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# Bilateral Carotid Duplex Ultrasound Protocol

## Introduction

A **carotid duplex ultrasound** is a noninvasive imaging test that uses high-frequency sound waves to evaluate blood flow in the carotid arteries (the main arteries in the neck supplying the brain) and nearby vessels. This exam is primarily done to detect **narrowing or blockages** in the carotid arteries, which could increase the risk of ischemic stroke [1]. Plaque buildup (atherosclerosis) in the carotids can lead to reduced blood flow or clot formation, so early diagnosis and treatment of a significant narrowing can help prevent strokes [2] [3]. The procedure is safe and painless – it does **not** use radiation or contrast, and there are essentially no risks or side effects associated with carotid ultrasound [4].

## Exam Overview

In a standard **bilateral carotid duplex exam**, the sonographer will systematically examine the arterial supply to the head on both sides of the neck. This includes scanning the **common carotid arteries (CCA)**, the **carotid bifurcations**, the **external carotid arteries (ECA)**, and the **internal carotid arteries (ICA)** up to their most distal extracranial segments [5]. In addition, the **vertebral arteries** (which run through the neck vertebrae to supply the posterior brain) are identified and assessed to confirm their flow direction [6]. A normal vertebral artery should have blood flow *toward* the brain (antegrade); if the flow is reversed or partially reversed, it may indicate a subclavian artery blockage, and thus the proximal **subclavian artery** on that side is examined as well [7]. By examining all these vessels bilaterally, the carotid duplex test provides a comprehensive evaluation of the extracranial cerebrovascular circulation.

## Imaging and Doppler Technique

The carotid duplex protocol involves both **B-mode ultrasound imaging** and **Doppler ultrasound** techniques:

- **B-Mode (Grayscale Imaging):** The arteries are first examined in grayscale (B-mode) in both transverse and longitudinal planes [8]. This allows visualization of the vessel walls and any plaque. The sonographer can characterize plaque echogenicity (e.g. whether it's calcified, fibrous, or soft) and surface texture (smooth, irregular, ulcerated) [8]. Grayscale imaging also helps measure the vessel lumen and identify anatomical landmarks (e.g. the bifurcation where the CCA splits into ICA and ECA).

- **Color Doppler Imaging:** Color flow Doppler is then applied in longitudinal views to screen for areas of turbulent or accelerated flow from the CCA through the ICA [9]. Turbulence or aliasing on color Doppler can indicate a significant stenosis. Color Doppler also helps in tracking the course of the vessels and in aligning the ultrasound beam for optimal Doppler angle.

- **Spectral Doppler Measurements:** Using a pulsed Doppler (with the insonation angle typically set around 45–60° relative to flow [9]), spectral Doppler waveforms are obtained at specific points along each vessel. **Peak Systolic Velocity (PSV)** and **End Diastolic Velocity (EDV)** are measured from these waveforms. According to protocol, velocities should be measured and recorded at minimum in the CCA and ICA (usually at several segments of each) [10]. In practice, technologists will sample the CCA (often 1–2 cm below the bifurcation), the ICA (at the origin and any point of highest velocity), and sometimes the ECA as well. These velocity measurements are critical for determining if a stenosis is present and how severe it might be.

- **Verifying Flow Direction:** Critically, the Doppler is also used to document the direction of flow in the vertebral arteries [10]. The probe is placed at the anterolateral neck to insonate the vertebral artery between the vertebrae. The normal finding is antegrade flow (blood moving toward the brain). If Doppler shows reversed flow in a vertebral artery, it suggests a **subclavian steal** phenomenon – meaning a high-grade stenosis or occlusion in the proximal subclavian artery is diverting blood from the brain circulation. In such cases, the subclavian artery on that side is examined with ultrasound for high-velocity flow or other signs of stenosis [7].

Throughout the exam, the sonographer adheres to standard technique to ensure accuracy: using the correct Doppler angle, placing the sample volume in the center of the artery, and avoiding artifact. The exam typically takes around 30 minutes and is usually performed with the patient lying flat and the head turned slightly away from the side being examined to optimize access.

## Segments Evaluated and Documentation

During a bilateral carotid duplex, the following vessel segments are evaluated (on both right and left sides), with representative images and waveforms recorded for each:

- **Common Carotid Arteries (CCA):** The CCA is examined along its length, typically with spectral Doppler samples taken in the **proximal**, **mid**, and **distal** CCA. The distal CCA (near the bifurcation) is especially important, as it's a common site for atherosclerotic plaque. PSV and EDV are measured in the CCA [10], and these values may later be used as a reference (denominator) for ratio calculations. The normal CCA waveform has a mixed resistance pattern (between the high-resistance ECA and low-resistance ICA patterns). Any plaque in the CCA is noted, and grayscale images are taken in two planes to document it.

