Optimal Peak Systolic Velocity Thresholds for Predicting Internal Carotid Artery Stenosis Greater than or Equal to 50%, 60%, 70%, and 80%

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Background: We aimed to determine the optimal peak systolic velocity (PSV) thresholds for predicting ≥50%, ≥60%, ≥70%, and ≥80% internal carotid artery (ICA) stenosis. *Methods:* Patients who underwent both carotid ultrasonography and cerebral angiography during hospitalization were consecutively and retrospectively enrolled. The degree of ICA stenosis was calculated using the North American Symptomatic Carotid Endarterectomy Trial method on cerebral angiography. The optimal PSV thresholds for predicting ≥50%, ≥60%, ≥70%, and ≥80% ICA stenosis were determined using receiver operating characteristic curves and the Youden index. *Results:* A total of 127 ICAs were analyzed. The optimal PSV thresholds for predicting ≥50%, ≥60%, ≥70%, and ≥80% ICA stenosis were 130 cm/s (sensitivity, 95%; specificity, 85%; positive predictive value [PPV], 75%; negative predictive value [NPV], 97%; overall accuracy, 88%), 160 cm/s (sensitivity, 91%; specificity, 94%; PPV, 83%; NPV, 97%; overall accuracy, 93%), 200 cm/s (sensitivity, 96%; specificity, 95%; PPV, 83%; NPV, 99%; overall accuracy, 95%), and 270 cm/s (sensitivity, 89%; specificity, 94%; PPV, 74%; NPV, 98%; overall accuracy, 94%), respectively. *Conclusions:* The optimal PSV thresholds for predicting ≥50%, ≥60%, ≥70%, and ≥80% ICA stenosis were 130 cm/s, 160 cm/s, 200 cm/s, and 270 cm/s, respectively. All of them had high diagnostic accuracies. **Key Words:** Carotid artery stenosis—carotid ultrasonography—peak systolic velocity—cerebral angiography.

Introduction

Internal carotid artery (ICA) stenosis is one of the major causes of ischemic stroke and transient ischemic attack (TIA). Several randomized controlled trials have proven the effectiveness of carotid endarterectomy (CEA) and carotid artery stenting (CAS) for patients with moderate to severe ICA stenosis. CEA yields a considerable benefit to patients with symptomatic ≥70% ICA stenosis[1] and a small benefit to patients with symptomatic 50%-69% ICA stenosis[2] and asymptomatic ≥60% ICA stenosis.[3] CAS is not inferior to CEA among high-surgical-risk patients with symptomatic ≥50% ICA stenosis and asymptomatic ≥80% ICA stenosis.[4] Therefore, diagnoses of ≥50%, ≥60%, ≥70%, and ≥80% ICA stenosis are important in deciding the treatment strategy.

Conventional cerebral angiography is regarded as the gold standard for assessing ICA stenosis. However, cerebral angiography has a .3%-1% risk of neurologic complications.[5,6] Therefore, noninvasive and convenient carotid ultrasonography is widely used for assessing ICA

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stenosis. Among numerous imaging and Doppler parameters, peak systolic velocity (PSV) is recommended as one of the primary parameters for predicting the degree of ICA stenosis.[7] There is an expert consensus about PSV thresholds for predicting ≥50% and ≥70% ICA stenosis.[7] On the other hand, there is no consensus about PSV thresholds for predicting ≥60% and ≥80% ICA stenosis. We aimed to reassess the optimal PSV thresholds for predicting ≥50% and ≥70% ICA stenosis and determine the optimal PSV thresholds for predicting ≥60% and ≥80% ICA stenosis.

Methods

Patients who were admitted to our departments from January 2011 to December 2014 and underwent both carotid ultrasonography and cerebral angiography during hospitalization were consecutively and retrospectively enrolled. They were identified from our single-center prospective database. Their clinical information was obtained from the database and their electronic medical records.

