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Common carotid artery peak systolic velocity ratio predicts high-grade common carotid stenosis

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Objective: **Screening for common carotid artery (CCA) stenosis with duplex ultrasound (DUS) velocity criteria alone can be limited by within-patient and between-patients hemodynamic variability. This study aimed to evaluate inter-CCA velocity ratio criteria to predict high-grade CCA stenosis.**

Methods: **This was a retrospective review of consecutive patients who underwent computed tomography angiography and DUS peak systolic velocity (PSV) measurements of bilateral CCAs, independently recorded, between 2008 and 2014. Patients with dampened CCA waveforms on DUS composed group B. The remainder without dampened waveforms constituted group A. Inter-CCA PSV ratios were calculated by dividing the higher CCA PSV by the lower one of the other side, so the ratios would always be ≥1. Ratios were subsequently paired with each respective unilateral CCA diameter stenosis and differential bilateral CCA diameter stenosis. A quadratic regression model was fitted to predict unilateral and differential stenosis. Receiver operating characteristic curve was used to determine optimal ratios for ≥50% and ≥80% CCA stenosis. The study excluded patients with carotid artery occlusion.**

Results: **From a total of 201 patients, 193 patients were included in group A and 8 in group B. Within group A, 31 patients had ≥50% unilateral stenosis and 17 had ≥50% differential stenosis. All stenoses ≥50% were identified on the same side with the higher PSV. Inter-CCA PSV ratio predicted ≥50% unilateral (r^2 = 0.536; P < .001) and differential stenosis (r^2 = 0.581; P < .001). In group B, all patients had ≥60% stenosis that was near or involved the vessel origin. An increasing inter-CCA PSV ratio showed a trend toward contralateral high-grade stenosis (r^2 = 0.596; P = .1). Receiver operating characteristic curves showed an optimal threshold CCA ratio ≥2.16 for ≥50% unilateral stenosis with 92% accuracy, 62% sensitivity, and 98% specificity (area under curve = 0.854; 95% confidence interval, 0.759-0.948) and a ratio ≥2.62 for ≥50% differential stenosis with 97% accuracy, 83% sensitivity, and 98% specificity (area under curve = 0.94; 95% confidence interval, 0.835-1).**

Conclusions: **DUS-based CCA PSV ratio can accurately predict unilateral and differential high-grade CCA stenosis. Also, in patients with unilateral dampened waveforms, it implied contralateral severe proximal stenosis. This parameter should be further validated in prospective studies and may serve as an adjunct screening tool to detect high-grade CCA stenosis. (J Vasc Surg 2015;62:951-7.)**

Common carotid artery (CCA) stenosis has been related to increased risk of ipsilateral embolic stroke.[1] It is important to screen for potentially symptomatic CCA stenosis with a modality that can be accurate, sensitive, reproducible, low cost, and safe, such as duplex ultrasound (DUS). Reliable screening with DUS may decrease the cost and radiation risks associated with conventional angiography and computed tomography (CT). In addition, detection of significant CCA stenosis may prompt advanced imaging for evaluation of internal carotid artery (ICA) stenosis, as CCA stenosis can affect all the velocity parameters distally and throw off the true range of ICA stenosis.[2] However, detection of proximal and mid CCA stenosis by DUS can be technically difficult because of anatomic limitations at the thoracic outlet level.

Few studies to date have attempted to validate DUS criteria that can screen for hemodynamically significant CCA stenosis and therefore guide toward more advanced contrast studies.[3-5] One significant limitation of those methods is that they are based on unilateral peak systolic velocity (PSV) and end-diastolic velocity (EDV) criteria alone, which may be subject to error because of within-patient and between-patients hemodynamic variability.[2,6-8] Although this applies to all patients of different age, gender, and comorbidities,[9] it is particularly important in patients hypertensive or hypotensive, with hyperdynamic circulation, depressed cardiac ejection fraction, and valvulopathy, all of which may result in a wide range of CCA velocities in patients with the same location and degree of stenosis.

