Color Doppler Ultrasound of Carotid and Vertebral Vessels: Anatomy, Technique and Reporting

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Abstract

Color Doppler study of carotid and vertebral arteries is a non-invasive, reliable and also easily available, cost-effective method for screening and follows up of patients at risk of stroke to differentiate patients need surgery or intervention from whom could be followed by medical management. I reviewed anatomy of cervical arteries and different techniques such as B- mode or gray scale scanning, color flow mapping and spectral analysis for evaluation of both carotid and vertebral arteries. [GMJ.2016;5(Supp.1):24-35]

Keywords: Color Doppler Sonography; Carotid; Vertebral, Stroke; Stenosis; Duplex.

Introduction

Stroke is one of major diseases in different countries [1]. Despite of developed countries the age of incidence and mortality of stroke seems to be higher in Iran [2]. Color Doppler study of carotid and vertebral arteries is a non-invasive, reliable and also easily available, cost-effective method for screening and follow up of patients at risk of stroke to differentiate patients need surgery or intervention from whom could be followed by medical management [3-5]. It is a well-established and the most common imaging modality used for evaluation of carotid arteries diseases [6,7]. Today at many centers it is the only imaging modality before endarterectomy or stent insertion [8-10].

The anatomy of carotid and vertebral arteries; the technique of color Doppler study of these vessels including B- mode or gray scale scanning, Color flow mapping and Spectral analy-

sis; characterization of atheromatous plaques; grading of stenosis secondary to atherosclerotic plaques; predicting any cardiovascular or intracranial diseases – either vascular or extravascular- which influence on Doppler spectral waveform will be discussed Subsequently.

Anatomy

The brain supplies by four vessels – two carotid and two vertebral arteries- and receives 15% of cardiac output. The right common carotid artery (CCA) [11] originates from brachiocephalic artery but left CCA originates from aortic arch directly. Both sides CCA ascend at both sides of neck and divided to internal and external carotid arteries (ICA and ECA) [12].

The origin of right CCA can be seen behind right sternoclavicular joint, but origin of left CCA cannot be seen by ultrasound.

The level of bifurcation of CCAs are variable, but usually at about level of the upper border

of the laryngeal cartilage. In about 90% of cases ICA lies posterolateral or lateral to the ECA. The distal end of CCA at the level of bifurcation widened to form the carotid bulb. But in some cases bulb only involve proximal ICA [8-13].

The right and left vertebral arteries [2] originate from right and left subclavian arteries respectively. They ascend through the posterior aspect of each side of neck and traverse transverse foramina of sixth till second cervical vertebrae and then curve around the atlas and enter intracranial fossa to join together and forming the basilar artery [8, 14, 15].

Figure 1 shows the schematic anatomy of major of carotid and vertebral arteries.

There are few variation in carotid and vertebral arteries. Rare cases of common origin of left CCA and subclavian artery or left brachiocephalic artery and or direct origin of right and left VA from aortic arch can be seen[8,16,17]. It is common for one vertebral artery to be larger than the other; usually left VA is larger and right VA is hypoplastic[8,15].

Technique

As other parts of body the examination consist of three step:

Figure 1. Schematic Anatomy of Carotid and Vertebral Arteries

1. B- mode or gray scale scanning
2. Color flow mapping
3. Spectral analysis

And also to conclude the exam it will be followed by evaluation of cervical portion of vertebral arteries and finally record and then report the exam and any limitation related to exam[13].

B-Mode Scanning

During this step the exam will be started in axial plane for rapid evaluation of carotid vessels including common carotid artery [11], level of bifurcation and as possible as parts of internal carotid artery [2] and external carotid artery [2]. By attention on the existing branches from ECA and also relative position of mentioned artery and ICA at the level of bifurcation, it is possible to differentiate these vessels from each other in axial plane [8, 13]. Any atheromatous plaque can be detected at this step and then its cross-section will be evaluated regarding shape and maximum thickness and content.

