

EYE TRACKING ABNORMALITIES IN PATIENTS WITH CEREBROVASCULAR DISEASE.*†

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ABSTRACT.

Ten patients with disequilibrium, ataxia, and cerebrovascular abnormalities were studied using computer aided eye tracking and vestibular function tests.

The patients had severe abnormalities in smooth pursuit (decreased gain) and saccade tests (increased delay, decreased accuracy). Optokinetic responses were less affected. The gain of the vestibulo-oculomotor reflex was sometimes affected. Patients with eye tracking abnormalities frequently had symptoms of difficulty reading and watching television. When the lesion was asymmetrical, abnormal eye tracking tests usually pointed to the side of the lesion.

Computer aided eye tracking tests are a useful adjunct to the evaluation of the patient with suspected vascular disease. They help to locate areas of central nervous system dysfunction, and produce an objective measurement of the severity of impairment.

Conversely, when impairment of the smooth pursuit or saccade system is detected in patients being evaluated for disequilibrium, an assessment of the patients' cerebrovascular system should be considered.

Patients may complain of disequilibrium, visual disturbances, and ataxia due to cerebrovascular disease. In order to better quantify the relationship between cerebrovascular disease and impairment of visual and vestibular reflexes, we performed computer aided measurements of eye tracking and vestibulo-oculomotor reflexes on a series of patients undergoing an investigation of their cerebrovascular system.

MATERIALS AND METHODS.

Patients who were scheduled for arteriography, digital subtraction arteriography, or ultrasound imaging of cerebral vessels, who complained of disequilibrium, visual disturbances, or were ataxic, were selected for this study. Their eye movements were recorded with electro-oculography and analyzed on a digital computer.^{1,2} Tests included evaluation of smooth pursuit, saccade and optokinetic reflexes as well as rotational and caloric testing of the vestibulo-oculomotor reflexes. All patients subsequently underwent digital subtraction or conventional arteriography of the cerebral vessels. Most of these patients also underwent CT scan of the head.

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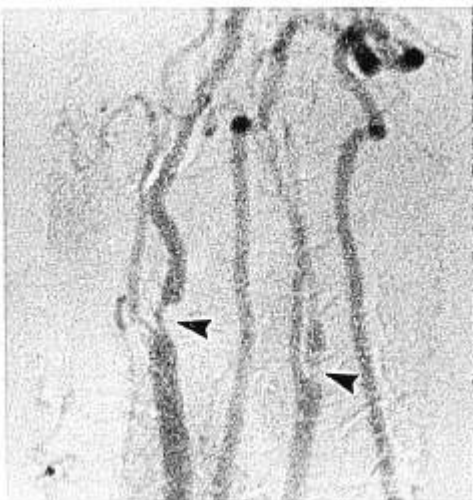


Fig. 1. This is an intravenous digital subtraction arteriogram (DSA) with the patient in RPO projection. This shows a high grade (80%) stenosis of the origin of the right internal carotid artery and an even more severe stenosis of the origin of the left internal carotid artery.

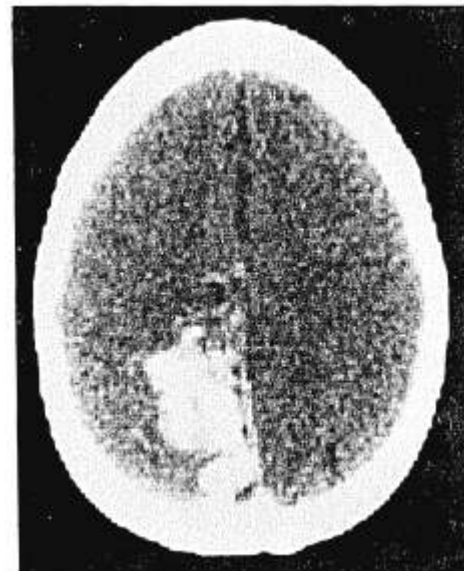


Fig. 2. Post contrast enhanced CT scan through the high supraventricular area. This shows an area of contrast enhancement in the medial left parietal lobe. Adjacent cuts showed serpiginous structures extending to and from this area of enhancement consistent with feeding arteries and draining veins of an arteriovenous malformation.

