Case Report

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A Case Study on the Utility of Transcranial Doppler Ultrasound in Acute Stroke Evaluation

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Abstract

The use of transcranial Doppler (TCD) ultrasound in the acute stage of large vessel occlusion diagnosis has, for a number of reasons, not seen widespread adoption. The high temporal fidelity of TCD provides information about the neurovasculature that neurological tests and standard computed tomography (CT) imaging cannot. This presents an opportunity in the early evaluation of patients that can help clinicians make informed decisions. The case study presented here illustrates the complementary information that TCD can provide in a situation where other available tests failed to fully elucidate the underlying pathology.

Keywords

transcranial Doppler ultrasound, large vessel occlusion, stroke, cerebral blood flow velocity, velocity curvature index

Introduction

Despite efforts in education and training, the identification of large vessel occlusions (LVO) in the acute stage is still a significant problem.[1] In a pathology where time to treatment is the most important factor in patient outcome,[2] tools that provide complementary diagnostic information are vitally important.[3] Recently, the potential utility of transcranial Doppler (TCD) ultrasound in the acute setting was presented in Thorpe et al.[4] In addition to the subjective evaluation of the TCD waveform,[5] that work presented an objective quantification of waveform morphology designated velocity curvature index (VCI). Curvature is a mathematical property of space curves which quantifies the degree to which a curve deviates from being straight. VCI is an application of that curvature metric specific to TCD, which quantifies the degree to which a beat morphologically deviates from normal. This case report presents a patient with a particularly difficult diagnosis due to mild symptoms and a delay in seeking treatment, where TCD demonstrated complementary utility to currently employed acute diagnostic methods.

Methods

This patient was observed as part of a large vessel occlusion feasibility study evaluating the utility of TCD in the acute setting. This was conducted at Erlanger Health System's Southeast Regional Stroke Center in Chattanooga, TN, and approved by the University of Tennessee College of Medicine Institutional Review Board (ID: 16-097). The TCD data were collected by a trained technician using 2-MHz handheld ultrasound probes on a DWL Doppler Box-X (DWL Inc, San Juan Capistrano, California). The middle cerebral artery (MCA) was insonated transtemporally. Waveform recordings were made in 30-second intervals across multiple depths between 45 and 60 mm. The segments were then processed using the method described in Thorpe et al[4] to compute the VCI for each segment. The formula used to compute local curvature ($c(t)$) of the cerebral blood flow (CBF) velocity ($v(t)$) is given by

$$c(t) = \frac{v''(t)}{\left(1 + v'(t)^2\right)^{\frac{3}{2}}}.$$

VCI is then computed as the mean of $c(t)$ taken across all time points defining the beat:

$$\mathrm{VCI} = \frac{1}{N_T}\sum_{t=0}^{T} c(t).$$

The TCD data were collected during the time between patient treatment and did not impact patient care. Computed tomography angiography (CTA) examinations were performed

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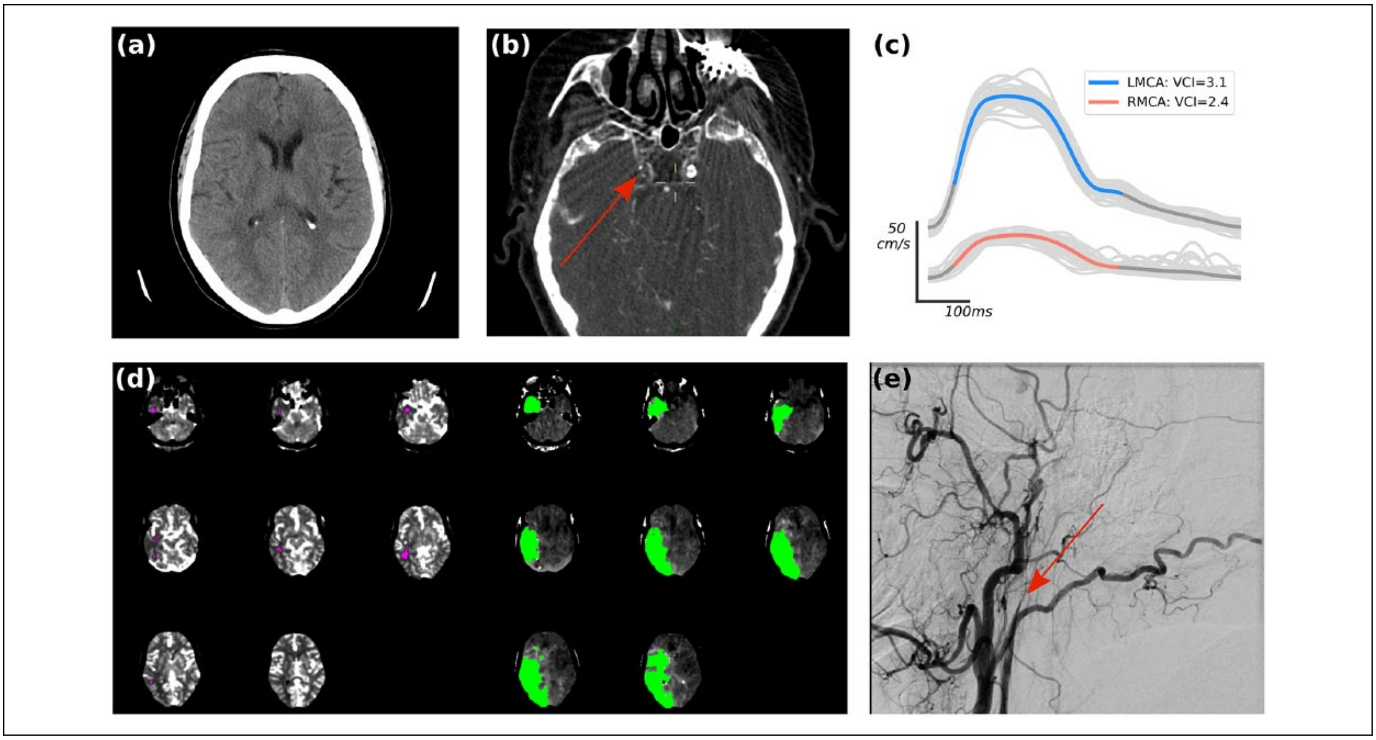

