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The Role of Carotid Ultrasonography in Patients with High Risk of Atherosclerosis

Balázs Oltean-Péter[1,2], István Kovács[1,2], Monica Chițu[1,2], Imre Benedek[1,2]

[1] Clinic of Cardiology, University of Medicine and Pharmacy, Tîrgu Mureș, Romania

[2] Center of Advanced Research in Multimodality Cardiac Imaging, Cardio Med Medical Center, Tîrgu Mureș, Romania

CORRESPONDENCE

István Kovács
Str. Gheorghe Marinescu nr. 38
540139 Tîrgu Mureș, Romania
Tel +40 265 215 551
E-mail: kov_istvan@yahoo.com

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Balázs Oltean-Péter • Str. Gheorghe Marinescu nr. 38, 540139 Tîrgu Mureș, Romania. Tel +40 265 215 551, E-mail: olteanbalazs1@gmail.com

Monica Chițu • Str. Gheorghe Marinescu nr. 38, 540139 Tîrgu Mureș, Romania. Tel: +40 265 215 551, E-mail: iuliachitu@yahoo.com

Imre Benedek • Str. Gheorghe Marinescu nr. 38, 540139 Tîrgu Mureș, Romania. Tel: +40 265 215 551, E-mail: imrebenedek@yahoo.com

ABSTRACT

Atherosclerosis is a systemic disease that most often affects the carotid arteries. Being usually asymptomatic in its early stages, it is diagnosed only in advanced stages, when treatment is more difficult and prognosis is poor. Carotid ultrasound (US) is the most commonly used method for diagnosing carotid artery disease and represents a proper method for screening in patients with cardiovascular (CV) risk factors. This paper shows the methodology and necessity of carotid imaging methods in patients at high risk of developing atherosclerotic lesions. We also review the findings that underline the need of carotid screening in patients with ischemic heart disease or with ischemic arteriopathy, showing that the carotid arteries are like 'mirrors' of the arterial system, which need to be assessed in every patient with CV risk factors, regardless of the presence or absence of symptoms.

Keywords: carotid ultrasonography, carotid artery, imaging methods, atherosclerosis, ischemic heart disease

INTRODUCTION

Atherosclerosis is a widespread disease nowadays and is the first cause of death in developed countries. Any large or medium artery in the human body may be affected by atherosclerosis; however, in early stages of the disease, patients are usually asymptomatic. The disorder can result in coronary artery disease, brain circulation problems (stroke), peripheral artery disease, or other organ circulation failure. Atherosclerosis is often simultaneously present at the level of several different arteries.[1]

The exact cause of this disease is not known. Hypertension, age, elevated levels of triglycerides and cholesterol, diabetes, smoking, and sedentariness play an important role in the appearance and progression of atherosclerosis.[2] The blood supply of the brain is offered through the internal carotid and vertebral arteries. The circle of Willis creates a communication between the vertebro-basilar and internal carotid systems, being capable of maintaining the cerebral blood flow in case of unilateral internal carotid or basilar artery occlusion or severe stenosis.[3]

The carotid arterial system is frequently affected by atherosclerosis. The most frequently affected area is the common carotid artery (CCA) bifurcation, where this artery divides into the internal and external carotid artery.[4]

The most common cause of stroke is atrial fibrillation and carotid artery oclusion.[5] The prevalence of stroke among asymptomatic patients with hemodynamically significant carotid artery lesion is 2–5% per year.[6] In the literature, it has been reported that stroke is caused in 20–30% by extracranial carotid artery plaques.

Carotid artery disease can be asymptomatic for a long time, as the symptoms can appear only when the blood flow to the brain is totally disrupted. The most common signs and symptoms include sudden numbness or weakness in the face or limbs, dizziness, severe headache, and trouble speaking and seeing.[7]

Carotid endarterectomy is the gold standard therapeutic option, but minimally-invasive carotid angioplasty retains its role in symptomatic patients, with unilateral lesions. This method is safer, with a lower rate of complications.[8]

ASSESSMENT OF CAROTID ARTERY LESIONS

The high prevalence of carotid artery disease in the general population brought forward the need of new imaging methods, which are capable to accurately assess carotid artery atherosclerotic lesions. Digital subtraction angiography (DSA) is still the gold standard method for the evaluation of carotid artery stenosis.[9] Recently, new non- and minimally invasive methods became available, which include ultrasonography, computed tomography angiography (CTA), and magnetic resonance angiography (MRA).[10]

