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Carotid ultrasound

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Abstract

Carotid duplex ultrasonography is a noninvasive technique for hemodynamically significant stenosis detection and cardiovascular risk estimation. Anatomic information of carotid arteries is provided by B-mode scanning. Hemodynamic features are displayed color-flow and pulsed Doppler imaging. Examination technique, normal carotid anatomy and flow pattern, and potential limitations are presented.

Keywords: duplex ultrasonography, common carotid artery, internal carotid artery, external carotid artery

Duplex ultrasonography is the initial diagnostic test used to detect atherosclerotic disease of the extracranial carotid arteries allowing the detection of stenosis (symptomatic and hemodynamically significant or asymptomatic), or for follow–up after carotid endarterectomy and stenting [1-3].

Examination technique

In the absence of dyspnea or back pain, carotid arteries are examined with the patient in the supine position. Hyperextension is ensured by placing a small foam pillow or a rolled-up towel under the neck. For enhancing neck exposure, the head is turned away from the examined side at about a 45-degree angle from the midline or slightly less. The patient can also be examined in a reclining chair with easily adjustable backrest and headrest [2,4,5].

Multi frequency linear transducers are preferable: high frequencies (7.5 to 12 MHz) for the distal two-thirds of the common carotid artery (CCA) and for the bifurcation region and lower frequency (5 MHz) for the origin of the CCA and the distal portion of the internal carotid artery (ICA) [3].

The most appropriate examination sequence is the two-step method. The first step is represented by a complete survey of the carotid arteries with B-mode and color flow imaging in two planes- transverse (anterior, lateral, or posterolateral approach) and longitudinal (anterolateral, posterolateral, and far-posterolateral approach) [2,4-6]. The second step of the e*xamination protocol is represented by the* in-depth investigation of the areas of interest using pulsed Doppler in longitudinal plane [3].

Normal carotid anatomy

The three carotid arteries – CCA, ICA, and the external carotid artery (ECA) – should be analyzed bilaterally by various parameters – origin, location and course, caliber, wall structure and motion, branches, and blood flow pattern [2,4-6].

The CCA usually originates from the innominate artery on the right side, and the aortic arch on the left side. For this reason, only the right CCA origin can be displayed (fig 1-3)

The CCA course is represented by an oblique line oriented upward from behind the sternoclavicular joint to the level of the upper border of the thyroid cartilage [6]. The proximal portion of the CCA is more profound. It may move up to 2-3 mm during systole, especially in pa-

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Fig 1. Short-axis view of the right common carotid artery. a. in the middle third of the neck. b. in the distal third of the neck. scm: sternocleidomastoid muscle. jv: internal jugular vein. tir: thyroid right lobe. cca: common carotid artery. sc. subclavian artery. ia: innominate artery.

Fig 3. The right common carotid artery. a. longitudinal view. b. transverse view. tabc: brachiocephalic trunk (innominate artery). vji: internal jugular vein. acc: common carotid artery.

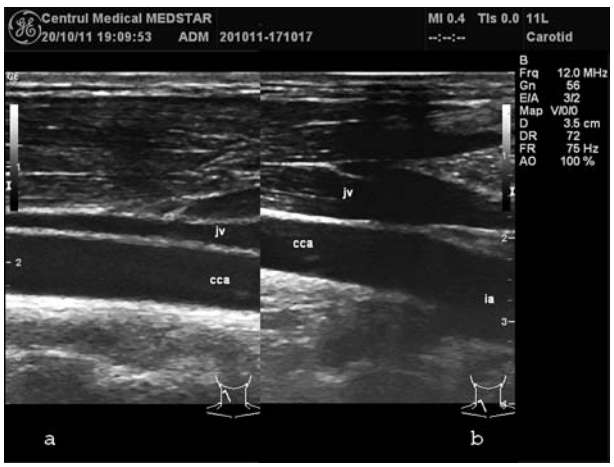

Fig 2. Longitudinal section of the right common carotid artery. a. in the middle third of the neck. b. in the distal third of the neck. Artifacts seen on the top are due to the neck contour. jv: internal jugular vein. cca: common carotid artery. sc. subclavian artery.