Figure 1. (a) Head CT only suggested a possible abnormality in the caudate region. (b) CTA revealed a severe tapering of the ICA, consistent with an occlusion. (c) Bilateral recordings of the MCA with TCD resulted in a morphological difference between hemispheres quantified by the VCI metric (3.1 LMCA, 2.4 RMCA). (d) CT perfusion imaging revealed a mismatch ratio of 39.7 between hemispheres. (e) The embolic risk was deemed too high during EVT to continue.

Note. CT = computed tomography; CTA = computed tomography angiography; ICA = internal carotid artery; MCA = middle cerebral artery; TCD = transcranial Doppler; VCI = velocity curvature index; LMCA = left middle cerebral artery; RMCA = right middle cerebral artery.

using a GE Lightspeed VCT 64-section multidetector scanner (GE Healthcare, Milwaukee, Wisconsin) with a slice thickness of 0.625 mm, and bolus injection of 70 mL of Omnipaque 350 (GE Healthcare) contrast material (4.0 mL/s). CTA images were reformatted in the coronal and sagittal plane, and 10-mm maximum intensity projection reconstructions were rendered for review.

Case Presentation

A 56-year-old Caucasian female presented to the emergency department with dizziness. The patient reported a symptom onset roughly 22 hours earlier. On arrival, the subject was assessed by the attending neurologist, and a National Institutes of Health Stroke Scale (NIHSS) score of 4 was recorded. A plain head computed tomography (CT) revealed an Alberta Stroke Program Early CT (ASPECT) score of 9—only the caudate region displayed an abnormality (Figure 1(a)). A subsequent CTA revealed rapid tapering of the right cervical internal carotid artery (ICA) consistent with a dissection or occlusion (Figure 1(b)). Despite the near complete blockage of the ICA, there was significant collateral flow present in the CTA imaging. However, CT perfusion imaging identified a volumetric mismatch ratio of 39.7, CBF ($<$30%) volume: 2.6 mL, perfusion (Tmax $<$ 6.0 seconds) volume: 103.3, mismatch volume: 100.7 mL (Figure 1(d)). The TCD analysis revealed a VCI of 2.4 and a mean velocity of 24.8 cm/s on the ipsilateral side and a VCI of 3.1 and mean velocity of 81.3 cm/s, contralaterally (Figure 1(c)). This is consistent with the LVO group identified in Thorpe and colleagues.[4,6] A mechanical thrombectomy was initiated to resolve the ICA occlusion but was aborted by the interventionist due to the embolic risks (the chance of the clot breaking apart was determined to be too high at the time of intervention) (Figure 1(e)). However, 72 hours after discharge, the patient deteriorated to an NIHSS score of 14.

Discussion

In studies of NIHSS threshold, a score greater than 8 is used in the prehospital setting to initiate further multimodal imaging of a suspected stroke.[7] Similarly, ASPECTS grading is often cut-off at 7 in studies of ischemic stroke differentiation and prognosis.[8] Given this, in many settings outside of a comprehensive stroke center, a patient with such a low NIHSS and high ASPECT would not have received a CTA—although its use is increasing, CTA imaging is still not in the NINDS guidelines for all centers.[9] In those instances, using TCD may have provided enough additional insight to justify further imaging. In addition, in this case, mechanical intervention was deemed too risky based on the available information (the TCD results were not available to the clinical team). Although speculative, it is possible that the additional vascular information provided by TCD may have influenced the decision to abort the endovascular treatment. However, the prognostic utility of TCD and VCI has not been fully explored. Regardless, TCD offers a noninvasive measure of blood flow that can provide clinicians with supplemental information in the acute setting.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: All of the authors, except Ruchir Shah, hold stock or stock options in Neural Analytics.

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