Validating common carotid stenosis by duplex ultrasound with carotid angiogram or computed tomography scan

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Background: No consensus exists for duplex ultrasound criteria in the diagnosis of significant common carotid artery (CCA) stenosis. In general, peak systolic velocity (PSV) >150 cm/s with poststenotic turbulence indicates a stenosis >50%. The purpose of our study is to correlate CCA duplex velocities with angiographic findings of significant stenosis >60%.

Methods: We reviewed the carotid duplex records from 2008 to 2011 looking for patients with isolated CCA stenosis and no ipsilateral internal or contralateral carotid artery disease who received either a carotid angiogram or a computed tomography scan. We identified 25 patients who had significant CCA disease >60%. We also selected 74 controls without known CCA stenosis. We performed receiver operating characteristics analysis to correlate PSV and end-diastolic velocity (EDV) with angiographic stenosis >60%. The degree of stenosis was determined by measuring the luminal stenosis in comparison to the proximal normal CCA diameter.

Results: Most patients had a carotid angiogram (21/25), four only had a computed tomography angiography and four had both. Eighteen patients had history of neck radiation. The CCA PSV ≥250 cm/s had a sensitivity of 98.7% (81.5%-100%) and a specificity of 95.7% (92.0%-99.9%), CCA PSV ≥300 cm/s had a sensitivity of 90.9% (69.4%-98.4%) and a specificity of 98.7% (92.0%-99.9%). The CCA EDV ≥40 cm/s had a sensitivity of 95.5% (95% confidence interval of 75.1%-99.8%) and specificity of 98.7% (92.0%-99.9%), EDV ≥60 cm/s had a sensitivity of 100% (75.1%-99.8%) and specificity of 87% (94.1-100%), and EDV ≥70 cm/s had a sensitivity of 86.4% (64.0%-96.4%) and specificity of 100% (94.1%-100%). The presence of both PSV ≥250 cm/s and EDV ≥60 cm/s had a 98.7% negative predictive value, and the presence of both PSV ≥250 cm/s and EDV ≥60 cm/s had 100% positive predictive value.

Conclusions: Establishing CCA duplex criteria to screen patients with significant stenosis is crucial to identify those who will need further imaging modality or treatment. In our laboratory, CCA PSV ≥250 cm/s and EDV ≥60 cm/s are thresholds that can be used to identify significant (>60%) CCA stenosis with a high degree of accuracy. (J Vasc Surg 2014;59:435-9.)

The incidence of isolated common carotid artery (CCA) stenosis is very low (1%-5%) and little is known about the clinical course of these lesions.1,2 It is suspected that patients with isolated CCA stenosis tend to be more symptomatic and present with amaurosis fugax, aphasia, or hemispheric symptoms.3 Carotid duplex scanning is highly accurate in detecting internal carotid artery disease with a well-established consensus for classification of ICA stenosis.4 However, up until today, there is no consensus whether the guidelines put by Grant et al can be applied or whether other criteria ought to be used to classify lesions in the CCA or the external carotid artery.

Most laboratories use a peak systolic velocity (PSV) of 150 cm/s with poststenotic turbulence to be associated with >50% CCA stenosis.5 Not having a validated criteria as we do for ICA disease, could subject many patients with CCA disease to additional studies like computed tomography angiography (CTA) or carotid digital subtraction angiogram (DSA). There is only one study that correlated CCA velocities with CTA. The authors found a CCA PSV >182 cm/s to be associated with >50% stenosis with 64% sensitivity and 88% specificity.6 The goal of our study is to correlate isolated cervical CCA duplex velocities with angiographic findings of CCA stenosis >60% using neck CTA or carotid DSA.

METHODS

We reviewed the carotid duplex records from January 2008 to December 2011 at the Michael E. DeBakey Veterans Affairs medical center in Houston, Texas. We
identified patients with isolated CCA velocities >200 cm/s and no ipsilateral internal or contralateral carotid artery disease based on carotid duplex. We then screened for those patients who received either a neck CTA or carotid DSA within 3 months of the carotid duplex. During the same time period, we reviewed patients with CCA PSV <200 cm/s who received either a neck CTA or a carotid DSA within 3 months of the carotid duplex. This was used as the control group. The 3-month period is well within the recommended 90 to 120 days per the Commission for the Accreditation of Medical Screening Services, as long as the patient does not develop new neurologic symptoms. This information is located in section 13.1.2.2.