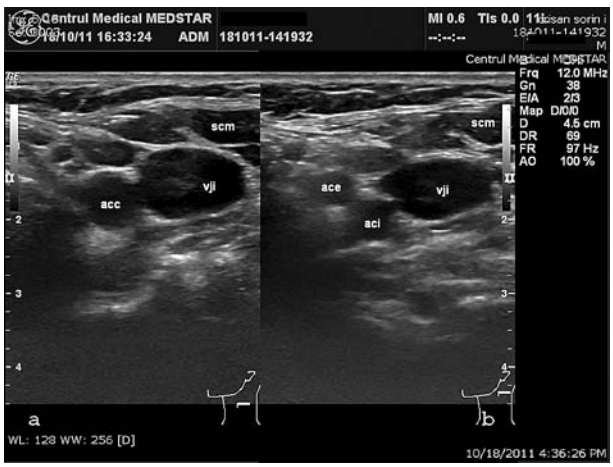

Fig 4. Transverse view of the left carotid arteries. a. in the middle third of the neck. b. in the cranial third of the neck. scm: sternocleidomastoid muscle. vji: internal jugular vein. acc: common carotid artery. ace: external carotid artery. aci: internal carotid artery.

tients with hypertension and anxiety disorders. The distal two-thirds of the artery are parallel to the skin surface. The principal CCA relations are anterolaterally with the sternocleidomastoid muscle and the internal jugular vein (IJV), and medially with the thyroid (fig 4). The IJV wall is thin and it is usually oval in cross section. Vein movements are modulated mainly by the respiratory cycle.

Ultrasound texture of the wall consists in three parallel zones. Internal and external layers are hyperechoic and the middle is hypoechoic. The inner layer is represented by the interface between circulating blood and tunica intima. The middle layer includes the intima and the media and the outer reflection is due to the adventitia. These three layers form the intima-media complex. The intima-media thickness (IMT) is represented by the distance between the two hyperechoic layers. It is displayed in long-axis view at the far wall in the last one centimeter of the CCA (fig 5). The normal IMT values are influenced by age and gender. A value less than 0.9 mm is considered to be normal. Higher values are a marker of subclinical atherosclerosis so that the IMT is one of the factors influencing prognosis in patients with hypertension [1,3,4].

Fig 5. Longitudinal view of the right common and internal carotid arteries. Normal intima-mediathickness. jv: internal jugular vein. bif: carotid bifurcation. cca: common carotid artery. ica: internal carotid artery.

Fig 6. Carotid bifurcation. a. cross-sectional view. b. long-axis view. Only the internal carotid artery is displayed in long-axis section due to the coronal plane of the bifurcation. vji: internal jugular vein. aci: internal carotid artery. ace: external carotid artery. acc: common carotid artery.

The CCA lumen has an average diameter of 6-7 mm. There are no collateral branches of the CCA. Usually, the CCA divides into the ICA and the ECA at the level of the superior border of the thyroid cartilage. The point of division is slightly dilated and it is known as the carotid bulb or the carotid sinus [2,4,5]. There are many variations in the location of the ICA relative to the ECA so that the display of the two arteries in a single longitudinal plane is possible in only 40-60% of cases. The ICA is located most frequently (49%) posterolateral to the ECA [5]. Due to the coronal plane of bifurcation, the ICA is located lateral to the ECA therefore longitudinal section can highlight only one artery (fig 6).

