

Abnormalities of Bell's phenomenon in amyotrophic lateral sclerosis

A clinical and electrophysiological evaluation

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SUMMARY A clinical and electromyographic study of oculomotor function was carried out in a series of 24 patients with amyotrophic lateral sclerosis (ALS). In 15 cases an alteration of Bell's phenomenon was found. In addition, three patients showed some impairment of conjugate ocular motility in the form of upward gaze palsy. All cases had preserved oculocephalic reflexes in the vertical and horizontal planes. On clinical and electromyographic grounds, three degrees of altered Bell's phenomenon are suggested: attenuated (short and unsustained upward displacement of the eyeballs after forced closure of the eyelids), abolished (no upward displacement), and inverted (downward instead of upward displacement of the eyes). These oculomotor alterations were not directly related to the type of ALS at onset of the illness, nor with its duration. However they were correlated with the relative degree of the clinical bilateral pyramidal tract signs at the supraspinal level. The common involvement of the corticogeniculate tract in ALS could explain the unexpectedly high incidence of alteration of Bell's phenomenon found in this disease, but it is non-specific and similar lesions from different causes may also produce it.

Oculomotor abnormalities are not commonly observed in patients with amyotrophic lateral sclerosis (ALS) in contrast with the frequent pathological evidence of mild neuronal damage at the brainstem ocular motor nuclei (Mann and Yates, 1974). Van Bogaert reviewed the subject critically in 1925, and more recently Bonduelle *et al.* (1970) described three cases of partial third nerve palsy and one patient with a combination of palsies of third and fourth cranial nerves from a series of 125 ALS cases. Abnormalities of conjugate-gaze have also been found occasionally in the form of restricted upward displacement with preservation of automatic reflex movements (Strumpell, 1894; Dereux, 1930; Hotz, 1956; Lapresle and Salisachs, 1976). Only once have we found described the isolated impairment of Bell's phenomenon in two out of three patients with ALS (Alvarez, 1977).

From a series of 24 consecutive patients with amyotrophic lateral sclerosis examined for clinical evidence of oculomotor abnormalities, a high incidence of impaired synergistic elevation of the eyeball on forced contraction of the eyelids (Bell's phenomenon) was observed. In addition, several cases were found to have an associated disturbance in the voluntary oculopalpebral movements. An ocular electromyographic (EMG) analysis was performed in some of these to corroborate the clinical findings of a gradual derangement in the physiological Bell's phenomenon in ALS.

Subjects and methods

Eye movements were examined in 24 ALS patients diagnosed by current clinical criteria, including EMG and muscle biopsy studies. According to the manner of onset, six cases were classified as the classic type, 10 cases as progressive bulbar palsy, and eight cases belonged to the lumbar type. The mean duration of the illness at the time of examination was 16.7 months (range 3 to 66 months).

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Those with the bulbar form had a shorter duration (13.3 months) than classical ALS (20.8 months) and the lumbar type (16.6 months). There were 14 males and 10 females, with a mean age of 52.9 years (range 35 to 75 years). Control groups were formed by two patients with the opercular syndrome (Bruyn and Gathier, 1969) and 17 normal volunteers (mean age of 47.3 years; range 27 to 62 years).

Ocular movements were evaluated in each case as follows: (a) gaze on command in all four planes; (b) gaze in pursuit of a moving target; (c) oculocephalic manoeuvre in the vertical and horizontal planes during steady ocular fixation; (d) Bell's phenomenon, examined by asking the patient to perform a sustained contraction of the orbicularis oculi muscles against a resistance, and checking associated upward displacement of the eyeballs. Accordingly, the Bell's phenomenon was evaluated clinically as being normal, attenuated (when there was either a limited or unsustained

upward displacement), abolished (no upward eyeball movement), and inverted (downward eyeball displacement) (Fig. 1). In a few cases a caloric test and optokinetic nystagmus were also examined.

To correlate the various degrees of abnormal Bell's phenomenon encountered with the relative severity of upper (UM) and lower (LM) motor neurone involvement at the bulbopontine and spinal levels, respectively, an arbitrary scale of severity was devised for these clinical parameters, ranging from 0 (normal) to 3 (severe abnormality).

Six ALS patients and one patient with the opercular syndrome, all with clinical evidence of an abnormal Bell's phenomenon, were evaluated electrophysiologically by means of two coaxial needle electrodes inserted in the orbicularis oculi and the rectus superior muscles. Recordings were carried out with the subject in the supine position. Signals were amplified by means of a two-channel Clinical Medelec EMG MS-5 recorder. As control



Fig. 1 Range of clinical abnormalities of Bell's phenomenon in ALS. *Right: abolished Bell's phenomenon. The voluntary upward displacement (A) and the upward oculocephalic reflex (B) were preserved while ocular displacement of Bell's phenomenon is absent (C). Middle: attenuated Bell's phenomenon. The eyeballs show a normal upward movement with the oculocephalic manoeuvre (A). During forceful eyelid closure upward displacement may be seen initially (B), followed by an early ocular falling (C). Left: inverted Bell's phenomenon. Although the patient has a normal voluntary upward gaze (A), eyeballs show a downward movement related to closing the eyes (B).*

subjects, two patients with dystrophia myotonica and one with idiopathic facial palsy, not showing impairment of Bell's phenomenon, were examined in a similar way.