Patients with ipsilateral ICA or CCA disease or contralateral carotid artery disease found on neck CTA or carotid DSA, not detected with the carotid duplex, were also excluded from the study. The Institutional Review Board approved the study.

Study design. Since there are no ultrasound guidelines to classify CCA stenosis, many patients with velocities >150 cm/s in our institution get another study like a CTA for further evaluation. The risk of cancer from CT scan radiation has recently been brought up as a potential serious public health problem. In addition, it is not unusual because of higher head and neck tumors in our patient population that we get consulted for CCA disease by the plastic surgery team planning a free flap using the external carotid artery or its branches as inflow. We elected to perform this study to correlate our vascular laboratory CCA velocities with another imaging modality to help guide the treatment.

We elected to exclude patients with ipsilateral ICA, CCA, or contralateral carotid disease, based on ultrasound or angiogram, to increase the sensitivity of the study. In the study by Slovut et al, the sensitivity of detecting >50% stenosis increased from 64% to 72% when these patients were excluded from the analysis. In addition, since we do not know the exact risk of stroke with CCA stenosis, we elected to choose a 60% stenosis as a first screening point to capture these patients and formulate a treatment plan. We do not necessarily treat asymptomatic 60% CCA stenosis in our practice, but it serves as a good initial screening test and formulates a treatment plan, such as performing close carotid surveillance, performing another imaging modality, or considering carotid intervention. In our practice, we consider on intervening on asymptomatic CCA stenosis >80% or symptomatic CCA stenosis >50%. Knowing that CCA velocities between 150 and 182 cm/s is associated with >50% stenosis, we chose 200 cm/s as the initial screening velocity to increase the sample sensitivity.

Statistics. We performed receiver operating characteristics (ROC) analysis to correlate PSV and end-diastolic velocity (EDV) with angiographic stenosis >60%. We also reported sensitivity, specificity, and positive and negative predictive values. We performed Mann-Whitney U test and chi-squared tests to look at the demographics between the two groups. To achieve statistical significance, we made sure that the control group to experimental group ratio is 3:1. The degree of stenosis was determined by measuring the luminal stenosis in comparison with the proximal normal CCA diameter (Fig 1).

RESULTS

We reviewed 112 charts in the experimental CCA stenosis group; only 25 patients met inclusion and exclusion criteria. Most of these patients had a carotid angiogram (21/25), four patients had a CTA only, and four patients had both. Eighteen (72%) patients had history of a radiated neck, and four (16%) were symptomatic at the time of the presentation. Eighteen patients (72%) were treated with a carotid stent using an embolic protection device, three (12%) underwent carotid endarterectomy, and four patients (16%) were treated medically. The majority, 14 cases, of the CCA stents were performed for asymptomatic stenosis >80%. The remaining four patients were symptomatic at the time of CCA stent, one with CCA >80% stenosis, one between 70% and 79% stenosis, and
two cases with 60% to 69% stenosis. Three hundred eighty-six patients in the control group were reviewed; 74 patients met the criteria for the study. All 74 patients had a neck CTA; the majority were performed to either evaluate the carotid disease or to evaluate for head and neck tumor. Twenty-three patients (31%) had a history of neck radiation. Demographics between the two groups were similar except the CCA stenosis group members were slightly younger in age (Table I). All the patients in both groups were male; most were Caucasian.

We also calculated the sensitivity, specificity, PPV, and NPV for PSV ≥250 cm/s in detecting >60%, 70%, and 80% CCA stenosis (Table II). The same was performed for CCA EDV ≥60 cm/s (Table III). The presence of both PSV ≥250 cm/s and EDV ≥60 cm/s had a 98.7% positive predictive value, and the presence of both PSV <250 cm/s and EDV <60 cm/s had a 100% negative predictive value.

**DISCUSSION**

The use of CT scans has dramatically increased over the past decades. Not having ultrasound consensus to guide management of CCA disease could lead to additional and maybe unnecessary imaging such as CTAs. This results in more radiation and contrast exposure that could have detrimental effects on our patients. In addition, in comparison to ICA disease, the literature is scarce in terms of the progression and the natural history of CCA disease. Only case series exist, which report patients with isolated CCA stenosis becoming symptomatic more frequently, compared with ICA stenosis patients. As a result, we elected to validate the CCA velocities performed in our vascular laboratory with CTA or DSA to guide our treatment. There is only one other article that has looked at validating CCA velocities with CTA by Slovut et al. It is estimated that patients with CCA disease will have tandem lesions;

**Table I. Patients’ demographics**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control group (n = 74)</th>
<th>CCA stenosis group (n = 25)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>68 (49-86)</td>
<td>66 (51-80)</td>
<td>.02 a</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>26 (35)</td>
<td>8 (32)</td>
<td>.78</td>
</tr>
<tr>
<td>Hypertension</td>
<td>49 (66)</td>
<td>16 (60)</td>
<td>.57</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>41 (55)</td>
<td>13 (52)</td>
<td>.77</td>
</tr>
<tr>
<td>Smoking</td>
<td>34 (46)</td>
<td>13 (52)</td>
<td>.60</td>
</tr>
</tbody>
</table>

CCA, Common carotid artery.