NONINVASIVE IMAGING METHODS

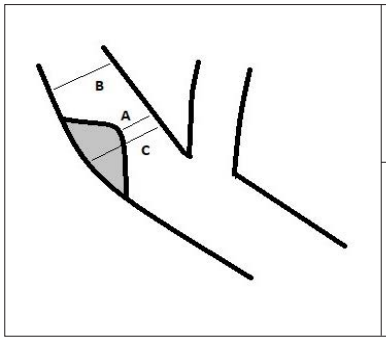
Carotid ultrasonography

Vascular ultrasound (US) is described as a reliable, accurate, and efficient method, which is capable to identify carotid plaques, to determine the intima media thickness (IMT), and to assess the atherosclerotic process.[11] Doppler and grayscale US are used for the assessment of the extracranial carotid artery system, as the first diagnostic step. Grayscale US allows the assessment of arterial walls, morphology, size, and surface of plaques, and the IMT, but it does not allow the determination of the degree of stenosis.[12,13] More researchers have demonstrated that hypoechoic or heterogeneous plaques are associated with a higher risk of stroke and cardiovascular events.[14,15] It has been demonstrated in many multiethnic cohort studies that the presence of irregularity or ulceration at the level of plaques has a negative prognostic value because they independently predict a higher risk for stroke.[16–18] While grayscale US allows the identification and morphological assessment of plaques, Doppler US allows the assessment of stenosis grade and its functional impact.[13] Color Doppler is used to identify stenotic segments and to visualize blood flow in the artery lumen, which can be turbulent in case of hemodynamically significant stenoses. It is also capable to determine flow velocity, but for an exact determination, pulse wave (PW) Doppler is needed.[19] In PW Doppler, the most frequently used parameters for measuring the grade of internal carotid stenosis are peak diastolic and systolic velocity.[20,21]

For the correct assessment of flow velocity, it is important for the angle of insonation to be as parallel as possible to the direction of the blood flow.[13] In 2003, the Society of Radiologists in Ultrasound published the standard criteria for the determination of internal carotid artery (ICA) stenosis.[22] This is composed of primary and secondary parameters. The most important parameter for the detection of a significant stenosis at the level of the ICA is peak systolic velocity (PSV). ICA end-diastolic velocity (EDV) and the internal carotid artery/common carotid artery (ICA/CCA) PSV ratio are also used for the determination of carotid stenosis (Table 1).[23,24] A hemodynamically significant stenosis is defined as a visible stenosis with a PSV >230 cm/s, EDV >100 cm/s, and an ICA/CCA ratio >4.25.

TABLE 1. Diagnostic criteria for carotid artery stenosis

	Primary parameter	Secondary parameters	
Grade of stenosis (%)	**ICA PSV (cm/s)**	**ICA EDV (cm/s)**	**ICA/CCV PSV ratio**
<50%	<125	<40	<2
50–69%	125–230	40–100	2–4
>70%	>230	>100	>4
Sub-occlusion	Low, high	Low, high	Low, high
Occlusion	Undetectable	–	–



$$\text{NASCET} = \frac{B - A}{B} \times 100$$

$$\text{ECST} = \frac{C - A}{C} \times 100$$

FIGURE 1. NASCET and ECST formula

Table 1 shows the most commonly used criteria for the diagnosis of carotid artery stenosis.

If the stenosis is in the CCA, PSV needs to be measured proximally (point b) and distally (point a) to the stenotic segment, in order to define the CCAa/CCAb and ICA/CCAa PSV ratios.[26] External carotid artery (ECA) stenosis without ipsilateral ICA occlusion may not be clinically significant.[27] The most commonly used parameters for the determination of stenosis in the ECA are PSV and the ECA/CCA systolic ratio.[28] If contralateral CCA occlusion is present, PSV can be elevated without the presence of a significant stenosis.[19] Besides the fact that US is recommended by several associations, including the American Heart Association and the American Stroke Association, as the first-line imaging method for asymptomatic patients, this method also has its limitations such as subjectivity (operator-dependent, may overestimate the degree of stenosis).[29]

