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Original Articles

The Role of Vertebral and Internal Carotid Artery Disease in the Pathogenesis of Vertebrobasilar Transient Ischemic Attacks

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Summary. Color-coded duplex sonography has improved the evaluation of the hemodynamics of the vertebral arteries (VA). A reliable differentiation between a normal vessel, hypoplasia, stenosis and occlusion of VA can now be made. We studied two groups of patients in a prospective study with isolated carotid artery disease ($n = 48$), and with a combination of carotid and vertebral artery disease ($n = 14$), to determine the role of VA in the pathogenesis of transient ischemic attacks (TIAs) in the vertebrobasilar system. Apart from the existing arteriosclerotic changes of the internal carotid arteries, the condition of the VA was of importance for the occurrence of TIAs in the vertebrobasilar territory. We found that 8% of the patients with isolated hemodynamically relevant stenosis or occlusion of one or both internal carotid arteries had a TIA in the vertebrobasilar territory. Patients with combined carotid and vertebral artery disease had an increase of TIAs in the same region in 71%. The high rate of TIAs in this group might be attributed to the combined effect of carotid and vertebral artery disease, as a third group ($n = 30$) with isolated vertebral artery disease showed TIAs in only 13%.

Key words: Color-coded duplex sonography – Carotid artery disease – Vertebral artery disease – Vertebrobasilar transient ischemic attacks

Introduction

Continuous-wave (CW) Doppler sonography was introduced for the identification of extracranial lesions of the carotid arteries [5, 20]. B-Mode, real-time ultrasonographic imaging became available later and is able to demonstrate vascular anatomy rather than hemodynamics. The combination of both, Doppler and B-mode, resulted in the development of duplex sonography, which allows a precise visualization of the vessel structure and the quantitative measurement of blood flow characteristics [1–3, 7, 31]. With the development of the abovementioned ultrasound imaging techniques, the extracranial carotid arteries became available for routine noninvasive examination. The vertebrobasilar arteries, however, were usually examined in a very cursory fashion [12, 15, 19, 25, 27, 32–34]. There are several reasons for this:

1. The anatomy of the vertebral arteries does not allow continous insonation as is the case with the carotid arteries [26];

2. The diagnostic value of ultrasound is currently underestimated owing to the lack of surgical implications in patients with stenosis of the vertebral artery [14], and hence

3. complete angiographic data as a reference method are not available in many cases.

For the vertebral system, CW-Doppler is sensitive enough for qualitative measurement of vertebral blood flow velocities, but not for the exact differentiation of the underlying vascular disease (e.g. stenosis vs. hypoplasia; [13]). The new method of color-coded Doppler imaging, combining the ability of ultrasound to image tissue with the measurement of blood flow velocities, was used in this study [6]. The duplex concept is based upon the ability to identify the walls of a vessel within a two-dimensional ultrasound image, and it employs a pulsed Doppler sample volume to measure blood flow velocities within the visualised artery. There are two locations for assessing the vertebral artery with this technique [2, 17]. One is the origin of the vertebral artery. The second is the midportion (pars transversia). Here the measurement of blood flow velocities is fairly accurate and reliable because of to the straight course of this segment of the artery. The transverse processes of the cervical spine (between the levels of C3 and C6) are the anatomical structures of reference.

It has often been concluded from clinical observations that transient ischemic attacks (TIAs) within the vertebrobasilar system may depend more on hemodynamic factors, such as a transient decrease of perfusion,

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than on recurrent embolism. Relatively little is known about mechanisms of stroke and associated clinical features in patients with the combination of vertebral artery and carotid artery disease. Earlier studies considered the importance of vertebrobasilar symptoms as a prognostic factor in patients with stenosis of the carotid arteries [4, 28]. However, no study has examined the coincidence of these symptoms with normal, hypoplastic, stenosed or occluded vertebral arteries in ultrasonographic findings [4, 8–11, 18, 22, 28]. We therefore investigated the role of the vertebral arteries in the pathogenesis of TIAs in the vertebrobasilar system with special emphasis on the question as to whether or not additional stenosis or occlusion of one or both carotid arteries is important. Our hypothesis was that additional carotid disease should result in a higher frequency of TIAs within the vertebrobasilar territory provided that hemodynamic factors are important. The possible role of additional embolic mechanisms was investigated in a group of patients with isolated changes of vertebral arteries.