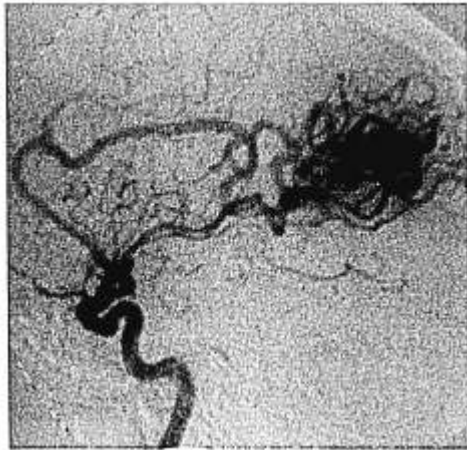


Fig. 3. Lateral view left internal carotid intra-arterial digital subtraction angiogram. This shows large arteriovenous malformation left parietal region supplied by branches of the anterior cerebral and middle cerebral arteries. An injection into the vertebral artery showed supply from branches of the posterior cerebral artery, also.

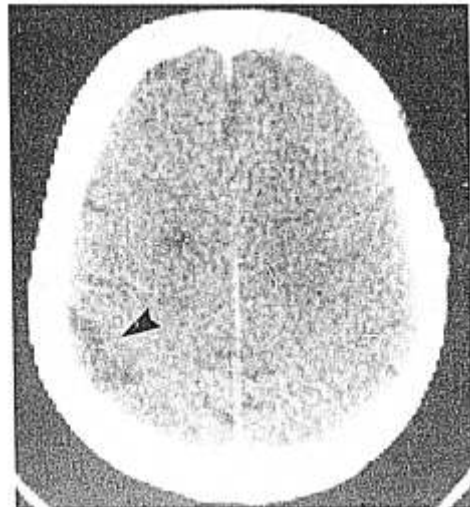


Fig. 4. CT. Two cuts from posterior post enhancement CT scan showing a peripheral low density area in the left parietal region consistent with an old infarct.

CASE REPORTS.

Case 1.

A 70-year-old female had symptoms of ataxia and disequilibrium with intermittent difficulties reading and watching television. Digital subtraction arteriogram showed 80% right internal carotid artery occlusion and almost complete occlusion of the left internal carotid artery (Fig. 1). She had decreased gain on smooth pursuit to left at both .2 and .4 Hz. She had increased saccade delays for right going saccades. She had normal optokinetic responses. Her vestibulo-oculomotor reflexes were reduced both to rotational and caloric stimulation. Optokinetic responses were normal.

Case 2.

A 40-year-old male had symptoms of disequilibrium, difficulty reading, and left sided headache of 7 months duration. CT scan

showed a left parietal lesion which enhanced with contrast (Fig. 2). Arteriogram showed this to be an arteriovenous malformation in the superficial parts of the left occipitoparietal area (Fig. 3). Saccade tests showed abnormally long saccade delays for right going saccades. He had borderline low caloric responses on the left. Smooth pursuit and OKN tests were normal.

Case 3.

A 69-year-old male developed episodes of loss of left sided vision and ataxia. He also developed inability to read. CT scan suggested an old infarct of the left parietal region (Fig. 4). An arteriogram showed almost complete left internal carotid occlusion (Fig. 5). Smooth pursuit was normal at .2 Hz, but was abnormal in both directions at .4 Hz. Saccade velocities were decreased bilaterally with right going saccades most affected. Saccade accuracy was diminished bilaterally, but saccade delay was