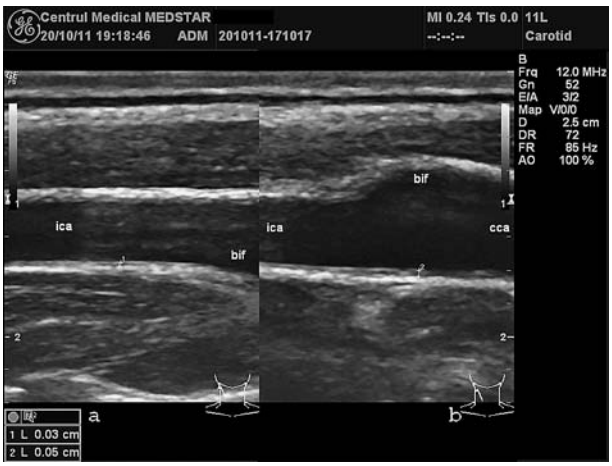

Fig 7. Long-axis view of the right internal carotid artery. Normal intima-media thickness. a. the mid internal carotid artery. b. the proximal segment of the internal carotid artery. ica: internal carotid artery. bif: carotid bifurcation. cca: common carotid artery.

The ICA has 6.5-7.5 mm diameter at the carotid sinus, and 4.3-5.3 mm, beyond the bulb [5]. There are three portions of the ICA: proximal part represented by the carotid sinus; mid ICA where the diameter becomes smaller; and distal ICA located at more than 3 cm above the bifurcation usually with curved course [3]. There are no collateral branches of the ICA in its extracranial course. The IMT can be measured in the proximal ICA and in the mid ICA (fig 7).

The ECA has a lower lumen than proximal ICA, equal to the mid and distal ICA. The artery can be easily recognized because it has a branch, the superior thyroid artery, which gets off at the level of hyoid bone [2,4-6].

Normal carotid flow pattern

Hemodynamic assessment is the next step of the examination by using color flow mapping and pulsed Doppler technique. ICA and ECA have different pulsatility patterns: low peripheral resistance in ICA with the presence of color throughout the cardiac cycle, increasing during the systole and decreasing during the diastole, and high peripheral resistance in ECA with the color decreasing or disappearing at the end of diastole.

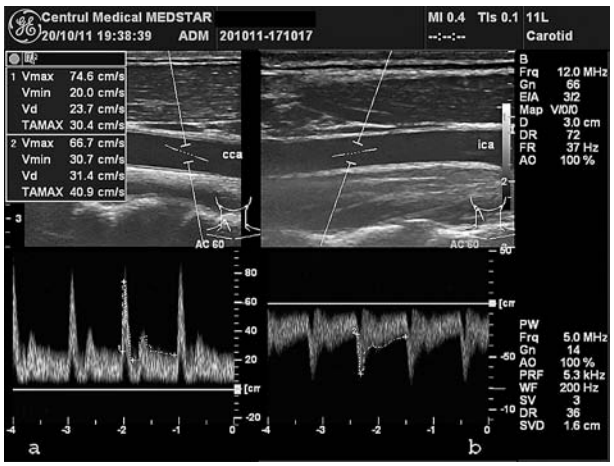

Fig 8. Long-axis section of the right common and internal carotid arteries. Typical Doppler spectrum. a. flow towards the probe in the common carotid artery. b. flow away from the probe in the internal carotid artery. cca: common carotid artery. ica: internal carotid artery.

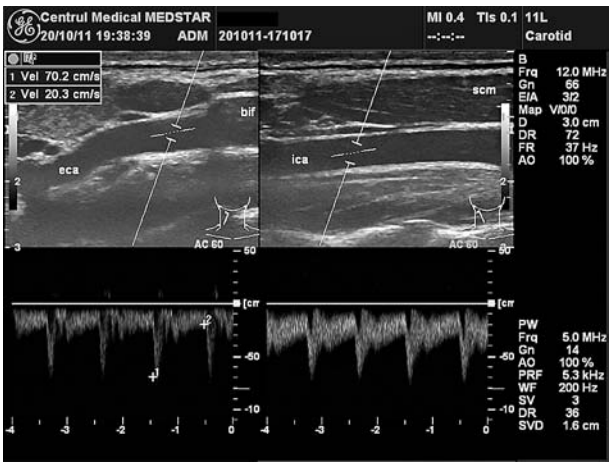

Fig 10. Longitudinal view of the right internal and external carotid arteries. Normal Doppler waveforms. a. external carotid artery. b. internal carotid artery. eca: external carotid artery. bif: carotid bifurcation. ica: internal carotid artery. scm: sternocleidomastoid muscle.

