As for CT examination, it was performed using CT 160-slice machine Toshiba Aquiline Prime by applying FOV 240 and slice thickness of 2.0 mm. In the case of CTA, the following parameters were used: FOV 240, KV 100, ma 150, scan time 5.4 s, slice thickness 0.5 mm, slice interval 0.3 mm, range 300, rotation time 0.5, and contrast application (0.8–1.2 mL/gym).

Four vessel angiography was performed in the INOVA GE Healthcare following a transfemoral catheterization with an automatic injection of the contrast substance (Omnipaque) in a bolus of 5–8 mL per each sequence.

Ultrasonography was performed in the majority of patients. We used Canon Inc Tus Al600 (APLIO I 600) apparatus, with a linear transducer of 7 MHz, for examination of the cervical arteries. Examination was performed in B mode and Doppler mode imaging.

2.3. Other examinations

Certain laboratory analyses were performed in each patient, as well as echocardiography and CT of the internal organs in some of them. National Institutes of Health Stroke Scale (NIHSS) was used for ischemic stroke evaluation, including its expended version [64], which ranges from 0 (stroke not present) to 42 (the gravest form of stroke). Scores on the Rankin scale were used for patients' clinical evaluation.

All authors have followed the Ethical Principles for Medical Research Involving Human Subjects outlined in the Declaration of Helsinki. All patients, or the members of their families, signed a written consent.

2.4. Statistical analysis

Various methods of descriptive and analytical statistics were applied. Thus, descriptive statistics was used to summarize clinical characteristics of the study group. An assumption of normal distribution was tested using Shapiro ilk tests ($p > 0.05$ normally distributed data assumed) and Q-Plots. Numerical variables were expressed as a mean ± SD in case of normal distribution or median (interquartile range) if variable did not follow normal distribution, and as percentages for categorical data. If normal distribution was met, the one-way ANOVA with Tukey correction was used for group comparisons, otherwise the non-parametric Kruskal-Wallis test was applied. Chi-square test was used to compare categorical variables. P-value below 0.05 was considered significant. All analysis was performed with the SPSS statistical analysis software, Version 20.0 (SPSS, Chicago, Illinois, USA).

3. Results

There were 188 patients enrolled during a period of the last 10 years, 53 of whom had vertebral (VAD) and/or basilar dissection (BAD), whilst the remaining 135 showed mainly the internal carotid artery dissection (ICAD). Combinations of VAD and ICAD were not found in the same patient.

3.1. Vertebrobasilar arterial dissection (VBAD)

VBAD in the mentioned 53 patients affected both men (58.5%) and women (41.5%), without a statistical significance ($p = 0.272$), who averaged 52.7 ± 12.7 (range, 33–86) years of age with a pick in the fifth (24.5%) and sixth decade (28.3%). As regards the cause, traumatic dissections or spontaneous ones were noticed, and rarely other causes (Table 1). Traumatic dissections were identified as a direct blunt neck trauma, fall, or hyperextension, lateral flexion or hyperrotation (in car accidents, sports engagement, etc.), or a minor trauma. Other causes (7.5%) mainly included fibromuscular dysplasia, connective tissue diseases, migraine, and respiratory infections. The remaining ones belonged to the mentioned spontaneous (idiopathic) dissections. There were more patients with hypertension than with diabetes, which showed the highest statistical significance ($p = 0.006$ and $p = 0.001$, respectively).

According to MRI examination, 61 dissections were noticed in 53 patients, most often affecting a single VA, i.e. almost in 80% (Fig. 1A and B), with occasional ischemia of the brain stem and/or the cerebellum (Fig. 1C) (Table 1). In some cases, a dissecting aneurysm was observed, either of the VA or of the posterior inferior cerebellar artery – PICA (Fig. 2A-D), which was associated with ischemia. Both the right (VAr) and left (VAl) vertebral arteries were very rarely affected, as well as the basilar artery (BA) alone, which showed an intimal flap, a double lumen. or a pseudoaneurysm (Fig. 3A) causing a pontine infarct (Fig. 3B). Involvement of both VAs and the BA was the least frequent event (Table 1). Dissection had a cervical localization (44.3%), cervicocranial (19.6%), or intracranial (36.1%). The majority of patients complained of headache (69.6%) in VAD and 28.6% in BAD, and neck pain (35.8%) on admission, whilst Horner syndrome was rarely present (8%), as well as some other symptoms and neurological signs (Table 2).

Doppler examination of the cervical VAs (Table 3), which was performed in 51 patients following admission, showed virtually a normal lumen size and normal blood flow in the majority of the right and left VAs (62.7% and 60.8%, respectively). In most of the remaining cases (Table 3) a stenosis was present (25.5% and 23.5%, respectively) and rarely an occlusion (roughly 12% and 16%, respectively), with a concomitant diminished flow or no flow. There were no statistically significant differences between the VAr and VAl alterations.

As regards the MRI signs of 61 dissections in 53 patients, the most frequent MR radiologic sign was intramural hematoma i.e. the semilunar sign, or "eccentric crescent," in 73,8% patients (Fig. 1A). A "candle flame" sign was observed in cases of the VA occlusion, whilst in some other instances an intimal flap or a double lumen were seen in the VA or the BA. A pseudoaneurysm was noticed in 21.3% of patients (Fig. 3A), as well as signs of stenosis, i.e. string and pearl signs in the remaining patients. There was no significant correlation between the frequency of various signs and the affected arteries, i.e. a single VA, both VAs, and VAs and BA ($p > 0.05$), or infarct occurrence ($p = 0.222$).