After mentioned early evaluation, the exam will be continued in longitudinal plane through CCA and level of bifurcation and visualized parts of ICA and ECA. Figures 2 and 3 show the normal shape of carotid arteries in gray scale.

At first intima-media thickness (IMT) will be measured at the level of the posterior wall of carotid bulb and ICA origin, using magnified view to overcome error in measurement (Figure4). After that any atheromatous plaque which seen at axial plane will be evaluated longitudinally to see and measure the length, content (calcification, lipid component or hemorrhage) and careful evaluation of intimal surface of plaque (to excluding ulceration). these features help us to characterized the atheromatous plaque (Figure5). Plaque characterization is important for estimation of further risk of stroke. For example there is evidences that echolucent plaques with more than 50% diameter stenosis are associated with risk of future stroke in symptomatic patients [18].

Color flow mapping

Using color flow box the vessels evaluated rapidly in longitudinal plane to see the pattern

of flow and to detect any flow disturbance at the site of atheromatous plaques. Hemodynamically significant stenosis caused by atherosclerotic disease result in flow disturbance at the site and just above the level of stenosis which will be as a mixture of bright colors (color flow aliasing) [6, 8]. Figure 6 shows significant aliasing of flow at the site of severe atherosclerotic stenosis [6] (Figure6). Power color Doppler can provide additional data for evaluation of surface of plaque and measurement of related stenosis, especially in large complicated plaques[19,20] (Figure7) [21].

Spectral analysis

Spectral waveform should be first obtained at CCA, ICA and ECA to evaluate flow at the

mentioned vessels which can be influenced by local, far proximal or distal atherosclerotic disease and or by systemic, cardiac or intracranial diseases. Then the spectrum should be obtained at the site of any atheromatous plaque for further estimation of degree of stenosis [4, 22]. Figure8 shows spectral waveform which obtained from the CCA.

Vertebral arteries evaluation

Finally to conclude the exam in longitudinal plane , cervical portion of vertebral arteries between transverse processes of cervical spines should be evaluated by color flow mapping, for detection of any possible congenital hypoplasia , flow direction and possible any stenotic changes(Figures9 and 10).

Figure 2. Normal Gray Scale of CCA in Longitudinal Plane

Figure 3. Normal gray scale of right CCA, bulb and also origin of ICA and ECA.

Figure 4. Magnified longitudinal view through CCA and bulb for measurement of IMT.

Figure 5. A calcified plaque at posterior wall of carotid bulb.

Figure 6. Severe aliasing of color flow seen at the site of a large atheromatous plaque causing severe stenosis at carotid bulb.

Figure 7. The upper image shows color flow mapping of a heterogeneous, irregular plaque. At the lower image power Doppler study result in well delineation of plaque and residual of patent lumen.

Figure 8. The spectral waveform obtained from upper CCA.

Figure 9. The cervical portion of the vertebral artery seen between transverse processes of cervical spines.

Figure 10. The cervical portion of the vertebral artery and vein seen between transverse processes of cervical spines, using conventional color (left) and power Doppler (right) modes.

IMT Evaluation

IMT should be measured at posterior wall of carotid bulb and ICA origin and a cutoff of 0.8 mm should be kept in mind. The IMT 0.8-1 mm is considered indeterminate, while an IMT greater than 1.1 mm is more accepted abnormal value [6, 13].

Plaque Characterization

Any atheromatous plaque should be evaluated in B- mod using axial and longitudinal planes for measuring length and maximum thickness , shape (circumferential, curvilinear , irregular ...) , content (calcification , lipid or hemorrhage) , surface (echogenic cap, irregularity and ulceration)[6,8,13].The plaques could be classified by the degree of associated stenosis, ultrasound morphology and intimal surface (Table1)[23], (Figure11).

Estimation of Degree of Stenosis

Regarding aliasing of flow at color flow mapping the area of significant stenosis can be detected and then mentioned stenotic area will be evaluated by spectral waveform (Figure12, Figure13).