Computed tomography angiography and magnetic resonance angiography

Both methods have a high sensitivity and specificity: 100% and 63% (CTA) vs. 100% and 85–96% (MRA).[30] CTA and MRA allow the assessment of carotid arteries from the emergence to the circle of Willis. Several studies have demonstrated that CTA and MRA provide more information about the morphology and composition of plaques than DSA.[31–33] These methods may overestimate the degree of stenosis and in some cases are incapable to differentiate between a tight stenosis and a total occlusion. The use of CTA is contraindicated in patients with renal failure or hypersensitivity to iodinated contrast agents. Another disadvantage of this method is radiation exposure. MRA has the advantage of no radiation exposure but cannot be performed in patients with metallic implants or pacemakers.[34]

MINIMALLY INVASIVE IMAGING METHODS

Digital subtraction angiography (DSA)

DSA is a minimally invasive method, which is still the gold standard of carotid artery assessment. This method is not the first choice for the assessment of carotid artery lesions, but all methods are compared with its specificity. The advantage of this method is that it is an indivisible part of the carotid stenting procedure, which can be applied in the same session. This method is also used when the diagnosis is uncertain. For the determination of the degree of stenosis (>70%), the most widely accepted and used method is the North American Symptomatic Carotid Endarterectomy Trial (NASCET) formula.[35] This method is based on the comparison of the residual lumen at the maximum stenotic segment with the normal distal diameter of the ICA.[36,37] Another frequently used criteria for the determination of ICA stenosis are the ones established by the European Carotid Surgery Trial (ECST), which in comparison to NASCET, use the estimated normal lumen size at the level of stenosis (Figure 1).[38]

The common carotid (CC) method is another method for the assessment of the degree of stenosis in the internal carotid artery system.[39] In the past decades, several researchers have studied the correlation between NASCET and ECST criteria. Literature data have underlined that the NASCET method underestimates the degree of stenosis compared to other available methods.[40,41]

LOCATION OF ATHEROSCLEROSIS

Several studies have assessed the association between calcification in the coronary arteries and other arteries. Literature data describe a clear and strong relationship between carotid and coronary artery disease.[42–44] Furthermore, the carotid arterial wall thickness is also correlated with the presence and severity of coronary artery disease and is capable to detect subclinical vascular disease in young and middle-aged patients.[45–47] Researchers found a positive correlation between the angiographic SYNTAX score, the coronary CALCIUM score, and the severity of carotid artery lesions.[48,49] The prevalence of limb artery atherosclerosis is also higher in this group of patients.[48]

CONCLUSIONS

Atherosclerosis is a systemic disease that frequently affects the carotid arteries, but the disease is frequently asymptomatic in its early phases, being diagnosed only in

advanced stages, when the treatment is difficult, and the prognosis is poor. Carotid grayscale US is a useful tool for the evaluation of arteries, being a reliable, accurate, and cost-efficient method, which is capable to directly assess the carotid arteries and indirectly give information about the stage of the systemic involvement of atherosclerosis. Carotid US should represent the first screening method of patients with high risk of atherosclerosis. This method will decide the need of other imaging methods such as CTA, MRA, or DSA, for a more accurate assessment when choosing the best treatment choice. Carotid US should also be performed in case of patients with ischemic heart disease or obstructive arterial disease, in order to assess the condition of the carotid arteries and the risk of stroke.

CONFLICT OF INTEREST

Nothing to declare.

