Doppler ultrasound of the carotid arteries: what a radiology resident should know

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Learning objectives

- To know the indications of carotid Doppler ultrasonography.
- To review the technical parameters to have into account to perform a correct sonographic examination.
- To recognize and illustrate the echographic findings in normal conditions and in most frequent carotid pathology.
Background

The carotid stenotic pathology is the cause of between 20-30% of stroke and transient ischemic attacks (TIA).

Most ischemic stroke episodes are due to embolisms as a result of thrombus formation due to hemodynamic alterations in carotid artery stenosis or migration of plaque fragments.

The major risk factors for carotid artery stenosis include older age, male sex, hypertension, smoking, hypercholesterolemia, diabetes mellitus, and heart disease.

Carotid Doppler ultrasonography is the preferred imaging modality for screening, diagnosis and monitoring of arteriosclerosis of extracranial arteries.

Among all the factors studied, the degree of carotid artery stenosis and plaque morphology and composition are the most directly related to the increased risk of stroke.

Carotid Doppler ultrasound indications are:

1. Patients with history of transient ischemic attack, stroke, or other neurologic signs or symptoms.
2. Asymptomatic patients with multiple cardiovascular risk factors or with coronary or peripheral atherosclerotic vascular disease.

Routine screening to detect clinically asymptomatic carotid artery stenosis in the general population is not recommended.
Findings and procedure details

ULTRASOUND MODALITIES (Fig. 1 on page 7)

- **Gray scale or B-mode**: it is used to evaluate the arteries anatomy and non-vascular abnormalities (plaques morphology, intima-media thickness...).
- **Color Doppler**: assessment of vascular flow and direction. It enables rapid identification of abnormal blood flow, but has low sensitivity.
- **Spectral Doppler**: graphic representation of the flow. It allows to evaluate the speed and direction of the flow.

MAIN TECHNICAL PARAMETERS

- **Doppler angle**: ideally it should be a 45°-60° angle, in which range a linear relation exists between velocity and the Doppler shifts.
- **Sample volume box**: it is the region of the US beam sensitive to the presence of echoes in the change of Doppler frequencies. The optimal box size is 2-3 mm and it should be placed in the center of the vessel and parallel to the direction of flow.
- **Color box**: its size must be adjusted and its orientation angled so that the angle of incidence on the blood flow is less than 60°.
- **Color velocity scale control**: it is the range of detected speeds. In a normal carotid US study it should be adjusted by 30-40 cm/sec and if subocclusions exist, the color velocity scale should be shifted down (<15 cm/sec).
- **Color gain**: increasing the gain amplifies acquired Doppler signal, but also increases the noise. Color gain should be set so that color reaches the intimal surface of the vessel.

HOW TO DO THE STUDY

The patient may lie down in the supine or semisupine position with the head hyperextended and tilted about 45° away from the artery being examined.

The study should be performed with a high-frequency linear array (7.5-10 MHz), assessing the common carotid artery (CCA), the bulb, the carotid bifurcation and the internal carotid artery (ICA). In certain short or muscular necks and with deep or high bifurcations, the 5 MHz convex array may be useful.
A transverse and longitudinal planes basal B-mode study should be done to assess the presence and appearance of atheromatous plaques. Color Doppler and spectral Doppler are used to evaluate the areas of turbulent flow and detect any stenotic segment in the vessel.

**IMAGING FINDINGS**

Diagnostic ultrasound offers the possibility of using both morphological and hemodynamic criteria. It is recommended to measure, in addition to the hemodynamic parameters, the thickness and length of the plaque as well as the residual lumen.

- **INTIMA-MEDIA THICKNESS**

  The intima-media thickness is considered an early sign of atherosclerosis and a risk factor to stroke and ischemic cardiopathy. It should be measured on gray-scale image and an intima-media thickness >1 cm is considered pathologic. It should be taken into account that a normal intimal thickening is related to aging. (Fig. 2 on page 7)

- **PLAQUE MORPHOLOGY**

  The plaque location, morphology, echogenicity, and texture have to be described to predict possible future complications.

  1. Homogeneous plaque: uniform echogenicity and texture. This pattern is seen in a fibrous lesion, often in the CCA. (Fig. 3 on page 8)
  2. Heterogeneous plaque: it has mixed areas of different echogenicity and it may present ulcerated surface (depression >2 mm). They are also called unstable or friable plaques. (Fig. 4 on page 8 Fig. 5 on page 9)

  The most brightly echogenic areas are usually associated with calcium, and hypoechoic content may represent lipid or intraplaque hemorrhage.