Ischemic stroke (IS) was diagnosed in 62.3% and transient ischemic attack (TIA) in 34.0% cases, whilst 3.8% of patients had only isolated symptoms. Atherosclerosis was present in 34%, predominantly in older patients with hypertension. Among the 61 identified dissections, VAD was most often accompanied by the IS in the cerebellum (mean, 32.8%) (Fig. 1C), less frequently in the medulla oblongata, and rarely in the pons, the thalamus, or the occipital region of the cerebral hemispheres (Table 1). BA dissections were most frequently accompanied by pontine infarcts (Table 1) (Fig. 3B). There was a significant correlation between dissection position and infarct location ($p = 0.006$).

Most of patients (66.0%) received antiplatelet therapy, that is, aspirin, dipyridamole, or clopidogrel, and majority of the remaining ones anticoagulant therapy, i.e. heparin or warfarin, usually for several months (32.1%). Surgical procedures were not applied, but in 18.9% of patients a stent was placed (Fig. 2E) or occlusion of a pseudoaneurysm was performed. Recurrent ischemia appeared in 1.9%, and TIA in 5.7% of patients. Radiologic control of luminal recovery was noticed in most of patients. In fact, a corresponding degree of recovery, i.e. between 50% and 100% of the vessel lumen, was observed in 61.7% of patients (Table 4). Clinically, 77,4% patients had good outcome (Rankin score defined

Table 1
Correlation between infarct localization and 61 VA dissection positions.

Arteries	Infarct localization					
	Cerebellum	Medulla	Pons	Occipital	Normal*	Total
Single VA	17 (40.5%)	8 (19.1%)	3 (7.1%)	3 (7.1%)	11 (26.2%)	42 (100%)
Both VAs	3 (25.0%)	3 (25.0%)	0 (0.0%)	0 (0.0%)	6 (50.0%)	12 (100%)
BA or BA& VAs	0 (0.0%)	1 (14.3%)	4 (57.1%)	0 (0.0%)	2 (28.6%)	7 (100%)
Total	20 (32.8%)	12 (19.7%)	7 (11.5%)	3 (4.9%)	19 (31.1%)	61 (100%)

* Patients with TIA and some others with no radiologic signs of ischemia.

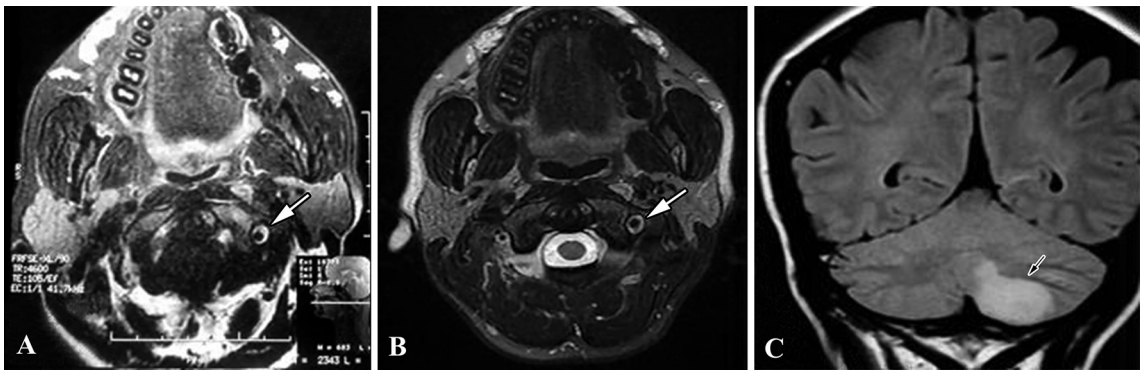

Fig. 1. Axial MRI scans in T2-weighted fat saturation to show the left vertebral artery (arrow) with an intramural hematoma on admission (A) and three months later (B) following anticoagulant therapy. Note an infarction of the left cerebellar hemisphere (arrow) on a coronal MRI scan (C) in the PICA territory.

≤2). Most of the patients were evaluated as having between 0 and 8, i.e. a minor stroke on the NIHSS scale.

3.2. Internal carotid artery dissection

ICAD was present in 135 patients ranging from 27 to 82 years of age (mean, 52.7) with a pick in the fifth decade, but the majority (81.4%) were in the 5th (29.6%), 6th (23.7%), and 7th decades (28.1%). This group consisted of 66.7% males and 33.3% females, which is of a high statistical significance ($p < 0.001$).

Overal, there were 153 dissections in 135 patients. The right internal carotid artery (ICAr) and the left one (ICAl) were almost equally affected, whilst both ICAs were relatively rarely involved (13.3%). The common carotid artery (CCA) was affected in only 2 cases (1.5%). As regards the cause of dissection, trauma (41.5%) and spontaneous dissections (44.4%) were more frequently noticed, and other causes were rarely present (Table 5). There was significantly more patients with hypertension, without diabetes or hyperlipidemia ($p < 0.001$) (Table 5).

Doppler examination of the ICA cervical segments on admission showed a practically normal lumen in a larger number of individuals, but a various degree of stenosis or occlusion was observed in the remaining patients, i.e. in 49.5% and 51.9%, respectively (Table 6). The occlusion itself was noticed in 9.4% and 11.8%, respectively. MR examination revealed a semilunar sign in the majority of patients, followed by a string and pearl sign in some cases, as well as a flame sign in those with an ICA occlusion (Fig. 4A) with a resultant brain ischemia (Fig. 4B). Pseudoaneurysms were found in 28.8% of patients.

