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The value of measuring saccadic eye movement in the investigation of non-compressive myelopathy

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SUMMARY Saccadic eye movement recording was performed in 53 patients with non-compressive myelopathy. Twenty one patients (40%) had subclinical abnormalities of saccadic movement, supporting a diagnosis of probable multiple sclerosis. When used in addition to the measurement of visual evoked potentials and brainstem auditory evoked responses, the detection of subclinical abnormalities increased from 40% to 57%. The detection rate of abnormalities by saccadic eye movement recording was equal to that of visual evoked responses, but more than that of brainstem auditory evoked responses. Prolonged latency of gaze was the most common saccadic latency abnormality detected. The majority of saccadic velocity abnormalities could be explained by disease in the medial longitudinal bundle. An unusual finding was that abduction velocity was increased in six patients. It is concluded that the simple measurement of saccadic eye movement is a valuable addition to other ancillary investigations for the diagnosis of multiple sclerosis. It also allows analysis of oculomotor function, commonly disordered in multiple sclerosis, but rarely investigated.

In multiple sclerosis saccadic eye movement is frequently clinically abnormal, with a high incidence of internuclear ophthalmoplegia[1] resulting from involvement of the medial longitudinal bundle.[2] Bipolar recording of the corneo-retinal potential is the simplest of several methods used for measuring saccadic eye movement,[3] and offers no serious technical difficulties. Despite the potential for using such a technique for either confirming the presence of an abnormality suspected clinically or demonstrating subclinical involvement, few studies of patients with multiple sclerosis have been reported.[4-6] Seldom has the measurement of saccadic eye movement been compared with other well established ancillary investigations in multiple sclerosis.[7,8] The greatest potential value of this test is in patients suspected of having multiple sclerosis, in whom the presenting lesion is located outside the brainstem, as in non-compressive myelopathy.[9,10]

A prototype system for measuring saccadic latency and velocity has been developed, and is described in detail elsewhere, together with results from normal subjects.[11] In this study we report results from 53 patients with non-compressive myelopathy and compare the diagnostic usefulness of saccadic eye movement recording (SEMR) with that of visual evoked potentials (VEP) and brainstem auditory evoked responses (BAER). We discuss the patterns of oculomotor abnormality found in a system frequently involved but not commonly investigated in multiple sclerosis.

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Patients and methods

Patients

Fifty three patients with the diagnosis of non-compressive myelopathy were studied. By definition they had evidence of a myelopathy, such as spastic paraparesis or a Brown-Sequard lesion, no demonstrable cord compression on myelography and no definite clinical evidence of disease above the spinal cord. There were 29 females and 24 males, average age 52·1 years (SD 14·0).

Ancillary investigations

(a) Measurement of saccadic latency and velocity[11]

The corneo-retinal potentials generated from both eyes were detected with bipolar electrodes and simultaneously displayed on two twin-channel oscilloscopes, one of which was