REFERENCES

1. Steg PG, Bhatt DL, Wilson PW, et al. One-year cardiovascular event rates in outpatients with atherothrombosis. *JAMA*. 2007;291:1197-1206.
2. McGill Jr, Henry C. Risk factors for atherosclerosis. The Thrombotic Process in Atherogenesis. *Springer*. 1978;104:273-280.
3. Vrselja Z, Brkic H, Mrdenovic S, Radic R, Curic G. Function of circle of Willis. *J Cereb Blood Flow Metab*. 2014;34:578-584.
4. Willeit J, Stefan K. Prevalence and risk factors of asymptomatic extracranial carotid artery atherosclerosis. A population-based study. *Arterioscler Thromb*. 1993;13;661-668.
5. Piotr S, Joshua B. Carotid Artery Disease. Circulation. 2006;114:244-247.
6. Walker M, Marler R, Goldstein M, et al. Endarterectomy for asymptomatic carotid artery stenosis. *JAMA*. 1995;273:1421-1428.
7. Griggs R, Bluth E. Noninvasive risk assessment for stroke: special emphasis on carotid atherosclerosis, sex-related differences, and the development of an effective screening strategy. *AJR Am J Roentgenol*. 2011;196:259-264.
8. Kakisis, JD, Avgerinos ED, Antonopoulos CN, et al. The European society of vascular surgery guidelines for carotid intervention: an updated independent assessment and literature review. *Eur J Vasc Endovasc Surg*. 2012;44:238-243.
9. Moore WS, Barnett HJ, Beebe HG et al. Guidelines for carotid endarterectomy. A multidisciplinary consensus statement from the Ad Hoc Committee, American Heart Association. *Circulation*. 1995;91:566-579.
10. Adla T, Adlova R. Multimodality Imaging of Carotid Stenosis. *Int J Angiol*. 2015;24:179-184.
11. Loizou CP. A review of ultrasound common carotid artery image and video segmentation techniques. *Springer*. 2014;52:1073-1093.
12. Adla T, Adlova R. Multimodality Imaging of Carotid Stenosis. *Int J Angiol*. 2015;24:179-184.
13. Serena J, Irimia P, Calleja S, Blanco M, Vivancos J, Ayo-Martín Ó. Cuantificación ultrasonográfica de la estenosis carotídea: recomendaciones de la Sociedad Española de Neurosonología. *Neurología*. 2013;28:435-442.
14. AbuRahma AF, Wulu Jr JT, Crotty B. Carotid plaque ultrasonic heterogeneity and severity of stenosis. *Stroke*. 2002;33:1772-1775.
15. Polak JF, Shemanski L, O'Leary DH, et al. Hypoechoic plaque at US of the carotid artery: an independent risk factor for incident stroke in adults aged 65 years or older. Cardiovascular Health Study. *Radiology*. 1998;208:649-654.
16. Prabhakaran S, Rundek T, Ramas R, et al. Carotid Plaque Surface Irregularity Predicts Ischemic Stroke The Northern Manhattan Study. *Stroke*. 2006;37:2696-2701.
17. 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;31:615-621.
18. Brinjikji W, Huston III J, Rabinstein A, et al. Contemporary carotid imaging: from degree of stenosis to plaque vulnerability. *J Neurosurg*. 2016;124:27-42.
19. Lee W. General principles of carotid Doppler ultrasonography. *Ultrasonography*. 2014;33:11-17.
20. Sitzer M, Fürst G, Fischer H, et al. Between-method correlation in quantifying internal carotid stenosis. *Stroke*. 1993;24:1513-1518.
21. Alexandrov A, Brodie DS, McLean A, et al. Correlation of peak systolic velocity and angiographic measurement of carotid stenosis revisited. *Stroke*. 1997;28:339-342.
22. Grant EG, Benson CB, Moneta GL, et al. Carotid artery stenosis: grayscale and Doppler ultrasound diagnosis – Society of Radiologists in Ultrasound consensus conference. *Radiology*. 2003;229:340-346.
23. Oates CP, Naylor AR, Hartshorne T, et al. Joint recommendations for reporting carotid ultrasound investigations in the United Kingdom. *Eur J Vasc Endovasc Surg*. 2009;37:251-261.
24. Evans NS. Carotid Artery Stenosis. *Cleveland Clinic Journal of Medicine*. 2016;24:47-56.
25. Brott TG, Halperin JL, Abbara S, et al. 2011 ASA/ACCF/AHA/AANN/AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS guideline on the management of patients with extracranial carotid and vertebral artery disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines, and the American Stroke Association, American Association of Neuroscience Nurses, American Association of Neurological Surgeons, American College of Radiology, American Society of Neuroradiology, Congress of Neurological Surgeons, Society of Atherosclerosis Imaging and Prevention, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of NeuroInterventional Surgery, Society for Vascular Medicine, and Society for Vascular Surgery. *J Am Coll Cardiol*. 2011;57:16-94.
26. Tahmasebpour HR, Buckley AR, Cooperberg PL, Fix CH. Sonographic examination of the carotid arteries. *Radiographics*. 2005;25:1561-1575.
27. Boontje AH. External carotid artery revascularization: indications, operative techniques and results. *J Cardiovasc Surg*. 1992;33:315-318.
28. Päivänsalo MJ, Siniluoto TM, Tikkakoski TA, Myllylä V, Suramo IJ. Duplex US of the external carotid artery. *Acta Radiologica*. 1996;37:41-45.
29. Ricotta A, AbuRahma E, Ascher M, et al. Society for Vascular Surgery. Updated Society for Vascular Surgery guidelines for management of extracranial carotid disease. *J Vasc Surg*. 2011;54:1-3.
30. Cosottini M, Pingitore A, Puglioli M, et al. Contrast-enhanced three-dimensional magnetic resonance angiography of atherosclerotic internal carotid stenosis as the noninvasive imaging modality in revascularization decision making. *Stroke*. 2003;34:660-664.
31. Randoux B, Marro B, Koskas F, et al. Carotid artery stenosis: prospective comparison of CT, three-dimensional gadolinium-enhanced MR, and conventional angiography. *Radiology*. 2001;220:179-185.
32. Josephson SA, Bryant SO, Mak HK, et al. Evaluation of carotid stenosis using CT angiography in the initial evaluation of stroke and TIA. *Neurology*. 2004;63:457-460.
33. Cumming MJ, Morrow IM. Carotid artery stenosis: a prospective comparison of CT angiography and conventional angiography. *AJR Am J Roentgenol*. 1994;163:517-522.
34. Mester A, Oltean-Péter B, Rodean I, et al. Magnetic Resonance Imaging of Myocardial Function Following Intracoronary and Intramyocardial Stem Cell Injection. *Journal of Interdisciplinary Medicine*. 2017;2:112-116.
35. Inzitari D, Eliasziw M, Gates P, et al. The causes and risk of stroke in patients with asymptomatic internal-carotid-artery stenosis. North American Symptomatic Carotid Endarterectomy Trial Collaborators. *N Engl J Med*. 2000;342:1693-1700.
36. Fox Allan J. How to measure carotid stenosis. *Radiology*. 1993;186:316-318.
37. North American Symptomatic Carotid Endarterectomy Trial Collaborators. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. *N Engl J Med*. 1991;325:445-453.
38. European Carotid Surgery Trialists Collaborative Group. MRC European Carotid Surgery Trial: interim results for symptomatic patients with severe (70–99%) or with mild (0–29%) carotid stenosis. *Lancet*. 1991;337:1235-1243.
39. Rothwell PM, Gibson RJ, Slattery J, et al. Prognostic value and reproducibility of measurements of carotid stenosis. A comparison of three methods on 1001 angiograms. European Carotid Surgery Trialists' Collaborative Group. *Stroke*. 1994;25:2440-2444.