Dissection was most often located in the cervical (58.2%) and cervicocranial (subpetrous) region (30.7%), but rarely intracranially (11.1%) (Table 7). In the latter case, the petrous and/or the cavernous segments of the ICA were affected. Headache was the most frequent symptom (42.2%), whilst neck pain was rare (17.8%), as well as Horner's syndrome (14.1%) and amaurosis fugax (11.1%) (Table 2). Ischemic stroke was the most frequent complication of ICA dissection (80%), followed by TIA (20%) (Table 7). The IS was predominantly present in the territory of the middle cerebral artery (MCA) (Fig. 4B), and then in border zones (watershed infarctions) in the MCA territory, but very rarely in the region of the anterior (ACA) or posterior cerebral arteries (PCA) (Table 8). Usually larger ischemic lesions were diagnosed (Fig. 4B), and rarely lacunar infarcts, i.e. in 7.0% and 16.7% of patients, respectively (Table 8).

In most patients antiplatelet and anticoagulant treatment was given (Table 9). The majority of medicated patients (54.2%) experienced a recanalization or a diminished stenosis of the ICA, whilst in 17.8% a stent was applied, and in 3.0% vascular surgery was performed (Table 9). Recurrent ischemic stroke was not observed, whilst TIA appeared in 1.5% of patients (Table 10). A good outcome (between 0 and 2 on the Rankin scale) was observed in over a half of patients, whilst the majority of them showed a score between 0 and 10 on the NIHSS scale.

3.3. The whole group of patients

Of the 188 patients, 53 experienced a vertebral or basilar artery dissection (28.2%), and the remaining 135 had a carotid dissection (71.8%), which is a statistically significant difference ($p < 0.001$). There were 121 men (64.4%) and 67 women (35.6%) with a statistically significant gender distribution ($p < 0.001$). Patients averaged 53.7 years of age, with a pick in the 5th decade (28.2%), and somewhat less in the 6th (25.0%) and 7th decades (25.5%). Dissection most often affected a single artery (87.2%), predominantly the ICA or the VA, and rarely two or more vessels. All in all, 214 dissections were noticed in 188 patients, either spontaneous or traumatic ones or, less frequently, those of other causes.

As for the arterial portions affected, dissection most often involved cervical segments of the VA and ICA, and less frequently their intracranial portions or branches (Table 7), which is of a high statistical significance ($p < 0.001$). Dissection more often affected the VA intracranial segments (36.1%). As regards the symptoms on admission, headache and neck pain (Table 2) were more frequent in VAD and BAD (69.6%% vs. 28,6%) than ICAD (42.2% vs.