Parameters such as peak systolic velocity (PSV), end diastolic velocity (EDV) of C.C.A , I.C.A & E.C.A, Spectral broadening and intra stenotic PSV to C.C.A PSV calculated and using available data from previous studies , the degree of stenosis estimated [24,25]. The importance of estimation of degree of stenosis is based on two large trial studies, i.e. The North American Symptomatic Carotid Endarterectomy Trial (NASCET) and the European Carotid Surgery Trial (ECST) which used two different method-based on angiography- for calculating the percentage stenosis and both showed the benefit of performing carotid endarterectomy in patients with significant ICA disease (Figure14)[8,26]. NASCET showed maximum benefit in patients with 70-99% of diameter

stenosis and lesser but significant benefit in patients with 50-69% of diameter stenosis. ECST showed maximum benefit in patients with 80-99% of diameter stenosis and lesser but significant benefit in patients with 70-79% of diameter stenosis. Subsequent comparison of the two showed that a 50% NASCET stenosis was broadly equivalent to a 70% ECST, while a 70% NASCET stenosis broadly equated to an 85% ECST [12,27].

Table-2 shows the recommendation for grading of stenosis based on NASET method, derived from Society of Radiologists in Ultrasound Consensus Conference which took place met in San Francisco, Calif, October 22-23, 2002[28].

Changes of spectral wave form by extra carotid causes

By evaluation of spectral waveform of both sides C.C.A, I.C.A & E.C.A some cardiac and systemic abnormalities (such as heart failure, valvular heart disease, anemia) and also intracranial problems) such as increased ICP, distal ICA stenosis or occlusion) can be predicated and prompt for further evaluation [29, 30].

Vertebral Arteries Evaluation

Important features than can be evaluated during color Doppler study of vertebral arteries include diameter of vessels (to excluding congenital hypoplasia), direction of flow (to exclude subclavian steal syndrome) (Figure15), flow disturbance secondary to focal stenosis and finally changes of waveform secondary to stenosis at non visible proximal and intracranial distal portions of vertebral arteries.

Conclusion

Based on mentioned different steps, the procedure should be reported finally and any limitations should be emphasis.

Table 1. Classification of Plaque

Hemodynamic (% Stenosis Diameter)	Morphologic	By Surface
H1, mild (<50%) H2, moderate (50%–69%) H3, severe (70%–95%) H4, critical (95%–99%) H5, occluding (100%)	P1, homogeneous P2, heterogeneous	S1, smooth S2, irregular (defect <2 mm) S3, ulcerated (defect >2 mm)

Figure 11. There is a calcified plaque with smooth surface but a small hypoechoic area at its superior aspect causing about 50% diameter narrowing (H2, P2, S1).

Figure 12. Spectral waveform at the site of ICA origin plaque shows PSV = 88 cm/s and EDV of about 20 cm/s consistent with less than 50% of diameter narrowing.

Figure 13. Spectral waveform at the site of ICA origin plaque shows PSV = 284 cm/s and EDV = 114 cm/s consistent with greater than 70% of diameter narrowing.

Figure 14. Methods of calculating and reporting the degree of stenosis based on NASCET and ECST trials.

Table 2. Consensus Panel Gray-Scale and Doppler US Criteria for Diagnosis of ICA Stenosis [28]

Degree of Stenosis (%)	Primary Parameters		Additional Parameters	
	ICA PSV (cm/sec)	Plaque Estimate (%)*	ICA/CCA PSV Ratio	ICA EDV (cm/sec)
Normal	<125	None	<2.0	<40
<50	<125	<50	<2.0	<40
50–69	125–230	≥50	2.0–4.0	40–100
≥70 but less than near occlusion	>230	≥50	>4.0	>100
Near occlusion	High, low, or undetectable	Visible	Variable	Variable
Total occlusion	Undetectable	Visible, no detectable lumen	Not applicable	Not applicable

*Plaque estimate (diameter reduction) with gray-scale and color Doppler US.

Figure 15. Color flow map and spectral waveform show flow toward the transducer but not toward the cranial fossa at vertebral artery, suggestive of subclavian steal syndrome. Note the opposite color of vertebral artery to the carotid artery.

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