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CDFI AND PDI FINDINGS IN EXTRACRANIAL ARTERY DISEASE

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SUMMARY – The development of duplex ultrasound instrumentation combining high-resolution B-mode imaging with Doppler flow analysis represents a major advancement in ultrasound cerebrovascular diagnosis. Duplex sonography enables not only estimation of arterial stenosis, but allows for visualization of the plaque morphology. The principal arterial abnormality detectable with B-mode sonography is plaque, which appears as echogenic material that thickens the arterial wall and obliterates the lucent zone between the intimal reflection and the adventitia. When an atherosclerotic plaque is detected, its severity, extent, morphology and location must be analyzed. The most common site of atherosclerotic plaque formation is at the carotid bifurcation. The European Carotid Surgery Trial (ECST) and North American Symptomatic Carotid Endarterectomy Trial (NASCET) have shown that the degree of internal carotid artery stenosis is a major predictor of ipsilateral ischemic stroke in patients presenting with transient ischemic attack or minor ischemic stroke. The main location of vertebral stenosis or occlusion is the origin (V0 segment), less commonly more distally in the cervical region (V1 segment) or intracranially (V4 segment). The left subclavian artery is more often affected by atherosclerosis than truncus brachiocephalicus. The main characteristic of occlusion or stenosis of truncus brachiocephalicus are spectral changes in the right subclavian, carotid and vertebral artery. Cerebral ischemia is the most serious consequence of cervical artery dissection. Internal carotid artery is the most commonly affected vessel. In extreme cases, artery dissections can extend from the aorta to the subclavian, carotid and vertebral arteries. The term 'vasculitis' encompasses a heterogeneous group of multisystemic disorders; CDFI examination demonstrates thickening of the arterial wall, usually circumferential, stenosis or occlusion of the arteries.

Key words: *Cerebrovascular disorders, diagnosis; Cerebrovascular disorders, ultrasonography, Doppler, color; Vasculitis, diagnosis*

Introduction

The development of duplex ultrasound instrumentation combining high-resolution B-mode imaging with Doppler flow analysis represents a major advancement in ultrasound cerebrovascular diagnosis. Duplex sonography enables not only estimation of arterial stenosis, but allows visualization of the plaque morphology. The method is completely noninvasive and thus suitable for follow-up of patients to detect progression of luminal obstruction. Duplex sonography also allows for assessment of other pathologic conditions such as vasculitis, cervical artery dissection, subclavian steal syndrome, and arterial hypoplasia.

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Carotid Arteries

Atherothrombotic stenosis of the origin of the internal carotid artery (ICA) is a common cause of carotid ischemic stroke. The risk of stroke increases with the severity of carotid stenosis and is reduced after carotid endarterectomy. Early carotid lesions, such as the fatty streak,

probably represent precursors of a mature carotid plaque. These early lesions occur in the carotid bulb posterolaterally where the are zones of high and low shear. They are influenced by a variety of risk factors such as hypertension, diabetes, smoking, and blood lipids to progress to plaques. Severe ICA stenosis, plaque surface, thrombus formation, distal embolism and plaque surface irregularity are associated with an increased risk of ischemic stroke, however, there is evidence that hemodynamic factors may also be important.

The most common site of atherosclerotic plaque formation is at the carotid bifurcation. The atherosclerotic plaque is composed of a dense cap of connective tissue embedded in smooth muscle cells, overlying a core of lipid and necrotic debris. The plaque contains monocyte-derived macrophages, smooth muscle cells, and T lymphocytes. Interaction between these cell types and connective tissue appears to determine the development of plaque, including important complications such as plaque rupture. The quantity of extractable lipid has been found to be greater in symptomatic plaques. This histology finding is consistent with the results of ultrasound studies demonstrating that echolucent, lipid-rich plaques are more often associated with symptoms.

Once the common carotid artery is identified, it is followed superiorly to the carotid bifurcation, at which point the internal and external (ECA) carotid artery should be identified and followed to their most distal segments. If the carotid bifurcation is high in the neck (near the mandible), the field of view of the ICA and ECA may be restricted; image quality problems may also result from vessel tortuosity or sharp medial angulation of ICA relative to the skin line.

