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IMAGING VIGNETTE

Manifestations of Cardiac Disease in Carotid Duplex Ultrasound Examination

Surabhi Madhwal, MD,* Sandra Yesenko, RVT,† Esther Soo Hyun Kim, MD,†
Margaret Park, RDCS, RVT,‡ Susan M. Begelman, MD,§ Heather L. Gornik, MD, MHS†
New York, New York; Cleveland, Ohio; and South San Francisco, California

CAROTID DUPLEX ULTRASOUND (CDUS), COMBINING GRAY-SCALE (B MODE) AND COLOR and spectral (pulsed-wave) Doppler, has become the modality of choice for the initial evaluation and surveillance of extracranial carotid artery disease, with a reported accuracy for the detection of carotid stenosis exceeding 90% (1).

The assessment of carotid artery stenosis severity using CDUS is largely dependent on the pattern and velocities of blood flow within the carotid arteries, with the peak systolic velocity (PSV) in the internal carotid artery generally serving as the primary diagnostic parameter. There are a number of cardiac disorders that can affect flow velocities and Doppler waveforms within the cerebrovasculature. It is important to recognize these disorders for multiple reasons, including the potential to inaccurately diagnose carotid artery stenosis. In addition, as CDUS may be obtained for the evaluation of nonspecific symptoms, such as dizziness or syncope, it may be possible to identify clues to the presence of a cardiac etiology through careful assessment of the Doppler waveforms. The sonographic clues on a CDUS examination that suggest an underlying cardiac disorder include abnormal spectral Doppler waveform morphology, waveform abnormality in multiple vessels (e.g., common/internal carotid and vertebral arteries), waveform abnormality bilaterally, and unusually low or high velocities in the absence of significant vascular lesions on color and/or gray-scale imaging.

We present a series of cases demonstrating classic CDUS manifestations of common cardiac disorders (Figs. 1 to 3) (1,2).

From the *Department of Cardiovascular Medicine, Mt. Sinai Medical Center, New York, New York; †Non-Invasive Vascular Laboratory, Heart and Vascular Institute, Cleveland Clinic, Cleveland, Ohio; ‡Echocardiography Laboratory, Heart and Vascular Institute, Cleveland Clinic, Cleveland, Ohio; and §Genentech, Inc., South San Francisco, California. Dr. Kim has served as a consultant for Philips Ultrasound and has received research support from GE Healthcare. Dr. Begelman is a paid employee of Genentech. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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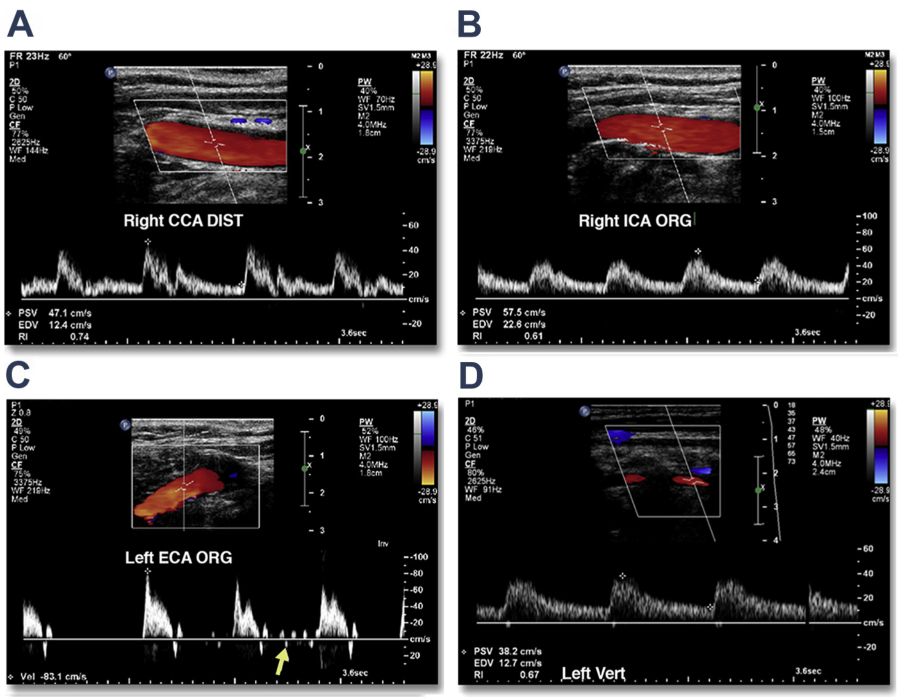

