The role of extracranial ultrasound in the prevention of stroke based on the new guidelines

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KEYWORDS
Ultrasound; Carotid stenosis; Stroke; Prevention; Guideline

Abstract
Extracranial ultrasonography is recommended to use as a baseline non-invasive method in the initial evaluation of either asymptomatic or symptomatic patients to define the possible stenosis on carotid artery.

The latest 2011 guidelines specify the sequence of examinations with certain classification of recommendations and level of evidence.

Carotid duplex ultrasonography plays an important role both in primary and secondary prevention of stroke and the results found determine the use of further investigations and management of patients with extracranial carotid and vertebral artery disease. In case of diagnostic uncertainty other brain imaging methods, like computed tomography angiography, magnetic resonance angiography and catheter-based angiography can be chosen to assess vascular lesions.

Carotid duplex ultrasound serves not only diagnostic purposes but can also be useful in the follow up processes. It is widely used for control examinations after revascularization procedures of the carotid or vertebrobasilar arteries.

By the establishment of indications of revascularization procedures degree of carotid stenosis is a major factor which therefore requires accuracy of the assessment. Carotid duplex ultrasound has some difficulties in this question. This diagnostic uncertainty is tried to be solved by improving the criteria system of stenosis grading in internal carotid artery.

The aim of this article is to give an overview about the importance and role of extracranial duplex ultrasonography in stroke prevention based on the latest guidelines.

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1. Introduction

Stroke is currently the third leading cause of death and the biggest single cause of major disability worldwide. Each year more than 700,000 people experience a new or recurrent stroke and on average someone dies every 4 min of a stroke [1]. Despite the diagnostic and treatment development in medicine the recovery rate from stroke is poor.

The well-documented and modifiable risk factors including e.g. hypertension, smoking, diabetes, obesity or dyslipidemia lead to both structural and hemodynamic...
The role of extracranial ultrasound in the prevention of stroke based on the new guidelines

The role of extracranial ultrasound in the prevention of stroke based on the new guidelines 95

Carotid and Vertebral Artery Disease [4].

line on the Management of Patients With Extracranial
AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS Guide-
of examinations both in primary and secondary stroke
cations and conditions.

The routine screening of asymptomatic patients with
carotid duplex US is not recommended if no clinical signs or risk factors for atherosclerosis can be detected (Class III, Level of Evidence: C).

The examination is also not beneficial in case of patients with neurological and psychiatric conditions which are unrelated to focal ischemic lesions, such as brain tumours, motor neuron diseases, infection and inflammation of the brain, epilepsy (Class III, Level of Evidence: C).

Standard physical examination contains auscultation of the cervical arteries. If during the examination of an asymptomatic patient presence of carotid bruit is revealed, it is reasonable to perform the measurement to detect the

hemodynamically significant carotid stenosis (Class IIa, Level of Evidence: C).

In asymptomatic patients with 2 or more risk factors including hypertension (HT), smoking, hyperlipidemia, family history of manifested atherosclerosis before the age of 60 years and ischemic stroke in a first-degree relative, duplex US may be considered (Class IIb, Level of Evidence: C).

The same recommendation can be applied in case of asymptomatic patients with symptomatic peripheral artery disease (PAD), coronary artery disease or atherosclerotic aortic aneurysm (Class IIb, Level of Evidence: C).

Fig. 1 summarizes the diagnostic approach of asymptomatic patients.

Beside the diagnostic aim of carotid duplex US, this
method is proven to be useful in the follow up as well. In case of a stenosis greater than 50% it is reasonable to repeat the examination annually to assess the progression or regression of the vascular alteration and the effect of therapeutic interventions. Less frequent control measurements are acceptable after stability establishment or in case of a change of patient’s candidacy for further intervention (Class IIa, Level of Evidence: C).

The establishment of the degree of carotid stenosis by
duplex US and angiography (magnetic resonance angiography — MRA, computed tomography angiography — CTA, digital subtraction angiography — DSA) is an important part of the indication of carotid reconstruction surgery in asymptomatic patients. Prophylactic carotid revascularization may be considered in highly selected asymptomatic patients if the degree of stenosis reaches at least 60% by angiography and 70% by duplex US (Class IIb, Level of Evidence: B) [5,6].

Elective coronary artery bypass graft (CABG) surgery makes previous carotid duplex US reasonable in patients with the following conditions: older than 65 years, history of cigarette smoking, PAD, left main coronary stenosis, history of stroke, TIA or carotid bruit (Class IIa, Level of Evidence: C).

3. Secondary vascular prevention

3.1. Carotid duplex US in secondary stroke prevention

Among survivors of ischemic stroke or TIA after the immediate management further investigations should be performed to assess the cause and pathophysiology of the event. The possible origin of ischemic stroke includes intra- or extracranial-artery atherosclerotic infarction, cardiac embolism, small-vessel disease, hypercoagulable state, dissection, sickle cell disease or it can be an infarct of undetermined cause.