The principal arterial abnormality detected by B-mode sonography is the plaque, which appears as echogenic material that thickens the arterial wall and obliterates the lucent zone between the intimal reflection and the adventitia. When an atherosclerotic plaque is detected, its severity, extent, morphology, and location must be analyzed. The B-mode appearance of the plaque correlates qualitatively with its histologic composition. A fibrofatty plaque that contains a large amount of lipid material is the least echogenic type of plaque and may be so faintly echogenic as to be difficult to identify sonographically (Figs. 1 and 2). A uniformly fibrous plaque is homogeneous in echogenicity, but may contain localized hypoechoic regions due to lipids. Strong reflections accompanied by acoustic shadowing are associated with areas of calcification. Acoustic shadowing from large calcified deposits may obscure the remainder of the vessel, so it may be impossible to determine the severity and significance of atherosclerotic lesion. Identification of a hypoechogenic zone within a plaque mainly points to intraplaque hemorrhage. This condition often results in thrombus accumulation, intimal breakdown and ulceration, or it may be responsible for rapid progression of stenosis from mild to critical levels of obstruction. A complicated plaque containing hemorrhage, calcification, and lipid deposits is generally considered to be more frequently symptomatic and dangerous than a non-complicated fibrofatty plaque. Furthermore, the extent of plaque should be visualized: focal or along a certain segment of the artery, proximal or distal portion, circumferential or eccentric. Complications such as plaque hemorrhage, arterial dissection and thrombosis may lead to occlusion of the artery (Fig. 3).

The European Carotid Surgery Trial (ECST) and North American Symptomatic Carotid Endarterectomy Trial (NASCET) have shown that the degree of ICA stenosis is a major predictor of ipsilateral ischemic stroke in patients presenting with transient ischemic attack (TIA) or minor ischemic stroke. According to the ECST method, carotid stenosis is measured as a visual estimate of the original lumen diameter at the site of maximal stenosis; the NASCET method uses the measurement of lumen diameter at a different point, a more distal unaffected portion of ICA. It has been suggested that an absolute measurement of the minimal residual lumen, corrected for magnification, be used as a measure of stenosis. However, the results of ECST and NASCET indicate that patients would not benefit equally from carotid endarterectomy. To be of any clinical use, the measurement of stenosis must take into account the original size of the artery.

Vertebral Arteries

Doppler sonography of vertebral arteries is limited with several factors. Vertebral arteries cannot be visualized continuously because of their partial course through the transverse part of cervical vertebrae. In less than 20%, the visualization of the origin of vertebral arteries is not possible; in 4% - 6% the origin of the vertebral artery is at the aortic arch. In some cases, the artery tortuosity can also be the cause of insufficient Doppler examination (Fig. 4). While aplasia of vertebral arteries is rare, hypoplasia is present in up to 2% - 3% of the population. The criteria for hypoplasia are: mean diameter <2 mm, decreased blood

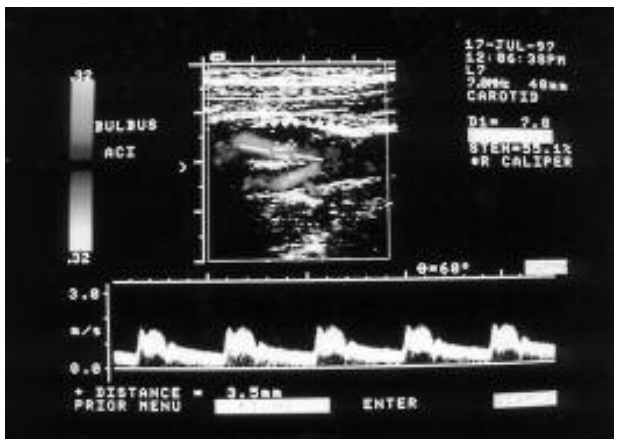

Fig. 1. ACI stenosis (55%) with a predominantly fatty plaque.

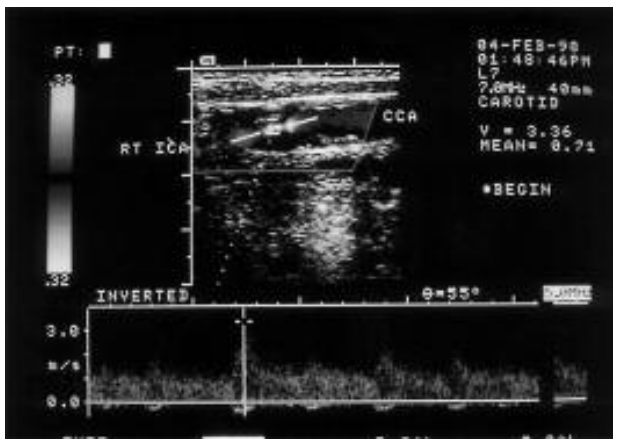

Fig. 2. ACI stenosis (80%) with a mixed, predominantly fatty plaque.