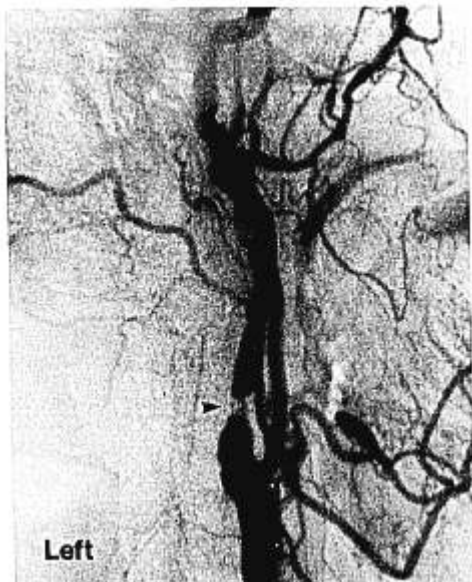


Fig. 5. A lateral view from left common carotid arteriogram shows a high grade (85%) stenosis of the origin of left internal carotid artery.



Fig. 6. A lateral view of left common carotid arteriogram shows an extremely high grade (90%) stenosis of the proximal internal carotid artery just distal to its origin. Right carotid arteriography showed predominant filling of the left anterior cerebral and middle cerebral vessels from the right internal carotid artery.

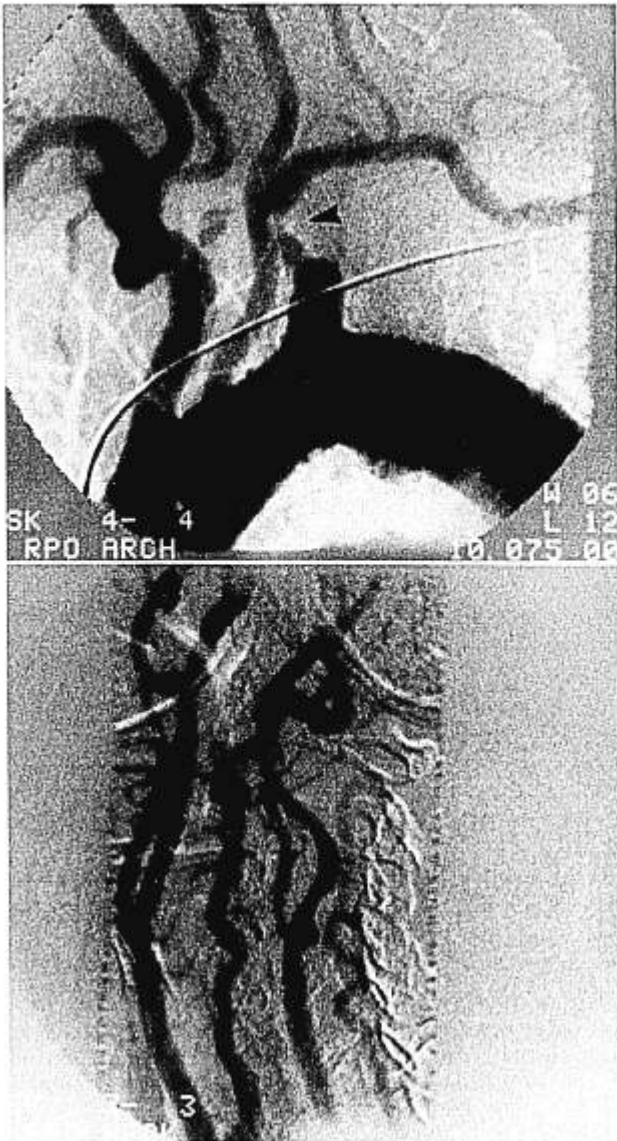


Fig. 7. These are two views from intravenous digital subtraction arteriogram. The top view is an RPO view of the aortic arch. This shows very high grade stenosis of the left subclavian artery just distal to its origin and proximal to the origin of the left vertebral artery. The RPO view of the carotid bifurcations shows a moderate (50 to 60%) stenosis of the origin of the left internal carotid artery with a relatively normal appearing right carotid bifurcation. Note the delayed flow in the left vertebral artery compared to the right vertebral artery due to the subclavian stenosis.

normal. Optokinetic gain (OKN) was diminished in both directions. The patient underwent a left carotid endarterectomy. Three months later, repeat tests showed return to normal values in all tests except smooth pursuit at .4 Hz which had improved but was still slightly outside the normal range.