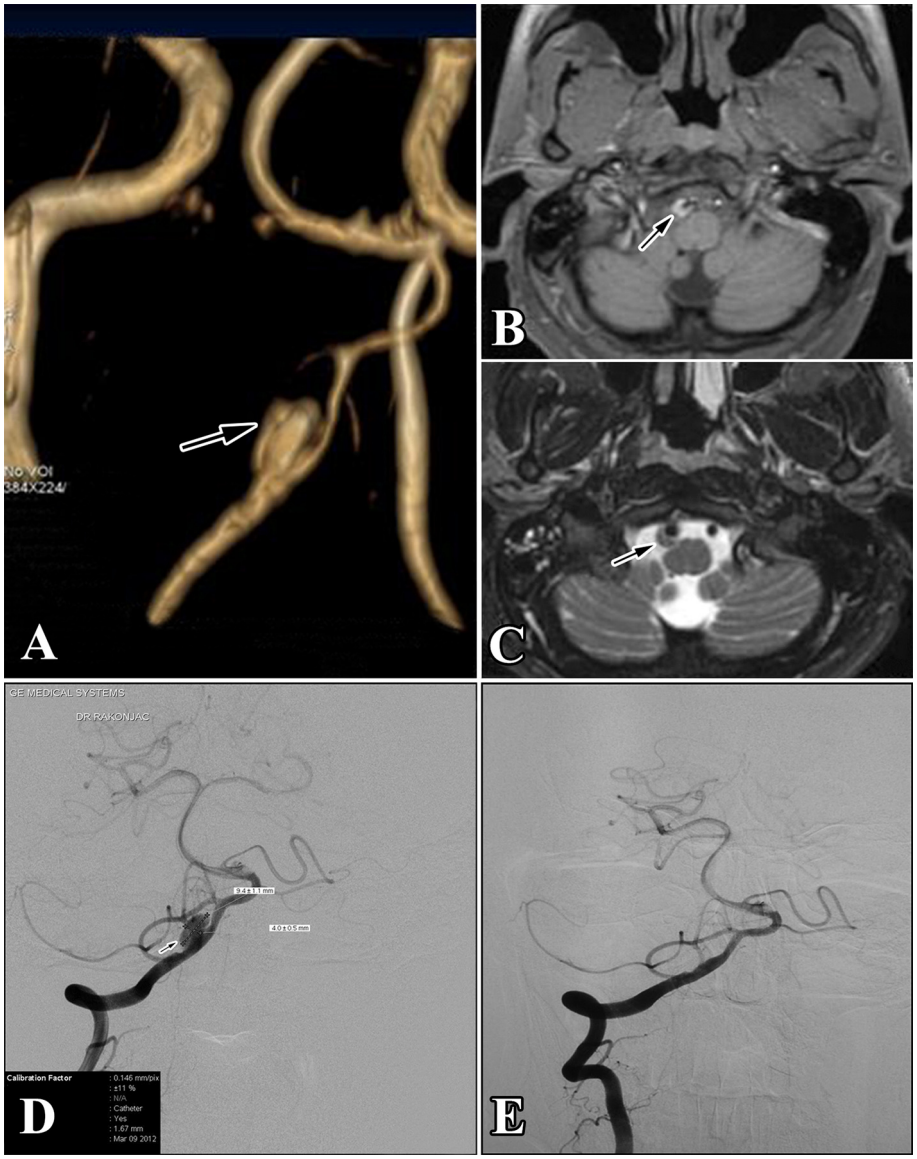

Fig. 2. A pseudoaneurysm (arrow) of the PICA's initial segment on a 3D MRA scan (A), and a dissection (arrow) of the right vertebral artery on a T1 fat saturation (B) and a T2 fat saturation image (C). Note a mild stenosis of the vertebral artery and the mentioned pseudoaneurysm (arrow) on DS angiograms before (D) and after stenting (E).

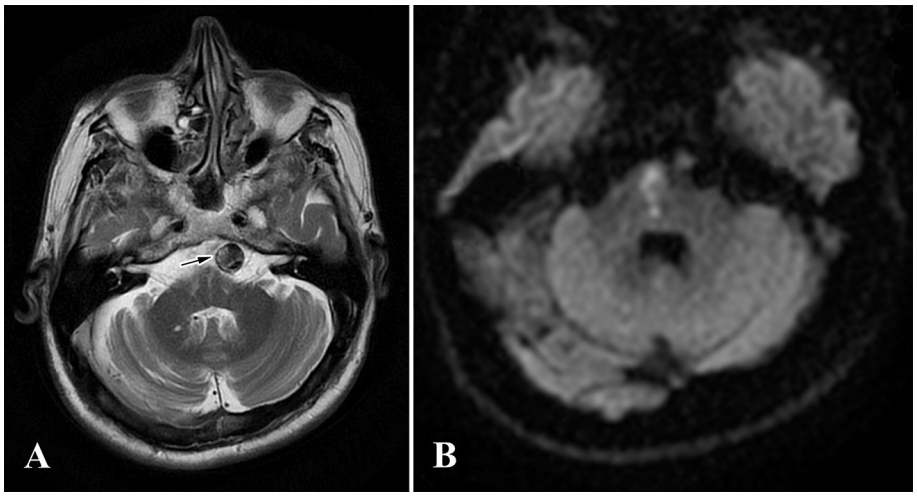

Fig. 3. A dissection and a pseudoaneurysm (arrow) of the basilar artery on a T2-weighted axial MRI scan compressing the pons (A), and a small paramedian pontine ischemic lesions on a DWI axial image (B).

Table 2
Symptomatology and ischemic manifestations in 188 patients.

Arteries involved	Symptoms and signs: No. (%)				Ischemic manifestations: No. (%)		
	headache	Horner's sign	Neck pain	Amaurosis	TIA	Persistent deficit	Symptomless
ICA	57 (42.2)	19 (14.1)	24 (17.8)	15 (11.1)	27 (20)	108 (80)	0 (0)
VA	32 (69.6)	4 (8)	18 (39.1)	0 (0)	17 (37)	28 (60.9)	1 (2.2)
BA	2 (28.6)	0 (0)	1 (14.3)	0 (0)	1 (14.3)	5 (71.4)	1 (14.3)
Total	91 (48.4)	23 (12.2)	43 (22.9)	15 (8.1)	45 (23.9)	141 (75)	2 (1.1)

Table 3
Doppler examination of the cervical VA segments in 51 patients.

Artery	Lumen size				
	Normal	Stenosis (<50%)	Stenosis(50%-70%)	Stenosis(75%-99%)	Occlusion
VAr:No. (%)	32 (62.7%)	9 (17.6%)	3 (5.9%)	1 (2,0%)	6 (11.8%)
VAl: No. (%)	31 (60.8%)	7 (13.7%)	3 (5.9%)	2 (3.9%)	8 (15.7%)

Table 4
Lumen recovery* at 6 months.

Arteries	<50%	Recanalization rate: No. (%)>50%	90–100%	Progression	No recanalisation
VA	11 (9.8)	7 (6.3)	62 (55.4)	2 (1.8)	30 (26.8)
BA	2 (4.9)	4 (9.8)	24 (58.5)	1 (2.4)	10 (24.4)
ICA	0 (0)	1 (20)	4 (80.0)	0 (0)	0 (0)
total	13 (8.2)	12 (7.6)	90 (57.0)	3 (1.9)	40 (25.3)

*It was calculated in 158 patients, since 26 failed to come to a control examination, and 4 patients died.

Table 5
Causes and risk factors of dissections in 188 patients.

Arteries:	Cause: No (%)			Risc factor: No (%)			
	trauma	spontaneous	other	hypertension	diabetes	hyperlipidemia	smoking
ICA	56 (41.5)	60 (44.4)	19 (14.1)	103 (77.0)	26 (19.3)	51 (37.8)	62 (54.9)
VA	22 (47.8)	20 (43.5)	4 (8.7)	30 (65.2)	6 (13.0)	16 (34.8)	20 (37.7)
BA	2(28.6)	5 (71.4)	0 (0)	7 (100)	2 (28.6)	5 (71.4)	3 (5.7)
Total	80(42.6)	85 (45.2)	23(12.2)	140 (74.5)	34(18.1)	72 (38.3)	85 (45.2)

Table 6
Doppler examination of the cervical ICA segments performed in 127 patients.