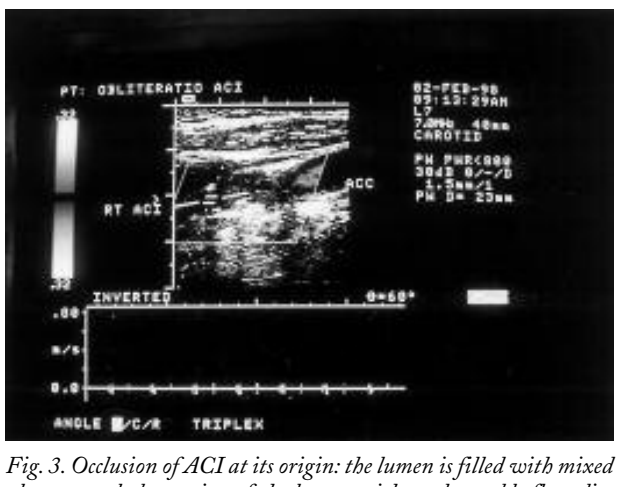

Fig. 3. Occlusion of ACI at its origin: the lumen is filled with mixed plaque; total obstruction of the lumen with no detectable flow distally.

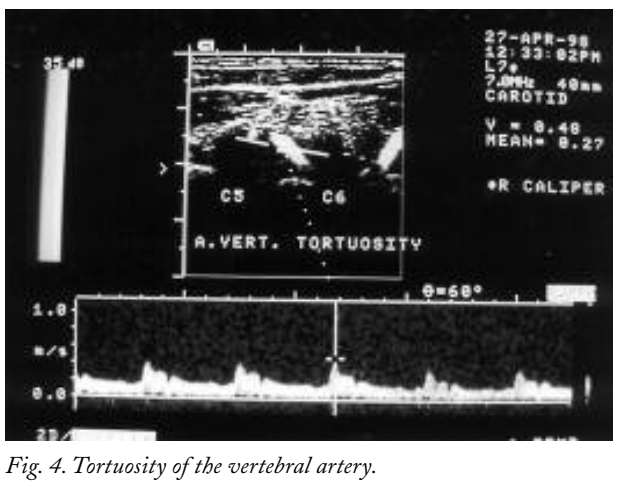

Fig. 4. Tortuosity of the vertebral artery.

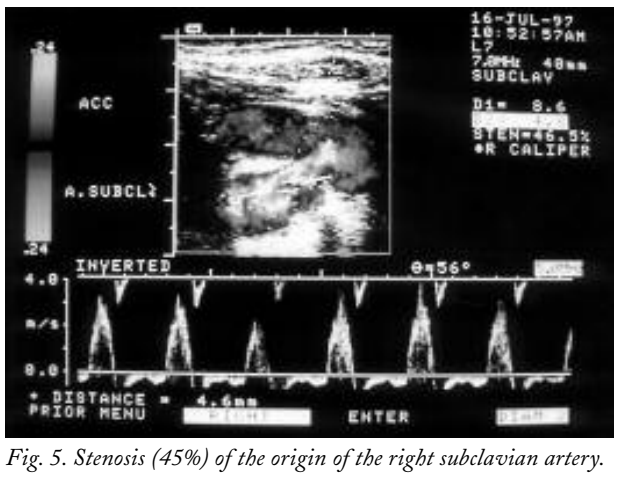

Fig. 5. Stenosis (45%) of the origin of the right subclavian artery.