- **Carotid Bifurcation:** The bifurcation region (where the CCA splits) is carefully evaluated with B-mode and color Doppler. This is the most common location for carotid plaque buildup. The exam will document any plaque here, including its extent and characteristics (e.g. calcifications or ulceration). If a stenosis is suspected at the bifurcation or proximal ICA, Doppler samples are taken right at that site to capture the highest velocity jet. Turbulent, non-laminar flow at the bifurcation on color Doppler can be a hallmark of significant stenosis.

- **Internal Carotid Arteries (ICA):** The ICAs are the continuations of the CCAs that supply blood to the brain. Each ICA is examined from its **origin** (at the bifurcation) as far distal as can be seen (usually the high cervical segment before it enters the skull). Spectral Doppler waveforms are obtained in the **proximal ICA**, and if possible in mid and distal segments (though distal might not always be visualized if very high in the neck). The highest PSV along the ICA is sought out and measured, as this often indicates the maximum stenosis if present. Multiple samples may be taken to ensure the peak velocity is found. **Plaque** in the ICA, if present, is documented. Normally, ICA flow is **low-resistance** – characterized by a relatively high EDV (continuous forward flow in diastole) because it feeds the brain which has low peripheral resistance. A diseased ICA with a stenosis will show an elevated PSV at the narrowing, possibly post-stenotic turbulence just distal to it, and maybe dampened waveforms downstream if severe. All these findings are recorded.

- **External Carotid Arteries (ECA):** The ECAs branch off the carotids to supply the face and scalp. Typically, the **proximal ECA** on each side is evaluated. The ECA is smaller in caliber than the ICA and has a **high-resistance** waveform (sharper systolic peak and very low or even reversed flow in diastole). Often a tell-tale feature like the **"temporal tap"** (tapping on the superficial temporal artery results in oscillations on the ECA waveform but not the ICA) is used to confirm one is sampling the ECA vs. ICA. The duplex exam will record an ECA waveform (PSV is measured, though EDV may be near zero in normal high-resistance conditions). Significant plaque in the proximal ECA is less common but can occur and would be noted. Generally, the ECA is less crucial than the ICA, but it's assessed to avoid missing disease or misidentification. A markedly high velocity in the proximal ECA with post-stenotic turbulence could indicate an ECA origin stenosis (which is treated only if severe and symptomatic, in most cases).

- **Vertebral Arteries:** The vertebral arteries are assessed at least at their origin (where they branch off the subclavian arteries in the lower neck) and proximal segment. In some protocols (like the provided one), the sonographer may attempt to visualize segments of the vertebral artery along the neck (labeled as origin, proximal, mid, distal segments in the protocol) and measure velocities in each. However, the **primary goal** is to determine patency and direction of flow. A normal vertebral artery has antegrade flow with a waveform similar to the ICA (forward flow in diastole, since it supplies the brain). The exam documents the presence of flow and its direction (often annotating it as "antegrade" or "retrograde" on the spectral tracing). If a **retrograde flow** is discovered (blood flowing backward, down the vertebral artery away from the brain), it strongly suggests a hemodynamically significant **subclavian artery stenosis** or occlusion on that side (known as **subclavian steal**). In some cases, a partial steal may be noted (e.g. waveform shows hesitant or bidirectional flow). These findings are important, as subclavian artery disease can cause neurologic symptoms (steal syndrome) or affect blood pressure in the arms. The duplex exam will also note the PSV in the vertebrals if measured, and whether the waveform is of normal shape. Any dramatically elevated velocity or abnormal waveform (e.g. dampened signal) in the proximal vertebral might indicate proximal stenosis. Ultimately, **confirmation of vertebral flow direction is a required component** of a complete carotid duplex study [5] [10].

- **Subclavian Arteries:** Although not always included in every carotid duplex protocol, many labs (including the one in this protocol) also examine the **proximal subclavian arteries** (especially the right subclavian, since the left subclavian originates directly from the aortic arch and is less commonly involved in steal). The subclavian artery is evaluated via supraclavicular or infraclavicular approach with Doppler. A normal finding is a **triphasic waveform** (sharp upstroke, brief reversal in early diastole, then forward in late diastole) and a PSV typically < 150–200 cm/s. If the subclavian artery has a high-grade stenosis, the PSV will be markedly elevated and the waveform may become monophasic. Additionally, a blood pressure difference > 15–20 mmHg between the right and left arms may be noted clinically in subclavian stenosis. In the context of the carotid duplex, **the protocol dictates examining the subclavian artery if the ipsilateral vertebral flow is abnormal**

**(reversed or diminished)** [7]. This ensures that a potential subclavian obstruction is documented. For example, if the right vertebral shows reversal of flow, the exam will include Doppler interrogation of the right subclavian origin to look for a focal high velocity (confirming stenosis). Documentation of subclavian findings (waveform and velocity) is useful for surgical planning, since a severely stenotic subclavian might need intervention especially if coronary-subclavian bypass grafts or internal mammary usage are considerations.

