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Transcranial Doppler and rCBF Compared in Carotid Endarterectomy

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SUMMARY In eight patients undergoing carotid endarterectomy, the mean velocity and an index of pulse amplitude in the middle cerebral artery were monitored continuously by transcranial doppler ultrasound. rCBF was measured by intracarotid injection of 133 Xenon shortly before and at the time of the carotid artery occlusion, and again a few minutes after carotid flow was reestablished. Comparison of the mean velocity in the MCA and the cortical convexity rCBF revealed relatively little hysteresis in their relationship from prior to after the occlusion. There was however, considerable variability in this relationship among patients. Both the rCBF and the velocity decreased substantially at occlusion in three cases, neither changed very much in three. While in two, though the rCBF decreased significantly, the velocity did not change. The index of pulse amplitude was somewhat more sensitive to the occlusion, decreasing in the seven cases in which it was recorded, including one in which the rCBF did not change.

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THE RECENT PERFECTION by Aaslid of the technique of doppler ultrasound to enable noninvasive examination of the flow through the circle of Willis and its major branches opens great opportunities for advancement of understanding of the pathophysiology of clinical cerebral vascular disease.[1-5] The purpose of this report is to describe preliminary experience with this technique in monitoring the blood flow velocity in the middle cerebral artery during carotid endarterectomy, considering this as a potential monitoring adjunct. The simultaneous monitoring of EEG and serial measurement of rCBF illuminates the quality and significance of information provided by this new tool.

Materials and Methods

Patients: seven men and one woman, all white, aged 52 to 76 had been selected by clinical and angiographic criteria for carotid endarterectomy, which was performed under general anesthesia with isoflurane, without a shunt. The surgery was uncomplicated in all cases. The occlusion time varied from eight to twenty-four minutes.

rCBF was measured by injection of 133 Xenon into the common carotid artery with the external carotid artery occluded, a few minutes prior to the common carotid occlusion, at the moment of occlusion, and a few minutes after release. The clearance of radioactivity from the cerebral convexity was monitored by a single uncollimated two inch diameter NaI scintellation detector and the rCBF determined from the slope of the first two minutes of clearance.[6]

EEG was monitored continuously from scalp electrodes placed according to the international 10–20 system. Arterial blood pressure was monitored via a radial artery catheter.

Transcranial doppler monitoring of the middle cerebral artery flow velocity was performed utilizing the TECA TC 2-64 instrument. This is a range gated pulsed doppler ultrasound system incorporating a frequency analyzer. The transducer operates at 2 MHZ at emitted power of 100 MW/cm_2. We utilized a modified prototype transducer which could be held in place on the patient's head in the temporal region with an elastic bandage. The instrument conventionally displays flow toward the transducer as upward directed pulse waves, while flow away from the transducer, e.g. in the proximal anterior cerebral artery, is displayed as downward directed waves. Only the horizontal (M1) segment of the middle cerebral artery, in addition to the proximal anterior and posterior cerebral arteries, is accessible to this technique.

The blood flow velocity is computed on line by the instrument according to the formula V (CM/SEC) = 0.039 F, where F is the doppler frequency shift in Hz. It is not possible to determine the angle between the ultrasonic beam and the direction of the artery. However if this is presumed to be less than 30 degrees, the error which is a function of the cosine of the angle will be less than 15 percent. Both the mean velocity and the ratio of the systolic peak/diastolic nadir instant velocities are displayed. The latter is an easily observed index of the pulse amplitude which we find is very sensitive to increased resistance proximal to the point of recording. It is systematically related to the more complicated "pulsatility index" described by Lindegaard et al.[5]

Results

The essential relationships between rCBF and the middle cerebral artery mean velocity is depicted in figure 1 and between rCBF and the systolic/diastolic ratio in figure 2. Prior to occlusion the rCBF varied between 17 and 56 cc/100 gm/min, the velocity between 15 and 90 cm/sec, and the systolic/diastolic ratio between 1.5 and 5.3. At occlusion the rCBF decreased in 5 patients and did not change significantly in 3. In one it fell to 6 cc/100 gm/min in association with unilateral flattening of the EEG. The occlusion time in this patient was twelve minutes. He had no disability and a normal EEG at the end of the procedure. In our own surgical experience, the rCBF threshold to EEG