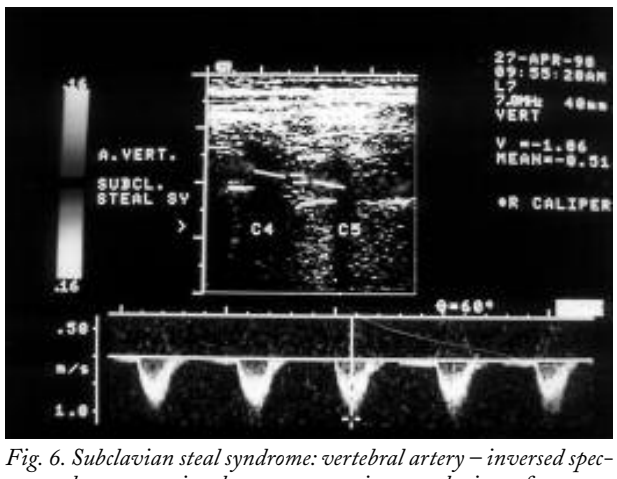

Fig. 6. Subclavian steal syndrome: vertebral artery – inversed spectrum due to proximal severe stenosis or occlusion of truncus brachicephalicus, or subclavian artery proximal to the origin of the vertebral artery.

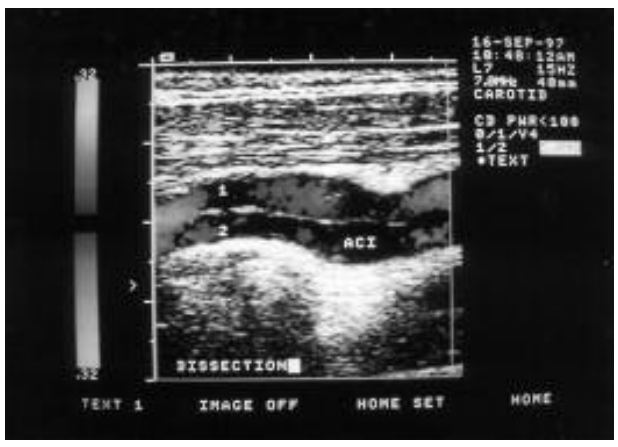

Fig. 7. Cervical artery dissection: dissection of ACC and ACI – two lumina.

flow velocities (especially diastole), and possible high resistance pattern. The mean diameter of vertebral arteries is 3.5 mm; asymmetry is present up to 15%. The main location of vertebral stenosis or occlusion is the origin (V0 segment), and less commonly more distally in the cervical region (V1 segment), or intracranially (V4 segment). Uncovertebral degenerative disease may dislocate the artery or compromise the blood flow.

Vertebral artery occlusion need not necessarily produce symptoms; it depends on collateral circulation. Branches that arise from truncus thyrocervicalis and truncus costocervicalis connect vertebral arteries with ascending cervical arteries and occipital artery; by vertebral occlusion these collateral pathways become functional, increase their lumina, and are detectable by color Doppler.

Subclavian Arteries, Truncus Brachiocephalicus

In a majority of cases, occlusion or stenosis of subclavian arteries is the result of advanced atherosclerosis, it is rarely caused by trauma, dissection of aortic aneurysm or resection of 'neck rib'. The left subclavian artery is more commonly involved, while the right subclavian artery can be examined from its origin because of its anatomical location (Fig. 5). In most cases, the subclavian arteries/truncus brachiocephalicus are stenosed or occluded at their origin, which allows for only indirect evaluation of the stenosis percentage. Severe stenosis of the subclavian artery, especially if located proximally to visualization, can be indirectly detected by spectral poststenotic disturbances more distally along the vessel and by the spectral curve analysis. It is usually difficult to obtain maximal systolic velocities because a stenotic signal is characterized by high amplitudes, low frequency, and negative components. In case of subclavian occlusion, blood flow reduction in the systole with regular negative deflection in the diastole can be observed.

The subclavian – steal syndrome results from reversal of flow through the vertebral artery from occlusion or stenosis of the proximal part of the subclavian artery or truncus brachiocephalicus artery (proximally from the origin of the vertebral artery) (Fig. 6). A 'partial' subclavian – steal syndrome is indicated by alternating flow in the vertebral artery, wheres the 'complete' form is indicated by retrograde flow in the vertebral artery; in both conditions, the arm 'steals' the blood from the vertebrobasilar circulation. Patients with the subclavian steal syndrome are more likely to experience TIA or cerebrovascular accident (CVA) involving the vertebrobasilar or carotid circulation. The resulting 'steal' phenomenon leads to the common symptoms of vertigo, syncope, and intermittent claudication of the upper extremity involved. Blood pressure measurement shows difference of more than 20 mm Hg between the left and right arm, and diminished pulses ipsilaterally in most cases. Due to sufficient collateral circulation, stenosis or occlusion of subclavian arteries leads to symptoms in less than one third of patients. A significant percentage of patients will have concomitant extracranial atherosclerotic disease. Carotid artery endarterectomy should be performed first in these patients and will likely resolve all symptoms. Transluminal angioplasty or, less frequently, carotid subclavian bypass graft remains the procedure of choice for patients suffering from disabling symptoms and can be performed with a low operative risk and morbidity, with good long-term results.