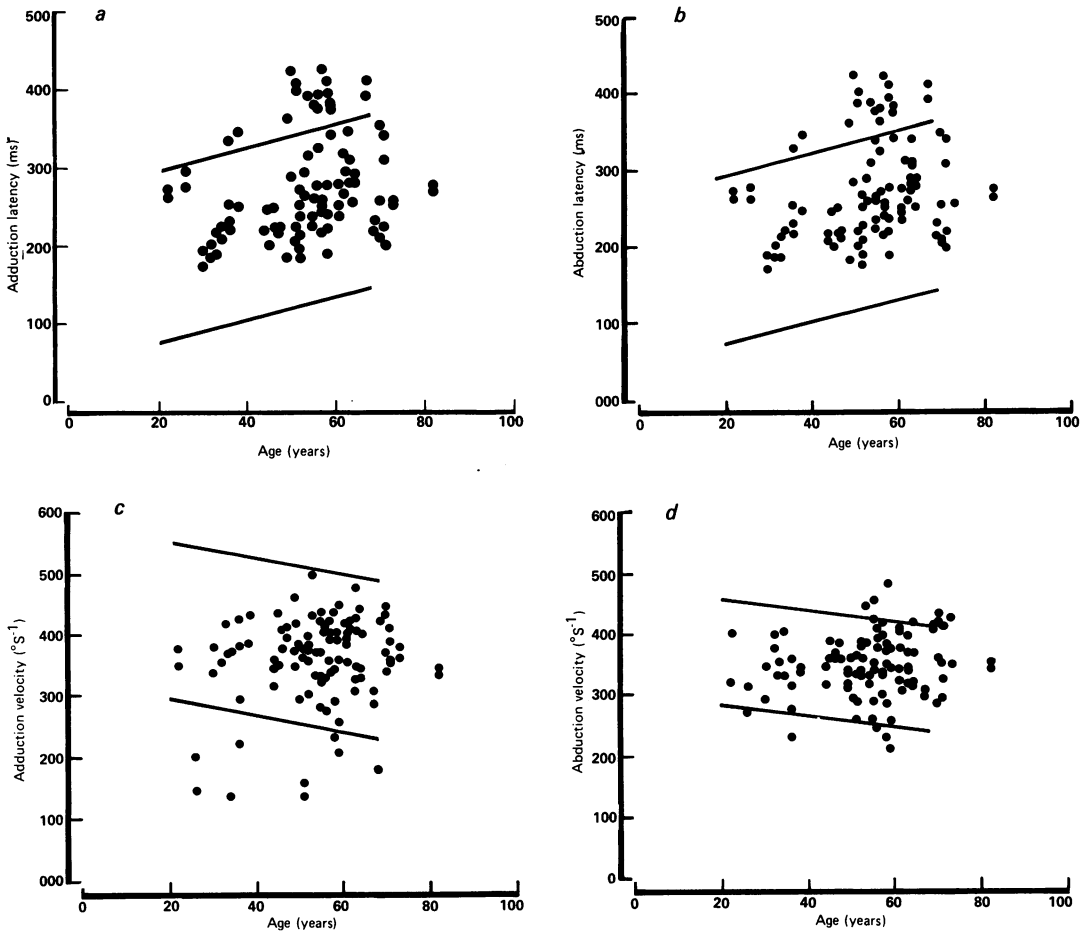

Fig *(a) Adduction latency at various ages in 53 patients with non-compressive myelopathy, in relation to 99% confidence limits for healthy subjects, (b) as (a) for abduction latency, (c) as (a) for abduction velocity, (d) as (a) for abduction velocity.*

photographed. Saccadic latency and velocity were measured off-line from the photographic record with a digitising pad and microcomputer. The subject sat in front of a visual display unit on which a BBC microcomputer produced a randomly moving white spot which appeared in the centre of the screen for a period of 2 to 4 seconds before moving horizontally 20° to the right or to the left of the starting position. An average was taken of the latency and velocity of five saccades in each direction.

Definition of the normal range of saccadic latency and velocity
Our normal values for saccadic latency and velocity have been published previously,[11] derived from 85 subjects (44 males, 41 females) whose average age was 41 years (range 20–68). Both latency and velocity differ for abduction and adduction and correlate with age. In this study the normal ranges for latency and velocity are defined by the 99% confidence intervals about the regressions upon age, as shown in the figure.

(b) Evoked responses
These were measured using standardised techniques. Visual evoked potentials were determined using a checkerboard reversal pattern stimulus, illumination 117 lux, full field 25°, individual checks 48 minutes. The normal range was defined by 99% confidence intervals about separate quadratic regression curves for males and females, weighted to take account of the variability of latency with age.[12]

The brainstem auditory evoked potential was measured using a monoaural click stimulus of 100 μs duration and alternate polarity (70 decibels above hearing level). Recording gain was 5 μV, low frequency filter 300 Hz and high frequency 3 kHz. The interwave latency of waves I, III and V and the ratio of the amplitudes of waves I/V were the only parameters measured.[13]

Statistical methods
The chi-squared test with Yates' correction, and McNemar's test for matched data were used as appropriate.

Results

Saccadic eye movement recording

Individual results for abduction and adduction, latency and velocity in relation to the 99% confidence intervals for healthy subjects are shown in the figure. The results in those patients showing one or more abnormality on electrophysiological testing are summarised in the table.