Materials and Methods

Sixty-two patients (mean age 62 years, SD 10 years, 48 males, 14 females) were studied prospectively between 1 October 1990 and 1 April 1991. All patients had hemodynamically relevant carotid artery disease (>50%), most of them (33 patients) an occlusion of the internal artery. Patients were divided into two groups: patients with isolated carotid artery disease (group 1), and patients with a combination of carotid and vertebral artery disease (group 2). A third group (group 3) with isolated hypoplasia (diameter <2 mm), stenosis or occlusion of the vertebral arteries was matched for sex and age (mean age 63 years, SD 9 years, 23 males, 7 females, Table 1). These patients had normal Doppler und duplex examinations of the carotid arteries. As a reference for diastolic and systolic velocity measurements in duplex sonography, we obtained data from a normal population ($n = 100$), age and sex matched without carotid and vertebral artery disease (group 4).

In all three patient groups the occurrence of TIA or stroke in the carotid or vertebrobasilar territory was evaluated by prior history and neurological examination. The clinical data of groups 1, 2, 3 are shown in Table 2. The diagnosis of vertebrobasilar TIA was based on the following clinical criteria [4, 29]:

Table 1. Number and degree of unilateral stenosis or occlusion of ICA (%) in groups 1–3. In group 1, four patients with bilateral occlusions. Group 1: isolated ICA disease; Group 3: isolated vertebral artery disease

	Group 1	Group 2	Group 3
Degree of ICA stenosis			
50–69%	8	1	–
70–90%	14	3	–
>90%	3	1	–
100%	23	9	–
VA disease			
Hypoplasia	–	–	1 (3%)
Stenosis	–	9 (64%)	24 (80%)
Occlusion	–	5 (36%)	5 (17%)
Total	48	14	30

Table 2. Clinical data in groups 1–3. I: Symptoms ipsilateral to carotid disease. C: Symptoms contralateral to carotid disease; VB: Symptoms in the vertebrobasilar system; TIA/PRIND/STROKE: Hemispheric symptoms

		Group 1 ($n = 48$)	Group 2 ($n = 14$)	Group 3 ($n = 30$)
Asymptomatic		22	1	26
VB		2	3	4
TIA/PRIND	I:	2	0	0
	C:	1	1	0
Stroke	I:	9	1	0
	C:	5	0	0
Amaurosis fugax	I:	5	1	0
	C:	0	0	0
TIA/PRIND	I:	0	0	0
and VB	C:	0	0	0
Stroke and VB	I:	2	6	0
	C:	0	0	0
Amaurosis fugax	I:	0	1	0
and VB	C:	0	0	0

1. homonymous hemianopia or bilateral "gray out" of the visual fields; (2). sensory and/or motor defect of any combination of extremities; (3). dysarthria, dysphagia, diplopia, vertigo; (4). ataxia, imbalance or unsteadiness. To warrant an accurate clinical diagnosis of vertebrobasilar TIA, the combination of at least two of these groups of symptoms had to be simultaneously present for selecting the patients with TIA in the vertebrobasilar system (VB).

All patients underwent continuous-wave Doppler sonography (CWDS) of the extracranial vessels (Sonotechnic GmbH LC-02, transducer 4 MHz). The examination included insonation of the periorbital branches of the ophthalmic artery to recognize a pathological flow (zero-flow, retrograde flow), as well as direct insonation of the whole extracranial segment of the carotid artery (left and right common, external, and internal carotid arteries). Appropriate tests were used to identify the vertebral arteries (VA). For evaluation of Doppler findings in the vertebral arteries, we employed the criteria described by Büdingen and von Reutern [5]. With a conventional 4-MHz hand-held probe, the optimal signals from the vertebral arteries at the atlas loop and in the supraclavicular fossae were obtained by acoustic control. The vertebral artery was identified by its retromastoid location, and repetitive compression at the atlas, when examining its origin in the supraclavicular fossa. The occipital artery was distinguished from the vertebral artery by compression over the occipital squama. Patients with signs of narrowed subclavian artery in CWDS were excluded.

