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Common carotid artery end-diastolic velocity and acceleration time can predict degree of internal carotid artery stenosis

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ABSTRACT

Objective: Whereas duplex ultrasound parameters for predicting internal carotid artery (ICA) stenosis are well defined, the use of common carotid artery (CCA) Doppler characteristics to predict ICA stenosis when the ICA cannot be insonated directly or accurately because of anatomy, calcification, or tortuosity has not been studied. The objective of this study was to identify CCA Doppler parameters that may predict ICA stenosis.

Methods: We reviewed all patients at our institution who underwent carotid duplex ultrasound (CDU) from 2008 to 2015 and also had a comparison computed tomography, magnetic resonance, or catheter angiogram. We excluded patients whose CDU examination did not correlate with the comparison study, those whose arteries were not visualized on the comparison study, and those with complete occlusion of the CCA. We collected CCA peak systolic velocity (PSV), end-diastolic velocity (EDV), and acceleration time (AT) in addition to CDU and comparison imaging interpretation of degree of stenosis. A multivariate model was used to identify predictors of ICA stenosis.

Results: There were 99 CDU examinations with corresponding comparison imaging included. For every increase of 10 cm/s in EDV in the CCA, the odds of a >50% ICA stenosis being present vs a ≤50% ICA stenosis decreased by 37% (odds ratio [OR], 0.63; 95% confidence interval [CI], 0.41-0.97; $P = .03$). For every increase of 10 cm/s in EDV in the CCA, the odds of a 70% to 99% ICA stenosis being present vs a ≤50% ICA stenosis decreased by 48% (OR, 0.52; 95% CI, 0.28-0.94; $P = .03$). A CCA EDV of 19 cm/s or below was associated with a 64% probability of a 70% to 99% ICA stenosis. For every 50-millisecond increase in AT in the CCA, the odds of a >50% stenosis being present vs a ≤50% ICA stenosis increased by 56% (OR, 1.56; 95% CI, 1.03-2.35; $P = .04$). A CCA AT of 80 milliseconds or above was associated with a 69% probability of a >50% ICA stenosis. There was no correlation between CCA PSV and ICA stenosis.

Conclusions: CCA EDV and AT are independent predictors of ICA stenosis and may be used in the setting of patients whose ICA cannot be directly insonated or when standard duplex ultrasound parameters of ICA PSV, EDV, or ICA/CCA ratio conflict. (J Vasc Surg 2017;■:1-6.)

Carotid duplex ultrasound (CDU) is the screening method of choice for the evaluation of extracranial carotid artery disease, given its excellent sensitivity and specificity.[1,2] The degree of internal carotid artery (ICA) stenosis is estimated using a combination of parameters including peak systolic velocity (PSV), end-diastolic velocity (EDV), ICA to common carotid artery (CCA) ratio, and presence of plaque on gray-scale images.[3] In many laboratories including ours, the degree of stenosis is stratified into categories of normal (no stenosis), <50% stenosis, 50% to 69% stenosis, and 70% to 99% stenosis.

Whereas these standard CDU parameters for predicting ICA stenosis are well defined, all are dependent on successful insonation of the ICA. Because of this, there are situations in which CDU interpretation is made difficult. These include when the ICA cannot be insonated directly because of anatomy or calcification and when the PSV, EDV, and ICA/CCA ratio do not correlate. Furthermore, tortuosity of the ICA can lead to inaccurate velocity measurements. Often in these cases, clinicians are forced to order additional imaging tests, such as computed tomography angiography (CTA), magnetic resonance angiography (MRA), or catheter angiography, incurring additional costs, inconvenience to the patient, and risks of renal failure and catheterization complications.

In contrast, it is rare for there to be difficulty in insonating the CCA. It can be visualized even in the setting of a very high carotid bifurcation, it is less prone to calcification than the ICA, and it is typically less tortuous than the ICA. Few studies have investigated whether

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characteristics of the CCA on CDU are useful in predicting ICA stenosis.[4] The objective of this study was to identify CCA duplex ultrasound parameters that can predict degree of ICA stenosis.

METHODS

The Ohio State University Institutional Review Board approved this study protocol (No. 2016H0017). Informed consent was not required from human subjects on the basis of the nature of the study protocol.