In a small proportion of patients with subclavian – steal syndrome, angiography fails to demonstrate retrograde basilar flow, whereas Doppler sonography detects transient retrograde blood flow, usually in case of 'partial' steal. Forced injection of contrast medium presumably conceals less pronounced steal phenomena. Thus, functional Doppler sonography is superior to angiography.

Truncus brachiocephalicus is less commonly affected with atherosclerotic disease than the left subclavian artery. The main characteristic of occlusion or stenosis of truncus brachiocephalicus are spectral changes in the right subclavian, carotid and vertebral arteries. In the first phase, low flow with low pulsatility and low resistance is observed in the arteries distal to severe stenosis or occlusion. In the second phase, retrograde flow is present in vertebral arteries, whereas in the third phase retrograde flow (at least in

the systole) can be observed in all arteries that supply blood to the brain.

Cervical Artery Dissection

Cerebral ischemia is the most serious consequence of cervical artery dissection (CAD). It can be due to hemodynamic factors or emboli. CAD accounts for up to one fifth of ischemic strokes occurring before age 45. The internal carotid artery is the vessel most commonly affected with CAD, usually in its pharyngeal and distal segments, more than 2 cm above the origin (Fig. 7). Vertebral artery dissections are located either in the V1 segment or V3 segment of vertebral artery. In extreme cases, arterial dissections can extend from the aorta to the subclavian, carotid, and vertebral arteries. Most dissections are subadventitial; the thicker outer coats and supporting tissues probably limit the risk of bleeding. Infarction occurs when the mural hematoma leads to narrowing of the arterial lumen or when thrombosis occurs.

The pathogenesis of dissections remains unknown in most cases. However, trauma and primary diseases of the arterial wall (Marfan's syndrome, osteogenesis imperfecta, fibromuscular dysplasia, cystic medial necrosis of intracranial vessels, etc.) are the main predisposing factors. Doppler examination demonstrates tapering of ICA lumen with or without thrombus; double lumen with an irregular membrane crossing the lumen; string and pearl sign; and usually, absence of atheroma. Alterations of blood flow are characterized by ipsilateral high resistance pattern in ACC, decreased or reversed flow in the ophthalmic artery, reduced or absent systolic blood flow, alternating flow directions, two spectra (real, false), and increased contralateral flow.

Vasculitis

The term vasculitis includes a heterogeneous group of multisystemic disorders characterized pathologically by inflammation and necrosis of the blood vessel wall. The sequels of vascular inflammation depend on the number, site and size of the blood vessels involved. Focal arterial lesions can produce aneurysms, vessel wall rupture and hemorrhage, while segmental lesions, which are more common, affect the entire vessel wall circumference and lead to stenosis, occlusion and infarction. Almost all forms of vasculitis can involve the vessels feeding the brain parenchyma and cause stroke-like episodes, but the frequency of central nervous system involvement is variable.

Vasculitis is usually considered to be primary (classified according to the size of the predominantly affected vessel and to the association with antineutrophil cytoplasm autoantibodies) or secondary (collagen vascular disorders, in malignancies, viral, bacterial, spirochetal and parasitic central nervous system infections, in Behçet's disease, or medication related).

The two main forms of large vessel (primary) vasculitis detectable by Doppler examination are giant cell (temporal) arteritis (GCA) and Takayasu's disease. In GCA, the superficial temporal, vertebral, ophthalmic, external and internal arteries are involved. In Takayasu's disease, the affected vessels are the aorta and its main branches to the limbs and head (subclavian, carotid and vertebral arteries). CDFI demonstrates thickening of the arterial wall, usually circumferential, stenosis or occlusion of the arteries. Treatment of vasculitis includes identification of the specific vasculitic syndrome, treatment of the underlying condition, steroids combined with or switched to a cytotoxic agent.