Diameters, end-diastolic and peak systolic flow velocities were measured in all groups in the middle part (V2 segment or pars costotransversaria) of the right and left vertebral artery by color-coded duplex sonography (CCDS; Acuson 128 Computed Sonography System, 7.5-MHz transducer). The color-coding allows a rapid identification of the vertebral artery between the transverse processes of the cervical spine (Fig. 1). Color flow systems help to place the Doppler sample volume within the colored vertebral artery and to measure the Doppler angle (generally between 45° and 60°). We assessed the vertebral hemodynamics at the vessel's midportion between C3 and C6. After obtaining a good image of the common carotid artery, a slight lateral shift of the transducer brought the vertebral artery into view. Periodic shadowing from the transverse processes of the cervical spine provide the necessary anatomical landmarks. The course of the vessel was then followed down to the subclavian artery to analyse the ostium and the proximal portion of the artery.

A vertebral artery with a lumen <2 mm was defined as hypoplastic. We assumed a stenosis in the following cases: 1. A stenosis

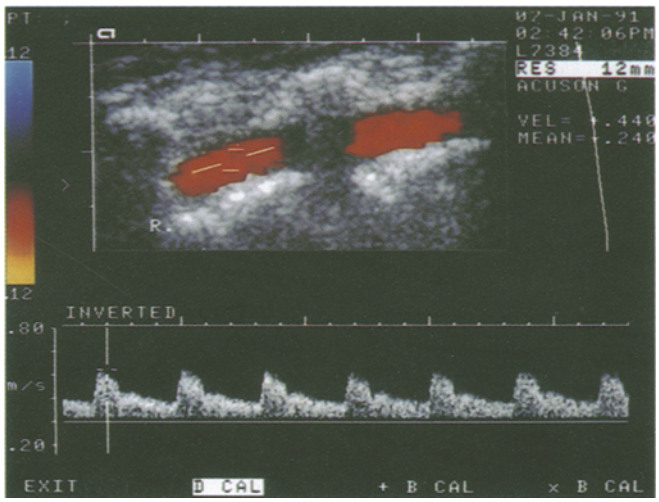

Fig. 1. Doppler sample volume within the red-colored vertebral artery. Periodic shadowing from the cervical spine. Doppler spectra from normal vertebral artery

of the proximal segment of the vertebral artery was visible in the color-coded duplex sonography. 2. In cases of insufficiently visualized origin of the vertebral artery, a normal lumen and marked (>50%) reduced end-diastolic and/or peak systolic blood flow velocities were measured in the middle part of the vessel in comparison with the contralateral vertebral artery. 3. Transcranial Doppler sonography (2-MHz Doppler, TC 2-64) presented an intracranially located stenosis of the vertebral artery (V4 segment). A visible vessel lumen of the vertebral artery without a blood flow signal and no Doppler signal indicated an occlusion of the artery. The Doppler sample volume was placed exactly within the vessel lumen.

Results

Clinical symptoms and arterial disease are summarized in Tables 1 and 2. Four patients in group 1 had bilateral occlusions of ICA, but no patient had the combination of occlusion and contralateral stenosis >50% or a bilateral stenosis >50% of the internal carotid artery (ICA). In group 2, only one patient (7%) was asymptomatic. Six patients (43%) had had a hemispheric stroke occurring in combination with VB-symptoms. Twenty-two patients (46%) with isolated ICA disease and normal vertebral arteries had no neurological signs or symptoms. In only 4% of the patients in this group, a combination of hemispheric stroke and VB-symptoms appeared. In group 3, no hemispheric symptom were observed.

We found a vertebrobasilar TIA-rate of 71% (10/14) in patients with combined carotid and vertebral disease, compared with only 8% (4/48) in the group with carotid disease alone (Table 3). Only 13% (4/30) of the third group with isolated hemodynamic changes of the vertebral arteries had TIAs in the vertebrobasilar system.