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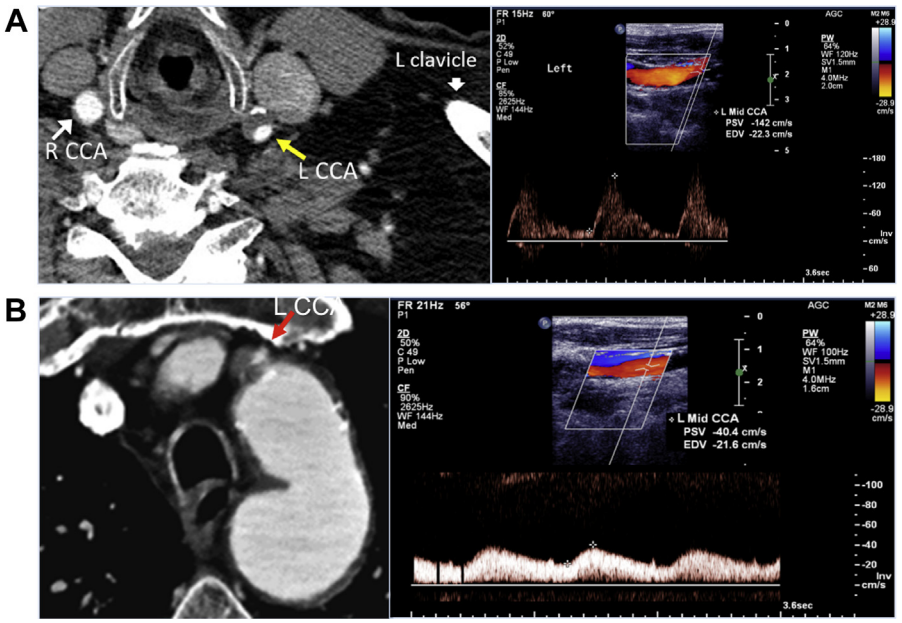

Fig 1. Examples of common carotid artery (*CCA*) stenosis with respective inter-CCA peak systolic velocity (*PSV*) ratio for each group. **A,** Left CCA mid stenosis 60%, spectrum broadening, ratio = 2.27 (left, 142 cm/s; right, 62.5 cm/s). **B,** Left CCA origin stenosis 70%, dampened waveform, ratio = 2.12 (right, 85.6 cm/s; left, 40.4 cm/s). The *long arrow* indicates left CCA stenosis. *EDV,* End-diastolic velocity.

To account for hemodynamic variations, we aim to introduce and evaluate an inter-CCA PSV ratio parameter that implements the contralateral CCA as a reference point to adjust for hemodynamic variability.

METHODS

We performed a retrospective review of consecutive patients who underwent both carotid DUS and CT angiography (CTA) within 3 months of each other, which is within the window of 90 to 120 days recommended by the Commission for the Accreditation of Medical Screening Services (§13.1.2.2),[10] as long as the patient does not develop new neurologic symptoms. All studies were performed at a Veterans Affairs tertiary referral medical center between January 2008 and December 2014. The DUS examinations were performed at an Intersocietal Accreditation Commission Vascular Testing-accredited laboratory by registered vascular technologists and interpreted by registered physicians in vascular interpretation. Patients with CCA occlusion were excluded. The Institutional Review Board approved the current study; individual patient consents were not required as this was a retrospective review and no identifiable patient information is published.

The CCA PSV measurements were obtained at 2 cm from the bulb to avoid overlap with extension of bulb lesions. The acquisition of CCA PSV between the two sides was within 5 minutes. Spectral waveforms of CCA were obtained with a multifrequency 7-MHz linear transducer (iU 22 ultrasound system; Philips Healthcare, Bothell, Wash) at ≤60 degrees insonation angle.

Table I. Demographics of the patient cohort

Variable	*Entire cohort (N = 201)*
Age, years	69 ± 9
Gender, male/female	201/0
Race, W/AA/H, %	74.6/13.4/11.9
Diabetes mellitus	69 (34.3)
Hypertension	182 (90.5)
Coronary artery disease	104 (51.7)
Smoking	102 (50.7)
Congestive heart failure	23 (11.4)
Hypercholesterolemia	59 (29.3)
COPD	43 (21.4)

AA, African American; *COPD,* chronic obstructive pulmonary disease; *H,* hispanic; *W,* white.
Data are presented as number (%) unless otherwise indicated.

The aortic arch, cervical, and head CTA protocol was electrocardiography gated and performed on a 64-slice multidetector CT scanner (Toshiba Aquilion 64; Toshiba America Medical Systems, Tustin, Calif), using 90 to 100 mL of iso-osmolar contrast agent iodixanol 320 (GE Healthcare, Cork, Ireland). Patients with compromised renal function were treated with intravenous hydration according to our institution's renal protection protocol. Axial images of 1-mm thickness were stored in a picture archiving and communication system. Quantitative analysis of CT images to determine location and maximal CCA diameter stenosis was performed by two