Abnormalities of saccadic movement were found in 21 patients of whom 14 had only one modality affected (seven latency, seven velocity); the remainder had abnormalities of both. Twelve of 14 abnormalities of saccadic latency could be explained by a disturbance of the gaze mechanism, with prolongation of abduction latency in one eye accompanied by prolongation of adduction latency in the other. Six patients had saccadic latency prolongation for gaze bilaterally, four for right gaze only and two for left gaze (one of whom, in addition, had an increased latency of adduction of the left eye).

Only three of the 14 patients with saccadic velocity abnormalities had gaze paresis alone, one to the right and two to the left. Two patients had reduced velocity of gaze (one to each side) together with reduction of adduction velocity in the ipsilateral eye (the "one and a half" syndrome.[14] An isolated reduction of adduction velocity was present in two patients, and of abduction velocity in one (all on the left). An increased velocity of abduction was found in six patients, two in the right eye and four in the left eye. Increased abduction velocity was not associated with decreased contralateral adduction velocity, which would have been indicative of internuclear ophthalmoplegia. There was an association between reduced velocity and increased latency for the same movement (Chi-squared = 4·36, $p < 0·05$).

Although none of the patients had clinically definite abnormalities of eye movement, several had questionable nystagmus. However, suspicion of nystagmus was not confined to those with abnormal measurements of saccadic eye movements. Three patients were thought to have had internuclear ophthalmoplegia in the past, though there was no clinical evidence of this when they were examined in this study. All three had abnormalities of saccadic eye movement measurements, with reduction of adduction velocity in the direction of gaze which had previously been affected clinically; in addition one patient had a gaze palsy to the opposite side ("one and a half syndrome"), and another had

Table *Results of SEMR (Velocity and latency), VEP, and BAER in the 30 patients in whom one or more test was abnormal*

			SEMR			
Sex	*Age (yr)*	*Clinical signs*	*Velocity*	*Latency*	*VEP*	*BAER*
Female	22				+	
Female	26		+	+	+	+
Female	30	L nyst			+	
Female	32				+	
Male	34	? INO	+			+
Female	56	R INO	+			
Female	38			+		+
Female	49	B nyst		+	+	
Male	50	B nyst	+	+		
Male	51	L INO	+	+	+	+
Female	52				+	+
Male	53	L nyst	+		+	
Male	54			+		
Male	55		+			
Male	55	B nyst		+		
Female	56	L nyst			+	
Male	56		+	+	+	+
Female	57			+		
Male	58		+			
Male	58	L nyst	+	+	+	+
Female	59		+	+	+	
Male	59			+		+
Female	61				+	
Female	63				+	
Female	64					+
Male	67	B nyst		+	+	
Male	70		+	+	+	
Male	70		+			
Female	73		+			
Female	82				+	
Totals (%)			14 (26)	14 (26)	17 (32)	9 (17)
			21 (40)	30 (57)	21 (40)	

(B = bilateral, L = left, R = right, nyst = nystagmus, INO = inter-nuclear ophthalmoplegia, + = a positive test result).

reduced abduction velocity to the same side giving a gaze paresis to that side.

Visual evoked potentials
Seventeen patients had prolongation of P100 latency, 14 as a unilateral finding, eight on the right and six on the left, and three bilaterally. Prolongation of VEP latency was significantly associated with increased latency of saccadic eye movement (Chi-squared = 4·04, $p < 0·05$).

Brainstem auditory evoked responses
Nine patients had abnormalities of the BAER. These were a heterogeneous group: two patients had no wave V, one on the left and the other bilaterally; another two patients had no wave III unilaterally, one on each side. A single patient had both waves III and V missing on the left. Of the remaining patients, in one case the I/V ratio was increased on the left, two other patients had abnormal III–V latencies on the right but in one it was associated with an absent wave V on the left. The final patient had left-sided increases of the III–V latency as well as increase in the I/V ratio. No association was found between abnormal saccadic eye movement recordings and abnormalities of the BAER.