A retrograde flow in the ophthalmic artery as a sign of a collateral flow from external to internal carotid artery was observed in 27% of the patients in group 1 and in 28% of patients in group 2 (Table 4). These data demonstrate a comparable rate of this collateral supply from the external carotid artery in each group.

Table 3. Classification of patients (n = 92) with/without transient ischemic attacks in the vertebrobasilar territory (VBI); Group 1: Isolated ICA disease; Group 1: ICA and VBI disease; Group 3: Isolated VBI disease

	n	VBI	No symptoms of VBI
Group 1	48	4/48 (8%)	44/48 (92%)
Group 2	14	10/14 (71%)	4/14 (29%)
Group 3	30	4/30 (13%)	26/30 (87%)

Table 4. Supraorbital Doppler examination (CWDS) in groups 1–3. Normal flow: orthograde flow (or); Pathological flow: 0-flow (0f) and retrograde flow (re) in the supratrochlear artery

Degree of ICA stenosis	Group 1 (n = 48)			Group 2 (n = 14)			Group 3 (n = 30)	
	or	re	0f	or	re	0f	or	0f/re
0%	0	0	0	0	0	0	30	0
50–69%	8	0	0	1	0	0	0	0
70–90%	14	0	0	3	0	0	0	0
>90%	2	1	0	1	0	0	0	0
100%	7	12	4	5	4	0	0	0

Table 5. Flow velocity measurements (m/s; arithmetic mean: AM; standard deviation: SD) in vertebral arteries (group 1); N: Normal population with normal carotid and vertebral duplex; S1: Unilateral ICA stenosis; O1, O2: Uni- or bilateral ICA occlusion; Systol: Systolic flow velocity; Diastol: Diastolic flow velocity

	n	Diastolic		Systolic	
		AM	SD	AM	SD
N:	100	0.2	0.1	0.6	0.2
S1:	25	0.2	0.1	0.6	0.2
O1:	19	0.3	0.1	0.7	0.2
O2:	4	0.5	0.2	1.4	0.6

The peak systolic and end-diastolic flow velocities (AM ± SD) in the vertebral artery of the normal population, measured with duplex sonography are shown in Table 5. In group 1, (without involvement of vertebral artery), the diastolic and systolic velocities in the vertebral arteries were moderately increased in patients with unilateral ICA occlusion (Table 5). An exception was the patients with bilateral occlusions of the internal carotid artery (n = 4). These patients showed markedly increased diastolic and systolic velocities in the vertebral arteries (Table 5).

Discussion

The pathogenic mechanisms underlying ischemic brain symptoms are obviously manifold. The spectrum of mechanisms ranges from arteriosclerotic carotid or vertebral lesions, to hemodynamically induced brain ischemia, and to embolic occlusions of intracranial arteries.

Therefore, we examined the influence of arteriosclerotic lesions and hypoplasia of the vertebral arteries on the frequency of transient or permanent ischemic brain symptoms, and especially on VB symptoms in cases of additional carotid artery disease (stenosis >50%). Patients with ICA occlusions, who additionally suffer from VB symptoms are known to have a prognosis that is worse than that of patients with ICA occlusions without VB symptoms [4].

In group 2 the high ICA occlusion rate (64%) and the higher frequency of VB symptoms indicate that hemodynamic mechanisms in cases of combined stenosis or occlusion of VA and ICA play a role in the pathogenesis of VB symptoms in this group. This will be supported by the reduced VB rate in group 3 with isolated alterations of vertebral artery compared with the combined ICA and VA disease. We suggest that apart from the existing arteriosclerotic changes of the internal carotid arteries (ICA), the condition of the vertebral arteries is of importance for the occurrence of TIA in the vertebrobasilar territory caused by thromboembolism and/or hemodynamic factors. The possibility of hemodynamic mechanisms has already been advanced in earlier studies [4, 11, 21, 24, 29, 30], that reported VB symptoms in hemodynamically significant stenosis or occlusion of the ICA without evidence of embolic phenomenona. Findings in other studies, similar to our data, showed a high prevalence of TIAs in the VB system in patients with common carotid artery occlusion, further supporting hemodynamic mechanisms [16, 23]. One possibility to explain this is the assumption of a steal phenomenon [16]. By steal, we mean a posterior to anterior flow through the posterior communicating artery.