Artery	Lumen size					
	Stenosis (<50%)	Stenosis (50%-70%)	Stenosis (75%-99%)	Occlusion	Preocclusive	Total
ICAr	5 (3.9%)	4 (3.1%)	9 (7.1%)	15 (11.8%)	30 (23.6%)	63 (49.5%)
ICAl	7 (5.5%)	3 (2.4%)	16 (12.6%)	12 (9.4%)	28 (22.0%)	66 (51.9%)

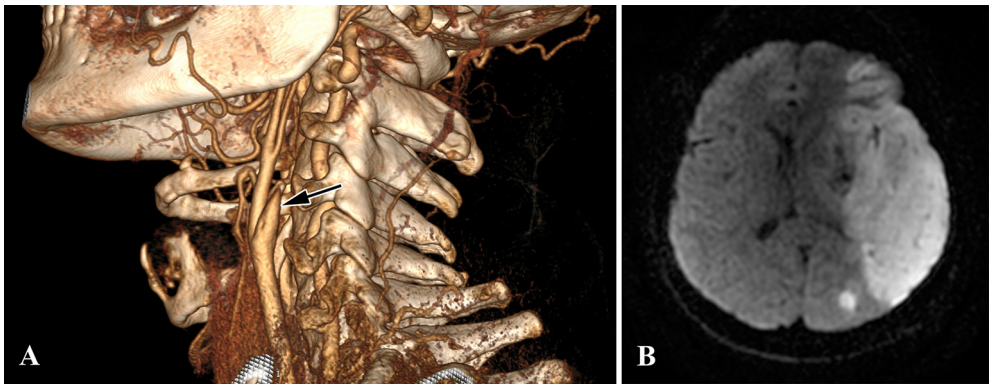

Fig. 4. A flame sign (arrow) of a dissection and tapered occlusion of the left internal carotid artery on a 3D CTA image (A), and a large ischemic region in the territory of the middle cerebral artery on an axial DWI image (B).

Table 7
Radiologic characteristics of the arterial dissection in 214 events.

Arteries	Arterial segments affected: No. (%)		Radiologic signs in TIA & ischemic stroke: No. (%)					
	Cervical & cervico-cranial	Intracranial	Flap/double lumen	Pseudo-aneurysm	Flame sign (occlusion)	String sign	Pearl sign	Semilunar sign/intramural hematoma
ICA	136(88.9)	17 (11.1)	33 (21.6)	44 (28.8)	77 (50.7)	60(39.5)	3 (2)	123 (80.4)
VA	39 (72.2)	15 (27.8)	19 (35.2)	8 (14.8)	30 (55.6)	20(37.0)	3(5.6)	39 (72.2)
BA	0 (0)	7 (100)	6 (85.7)	5 (71/4)	0 (0)	5 (71.4)	0 (0)	6 (85.7)
Total	175(81.8)	39 (18.2)	58 (27.1)	57 (26.6)	107 (50.2)	85(39.9)	6(2.8)	168 (78.5)

Table 8
Distribution of ischemic strokes in patients with carotid dissections.

Artery	Single ICA	Both ICAs	Single CCA
MCA	59.1%	61.1%	0.0%
ACA	5.2%	0.0%	0.0%
PCA	1.7%	5.6%	0.0%
Watershed	11.3%	0.0%	1.6%
Lacunar	7.0%	16.7%	0.0%

17,8%) ($p < 0.008$ and $p < 0.007$, respectively). Only 1.1% of patients were symptomless (Table 2). Finally, we found 26.6% pseudoaneurysms in our patients.

As for a correlation between the MRI signs and IS or TIA (Table 2), ischemic stroke was most often caused by occlusion, i.e. flame sign (Fig. 4A and B) of the ICA, it was less frequently related to the presence of a string sign, and rarely to other radiologic signs. On the other hand, TIA was most frequently associated with existence of a string sign (Table 7). Ischemic stroke caused by VAD most often affected the cerebellum (Table 1) (Fig. 1C), and IS following ICAD was most frequent in the MCA territory (Table 8) (Fig. 4B). Atherosclerosis was diagnosed in 17.5% of patients, more often in VAD than in ICAD patients ($p < 0.001$). Unlike dissection, atherosclerosis was much less frequently manifested with headache.

Headache was the most frequent symptom (42.2%) in ICAD, whilst neck pain was rare (17.8%), as well as Horner's syndrome (14.1%) and amaurosis fugax (11.1%) (Table 2). The majority of VAD and BAD patients complained of headache (69.6% vs. 28.6%) and neck pain (39.1% vs. 14.3%) on admission, Horner syndrome was rarely present in the whole group of patients (12.2%), as well as some other symptoms (Table 2). There was a significant correlation ($p < 0.001$) of the brain ischemic event appearance and hypertension and cigarette smoking, but without a statistical significance in the latter case (Table 5).

The majority of patients received antiplatelet (58.7%) and anticoagulant medication (38.6%), respectively (Table 9), whilst a minority had additional surgical (2.2%) or endovascular interventions – 18.1% (Fig. 2E). The lumen improvement was observed in 72,8% of all patients 6 months following therapy, but almost a complete recovery was achieved in 57% (Table 4). A good outcome (Rankin score $\leq$ 2) was observed in the majority of patients (61,2%). Most patients had a mild or moderate stroke by evaluating on the NIHSS scale at discharge, with a mean value of 5.57 ± 7.72, and of 0.67 ± 5.49 regarding delta baseline-discharge NIHSS (Table 11). Recurrent ischemic stroke was noticed in 2.6% patients, and recurrent TIA in 3.2% of them 6 months following therapy (Table 10). Mortality was registered in 2.1% of the patients (Table 10).