40. Saba L, Giorgio M. A comparison between NASCET and ECST methods in the study of carotids: evaluation using Multi-Detector-Row CT angiography. *Eur J Radiol*. 2010;76:42-47.
41. Staikov IN, Arnold M, Mattle H, et al. Comparison of the ECST, CC, and NASCET grading methods and ultrasound for assessing carotid stenosis. *J Neurol*. 2000;247:681-686.
42. Craven TE, Ryu JE, Espeland MA, et al. Evaluation of the associations between carotid artery atherosclerosis and coronary artery stenosis. A case-control study. *Circulation*. 1990;82:1230-1242.
43. Salonen JT, Riitta S. Ultrasonographically assessed carotid morphology and the risk of coronary heart disease. *Arterioscler Thromb*. 1991;11:1245-1249.
44. Jashari F, Ibrahimi P, Nicoll R. Coronary and carotid atherosclerosis: similarities and differences. *Atherosclerosis*. 2013;227:193-200.
45. Hodis HN, Mack WJ, LaBree L, et al. The role of carotid arterial intima-media thickness in predicting clinical coronary events. *Ann Intern Med*. 1998;128:262-269.
46. Kablak-Ziembicka A, Tracz W, Przewlocki T, et al. Association of increased carotid intima-media thickness with the extent of coronary artery disease. *Heart*. 2004;90:1286-1290.
47. Lester SJ, Eleid MF, Khandheria BK, Hurst RT. Carotid Intima-Media Thickness and Coronary Artery Calcium Score as Indications of Subclinical Atherosclerosis. *Mayo Clin Proc*. 2009;84:229-233.
48. Ikeda N, Kogame N, Iijima R, Nakamura M, Sugi K. Impact of carotid artery ultrasound and ankle-brachial index on prediction of severity of SYNTAX score. *Circ J*. 2013;77:712-716.
49. Oei HH, Vliegenthart R, Hak AE, et al. The association between coronary calcification assessed by electron beam computed tomography and measures of extracoronary atherosclerosis: the Rotterdam Coronary Calcification Study. *J Am Coll Cardiol*. 2002;39:1745-1751.