- **INTERNAL CAROTID ARTERY (ICA) AND COMMON CAROTID ARTERY (CCA) STENOSIS** (Fig. 6 on page 9)

  The typical ICA flow pattern is of low resistance, with end-diastolic flow velocity well above the zero baseline.

  To evaluate a ICA/CCA stenosis, we have to determine the pico-systolic velocity (PSV) in the area of greater stenosis and the morphological appearance of the atherosclerotic plaque in the B-mode image and with color Doppler. The use of accessory criteria such as the PSV ICA/CCA ratio or end-diastolic velocity should only be reserved for isolated...
cases in which the main parameters were inconclusive (borderline values of PSV), or in special clinical conditions that may condition the appearance of pitfalls (contralateral stenosis and tandem stenosis).

Severe ICA/CCA stenoses (> 70%) are hemodynamically significant, so surgical treatment will be indicated (endartectomy or angioplasty). The sonographic findings are: PSV >230cm/sec, reduction of vessel lumen >50%, spectral broadening, postestenosis turbulence at color/power Doppler imaging, color aliasing despite high color velocity scale setting (>100 cm/sec), end diastolic velocity >100 cm/sec and PSV ICA/CCA ratio >0.4.

The differentiation between a near occlusion and a total ICA occlusion is often a difficult task. In this clinical situation, velocity parameters may not apply and the color or power Doppler technique should be used in order to demonstrate a markedly narrowed lumen. (Fig. 7 on page 10 Fig. 8 on page 10 Fig. 9 on page 11 Fig. 10 on page 11)

• **EXTERNAL CAROTID ARTERY (ECA) STENOSIS**

ECA supplies the face and the scalp and, in general, it is not a source of emboli to the brain.

The ECA Doppler spectrum has a high resistance waveform, the PSV is normally higher than the ICA because it is a smaller peripheral vessel.

Disease in the ECA is often seen, but is usually not of clinical import, unless the ECA is serving as a collateral source of and occluded ICA. (Fig. 11 on page 12)

• **VERTEBRAL ARTERY AND SUBCLAVIAN STEAL**

The normal vertebral artery Doppler spectrum has a low resistance waveform, similar to the ICA, and antegrade flow direction. (Fig. 12 on page 12)

Carotid US is not accurate for identification of a focal stenosis in the vertebral artery, because it usually appear at the origin.

In case of subclavian steal syndrome, the flow direction may be reversed. There are three types of subclavian steals: occult steal (minimal hemodynamic changes), partial subclavian steal (partially reversed flow) and complete subclavian steal (flow completely reversed). (Fig. 13 on page 13)
Fig. 1: Ultrasound modes.

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Fig. 2: Intima-media complex
Fig. 3: Hypoechogetic plaques.

Fig. 4: Hyperechogetic plaques.
**Fig. 5:** Ulcerated plaques.

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**DOPPLER CRITERIA ICA STENOSIS**

<table>
<thead>
<tr>
<th>Degree of stenosis (%)</th>
<th>PSV (cm/sec)</th>
<th>EDV (cm/sec)</th>
<th>PSV/ICA/CCA ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;125</td>
<td>&lt;40</td>
<td>&lt;2</td>
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<td>&lt;125</td>
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<td>&lt;2</td>
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<td>50-69</td>
<td>125-230</td>
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<tr>
<td>&gt;70</td>
<td>&gt;230</td>
<td>&gt;100</td>
<td>&gt;4</td>
</tr>
</tbody>
</table>

**Fig. 6:** Doppler criteria ICA stenosis.
Fig. 7: ICA stenosis <50%.

Fig. 8: ICA stenosis 50-69%
**Fig. 9:** ICA stenosis >70%.

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**Fig. 10:** CCA stenosis >70%
**Fig. 11:** ECA stenosis.

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**Fig. 12:** Normal vertebral artery.

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Fig. 13: Subclavian steal syndrome.

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Conclusion

Carotid Doppler ultrasound allows to assess carotid pathology with great reliability, but requires a systematic and careful study.

It is important to know and optimize the technical parameters that can affect the accuracy of the sonographic examination.

The sonographic features about the stenosis percentage and plaque morphology guide surgical decision.
References