*Statistically significant.

Continuous data are presented as median (range) and categoric data as number (%).

**Fig 2.** The receiver operating characteristics (ROC) curve for peak systolic velocity (PSV) ≥250 cm/s in detecting common carotid artery (CCA) stenosis >60%.

**Table II.** The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for peak systolic velocity (PSV) ≥250 cm/s in detecting >60%, 70%, and 80% common carotid artery (CCA) stenosis

<table>
<thead>
<tr>
<th>% Stenosis</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;60</td>
<td>98.7</td>
<td>95.7</td>
<td>98.7</td>
<td>95.7</td>
</tr>
<tr>
<td>&gt;70</td>
<td>96.2</td>
<td>100</td>
<td>100</td>
<td>87</td>
</tr>
<tr>
<td>&gt;80</td>
<td>90.5</td>
<td>100</td>
<td>100</td>
<td>65.2</td>
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rosis.13-15 The acceleration of atherosclerosis because of edo- 
ioniing effects include carotid radiation therapy for head and neck cancer. Radiation 
cludes a large proportion of patients who received neck 
ning such as necrosis, infection, and skin breakdown.19

Table III. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for end-diastolic velocity (EDV) >60 cm/s in detecting >60%, 70%, and 80% common carotid artery (CCA) stenosis

<table>
<thead>
<tr>
<th>% Stenosis</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;60</td>
<td>100</td>
<td>87</td>
<td>96.2</td>
<td>100</td>
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<tr>
<td>&gt;70</td>
<td>98.7</td>
<td>95</td>
<td>98.7</td>
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<tr>
<td>&gt;80</td>
<td>92.9</td>
<td>93.3</td>
<td>98.7</td>
<td>70</td>
</tr>
</tbody>
</table>

it occurs in as many as 25% to 33%.12 In comparison to the Slovut et al validation study, which included patients with ICA and CCA stenosis or occlusion, our study only included patients with isolated CCA disease. They showed that a PSV >182 cm/s was the most accurate with a sensitivity of 64% and specificity of 88% in detecting CCA stenosis ≥50%. The sensitivity increased to 72% when only isolated CCA stenoses were analyzed. They also showed that an EDV >30 cm/s was the most accurate in detecting ≥50% stenosis with a sensitivity of 54% and specificity of 74%. Their cohort included 64 patients, but only 25 patients with a stenosis >60% with a mean age of 65 years, which is similar to our cohort. We found a PSV >250 cm/s to have a sensitivity of 98.7% and specificity of 95.7%. As for EDV >60 cm/s, it carried a sensitivity of 100% and a specificity of 87%. A more striking result, the presence of both PSV ≥250 cm/s and EDV ≥60 cm/s, has a 100% positive predictive value for detecting >60% CCA stenosis. The presence of both PSV <250 cm/s and EDV <60 cm/s was associated with a 98.7% negative predictive value.

One of the potential limitations of our study is that it includes a large proportion of patients who received neck radiation therapy for head and neck cancer. Radiation therapy is known to be associated with injury to the extracranial carotid.13-15 The ionizing effects include carotid stenosis, thrombosis, fibrosis, and accelerated atherosclerosis.16-18 The acceleration of atherosclerosis because of radiation therapy is well known. As a result, we made sure that this patient population is represented in our control group with 31% of the patients with prior history of neck radiation. Toprak et al performed 50 sonographic evaluations on patients pre- and postradiation therapy.16 They concluded that radiation caused new plaque formation and increase in the size of pre-existing plaques.16 Cheng et al performed a prospective study on the effects of radiation on carotid stenosis.17 They found an annual progression rate from less than 50% to 50% or greater stenosis in 14.5% of irradiated arteries compared with only 4.8% on nonirradiated arteries.17 In addition, patients with irradiated necks are at an increased risk of developing symptomatic carotid disease.18 This warrants close surveillance in this patient population and possibly intervention to reduce risk of stroke. Radiation therapy further complicates management by increasing problems related to wound healing such as necrosis, infection, and skin breakdown.19

The majority of the CCA stenosis patients in our cohort that met criteria for intervention were treated with a carotid stent.