Case 4.

A 65-year-old male developed disequilibrium, intermittent loss of vision, and ataxia. Arteriography showed almost complete obstruction of the left internal carotid artery (Fig. 6), with the left cerebral circulation filling from the right side through the circle of Willis. The patient had decreased gain for smooth pursuit at .4 Hz in both directions and had severe increase in saccade delay bilaterally, but accuracy and velocity were not affected.

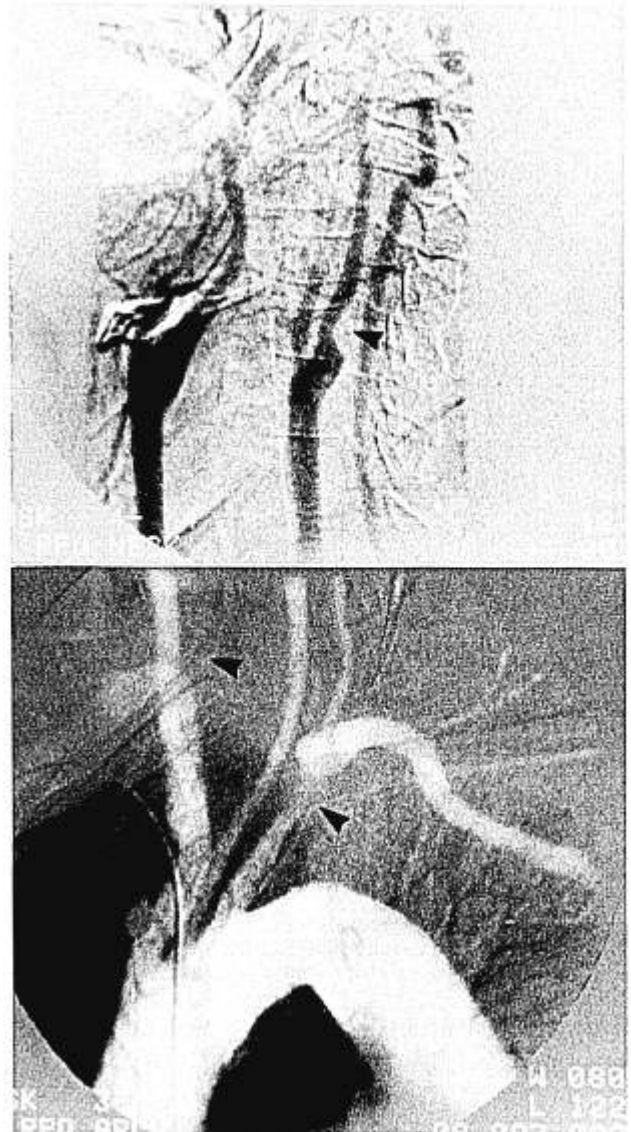


Fig. 8. This is an intravenous digital subtraction arteriogram. The RPO view of the aortic arch (top bottom) shows a high grade stenosis of the subclavian artery proximal to the origin of the vertebral artery and faint filling of a hypoplastic right vertebral artery. The RPO view of the carotid bifurcations (top, bottom) shows a moderate (50 to 60%) stenosis of the left internal carotid artery with relatively normal appearing right carotid bifurcation.

Case 5.

An 87-year-old female complained of episodes of disequilibrium and difficulty reading, lasting 2 weeks, for the last 2 years. Arteriogram showed a severe stenosis of the left subclavian artery proximal to the vertebral artery origin (Fig. 7) and moderate stenosis of the left internal carotid artery. Smooth pursuit tests showed decreased gain at .4 Hz with left going pursuit severely limited. Saccade showed severe increase in saccade delay and marked scatter in saccade accuracy. She also had a decreased caloric response on the right.