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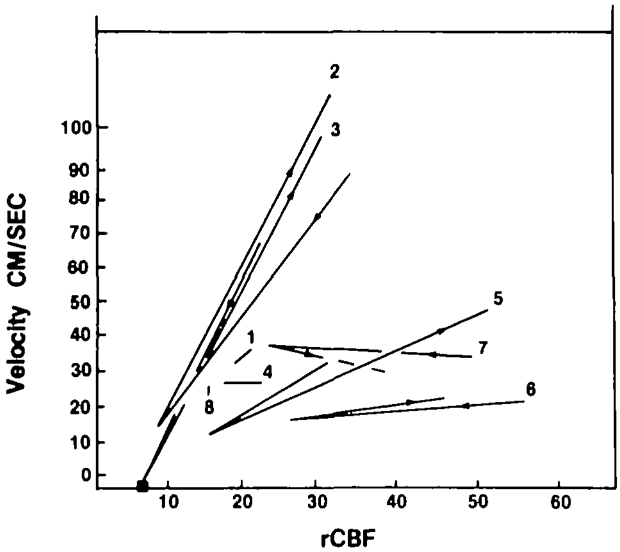

FIGURE 1. *The relationship between mean velocity of flow in the M1 segment of the middle cerebral artery and the Rcbf at the convexity for each of the eight patients. In each case the arrows indicate the sequence of measurements from prior to occlusion → occlusion → following release of occlusion. The solid square indicates the measurement associated with unilateral EEG flattening of the EEG. The continuous record of patient 7 is in Figure 3.*

flattening is about 9 cc/100 g/min with isoflurane anesthesia.[6] In all cases in which the velocity also decreased, it remained relatively constant through the occlusion period except for changes attributable to blood pressure change. The velocity did not change in two patients in whom there was significant rCBF reduction.

For all cases there was relatively little hysteresis in the relationship between rCBF and velocity, i.e. the slope from the relationship prior to occlusion to that at occlusion was not much different from the slope from the relationship at occlusion to that after release of occlusion. There was however considerable variability in the rCBF/velocity relationship among patients.

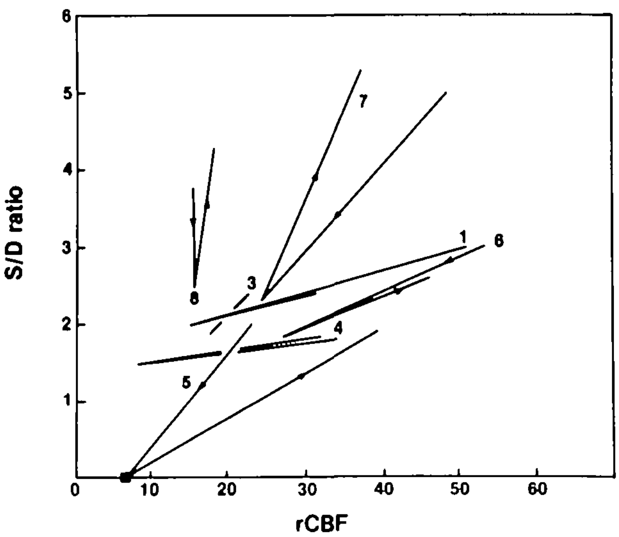

FIGURE 2. *The relationship between the ratio of systolic/diastolic velocities and the Rcbf in seven of the patients. The continuous record of patient 7 is in Figure 4.*