Another limitation of this study is its small sample size and the retrospective nature of study. The small sample size was a result of identifying isolated CCA disease. Also, we were surprised by the high sensitivity and specificity of the study. This could be explained by the high PSV and EDV in the majority of the CCA stenosis patients, since most of these patients had a history of neck radiation.

CONCLUSIONS
Little is known about the natural history of CCA disease. There is no velocity criterion to classify CCA disease. In this study, we were able to correlate ≥60% angiographic CCA stenosis with PSV >250 cm/s and EDV >60 cm/s. This is the criteria we currently use in our vascular laboratory to identify patients with CCA disease and guide their treatment accordingly. We encourage other vascular laboratories to validate their CCA velocities or to have a multi-institution validity study to come up with a consensus criterion.

AUTHOR CONTRIBUTIONS
Conception and design: CB
Analysis and interpretation: NB, PK, CB
Data collection: JM, SM, DF, GP, NB, PK, PL, CB
Writing the article: JM, CB
Critical revision of the article: GP, NB, PK, PL, CB
Final approval of the article: CB
Statistical analysis: NB, PK, CB
Obtained funding: Not applicable
Overall responsibility: CB

REFERENCES
DISCUSSION

Dr Ali AbuRahma (Charleston, WVa). As you acknowledged, the sample size is small (ie, 25 patients), which makes the following questions very critical, did you compare the accuracy of CTA and conventional angiography at your institution since you relied on CTA on your correlation, and with small sample size, that could make a huge difference? Why did you choose to analyze patients with 60% stenosis of the common carotid, since most of us do not recommend intervention for these patients — why not above 80% stenosis? Finally, why did you choose a peak systolic velocity of 200 cm/s, below of which patients were excluded? I appreciate your comments.

Dr Jesus M. Matos. In terms of whether we actually looked at CTA vs angiogram, we did not. As you know, studies have looked at both imaging modalities in the past, and both have similar sensitivities and specificities in terms of stenosis correlation with ultrasound stenosis criteria. In terms of why we picked 60% stenosis, we agree with you that we will not intervene on asymptomatic 60% stenosis; however, we believe it will be a good start to screen patients and decide on the next step. Do you order another imaging modality, or do you actually start considering intervening on those patients?

And in terms of the velocities of 200 cm/s, we know that a PSV of 150 to 180 cm/s is associated with 50% stenosis, we decided to increase the velocity to capture stenosis >50%. That is why we used it as our criteria to exclude and include patients.

Dr Gregory Moneta (Portland, Ore). My question is also about the 60% level. Why 60%? Was this a predetermined level of stenosis for evaluation, or is this just where your data gave you the best results?

Dr Matos. No, we actually looked at all the different percentages. Since there is no consensus, and when reviewing the literature, a velocity of 150 to 180 cm/s is associated with ~50% stenosis. As mentioned previously, we will consider intervening on asymptomatic 70% to 80% stenosis or more. We wanted to look at 60% because at this velocity, we could start to consider another imaging modality or considering treatment. We actually use this criterion at our Veterans Affairs Medical Center, and it has correlated well with CTAs since the study was performed.

Dr Mahmoud Malas (Baltimore, Md). I agree with Dr AbuRahma. I actually even challenge operating on asymptomatic patients with greater than 70% stenosis. The main question is: How do we apply your findings clinically? Do you have any suggestions on a threshold for operating on asymptomatic common carotid artery with high-grade stenosis?

Dr Matos. This is a very rare entity, especially to have a series of just isolated common carotid artery stenosis patients. Nobody knows how to manage these patients. Previous published case series have speculated that common carotid artery stenosis tend to have a higher percentage of becoming symptomatic when compared to internal carotid artery stenosis. There are no guidelines for this disease, so we are not proposing when treatment should take place, but we are proposing a noninvasive screening modality.

Dr Michael Silane (Pelham Manor, NY). The morphology of the plaque is important. If the 60% narrowing is along one wall, then it is truly 60% narrowed. But if it is a circumferential lesion and it is 60% narrowed, you really are looking at an 84% cross-sectional area narrowing. Did you take that into account for that?

Dr Matos. No, we did not. We measured the narrowest point in the lesion.