4. Discussion

Dissection is a rare event, so that the annual incidence of AD is from 1.0 to 5.1 per 100,000 population, but most often between 2.5 and 3 for ICAD, and from 1.3 to 1.5 for VAD [1,8,17,63,65,66]. Due to that, usually smaller samples of patients are presented in literature. Our group of 188 patients is one of the largest reported so far. To our knowledge, only a few authors described much larger groups, i.e. 1958 patients [67], 983 [21], 970 [8,68], and 740 patients [29], respectively.

4.1. The affected arteries

A dissection mechanisms can damage one or more cervical, intracranial or cervicocranial arteries. Our patients mostly experienced the ICA dissection (71.8%), and less frequently the VA dissection (28.2%), which is in agreement with other reports [1,8,57]. However, VAD is somewhat more frequent in younger patients, and in some adult groups [1,58], but especially in the Asian population [65,66]. Besides, the intracranial dissections were more often in the latter population [8,41].

Most frequently, a single artery was affected in our series (87.2%), either ICA, VA or BA. Two-vessel involvement was noticed in 11.7%, either both ICAs, both VAs, or VA and BA. The latter was reported in 18–25% of patients with blunt neck trauma, but less frequently in spontaneous dissections [1,38]. Three arteries were affected in 1.1% of our patients, i.e. BA and both VAs, as compared to 1.5% by some authors [8,24,29,38,40,42,54]. Four-vessel involvement, e.g. both ICAs and VAs, was registered by us in a subsequent patient (in preparation), and by others in 0.1–0.5% [5,23,25,26,28,30,31,35,37–40].

Most often cervical arteries are affected, and less frequently intracranial or cervicocranial vessels, i.e. in 11% to 27% of patients, respectively, although more often in Asian population [1,8,65]. In these instances, the posterior circulation is more frequently involved (76–93%) than the anterior circulation [41].

Table 9
Acute treatment of patients with dissection.

Arterial	Surgical: No. (%)		Drug treatment: No. (%)		
	Endovascular (stent)	Vascularsurgery	Antiplatelet	Anticoagulant	Notreatment
ICA	24 (17.8)	4 (3)	73 (55.7)	54 (41.2)	4 (3.1)
VA	6 (13.0)	0 (0)	28 (60.9)	17 (37.0)	1 (2.2)
BA	4 (57.1)	0 (0)	7 (100)	0 (0)	0 (0)
Total	34 (18.1)	4 (2.2)	108 (58.7)	71 (38.6)	5 (2.7)

Table 10
Outcome of patients with dissection.

Arteries	Recurrent event:No. (%)		OutcomeNo. (%)	
	Ischemic stroke	TIA	Alive	Deceased
VA	4 (3.0)	2 (1.5)	131 (97.0)	4 (3.0)
BA	1 (2.2)	3 (6.5)	46 (100)	0 (0)
ICA	0 (0)	1 (14.3)	7 (100)	0 (0)
Total	5 (2.6)	6 (3.2)	184 (97.9)	4 (2.1)

Table 11
Outcome assessment of patients with dissection.

Arteries	Discharge NIHSS					Delta baseline-discharge NIHSS				
	min	max	median	mean	SD	min	max	median	mean	SD
ICA	0	42	4	7.04	8.54	−39	12	1	0.41	6.3
VA	0	7	0	1.37	1.95	−3	7	1	1.28	1.97
BA	0	12	5	4.86	4.20	−4	8	1	1.71	4.31
Total	0	42	5	5.57	7.72	−39	12	1	0.67	5.49

4.2. Predisposing factors and causes

Among the vascular risk factors, hypertension is most often present (26.7%–68.9%), as well as hyperlipidemia (17–51%) and smoking (12.8–52.0%), but less frequently diabetes (2.0–24.9%) and migraine (up to 21.2%) [1,41,50,51,54,57,58,68–71]. Our findings are within this range, except hypertension, which was more frequent due to older age of our patients (Tables 1 and 4).

Blunt trauma as a cause of dissection is reported in 25–40% [19,23,24,33,34,37,38,46,59,72–74], which is somewhat less frequent than in our patients (42.6%) (Table 5). Blunt neck trauma may have either a direct effect, e.g. neck or face blow, cervical or face manipulative therapy, safety belt injuries, an elongated styloid process, a mandible or vertebrae fracture or dislocation, strangulation or hanging [7,30,47,52,53,56,63,73–76], or infrequently penetrating neck injuries [77,78]. The force can predominantly exert an indirect influence, i.e. by neck lateral hyperflexion, hyperextension or contralateral rotation of the head and neck, especially in exercise, sports and traffic accidents, and rarely in dental practice, by turbulent flight or roller coaster riding [6,25,31,38,47,49,59,61,72,73,79–81]. In our patients, mostly a direct blow or minor trauma caused a dissection.

A nondiagnosed minor trauma seems to be much more frequent in "spontaneous" dissections, i.e. up to 40% [1,7,38,46], and even up to 75% in some groups of patients [57]. A minor direct or indirect trauma is mainly related to coughing, sneezing, sexual intercourse, and defecation [45,57,82]. Local and general infections, as well as other types of inflammation, including various types of arteritis, can also result in arterial dissections [48,51,58,83]. Iatrogenic injuries of the cervical and intracranial arteries are possible as well, including local anesthetic injection, and neck, oral, transnasal and skull base surgery [49,55,84]. Certain types of medication can occasionally produce dissections [50,54,85], then arterial elongation [60], fibromuscular dysplasia and connective tissue diseases [8,12,42,86–88], polycystic kidney disease, pregnancy and postpartum [89–91], as well as certain gene mutations [9,86,92–94]. Some of these causes were also observed in our patients. In general, however, dissections are most likely a multifactorial process [1,8].