Carotid ultrasonography was performed by experienced neurologists using a LOGIQ E9 (GE Yokogawa Medical Systems, Hino, Tokyo, Japan) with a 3-8 MHz linear transducer or an HI VISION Preirus (Hitachi Aloka Medical, Mitaka, Tokyo, Japan) with a 4-9 MHz linear transducer. Patients lay in a supine position with their heads turned away from the side being examined and their necks extended during the examination. The ICA was examined on B-mode and color Doppler imaging in longitudinal and transverse planes using anterior, lateral, and posterior approaches. The sample volume was set in the ICA and displayed as linearly as possible to measure PSV in the longitudinal plane. The Doppler angle was kept at <60°. When a stenotic lesion was found in the ICA, the sample volume was thoroughly moved in the lesion to obtain the highest PSV. PSV was bilaterally measured and corrected using the Doppler angle.

Cerebral angiography was performed using the intra-arterial digital subtraction technique with selective catheterization of extracranial arteries via the femoral, brachial, or radial artery route. Biplane angiograms of the ICA were bilaterally obtained. The angiograms were interpreted by a neurologist who was unaware of the results of carotid ultrasonography. The degree of ICA stenosis was calculated using the North American Symptomatic Carotid Endarterectomy Trial (NASCET) method defined as the luminal diameter at the point of maximal stenosis divided by the luminal diameter at the normal part of the ICA.[8] Near-occlusion defined as severe stenosis with delayed ICA filling, the reduced distal lumen, and intracranial collateral vessels was assigned to 95% stenosis according to the NASCET method.[8,9]

Occluded ICAs, ICAs whose degree of stenosis calculated using the NASCET method was <0%, ICAs whose PSV or angiogram was missed, and ICAs with dissection were excluded.

The correlation between PSV and the degree of ICA stenosis calculated using the NASCET method on cerebral angiography was assessed using the Spearman rank correlation coefficient. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), overall accuracy, and the Youden index[10] of various PSV thresholds at intervals of 10 cm/s were calculated using receiver operating characteristic (ROC) curves of PSV for predicting ≥50%, ≥60%, ≥70%, and ≥80% ICA stenosis. The optimal PSV thresholds were determined by maximizing the Youden index. The reanalysis was performed after exclusion of ICAs with contralateral >70% ICA stenosis or occlusion. A P value of <.05 was considered statistically significant. Statistical analyses were performed using JMP 10.0.2 statistical software (SAS Institute Inc., Cary, NC).

Results

A total of 369 patients (111 women, 65 ± 14 years) and their 738 ICAs were enrolled. Two hundred and seventy-two patients had ischemic stroke, 59 patients had TIA, 36 patients had intracerebral hemorrhage, and the remaining 2 patients had ICA dissection. Forty-eight occluded ICAs, 466 ICAs whose degree of stenosis calculated using the NASCET method was <0%, 94 ICAs whose PSV or angiogram was missed, and 3 ICAs with dissection were excluded, and the remaining 127 ICAs were analyzed. Cerebral angiography showed that 87 ICAs had 0%-49% stenosis, 7 ICAs had 50%-59% stenosis, 7 ICAs had 60%-69% stenosis, 8 ICAs had 70%-79% stenosis, and the remaining 18 ICAs had ≥80% stenosis including 8 ICAs with near-occlusion.

The scatter plot of PSV and the degree of ICA stenosis calculated using the NASCET method on cerebral angiography is shown in Figure 1. There was a strong

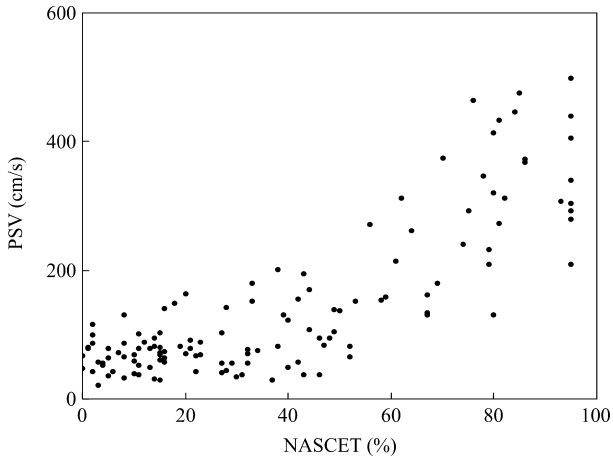

Figure 1. *The scatter plot of PSV and the degree of internal carotid artery stenosis calculated using the NASCET method on cerebral angiography. Abbreviations: NASCET, North American Symptomatic Carotid Endarterectomy Trial; PSV, peak systolic velocity.*