As initial evaluation all patients with the symptoms of TIA or ischemic stroke should have non-invasive brain imaging (Class I, Level of Evidence: C).

As a first step duplex US is recommended to detect carotid stenosis for patients with acute, focal neurological symptoms, which reflect the insufficient supply of certain brain territories from the left or right ICA (Class I, Level of Evidence: C).
### Table 1  Classification of recommendations and level of evidence.

<table>
<thead>
<tr>
<th>May be considered</th>
<th>Class I</th>
<th>Class IIa</th>
<th>Class IIb</th>
<th>Class III no benefit or Class III harm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit → risk</td>
<td>Benefit → risk Additional studies with focused objectives needed; additional registry data would be helpful Procedure/treatment may be considered</td>
<td>Benefit → risk Additional studies with broad objectives needed Procedure/treatment should be performed/administered</td>
<td>Benefit ≥ risk Additional studies with broad objectives needed Procedure/treatment may be considered</td>
<td>COR III: No benefit</td>
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<tr>
<td></td>
<td>It is reasonable to perform procedure/administer treatment</td>
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<td>Procedure/test Not helpful</td>
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<tr>
<td></td>
<td>Procedure/test Treatment should be performed/administered</td>
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<td></td>
<td>Treatment No proven benefit</td>
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<td>Procedure/test Treatment should be performed/administered</td>
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<td>Procedure/test Treatment should be performed/administered</td>
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<td>Excess cost w/o benefit or harmful</td>
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#### Level A
- Multiple populations evaluated
- Data derived from multiple randomized clinical trials or meta-analyses

#### Level B
- Limited populations evaluated
- Data derived from a single randomized trial or nonrandomized studies

#### Level C
- Very limited populations evaluated
- Only consensus opinion of experts, case studies, or standard of care
The role of extracranial ultrasound in the prevention of stroke based on the new guidelines

If duplex US cannot be obtained or does not result in clear and diagnostic results, MRA or CTA is indicated as further imaging tools in the detection of carotid stenosis (Class I, Level of Evidence: C).

Correlation of findings detected by different non-invasive methods is very important in the aspect of quality assurance in every laboratory.

When extracranial vascular alterations are found with such severity which cannot explain the neurological symptoms, further investigation should be performed to reveal the possible cardiac origin by means of echocardiography (Class I, Level of Evidence: C). Echocardiography serves as the gold standard in the examination of these patients. Detection of the source of cardiac embolism is of great importance regarding that this mechanism accounts for 15—30% of ischemic stroke or TIA [7,8].

Fig. 2 shows the diagnostic steps recommended in patients with symptoms of ischemic stroke or TIA.

3.2. Investigations if carotid reconstruction is planned

When the result of carotid duplex US raises the need for carotid reconstruction, further angiographic examinations (MRA, CTA, catheter-based contrast angiography) can be beneficial to assess the severity of the stenosis and to detect additional intrathoracic and intracranial vascular lesions not seen by duplex US (Class IIa, Level of Evidence: C).

The angiographic method chosen is influenced by other conditions of the patient (Fig. 3).

In patients with extensive arteriosclerosis and renal insufficiency MRA without contrast material is reasonable to be performed (Class IIa, Level of Evidence: C).

DSA may also be considered in case of renal dysfunction because of the advantage of limiting the amount of potentially nephrotoxic contrast material (Class IIb, Level of Evidence: C).

When MRA is contraindicated, e.g. in patients with claustrophobia or implanted pacemaker, CTA can be effective for patient’s evaluation (Class IIa, Level of Evidence: C).

When duplex US, CTA, or MRA suggests complete carotid occlusion, catheter-based contrast angiography might be reasonable to decide whether carotid lumen is suitable for revascularization procedure (Class IIb, Level of Evidence: C).

3.3. Non-invasive control after CEA/CAS

Carotid endarterectomy (CEA) is the gold standard for the treatment of carotid atherosclerosis. It is recommended if the degree of stenosis is more than 70% measured by non-invasive methods (Class I, Level of Evidence A) [9], or more than 50% with catheter angiography (Class I, Level of Evidence: B) [10] in symptomatic patients (TIA or ischemic stroke within the past 6 months) at average or low surgical risk with an anticipated perioperative stroke or mortality rate less than 6%.

Carotid artery stenting (CAS) is an alternative method of CEA, which might be considered for patients with severe (>70%) stenosis, especially if the stenosis is difficult to access surgically (Class IIb, Level of Evidence: B) [11].

Non-invasive control of the extracranial arteries can be useful 1 month, 6 months and annually after revascularization (CEA/CAS) to ascertain the patency and to exclude the development of ipsi- or contralateral lesions (Class IIa, Level of Evidence: C).

