Measurement Conditions of End-Diastolic Ratio of Common Carotid Arteries Alter Diagnostic Ability for Large Artery Intracranial Occlusive Disease

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Background: End-diastolic ratio, calculated by the side-to-side ratio of end-diastolic flow velocities of the common carotid arteries, is an indicator for large artery intracranial occlusive disease. However, the diagnostic ability of end-diastolic ratios derived from different measurement conditions is unclear. *Methods:* End-diastolic ratios were measured twice by single carotid duplex ultrasonography. End-diastolic $ratio_{1st}$ was calculated from separate end-diastolic flow velocities measured during routine assessment. End-diastolic $ratio_{2nd}$ was calculated almost simultaneously without head rotation. For each end-diastolic ratio, the measurement conditions and prediction ability for occlusions of the internal carotid artery or proximal portion of the middle cerebral artery using an established cutoff of 1.4 or greater were compared. *Results:* Two hundred thirty-three patients (147 men, median 67 years) were registered, with available intracranial artery information in 158 patients (67.8%) and occlusions detected in 7 patients (4.4%). End-diastolic $ratio_{1st}$ was significantly higher than end-diastolic $ratio_{2nd}$ (median 1.21 versus 1.08, $P < .001$). Compared with end-diastolic $ratio_{1st}$, end-diastolic $ratio_{2nd}$ had a significantly shorter time interval (median 709 versus 28 seconds, $P < .001$) and smaller pulse rate difference (1.54 ± 5.10 versus $.25 \pm 4.63$ beats per minute, $P = .004$). To predict occlusions, the sensitivity, specificity, and overall accuracy for end-diastolic $ratio_{1st}$ of 1.4 or greater were 85.7%, 70.9%, and 71.5%, respectively, and for end-diastolic $ratio_{2nd}$ of 1.4 or greater were 85.7%, 98.0%, and 97.5%, respectively. End-diastolic $ratio_{2nd}$ had better specificity and overall accuracy than end-diastolic $ratio_{1st}$ ($P < .001$). *Conclusions:* End-diastolic ratio varies with measurement conditions. Combined end-diastolic flow velocities measurement may improve diagnostic ability for large artery intracranial occlusive disease. **Key Words:** Carotid duplex ultrasonography—common carotid artery—end-diastolic ratio—measurement condition—diagnostic ability—large artery intracranial occlusive disease.

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Introduction

Large artery intracranial occlusive disease (LAICOD) is now the most common stroke subtype worldwide, and has a high risk of recurrent stroke.[1,2] Even when asymptomatic, chronic hemodynamic compromise is associated with a high incidence of subsequent ipsilateral ischemic events.[3,4] Duplex ultrasonography is widely used for screening for carotid arterial diseases, and is safe for nearly all patients, without risk of complications, and is cost-effective.[5,6] However, LAICOD is difficult to evaluate directly, as it cannot be visualized from the cervix.

Among the various imaging and Doppler parameters, end-diastolic (ED) ratio, which is calculated by the side-to-side ratio of end-diastolic flow velocities (EDVs) of the common carotid arteries (CCAs), has been used to determine LAICOD. For example, Yasaka et al reported that occlusions of the internal carotid artery (ICA) or proximal portion of the middle cerebral artery (MCA) were distinguished from branch occlusions of the MCA or control subjects by an ED ratio of more than 1.3 in patients with acute ischemic stroke.[7] Similarly, Kimura et al demonstrated that both cardioembolic and atherothrombotic ICA occlusions were distinguished from control subjects by an ED ratio of more than 1.4.[8] The guidelines from the Japan Academy of Neurosonology recommends a cutoff of 1.4 or greater for screening for occlusive lesions of the distal portion of the ICA.[9] However, the diagnostic value of an ED ratio of 1.4 or greater is not well validated, except for patients with acute ischemic stroke. Further, the optimal measurement conditions for the ED ratio are not described in the guidelines.[9] Although EDVs are routinely measured for both CCAs with the head turned sideways, there may be differences in the measurement conditions that lead to variations in the ED ratio. However, the effects of measurement conditions on diagnostic ability of the ED ratio have not been reported.

Herein, we examined the hypothesis that the ED ratio varies with changes in the measurement conditions, and that simultaneous, rather than separate, measurement of EDVs will improve the prediction ability for LAICOD. We tested our hypothesis by measuring the ED ratio twice in a single carotid duplex ultrasonography using different measurement conditions. The aim of the present study was to elucidate the effects of measurement conditions of ED ratio on diagnostic ability for LAICOD.

Materials and Methods

Consecutive patients who received carotid duplex ultrasonography in the Brain Center Unit, Kyushu University Hospital, were retrospectively enrolled between October 1, 2014 and December 31, 2016. An experienced neurologist (KT; registered neurosonographer of the Academy of Neurosonology) performed the examination. Carotid duplex ultrasonography was performed with commercially available equipment (ProSound alpha-10 system, Hitachi, Ltd., Healthcare Co., Tokyo, Japan) with a multifrequency (5.0-13 MHz) linear-array ultrasound transducer (UST-5412, Hitachi, Ltd.) for harmonic imaging. The pulse repetition frequency was 3.9 kHz, and the low-cut filter was set automatically depending on the flow velocity measurement range. Using pulsed wave Doppler, the EDV of the CCA was measured in the longitudinal plane and corrected using the Doppler angle. The sample volume was 2 cm or greater proximal from the bifurcation in the CCA, and the Doppler angle was kept at less than 60°. Pulse rate at EDV measurement was calculated from the time duration of the Doppler waveform.

The timeline for measuring EDVs is shown in Figure 1. During scanning, patients lay in a supine position, with

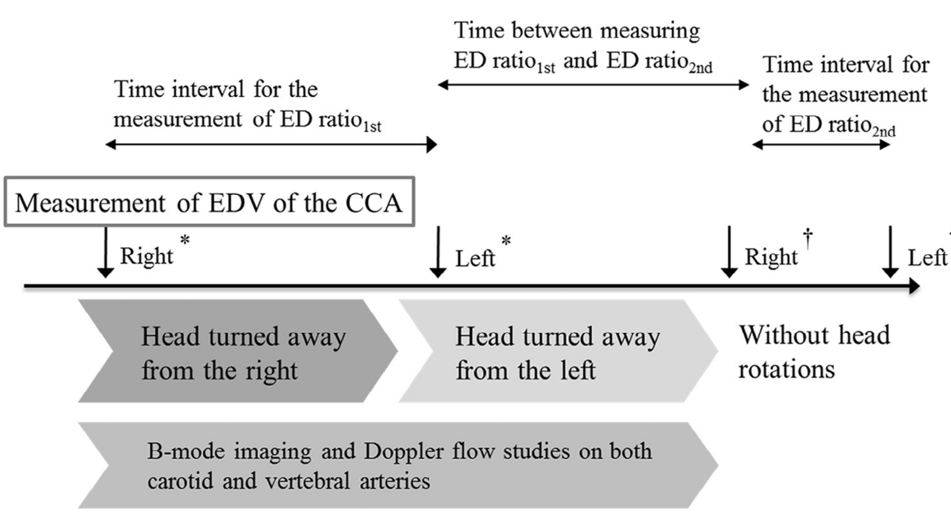

Figure 1. *Timeline for measurement of the 2 end-diastolic (ED) ratios. End-diastolic flow velocity (EDV) from measurements marked "*" were used for calculating ED ratio$_{1st}$. EDV from measurements marked "†" were used for calculating ED ratio$_{2nd}$.*