In our study, we demonstrated the importance of a normal hemodynamic function without arteriosclerotic alterations of the vertebral arteries in the presence of carotid stenosis or occlusion. In the presence of a bilateral occlusion of the internal carotid artery, the angle corrected measurements of blood flow velocities with color-coded duplex sonography showed a compensatory increase in systolic and diastolic flow velocities in the normal vertebral arteries in all patients. This indicates a compensatory increase in vertebral artery velocity and flow representing hemodynamic changes in cases of ICA occlusion. The combination of increased vertebral artery velocity and the occurrence of TIA in the VB territory might be explained by the above-mentioned steal phenomenon. Another hypothesis is that there are increased flow velocities and turbulent flow patterns in vessels with high-grade stenosis, or "jet effect" contralateral to occluded ICA, inducing emboli to the intracranial arteries by loosening platelet aggregates.

In conclusion, we observed a high correlation between disease of the carotid and vertebral arteries and the occurrence of TIAs in the vertebrobasilar territory. In patients with a vertebrobasilar TIA, vertebral artery disease together with carotid disease was observed in 71%. In the group with isolated carotid disease, VB-TIA occurred in only 8% of the patients. The group with isolated pathology of the vertebral arteries had VB-TIA in 13%. This observation illustrates the important role the vertebral arteries play in the pathophysiology of TIA in the posterior circulation. This findings may explain differences in the recovery from VB symptoms after endarterectomy in cases of ICA stenosis with VB-TIA [4, 18, 22, 28], as no report of associated VA disease occurred in these studies. We believe that some patients with combined VA and carotid artery disease who suffer from VB symptoms may benefit from a carotid endarterectomy. Because of the small number of patients with combinated VA and carotid artery disease in our study, we think that therapeutic rules should be established once a larger study has been completed.

References

1. Ackerstaff RGA, Hoeneveld H, Slowikowski JM (1984) Ultrasonic duplex scanning in atherosclerotic disease of the innominate, subclavian and vertebral arteries. A comparative study with angiography. Ultrasound Med Biol 4:409–418
2. Bendick PJ, Glover JL (1990) Hemodynamic evaluation of vertebral arteries by duplex ultrasound. Surg Clin North Am 70:235–245
3. Bendick PJ, Jackson VP (1986) Evaluation of the vertebral arteries with duplex sonography. J Vasc Surg 3:523–530
4. Bogousslavsky J, Regli F (1985) Vertebrobasilar transient ischemic attacks in internal carotid artery occlusion or tight stenosis. Arch Neurol 42:64–68
5. Büdingen HJ, Von Reutern GM, Freund HJ (1976) Die selektive Prüfung der Nackenarterien mit Hilfe der direktionalen Dopplersonographie. Arch Psychiatr Nervenkr 222:177–190
6. Delcker A, Diener HC (1991) Farb-Duplex-Sonographie zur Beurteilung der hirnversorgenden Arterien. Münch Med Wochenschr 133:182–185
7. Diener HC, Sebold H, Dichgans J, Andris M, Springer G (1983) Stenosen und Verschlüsse der extracraniellen Arterien. Dtsch med Wschr 108:496–500
8. Dyken ML, Klatte E, Kolar L, Spurgeon C (1974) Complete occlusion of common or internal carotid arteries. Arch Neurol 30:343–346
9. Ford JJ, Baker H, Ehrenhaft JL (1975) Carotid endarterectomy for nonhemispheric transient ischemic attacks. Arch Surg 110:1314–1317
10. Furlan AJ, Whisnant JP, Baker HL (1980) Long-term prognosis after carotid artery occlusion. Neurology 30:986–988
11. Grillo P, Patterson RH (1975) Occlusion of the carotid artery: prognosis (natural history) and the possibilities of surgical revascularization. Stroke 6:17–20
12. Hartnell GG (1986) Doppler ultrasound and digital vascular imaging. Br J Hosp Med 36:433–436
13. Hennerici M, Aulich A, Sandmann W, Freund HJ (1981) Incidence of asymptomatic extracranial arterial disease. Stroke 12:750–758
14. Horvath W (1985) Diagnostik von Veränderungen der supraaortalen extracraniellen Gefäße mit besonderer Berücksichtigung der Kollateralwege-Echtzeitsonographie, Doppler-Ultraschall, Angiographie. Röntgen-Bl 38:38–44
15. Kaneda H, Irino T, Minami T (1977) Diagnostic reliability of the percutaneous ultrasonic Doppler technique for vertebral arterial occlusive diseases. Stroke 8:571–579
16. Levine SR, Welch KMA (1989) Common carotid artery occlusion. Neurology 39:178–186
17. Lewis BD, James EM, Welch TJ (1989) Current applications of duplex and color Doppler ultrasound imaging: Carotid and peripheral vascular system. Mayo Clin Proc 64:1147–1157
18. McNamara JO, Heymann A, Silver D (1977) The value of carotid endarterectomy in treating transient cerebral ischemia of the posterior circulation. Neurology 27:682–684