Figure 1. Normal Carotid Duplex Ultrasound Examination

A normal common carotid artery (CCA) spectral Doppler waveform **(A)** has a sharp systolic increase with flow throughout diastole (low-resistance waveform) due to a preponderance of carotid flow entering the ICA (internal carotid artery). Transient early diastolic flow reversal may be seen in proximal to mid CCA. **(B)** The ICA Doppler waveform demonstrates significant continuous forward flow throughout diastole. There is normal, laminar flow without spectral broadening, and the peak systolic velocity is typically $<$100 cm/s. **(C)** In contrast, the Doppler waveform of the external carotid artery (ECA) has a sharp systolic increase, rapid decrease in flow toward baseline, and minimal (if any) sustained diastolic flow. Transient flow reversal in early diastole is common. This pattern of flow is characteristic of blood supply to high-resistance vascular beds, such as the limbs or the osseous and muscular structures of the head and neck. The temporal tap maneuver **(arrow)** produces ECA waveform oscillations during manual tapping of a branch of the superficial temporal artery near the temple and aids in the accurate identification of the ECA. **(D)** The Doppler waveform of the cervical vertebral artery typically has an appearance similar to that of the ICA with a low resistance pattern and sustained diastolic flow. There are areas of drop out in B mode due to acoustic shadowing from the cervical spine. ORG = origin.

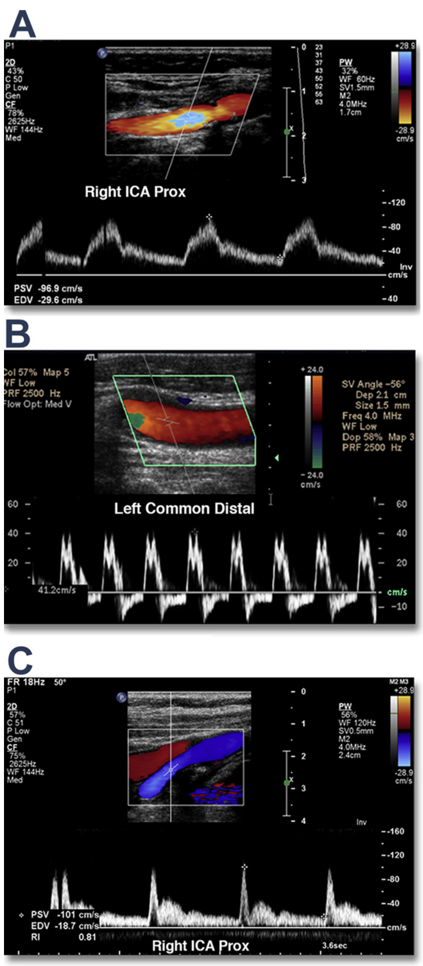

Figure 2. Severe Aortic Valve Stenosis, Severe Aortic Regurgitation, and Hypertrophic Cardiomyopathy

(A) Severe aortic valve stenosis. Doppler waveforms demonstrate a delayed systolic upstroke (prolonged acceleration time) with blunted amplitude and rounded waveform appearance consistent with severe aortic valve stenosis. This waveform appearance has been termed *pulsus tardus et parvus* and is most typically seen in association with severe aortic valve stenosis. Velocity measurements are generally not significantly affected by aortic stenosis in the absence of left ventricular systolic dysfunction or severely impaired cardiac output. **(B)** Severe aortic regurgitation. Doppler waveforms demonstrate an exaggerated, rapid upstroke. There are 2 distinct systolic peaks separated by a dicrotic notch with the height of second peak equal to or taller than the height of the first (bisferious waveform). Pan-diastolic flow reversal is noted in this case. The presence of a bisferious waveform in the carotid arteries has been shown to be more sensitive for detection of aortic insufficiency than diastolic flow reversal, but the latter is likely a more specific sign (2). **(C)** Hypertrophic cardiomyopathy. Doppler waveforms demonstrate an exaggerated, rapid upstroke followed by rapid descent. An increased peak systolic velocity is noted, corresponding to the rapid systolic upstroke, and is followed by systolic cleft and dome. There is decreased flow throughout diastole with an abnormally high-resistive waveform morphology noted. The spike-and-dome pattern of ventricular outflow obstruction is a classic finding of hypertrophic cardiomyopathy and can be seen in both the aorta and the carotid arteries. ICA = internal carotid artery; Prox = proximal.