Case 6.

A 76-year-old male presented with episodes of disequilibrium, ataxia and difficulty reading. Digital subtraction arteriogram showed stenosis of the left subclavian artery proximal to the origin of the vertebral artery and a hypoplastic right vertebral artery and stenosis of the left internal carotid artery (Fig. 8).



Fig. 9-A. Lateral view of a left common carotid arteriogram shows relatively high grade stenosis of the origin of the internal carotid artery and external carotid artery. There is a relatively high grade stenosis of the carotid siphon.

Smooth pursuit had decreased gain to the left. Saccade had decreased accuracy bilaterally and increased delays to the left. VOR had decreased gain and caloric tests had bilateral decreased responses. Optokinetic responses were normal.

Case 7.

A 75-year-old female experienced progressive disequilibrium and difficulty reading. Arteriogram shows high grade stenosis of left internal carotid artery and fairly extensive atherosclerosis of both carotid siphons and of the left middle cerebral artery (Figs. 9-A and B). Both anterior cerebral arteries filled from the right sided injection via a large anterior communicating artery (Figs. 9-A and B). Smooth pursuit showed decreased gain bilaterally particularly at .4 Hz. Saccade showed increased delays, decreased accuracy, and decreased velocity in both directions. Optokinetic tests showed decreased gain in both directions and caloric tests showed a barely significant left caloric weakness.

Case 8.

A 73-year-old female with severe hypertension was admitted to the hospital with severe disequilibrium, ataxia, and difficulty moving her eyes. Neurological evaluation suggested an acute brain stem stroke. The patient gradually improved. When she was ambulatory with help, eye tracking and vestibular tests, and digital subtraction angiography were performed. The carotid bifurcation showed bilateral atherosclerosis but no significant stenosis. Smooth pursuit showed severe decrease in gain both at .2 and .4 Hz in both directions. Saccade test showed both increased delays and decreased accuracy bilaterally. Optokinetic responses were reduced to the right and normal to the left. VOR was normal. After her hypertension was controlled, her symptoms improved.

Case 9.

A 64-year-old female had an 11-year history of severe hypertension. Approximately 2½ years ago she developed a severe gait

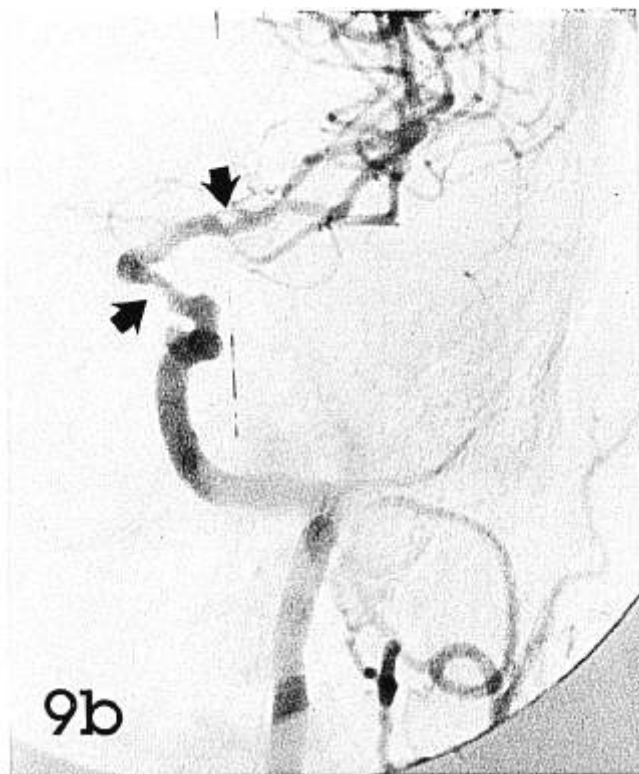


Fig. 9-B. This slightly oblique AP view of the left common carotid injection shows the stenosis in the carotid siphon and also a moderate stenosis in the horizontal portion of the left middle cerebral artery. The horizontal segment of the anterior cerebral artery is hypoplastic.