Comparative sensitivity of different tests
Thirty out of a total of 53 (57%) patients with non-compressive myelopathy had one or more abnormal test result (table), thus demonstrating dissemination of pathology and supporting a diagnosis of "clinically probable multiple sclerosis".[15] McNemar's test was used to compare sensitivities: SEMR was more sensitive than BAER (40% v 17%, $p < 0·01$) but no significant differences in sensitivity were found between SEMR and VEP (40% v 32%), or between VEP and BAER (32% v 17%). If only two of the three tests were used, the number of patients with abnormal electrophysiological tests fell from 30 to 29, 23, or 21 for the omission of BAER, VEP or SEMR respectively.

Discussion

Saccadic eye movement recording (SEMR) was of considerable diagnostic value in our study group of patients with non-compressive myelopathy, demonstrating dissemination of pathology in 40%. The detection rate increased from 40%, using VEP and BAER only, to 57% in conjunction with SEMR, which was shown to be more sensitive than BAER. Indeed BAER could have been omitted with little effect on the results, being solely responsible for diagnosis in only one patient.

Knezevic *et al*[7] found that the proportion of patients in whom a diagnosis of multiple sclerosis could be made increased if SEMR was used in conjunction with BAER, although the increase was only marked in the "probable" multiple sclerosis group. As in this study the sensitivity of SEMR was greater than BAER, with 16 cases showing abnormalities with SEMR alone compared with only three with BAER alone. Sanders *et al*[8] recommended the use of both SEMR and BAER to optimise detection of brainstem disease although SEMR detected the larger number of asymptomatic abnormalities.

The test itself is quick and easy to perform, well tolerated by patients, and has good reproducibility.[11] It may be improved by conversion of the analogue signal to digital form which allows on-line analysis by computer.[16,17] Such a system would make it possible to measure other eye movements, such as the velocity of smooth pursuit.

Our results are not exactly comparable with studies of similar patients in which other types of eye movement, such as the velocity of smooth pursuit, have been measured.[5,6] Reulen *et al*[6] claimed that qualitative assessment of the accuracy of saccadic movement was also of value. We were unable to confirm this as we found that abnormalities such as hypometria occurred as frequently in the control population as in our patients. Solingen *et al*[4] also found a mild degree of fixation instability in normal subjects.

The large control population (85) that we used enabled us to recognise the importance in defining abnormal results of the patient's age (but not sex), and the type of movement, whether adduction or abduction. A variety of abnormalities of saccadic eye movement was found. Nearly all latency abnormalities produced a delay in reaction time of gaze to one or both sides rather than delaying individual movements of either eye. The association between VEP abnormalities, which were unilateral in the majority of cases, and latency abnormalities, which were usually for gaze, is in contrast with other reports[6,18] and may indicate that lesions in the primary visual pathway influence saccadic latency.

Velocity abnormalities were heterogeneous. Slowing of adduction (medial longitudinal fasiculus syndrome) was common, but when it was present we did not find that it was usually bilateral, in contrast with clinical observation[2] and other oculographic studies.[19] More frequently it was part of a gaze paresis, and when found bilaterally was associated with a contralateral gaze paresis as in the "one and a half" syndrome.[14] This syndrome has only rarely been reported in multiple sclerosis, and is thought to be caused by unilateral involvement of the dorsal tegmentum of the lower pons.[20] However, abnormalities of the velocity of either adduction or abduction may be found in internuclear ophthalmoplegia,[21,22] pre-

sumably depending on the balance of excitation and inhibition of the medial recti. Disease of the medial longitudinal fasciculus may therefore explain the abnormalities of saccadic velocity observed in this study and it is unnecessary to invoke lesions in other sites.

A most unusual finding was an isolated increase in abduction velocity in six cases. This abnormality is unexplained; it is unlikely to result from disease of the medial longitudinal fasciculus since it was not associated with slowed adduction in the same or the opposite eye. As far as we are aware, increased velocity of abduction has not been reported in multiple sclerosis, but has been described in myaesthenia gravis.[23]

In conclusion, saccadic eye movement recording is a sensitive test for the "second lesion" in multiple sclerosis, reflecting the high incidence of oculomotor abnormalities in this disease. The technique readily enables analysis of clinical and subclinical disorders of eye movement.

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