References

1. DEMARIN V (ed.) Priručnik iz neurologije. Prosvjeta, Bjelovar d.d., 1998.
2. DEMARIN V. Stroke: Present state and perspectives. Period Biol 1995;98:95-7.
3. PODOBNIK-ŠARKANJI S, DEMARIN V, RUNDEK T, LOVRENČIĆ-HUZJAN, A. Risk factors for carotid artery atherosclerosis. Acta clin Croat 1995;34:145-55.
4. BARTELS E. Color-coded duplex ultrasonography of the cerebral vessels. Stuttgart: Schattauer Verlagsgesellschaft mb H, 1999.
5. ROTHWELL PM, GIBSON R, WARLOW CP. Interrelation between plaque surface morphology and degree of stenosis on carotid angiograms and the risk of ischemic stroke in patients with symptomatic carotid stenosis. Stroke 2000;31:615-21.
6. De BRAY JM, BAUD JM, DELANOY P, CAMUZAT JP, DEHANS V, DESCAMP-LWE CHEVOIR J, LAUNAY JR, LUIZY F, SENTOU Y, CALSE P. Reproducibility in ultrasonic characterization of carotid plaques. Cerebrovasc Dis 1998;8:273-277.
7. GRIEWING B, MORGENSTERN C, DRIESNER F, KALLWELLIS G, WALKER ML, KESSLER C. Cerebrovascular disease assessed by color-flow and power Doppler ultrasonography. Stroke 1996;27:95-100.
8. ROTHWELL P.M., WARLOW C.P. Making sense of the measurement of carotid stenosis. Cerebrovasc Dis 1996;54-58.
9. GOLLEDGE J, GREENHALGH RM, DAVIES AH. The symptomatic carotid plaque. Stroke 2000;31:774-781.
10. FERRO J.M., Vasculitis of the central nervous system. J Neurol 1998;245:766-776.

Sažetak

NALAZI CDFI I PDI KOD EKSTRAKRANIJSKE ARTERIJSKE BOLESTI

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Razvoj ultrazvučnih dupleks uređaja koji ujedinjuju B-prikaz visoke rezolucije sa spektralnom krivuljom pridonio je značajnom napretku u dijagnostici cerebrovaskularnih bolesi. Dupleks ultrasonografija omogućuje ne samo procjenu stupnja stenoze, nego i prikaz morfologije plaka. Najčešći poremećaj krvnih žila vidljiv pomoću B-prikaza je plak koji se prikazuje kao ehogena struktura koja zadebljava stijenku arterije i obliterira prostor između intimalne refleksije i adventicije. Kada se prikaže aterosklerotski plak, treba analizirati njegov položaj, prostiranje, morfologiju i stupanj stenoze. Najčešće mjesto stvaranja aterosklerotskog plaka je karotidna bifurkacija. Studije European Carotid Surgery Trial (ECST) i North American Symptomatic Carotid Endarterectomy Trial (NASCET) pokazale su da je stupanj stenoze unutarnje karotidne arterije najvažniji predskazatelj istostranog ishemijskog udara u bolesnika s prolaznim ishemijskim napadajem ili blažim oblikom moždanog udara. Najčešće mjesto stenoze ili okluzije vertebralnih arterija je polazište (segment V0), a rjeđe distalno u cervikalnom dijelu (segment V1) ili intrakranijski (segment V4). Lijeva subklavijska arterija češće je zahvaćena aterosklerotskim promjenama nego brahiocefalni trunkus. Glavno obilježje okluzije ili stenoze brahiocefalnog trunkusa je promjena spektra u desnoj subklavijskoj, karotidnoj i vertebralnoj arteriji. Moždana ishemija je najozbiljnija posljedica disekcije vratnih arterija. Najčešće je zahvaćena unutarnja karotidna arterija. U krajnjim slučajevima disekcija se može protezati od aorte do subklavijskih, karotidnih i vertebralnih arterija. Pojam vaskulitis obuhvaća heterogenu skupinu multisistemskih poremećaja. Ultrazvučnom (dupleks) pretragom prikazuje se zadebljanje stijenki arterija, najčešće cirkumferentno, stenoza ili okluzija arterija.

Ključne riječi: *Cerebrovaskularne bolesti, dijagnostika; Cerebrovaskularne bolesti, ultrasonografija; Ultrasonografija, Doppler, obojeni; Vaskulitis, dijagnostika*