3.4. Non-invasive imaging in vertebrobasilar insufficiency

Vertebral artery atherosclerosis is responsible for approximately 20% of posterior circulation stroke, which can be an underestimation because of the difficult visualization of vertebral arteries by ultrasonography [12].

The symptoms of vertebral artery disease include dizziness, vertigo, diplopia, tinnitus, blurred vision, perioral numbness, ataxia, bilateral sensory deficits and syncope.

After clinical history and examination of the patient non-invasive imaging is needed in the initial evaluation process.

In patients with symptoms suggesting posterior circulation deficits MRA or CTA should be preferred over ultrasonography to detect vertebral artery disease (Class I, Level of Evidence: C).

If the location and degree of stenosis cannot be defined with certainty by these non-invasive methods and the
patient with vertebrobasilar insufficiency symptoms may be a candidate to undergo revascularization procedure, catheter-based contrast angiography is reasonable to assess the pathoanatomy of the artery (Class IIa, Level of Evidence: C).

After vertebral artery revascularization non-invasive control of extracranial vertebral arteries is probably indicated 1 month, 6 months and then annually after the procedure (Class IIa, Level of Evidence: C).

4. Difficulties in stenosis grading

The patients' selection for surgical or endovascular intervention is based on the degree of carotid stenosis, therefore an accurate assessment is required by means of non-invasive imaging and in some cases by catheter-based angiography.

Several methods can be used during catheter-based angiography for stenosis measurement, but the most frequently used one is the NASCET (North American Symptomatic Carotid Endarterectomy Trial) [13], which define the degree of stenosis by measuring the minimal residual lumen at the level of the stenosis, then comparing it with the diameter of the more distal ICA, where the arterial walls become parallel.

The diameter of the artery cannot be assessed directly by carotid duplex ultrasound. This method uses blood flow velocity to indicate the severity of stenosis. Duplex ultrasound may be insensitive to distinguish high-grade stenosis from complete occlusion [14].

The severity of stenosis measured by ultrasound can be categorized into 2 groups: 50–69% stenosis when flow velocity exceeds the normal value due to plaque formation, and 70–99% stenosis in case of more severe atherosclerotic alterations. In case of 50–69% stenosis the peak systolic velocity is in range of 125–230 cm/s and a plaque can be seen in the ultrasound picture. The ratio of peak systolic velocities of internal to common carotid artery is between 2 and 4, while the end-diastolic velocity of ICA reaches 40–100 cm/s.

In case of >70% stenosis the peak systolic velocity exceeds 230 cm/s in ICA, the ratio of this value of internal to common carotid artery is above 4 and end-diastolic velocity accelerates above 100 cm/s in ICA [15].

The velocities of 70% and less severe stenosis overlap, which results in difficulties in the degree grading and which therefore indicates the use of other vascular imaging methods as well.

Several factors can reduce the accuracy of ultrasound measurements, like obesity, vascular tortuosity, high carotid bifurcation or in situ carotid stents and it is also influenced by operator expertise.

Because of the some diagnostic uncertainty new efforts tend to be invested to improve the accuracy of these measurements. The multi-parametric German “DEGUM ultrasound criteria”, which contained Doppler and imaging criteria combination, have been revised and transferred to NASCET measurement. The criteria are categorized into main and additional groups, in combination if which the accuracy of carotid stenosis grading by ultrasonography can be improved [16].

5. Discussion

In 2011 a new guideline was published by ASA/ACCF/AHA/AANN/AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS [4] which specifies the principles of the management of patients with symptomatic or asymptomatic carotid and vertebral artery disease.

The importance of non-invasive imaging methods in the diagnostic routine is evident. Extracranial duplex ultrasound combining 2-dimensional real-time imaging with Doppler measurements is widely used as one of the initial diagnostic tools in patients’ evaluation regarding its cost-effectiveness, repeatability and safety.

The 2011 guideline defines the place of carotid duplex US in the sequence of initial examinations both in asymptomatic patients and in patients with symptoms of stroke, TIA or vertebrobasilar insufficiency.
The role of extracranial ultrasound in the prevention of stroke based on the new guidelines

With different classification of recommendations and level of evidence extracranial duplex US is still present and play an important role both in diagnosis and thus in primary and secondary prevention of cerebrovascular events and in the follow up of patients. The results gained from duplex US determine the use of other imaging methods (MRA, CTA, catheter-based angiography) which ensure a more accurate mapping of patients’ vascular lesions and are an important part of patients’ selection for revascularization.

The diagnostic uncertainty in case of carotid duplex US caused by difficulties in stenosis grading can be improved by using main and additional criteria system proposed by the Revision of DEGUM ultrasound criteria [16].

References