Selection of patients. We reviewed all patients who underwent CDU from 2008 to 2015 at The Ohio State University Wexner Medical Center, a tertiary referral academic medical center, who had CDU degree of stenosis of the ICA confirmed with CTA, MRA, or catheter angiography. These studies were previously selected for quality review as part of the Intersocietal Accreditation Commission (IAC) standards and guidelines for vascular testing accreditation.[5] All CDU examinations and their comparison studies were read by a single blinded vascular surgeon (B.S.). We excluded patients whose CDU examination did not correlate with comparison imaging, those whose arteries were not visualized on comparison study, and those with complete occlusion of the CCA.

Sonographic procedures and outcomes. CDU examinations were performed using Philips iU22 (Philips Biomedical Systems, Bothell, Wash), Logiq 9E (General Electric, Milwaukee, Wisc), and Zonare (Zonare Inc, Mountain View, Calif) scanners with a 7.5 MHz linear array transducer and 5 MHz Doppler frequency. Both longitudinal and transverse views of the ICA, CCA, and external carotid artery bilaterally with gray-scale images and color and Doppler flow were obtained. Standard sonographic techniques, including aligning the cursor parallel to the vessel wall, obtaining waveforms using a small sample volume ideally placed in the center of flow, and keeping the Doppler angle at 60 degrees, were used. All CDU examinations were performed by eight registered vascular sonographers and interpreted by five vascular surgeons at the Ross Heart Hospital vascular laboratory of The Ohio State University Wexner Medical Center, an IAC accredited laboratory.

PSV, EDV, and systolic acceleration times (ATs) of the proximal, mid, and distal CCA were collected from VascuBase (Consensus Medical Systems Inc, Richmond, BC, Canada). AT was manually measured by a single investigator (D.S.S.) by placing a caliper on the level at which the gradient begins to rise at the end of diastole to the first peak of systole (early systolic peak; Fig 1). If the flow velocity waveform showed two peaks, the time from the upstroke to the first peak was regarded as the AT.

Statistical analysis. All data were collected and analyzed using Microsoft Excel (Redmond, Wash) and Stata Statistical Software, Release 14 (College Station, Tex). A multivariate model was used to identify predictors of ICA stenosis. A P value $< .05$ was considered statistically significant.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective study
- **Take Home Message:** A common carotid artery (CCA) end-diastolic velocity of 19 cm/s or below was associated with a 64% probability of a 70% to 99% internal carotid artery stenosis. For every 50-millisecond increase in acceleration time in the CCA, odds of a >50% stenosis increased by 56%.
- **Recommendation:** The authors recommend using CCA end-diastolic velocity and acceleration time in situations in which the internal carotid artery cannot be directly or accurately insonated.

RESULTS

In the study period, 12,939 CDU examinations were performed overall. A total of 111 CDU examinations with comparison imaging were identified; 12 were excluded because of discrepancy between the CDU examination and comparison imaging, leaving 99 CDU examinations with confirmatory comparison imaging; these 99 CDU examinations composed the study group.

Table I illustrates the odds of a >50% stenosis being present for a specific increase in PSV, EDV, or AT based on univariable generalized estimating equation population-averaged logistic regression. For every increase of 10 cm/s in EDV in the proximal CCA, the odds of a >50% ICA stenosis being present vs a ≤50% ICA stenosis decreased by 37% (odds ratio [OR], 0.63; 95% confidence interval [CI], 0.41-0.97; $P = .03$). For every 50-millisecond increase in AT in the distal CCA, the odds of a >50% stenosis being present vs a ≤50% ICA stenosis increased by 56% (OR, 1.56; 95% CI, 1.03-2.35; $P = .04$). We did not identify a correlation between CCA PSV and ICA stenosis.

Table II demonstrates the odds of a 70% to 99% stenosis being present for a specific increase in PSV, EDV, or AT based on univariable structural equation model multinomial logistic regression. For every increase of 10 cm/s in EDV in the proximal CCA, the odds of a 70% to 99% ICA stenosis being present vs a ≤50% ICA stenosis decreased by 48% (OR, 0.52; 95% CI, 0.28-0.94; $P = .03$).

The sensitivity and specificity of the proximal CCA EDV in predicting ICA stenosis are maximized at 19 cm/s (Fig 2). Accordingly, a proximal CCA EDV of 19 cm/s or below is associated with a 64% probability of a 70% to 99% ICA stenosis (Fig 3). The sensitivity and specificity of the distal CCA AT are maximized at 80 milliseconds (Fig 4). Accordingly, a distal CCA AT of 80 milliseconds