4.3. Patients and symptomatology

According to various reports, mean age of patients with dissection ranges from 42.0% to 55.3%, which is in agreement with our results (53,7%) [1,8,41,57,62,68]. A somewhat higher averaged value in our cases is explained by the fact that most of the younger patients were transferred to one of the Vascular or Pediatric Clinics. According to the mentioned authors, males are usually more affected in ICAD (72–75%) than in VAD (about 28%). Similar results were found in our group, i.e. 64.4% vs. 35.6%.

The initial symptoms are commonly related to headache, which appears in 17–85% of patients [57,59,68], and neck pain with a frequency of 25% in ICAD [57], whilst headache and pain together occur in 20.6–75.0% [36,41,62]. Headache and/or neck pain were more frequent in our patients with VAD (69.6% vs. 39,1%) than in those with the right or left ICAD (42% vs. 17,8%) (Table 2), which is similar to some reports [1], but lower in another one [58]. Both symptoms are less frequent in dissections accompanied by atherosclerosis [62,96]. Headache and pain in patients with stroke following dissections appear in 20.6% as the initial symptom [62]. The remaining findings are mainly reffered to neurological signs [1,8,57,65,97,98]. Symptomless patients are very rare (0.1–4%), which also was the case in our study (1.1%) (Table 2).

4.4. Radiologic findings

MRI was applied in all patients with dissections, but also CTA, DSA, and Doppler sonography occasionally [14,41,57,99–101]. Occlusion was seen in up to 18%, and a <50% stenosis in 73%. According to some reports [43], intimal flap was present in 22.8%, a flame sign in 15.9%, pearl and string signs in 13.3%, and double lumen in 16.9%. In our patients with stroke following VAD and ICAD, the flame and pearl-and-string signs, that is an occlusion and a multiple stenosis, were obviously much more frequent (Table 7).

Pseudoaneurysms (PsAn) are diagnosed in 15.6–38.0% patients [4,8,11,15,16,28,41,43], and our results (28.8% of the ICA and 21.3% of the VBAD), which were associated with ischemia, are within this range. In general, PsAn are a conequence of the arterial wall weakness, due to fragmentation of the internal elastic lamina, or a rupture of the vasa vasorum [1,8,15]. They can cause ischemic lesions (42%), subarachnoid hemorrhage – SAH (46%), or compression of the brain or cranial nerves in most of the remaining patients. Ischemic lesions may affect various parts of the brain [8,15,69]. SAH is caused by a PsAn rupture [8,16]. Compression of the brain and cranial nerves may cause certain neurological signs. Thus, a BA dissecting aneurysm may compress the pons [46], as was the case in our study (Fig. 3A). Similarly, PsAn of the VA and ICA cervical segments occasionally compress the adjacent autonomic or cranial nerves [12,13,57,97,98,102].

Endovascular treatment is commonly applied in these patients, e.g. a stent or overlapping stents, coils or stent-assisted coils, or flow diverters, in order to to prevent rebleeding [15]. Surgical interventions are rarely performed, e.g. wrapping, arterial reconstruction, or proximal ligation [8].

4.5. Ischemia occurrence

It manly comprises ischemic stroke (IS) of the brain or spinal cord, TIA, retinal infarcts, amaurosis fugax, and certain autonomic or cranial nerves [8,17,36,41,43,62,71,72,76,81,98,103,104]. IS of the brain is present in 30–64% of patients, either as a larger ischemic area or, rarely, as small lacunar lesions [36,69]. IS of the spinal cord appears in 4–10% in those with a VA dissection [10,105]. IS and TIA together occur in 30–78% [8,41,69]. They are more frequent in ICAD (68.9–76.0%) than in VAD or BAD (31.1–38.0%) of adults [1,8], but it is a reverse situation in some pediatric and Asian patients [1,8,41,55,66,68]. In the latter cases, ischemia involves the posterior circulation in up to 77%, and the anterior one in only about 23% [41].

Intracranial VAD and BAD, which are often followed by IS [36,43], are more frequent than intracranial ICAD [8,41]. Nevertheless, VAD may cause the BA occlusion [36,106]. As for IS following ICAD (Table 8), the infarcts are most often located in the territory of the middle cerebral artery (85.1–99.0%), and rarely of the anterior cerebral artery (0.5–7.2%) and posterior cerebral artery (2.0–7.7%) regions [69]. Watershed infarcts are present in 5% of patients, which is less than in our patients (12.9%). VAD is most often followed by cerebellar and medullary infarctions [95,107], as was the case in our study (Table 1). BAD is most frequently associated with pontine infarcts, and rarely with thalamic and occipital lesions [36,108], including our patients (Table 1). Intracerebral hemorrhage is infrequent [62].

IS is most often caused by artery-to-artery embolism (55.0–85.5%), and rarely by a local branch occlusion (31.7%), in situ thrombosis (6.3%), hemodynamic factors (0.8–1.2.%), and by a combination of the mentioned factors [36,43].

All in all, dissections are responsible for only 1% to 2% of all ischemic strokes in adults [1,8]. However, dissections in younger patients causes from 10% to 25% of all strokes [1,8].