All findings from the above segments are typically documented in an official report. The report will note which arteries were assessed and describe any disease. Key documentation includes the **highest velocities measured** (often the report will tabulate PSV and EDV for each segment or the key segments), **presence of plaque** (and whether it's calcified or causing acoustic shadowing, etc.), and **any hemodynamic abnormalities** like turbulence or altered flow direction [11] [12]. Modern vascular labs often use standardized worksheets or software that automatically calculate ratios (ICA/CCA velocity ratios) and categorize stenosis severity based on the input velocities.

## Interpretation of Results

Interpreting a carotid duplex involves correlating the velocity measurements and imaging findings with established criteria to estimate the **degree of stenosis** in the internal carotid artery (since ICA stenosis is most directly linked to stroke risk). Over the years, vascular labs have developed criteria based on clinical research. One widely used benchmark was the **Society of Radiologists in Ultrasound (SRU) consensus criteria (2003)**, which among other things set **ICA PSV ≥ 125 cm/s as a threshold for ≥50% stenosis**. However, there has been variability in criteria among labs, and ongoing research has aimed to refine these thresholds [13] [14].

Most recently, in **2023, the Intersocietal Accreditation Commission (IAC) Vascular Testing Division released updated recommendations** based on a multi-center study. This research confirmed that the old 125 cm/s cutoff for 50% stenosis was too sensitive (leading to overestimation of disease) and recommended using a higher PSV threshold of **180 cm/s for diagnosing a ≥50% diameter stenosis** [14]. The IAC now *strongly recommends* labs adopt these modified criteria to improve accuracy and consistency [15] [14]. Below is a summary of current interpretive criteria for ICA stenosis severity, incorporating these updates (values apply to the **internal carotid artery** unless otherwise specified):

- **Normal (0% stenosis) or Minimal (<50%) Stenosis:** Peak systolic velocity < 180 cm/s, with no hemodynamically significant plaque seen. The ICA/CCA PSV ratio will be < 2.0, and the end-diastolic velocity (EDV) typically < 40 cm/s [14] [16]. In general, PSV under 180 with no visible narrowing corresponds to no more than mild (less than 50%) carotid narrowing.

- **50–69% Stenosis (Moderate):** Peak systolic velocity in the ICA is elevated, roughly in the range of 180–230 cm/s [16]. There is usually **visible plaque** causing an estimated ≥50% diameter reduction on B-mode imaging or color Doppler [16]. The ICA/CCA PSV ratio will fall in an intermediate range (approximately 2.0–4.0), and the ICA EDV rises to about 40–100 cm/s [16]. These findings indicate a moderate stenosis. For example, an ICA PSV of 200 cm/s and an ICA/CCA ratio ~3 with a clearly visualized plaque would be consistent with a ~60% stenosis.

- **Severe Stenosis (≥70% but not near occlusion):** The ICA peak systolic velocity exceeds **230 cm/s**, often far higher in tight lesions [17]. The ICA/CCA PSV ratio will be > 4.0, and ICA EDV > 100 cm/s in a high-grade narrowing [17]. Typically, a PSV in the 250–400+ cm/s range with an EDV over 100 and a high ratio indicates a severe stenosis of 70–99%. On B-mode imaging, the residual lumen of the ICA may be very narrow. Post-stenotic turbulence is usually present just beyond the tightest area (seen as spectral broadening and chaotic color flow). It's worth noting that while PSV tends to keep increasing with higher degrees of stenosis, extremely tight stenoses can sometimes cause **dampened** distal waveforms if the flow starts to drop off.

- **Near Occlusion:** This term is used when the ICA is almost occluded, with only a tiny trickle of flow through a very narrow lumen. In such cases, velocities can be **variable** – sometimes extremely high in the small jet, but sometimes paradoxically low if very little flow gets through [17]. A classic sign of near-occlusion on B-mode is an **extremely thinned ICA lumen** distal to the plaque, often with markedly reduced flow volume. The Doppler waveform may show a "high, low-string flow" pattern (high velocity but low volume) or just very low velocities because of minimal flow [18] [17]. The key is the visual confirmation that the artery is patent but almost closed. In reporting, near occlusion is distinguished from a standard severe stenosis because it can affect the reliability of velocity criteria (e.g. an ICA nearly occluded might not have a very high PSV simply because hardly any blood can get through).