19. Meyer J, Sheehan S, Bauer R (1960) An arteriographic study of cerebrovascular disease in man. Arch Neurol 2:27–41
20. Müller HR (1976) Die Dopplersonographie der Karotiden. Internist 17:570–579
21. Naritomi H, Sakai F, Meyer JS (1979) Pathogenesis of transient ischemic attacks within the vertebrobasilar arterial system. Arch Neurol 36:121–128
22. Owens ML, Atkinson JB, Wilson SE (1980) Recurrent transient ischemic attack after carotid endarterectomy. Arch Surg 115:482–486
23. Podore PC, Rob CG, De Weese JA, Green RM (1981) Chronic common carotid occlusion. Stroke 12:98–100
24. Riles TS, Kopelman I (1980) Carotid artery stenosis with contralateral internal carotid occlusion: Long-term results in 54 patients. Surgery 87:363–368
25. Ringelstein EB (1985) Ultraschalldiagnostik am vertebrobasilären Kreislauf Teil II: Transnuchale Diagnose intrakranieller vertebrobasilärer Stenosen mit Hilfe eines neuartigen Impulsschall-Doppler-Systems. Ultraschall 6:60–67
26. Ringelstein EB, Kolmann HL, Kruse L (1983) Dopplersonographie der extrakraniellen Hirnarterien: In erster Linie ein didaktisches Problem. Ultraschall 4:182–187
27. Ringelstein EB, Zeumer H (1982) The role of continuous wave Doppler sonography in the diagnosis and management of basilar and vertebral artery occlusions, with special reference to its application during local fibrinolysis. Neurology 228:161–170
28. Rosenthal B, Cossmann D, Ledig B (1978) Results of carotid endarterectomy for vertebrobasilar insufficiency. Arch Surg 113:1361–1364
29. Stanwood J (1984) Ophthalmologic aspects of cerebrovascular disease. In: Toole JF (ed) Cerebrovascular disorders. New York, Raven Press, pp 231–250
30. Thiele BL, Young JV, Chikos PM (1980) Correlation of arteriographic findings and symptoms in cerebrovascular disease. Neurology 30:1041–1046
31. Touboul PJ, Bousser MG, LaPlane D, Castaigne P (1986) Duplex scanning of normal vertebral arteries. Stroke 17:921–923
32. Visona A, Lusiani L, Castellani V (1986) The echo Doppler (duplex) system for the detection of vertebral artery occlusive disease: comparison with angiography. J Ultrasound Med 5: 247–250
33. Winter R, Biedert S, Staudacher Th, Betz H, Reuther R (1987) Vertebral artery Doppler sonography. Eur Arch Psychiatr Neurol Sci 237:21–28
34. Winter R, Widder B, Diener HC (1990) Neuere Entwicklungen bei der Ultraschalluntersuchung der hirnversorgenden Arterien und ihre klinische Wertigkeit. Nervenarzt 61:451–461