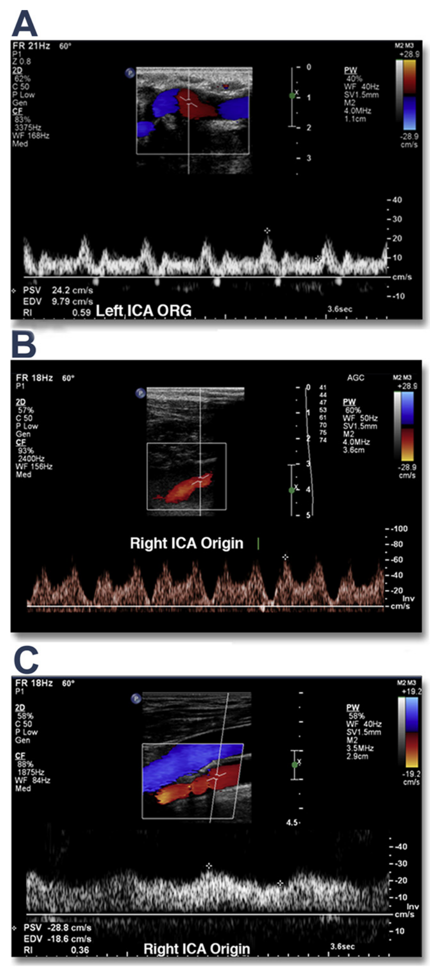

Figure 3. Low Cardiac Output, Intra-Aortic Balloon Pump, and Left Ventricular Assist Device

(A) Low cardiac output. Doppler waveforms demonstrate unusually low peak systolic velocity, but have preserved upstroke. These findings suggest a low cardiac output state. In this particular case, the patient had dilated cardiomyopathy with a left ventricular ejection fraction $<$20%. In the setting of low cardiac output, caution is advised when using standard velocity criteria for the assessment of ICA stenosis. In such cases, use of the velocity ratio (i.e., the ICA/CCA peak systolic velocity ratio) is likely more accurate than absolute velocities for determination of severity of stenosis. **(B)** Intra-aortic balloon pump. Doppler waveforms obtained from a patient undergoing treatment with an intra-aortic balloon pump (IABP) at a 1:1 setting. As expected, IABP-assisted waveforms have 2 systolic peaks for each pulse, the first reflecting intrinsic left ventricular contraction and the second due to balloon inflation. End-diastolic velocity cannot be determined in the setting of an IABP. Flow reversal is commonly seen after the second (augmented) peak reflecting balloon deflation. For more accurate measurement of carotid velocities, one should turn off the IABP while insonating the vessels. If this is not possible, velocity from the first (nonaugmented) peak should be used as the peak systolic velocity. **(C)** Left ventricular assist device (LVAD). Doppler waveforms from a patient with advanced cardiomyopathy and a functional LVAD demonstrate low-velocity flow with delayed upstroke and loss of pulsatility. Carotid Doppler waveform morphology among patients with LVADs is variable and highly dependent on pump settings. In this particular case, continuous arterial flow likely reflects a higher pump rate. Abbreviations as in Figure 1.

Address for correspondence: Dr. Heather L. Gornik, Non-Invasive Vascular Laboratory, Cleveland Clinic Heart and Vascular Institute, 9500 Euclid Avenue, Desk J35, Cleveland, Ohio 44195. *E-mail: gornikh@ccf.org*.

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