- **Total Occlusion:** If no flow is detected in the ICA and the lumen is filled with echogenic material (thrombus/plaque) or is completely collapsed, this indicates **100% occlusion**. In total occlusion, **no Doppler signal** can be obtained through the ICA (PSV and EDV are undetectable) [19]. Often secondary signs help confirm it, such as reversed flow in the ECA (the ECA can backfill the ICA stump in some cases) or markedly increased flow in the contralateral carotid (collateral circulation). Total occlusion is a critical finding – unlike stenoses, it generally cannot be treated with surgery (endarterectomy is not performed on an occluded vessel), but it has implications for patient stroke risk and collateral blood supply.

These criteria primarily apply to the **internal carotid artery**, since that is the most clinically relevant vessel for stroke prevention. When interpreting the exam, the radiologist or vascular technologist will correlate the measured velocities with these thresholds and also consider the imaging appearance of plaque. Importantly, interpretation doesn't rely on a single number in isolation – **all Doppler and grayscale findings are considered together**. For example, if an ICA's PSV is measured at 170 cm/s (which is below the 180 cutoff), but there is extensive plaque narrowing the lumen >50% and there is post-stenotic turbulence plus an elevated ICA/CCA ratio ≥ 2.0, this would still be interpreted as a significant (moderate) stenosis [20]. Likewise, an ICA PSV might be artifactually low due to poor angle or if near-occlusion is present, so one would then rely more on the image and other waveform features. The **latest guidelines emphasize a multi-parameter approach**, including plaque visualization and ratios, to improve diagnostic accuracy [20].

Beyond the ICA criteria, the exam interpreter also evaluates the **vertebral arteries** and **subclavian arteries** if examined. A normal vertebral artery should have an antegrade flow with a velocity usually in the range of 20–60 cm/s PSV (highly variable). If a vertebral artery shows any reversal of flow, it is typically reported as evidence of a subclavian steal phenomenon. The side (right or left) and extent (partial vs. complete reversal) will be noted. For the **subclavian artery**, while there are no universal velocity criteria like for carotids, a **PSV > 200 cm/s** in the subclavian is often considered suggestive of a ≥50% stenosis, especially if coupled with post-stenotic turbulence and brachial blood pressure differential. The report would mention if the subclavian waveform is abnormal or if there's a significant pressure drop in the ipsilateral arm. All these findings provide a comprehensive picture: for instance, a report might conclude "Severe 80% stenosis of the proximal right ICA with trickle flow (near occlusion) [21]; right vertebral artery flow is reversed consistent with subclavian steal; high-grade stenosis of the right subclavian origin is suspected as the cause of the steal." This level of detail helps guide further management (e.g. whether the patient needs carotid endarterectomy, stenting, or if a subclavian intervention is warranted).

## Conclusion

The bilateral carotid duplex ultrasound is a cornerstone investigation for patients at risk of stroke or with symptoms of cerebrovascular disease. By following a structured protocol – imaging the key arterial segments and obtaining Doppler measurements – the test can reliably identify carotid artery stenosis, occlusions, and other vascular abnormalities in the neck. It is a **noninvasive, painless, and safe** procedure that provides critical information to guide clinical decisions [4]. An accurate carotid duplex study, interpreted with up-to-date criteria [15] [14], allows physicians to stratify stroke risk and plan interventions (like carotid endarterectomy, stenting, or medical therapy) to prevent major neurologic events. In summary, the bilateral carotid duplex protocol is an invaluable tool for stroke prevention, combining detailed anatomical visualization with hemodynamic assessment of blood flow in the head and neck arteries.

**Sources:**

- Mayo Clinic Staff. *Carotid ultrasound – About this test.* MayoClinic.org. Explains the purpose of carotid ultrasound in detecting narrowed or blocked arteries and reducing stroke risk [2] [3]. Also notes the procedure's safety (no risks or harm) [4].
- Society for Vascular Technology (UK). *Professional Performance Guidelines: Extracranial Carotid Duplex Ultrasound.* Describes the standard examination protocol: scanning CCA, bifurcation, ECA, ICA bilaterally, checking vertebral artery flow direction, and measuring PSV/EDV in key vessels [5] [10]. Emphasizes documenting vertebral flow and using Doppler to detect velocity increases or turbulence from CCA through distal ICA [9]. Includes older criteria table for ICA stenosis (NASCET-based) for reference [12] [21].
- Intersocietal Accreditation Commission (IAC) Vascular Testing. *Updated Recommendations for Carotid Stenosis Interpretation Criteria – Nov 2023.* Official communication recommending higher threshold for ICA velocities: identifies that PSV < 180 cm/s corresponds to <50% stenosis, replacing the old 125 cm/s benchmark [14]. Provides revised criteria for 50–69% and ≥70% stenoses, and discusses considering all parameters (PSV, ratios, plaque, turbulence) for accurate interpretation [20] [16].

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