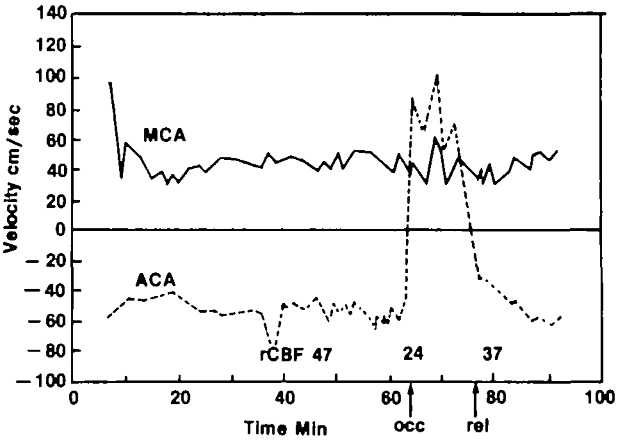

FIGURE 3. *The continuous record of the middle cerebral and anterior cerebral artery velocities in patient 7. Demonstrating reversal of direction of flow in the anterior cerebral artery at occlusion. "Negative" velocity indicates direction of flow away from the skull surface, i.e. the normal direction in the anterior cerebral artery.*

The systolic/diastolic ratio was more sensitive to the occlusion than was the velocity, or even the rCBF, decreasing in all seven cases in which it was recorded. In two cases significant hysteresis was evident, as shown in figure 2.

Figure 3 shows the velocity record from patient 7 in whom, fortuitously, the angle of insonation of the middle cerebral artery was the same as that for the anterior cerebral, so that both could be monitored (the transducer was fixed in place and not accessible during the surgery). The record graphically shows the abrupt appearance of competent collateral rCBF represented by reversal of the anterior cerebral artery direction of flow and changing from 55 cm/sec away from the trans-

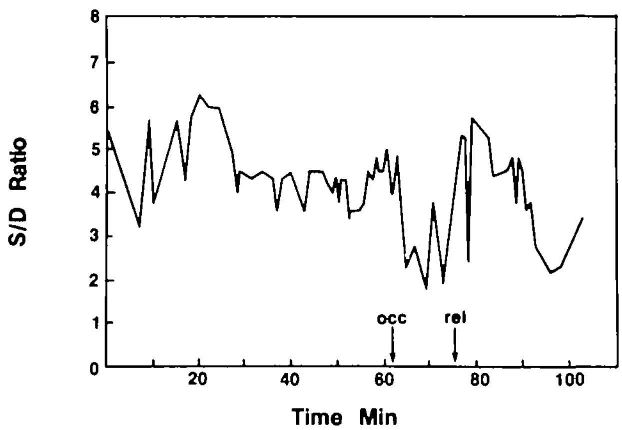

FIGURE 4. *The continuous record of the systolic/diastolic velocity ratio in the middle cerebral artery in patient 7, illustrating its sensitivity to the occlusion notwithstanding the absence of a change in the mean velocity.*

ducer located on the temporal bone to 75 cm/sec toward the transducer, while no significant change occurred in the middle cerebral artery velocity notwithstanding a 50 percent reduction in Rcbf. In Figure 4 is the record of the systolic/diastolic ratio, indicating a reduction in amplitude of the pulse.

Discussion

The variability in the relationship between rCBF and velocity makes it uncertain whether the transcranial doppler can be used as a reliable adjunct to surgical monitoring. More experience will be needed, most importantly with the patients who develop severe rCBF reduction and unilateral loss of EEG activity. At the same time the sensitivity of the systolic/diastolic ratio suggests that it adds useful important information reflecting increased proximal resistance, and probably reduced perfusion pressure.

The general conclusion from these preliminary observations is that the transcranial doppler measurements and the rCBF are qualitatively different indices of the brain circulation. One should not be utilized to validate (or invalidate) the other. The rCBF reflects cortical flow at the cerebral convexity. In that location it should be relatively more sensitive to the leptomeningeal anastomotic collateral circulation. The transcranial doppler measurements are indices of the flow and perfusion pressure in the extraparenchymal proximal middle cerebral artery (and other portions of the circle of Willis), and would, among other things tell more about the lenticulo-striate circulation. Though the quantitative significance of the velocity measurement is limited in the absence of knowledge of the vessel's diameter, the preliminary observation of within patient consistency between rCBF and velocity suggests the possibility of a semiquantitative reliability for serial measurements within the same patient. Its significance appears further enhanced, qualitatively, by the apparently greater sensitivity of the systolic/diastolic ratio to proximal resistance.

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