impairment and was unable to walk. She had intermittent episodes of dysarthria which cleared spontaneously. She gradually improved over a 6 month period then again became worse 2 weeks prior to testing. She developed severe worsening of her gait impairment and difficulty reading. She also has postural vertigo with the left side down. Her blood pressure was 219/130. On examination she appeared to have limitation of horizontal as well as upward gaze. CT scan revealed cerebral atrophy with multiple focal low density areas in both frontal and parietal regions (Fig. 10). This was compatible with multiple small infarcts. A previous angiogram showed arteriosclerotic changes without significant stenosis. Smooth pursuit had marked decrease in gain on .2 and .4 Hz bilaterally. She had severe decrease in saccade velocity accuracy and increase in saccade delay bilaterally. VOR was only slightly decreased and calorics were normal. The patient gradually improved with control of her hypertension and ambulatory rehabilitation.

Case 10.

A 66-year-old male had episodes of vertigo with nausea and vomiting and right sided tinnitus. Between episodes he had no disequilibrium, ataxia, or visual symptoms. Because of a right carotid bruit the patient had an ultrasonic arteriogram which showed over 80% stenosis of the right carotid artery. This was confirmed on contrast arteriography. Smooth pursuit, saccade and OKN were normal. VOR showed decreased gain to left and caloric tests showed a 45% right caloric weakness. Symptoms and findings are summarized in Table I.

DISCUSSION.

Patients are generally referred for cerebrovascular evaluations because of transient ischemic attacks, carotid bruits or neurological changes suggestive of impending cerebrovascular accident. Some of these

unrelated to his cerebrovascular disease or related to end artery disease in the labyrinthine blood supply. Adequate cross circulation at the circle of Willis can apparently perfuse both hemispheres sufficiently to produce normal eye tracking even in significant unilateral carotid obstruction. One patient who was tested before and after carotid endarterectomy had resolution of his saccade abnormalities and improvement in smooth pursuit.

CONCLUSION.

Patients with cerebrovascular disease may develop abnormalities in their eye tracking system. When they do, they have symptoms of disequilibrium and difficulty with visual tasks requiring precise or rapid eye movements. Such patients have increased intervals between the onset of target movement and the onset of eye movement (saccade delay) suggesting an increase in the time required for the visual information to complete its trip through the visual oculomotor reflex pathways. The accuracy and the velocity of saccades is also affected. In most cases of saccade impairment, carotid disease was bilateral and the greatest impairment occurred in saccades away from the side of the major occlusion (contralateral). Patient 2 had a precisely located lesion in the left parietal cortex. He had abnormal saccade delays for right going (contralateral) saccades, a finding similar to those of Baloh³ in man and Lynch⁴ in monkeys. The smooth pursuit system was affected by a decrease in gain usually worse for pursuit in the direction of the greater occlusion (ipsilateral). This agrees with the finding of Baloh.³

Although carotid artery occlusion does not necessarily mean damage to central nervous system structures, this study suggests that when patients with suspected cerebrovascular disease have symptoms of eye tracking dysfunction, they frequently have measurable contralateral saccade abnormalities and ipsilateral pursuit abnormalities on computer aided measurements, suggesting central nervous system impairment. The more commonly used optokinetic test, however, is usually normal. The vestibulo-oculomotor reflex is only involved in more extensive vascular occlusion or when vertebral arteries are also impaired. Postoperative resolution of saccade abnormalities and improvement in smooth pursuit suggests the need for further studies in patients with carotid occlusive disease over time, as well as pre and postoperative measurements. Such information would further clarify our indication for endarterectomy in patients with carotid occlusive disease.

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