4.6. Internal carotid versus vertebral and basilar artery dissections

First of all, ICAD is more frequent than VBAD. According to some authors, the former appears in almost 70% and the latter in about 30% [68], which is very similar to our results (71.8% versus 28.2%). ICAD most often appears in older people, and VBAD in younger patients [1,66]. Bilateral ICAD is usually twice as often as VAD [68]. However, intracranial segment of the VA was more often affected (in 36.1% of our patients) as compared to the same ICA segments (11.1%) (Table 7), and it is often accompanied by IS [8,41,65,68]. In the former cases, there is the same situation with pseudoaneurysms and the subarachnoid hemorrhage [8,36,43]. The former appears in 26.6% of the 188 patients. The latter has a higher incidence (27–54%), especially in intracranial VBAD patients (up to 60%) [8,36,41].

Headache and/or neck pain were the most frequent symptoms in both groups of patients, with a frequency up to 80% of cases, both being usually stronger in VAD patients [1,8,57,58,62,68]. In our VAD patients, headache was present in 69.6% and neck pain in 39.1%, whilst smaller values were registered in the ICAD patients (42.2% and 17.8%, respectively) (Table 2). Pseudoaneurysm had a similar frequency in our VBAD (21.3%) and ICAD patients (28.8%).

Ischemic stroke is, in general, more frequent in ICAD (68.9–76.0%) than in VBAD (31.1–38.0%) adults [1,8], which is in agreement with our results, i.e. IS in 60.9% of the VAD patients, and 80% in the ICAD cases) (Table 2). However, it is a reverse situation in young patients and in Asian population [1,41,55,57,66,68]. Nevertheless, lumen recovery was observed in many patients after a few months treatment [1,8,38,57].

4.7. Treatment

Among various medications, i.e. antiplatelet, anticoagulant and thrombolytic medication, as well as surgical repair [1,19,38,57,59], we most often applied antiplatelet therapy (58.7%), and less frequently anticoagulant medication (38.6%) (Table 9). In 17.8% of the ICAD patient and in 18.9% of the VBAD cases, stent was applied, whilst in 3.0% vascular surgery was performed in ICAD, but in none of VBAD, which is similar to other reports [1,13,15,22,38,51,57,77,78]

4.8. Outcome

Good outcome, i.e. between 0 and 2 on the Rankin scale, is seen in up to 79% of patients [1,8,19,21,29,31,57,67,96,103], which is more than in our patients (61,2%), probably due to their older age. Recurrent intracranial dissections appear in 9% of patients [1,109], which is more frequent than in our patients (2.6% with recurrent stroke, and 3.2% with recidivant TIA in the whole group, respectively) (Table 10). Mortality rate is usually between 0% and 9.5%, but most often from 1.6 to 5% [1,8,57,103], which is in agreement with our findings (2.1%) in the whole group (Table 10). Nevertheless, there are no differences in antiplatelet and anticoagulant therapy related to outcome [104].

4.9. Ethnic characteristics

After comparison of our results with other reports, it is obvious that our patients are different in certain features. For instance, a dissection of both ICA and VA or BA was not observed in the same patients, which also was the case in a triple dissection (Table 1). Headache and neck pain were more frequent in our VAD than in the ICAD patients, which is quite opposite to other reports [1,8,57,58,68]. Horner's syndrome was observed only in 14.1% regarding our ICAD patients, and in 8% in VAD ones (Table 2), which is less frequent than in other reports, i.e. 21–25% [57,97,98]. Subarachnoid hemorrhage (SAH) was not present in our patients (since any individual with SAH was transported to the Clinic of Neurosurgery), but it was registered in other reports, even in up to 54% [8,28,41].

Further, watershed infarcts are present in 12.9% of our patients, but only in 5% in the literature. Similarly, recurrent IS or TIA occurred in 2.6% and 3.2%, respectively, in our patients, but up to 16,7% in other ones [1,8]. Mortality rate is mainly up to 5.0% in the reported patients, but only in 2.1% in our patients. Certain racial and ethnic characteristic were already described in the literature [1,8,65,68,95], but the reason for that is unclear [8].

5. Conclusion

In our group of patients, there was a predominance of ICA dissection over VA and BA dissection. One of these vessels was most often affected, whilst two or three of them were rarely observed. There was a significant correlation of dissection, on the one hand, and trauma and vascular risk factors on the other hand. Headache and neck pain were the most frequent symptoms. Ischemic stroke was present in the majority of patients. It mainly affected the cerebral hemispheres, cerebellum, medulla oblongata, and pons. Over 60% of our patients had a good outcome, whilst mortality was noticed in about 2% of them. A great discrepancies in percentages

regarding mortality, certain causes and symptoms can be explained by small groups of the examined patients reported in the literature. Hence, examination of our 188 patients gave reliable and precise results.

CRediT authorship contribution statement

BGB: Conceptualization, Methodology, Writing - review and editing. **TDJ:** Patients' monitoring, Writing - review and editing. **MV:** Data curation, Investigation, Formal analysis, Writing - review and editing. **NS:** Patientś medication and monitoring, Writing - review and editing. **DK:** Methodology, Writing - review and editing. **ML:** Methodology, Writing - review and editing. **IM:** Data analysis, Investigation, Writing - review and editing. **TA:** Patientś medication and monitoring, Writing - review and editing. **AĆ:** Data curation, Investigation, Formal analysis, Writing - review and editing. **SM:** Conceptualization, Supervision, Data analysis, Writing - review and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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