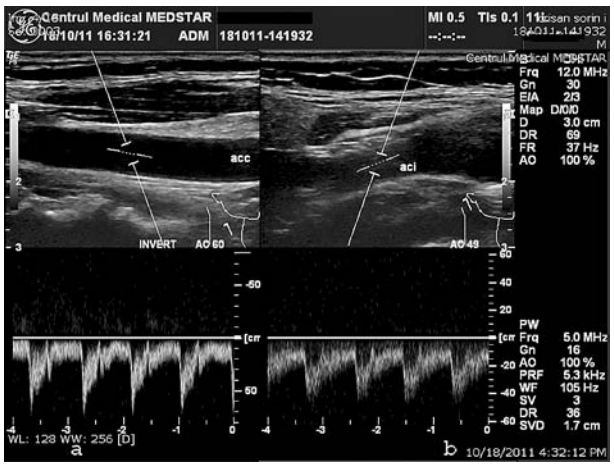

Fig 9. Longitudinal view of the right common and internal carotid arteries. Normal Doppler waveforms Direction of common carotid artery flow is inverted in order to compare wave features. a. common carotid artery Doppler waveforms. b. internal carotid artery waveforms. acc: common carotid artery. aci: internal carotid artery.

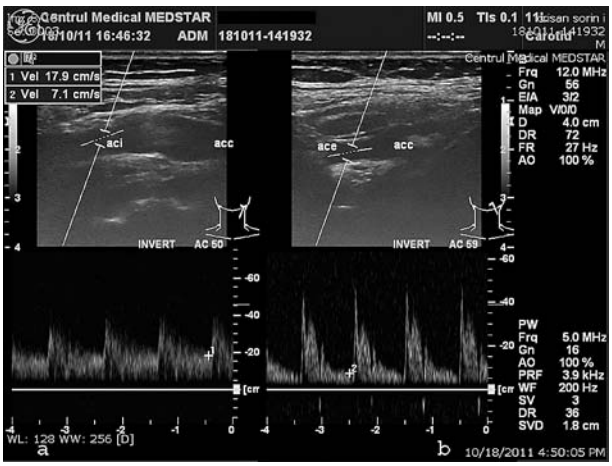

Fig 11. Longitudinal view of the left internal and external carotid arteries. Normal Doppler waveforms. Flow direction is inverted by the ultrasound machine. a. internal carotid artery. b. external carotid artery. aci: internal carotid artery. acc: common carotid artery. ace: external carotid artery.

Pulsed Doppler examination is performed in longitudinal view. The sample volume is placed within the lumen without touching the wall with ultrasound incident angle under 60°. The peak systolic velocity is usually less than 125 cm/s. Two pulsatility patterns of carotid arteries are usually seen: moderate pulsatility in the CCA, with tall and broad systolic peak and low end-diastolic velocity, and low pulsatility in ICA, with broad systolic peaks and significant end-diastolic flow velocity [2,4-6] (fig 8-11).

Limitations, sources of error and pitfalls

The most common limitations of the ultrasound examinations are the large size of the transducer, left CCA origin, deep location of the CCA, short neck, big beard, involuntary head movements, and important dyspnea. The two principal sources of error are represented by the low level of operator expertise and the lack of time for a complete examination. Ultrasound

artifacts, as hyperechoic lumen, marginal acoustic shadow, and aliasing, and hyperkinetic syndrome are other sources of error. Variants of origin, caliber, course (tortuosity, coiling or kinking), and bifurcation (spatial position, absence of carotid bulb) may be potential pitfalls.

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