Quantitative data were submitted to statistical analysis by application of Student's *t* test. Results were regarded as statistically significant when *P* values were less than 0.05.

Results

The oculomotor disorders found in the 24 patients with amyotrophic lateral sclerosis are summarised in Table 1. Three cases had a severe limitation of voluntary upward movements. This was associated in two with a moderate impairment of saccadic fixation on lateral gaze, together with spasmodic fixation and an inability to close their eyes voluntarily with preservation of spontaneous and reflex blinking (Fig. 2). Fifteen patients, including the three mentioned above, showed an impaired Bell's phenomenon of varying degree.

According to the classification outlined, three cases had an attenuated Bell's phenomenon, in 10 cases it was abolished, and in two it was inverted. Oculocephalic reflexes were preserved in every instance, as were the oculovestibular (caloric) reflexes and the optokinetic nystagmus in the few tested cases.

A mild limitation of upward gaze was found in the two patients with opercular syndrome who also showed an abolished Bell's phenomenon. Bell's phenomenon was elicited without difficulty in all healthy control subjects.

The severity of involvement of upper (UM) and lower (LM) motor neurones at the bulbopontine and spinal levels is detailed in Table 2. The severity of clinical damage for UM and LM at the bulbar level was significantly greater (2.3 and 1.36, respectively) in patients with impaired Bell's phenomenon when compared with those in whom it was preserved (0.5 and 0.46, respectively), the difference reaching statistical significance at the $P < 0.01$ and $P < 0.05$ levels (Table 3). The same

Table 1 Oculomotor disorders in 24 cases of amyotrophic lateral sclerosis

Case	Type of ALS	Duration (months)	Bell's phenomenon	Voluntary gaze on command	Pursuit movements	Oculocephalic manoeuvre	Other oculomotor disorders
1	CMR Classical	7	Normal	Normal	Normal	Normal	No
2	JRN Classical	21+	Abolished	Normal	Normal	Normal	No
3	LPP Classical	13	Attenuated	Normal	Normal	Normal	No
4	ASS Classical	12	Attenuated	Normal	Normal	Normal	No
5	FAO Classical	5	Abolished	Impaired upward and lateral (left)	Normal	Normal	Paralysis of voluntary eyelid occlusion. Spasmodic fixation
6	CJE Classical	8	Normal	Normal	Normal	Normal	No
7	ACE Lumbar	29	Normal	Normal	Normal	—	—
8	MPM Lumbar	66+	Abolished	Impaired upward	Normal	Normal	No
9	CGG Lumbar	5	Normal	Normal	Normal	Normal	No
10	MRR Lumbar	7	Normal	Normal	Normal	Normal	No
11	ABG Lumbar	12	Abolished	Normal	Normal	Normal	No
12	JMV Lumbar	14	Normal	Normal	Normal	—	—
13	MAN Lumbar	49+	Abolished	Normal	Normal	Normal	No
14	JLZ Lumbar	18	Normal	Normal	Normal	Normal	No
15	FAV Progressive bulbar palsy	16	Normal	Normal	Normal	Normal	No
16	BCG Progressive bulbar palsy	23	Abolished	Impaired upward and lateral	Normal	Overactive	Paralysis of voluntary eyelid occlusion. Spasmodic fixation
17	OAG Progressive bulbar palsy	7	Normal	Normal	Normal	Normal	No
18	PPT Progressive bulbar palsy	11	Attenuated	Normal	Normal	Normal	No
19	JSC Progressive bulbar palsy	6	Abolished	Normal	Normal	—	—
20	MIA Progressive bulbar palsy	23	Abolished	Normal	Normal	Normal	No
21	TMN Progressive bulbar palsy	18	Inverted	Normal	Normal	Normal	No
22	CTR Progressive bulbar palsy	8	Normal	Normal	Normal	Normal	No
23	GAE Progressive bulbar palsy	17+	Abolished	Normal	Normal	Normal	No
24	JCP Progressive bulbar palsy	22	Inverted	Normal	Normal	Normal	No
25	GAE Progressive bulbar palsy	7	Abolished	Normal	Normal	Normal	No
26	JCP Progressive bulbar palsy	3	Normal	Normal	Normal	—	—

+ = follow-up examination; — = not examined.



Fig. 2 Case 15. Supranuclear palsy of eyelid occlusion and abolished Bell's phenomenon (D). Reflex blinking is normal (A). Pathological laughter (B) and upward gaze palsy (C) may also be observed in the same case.

scoring for the limbs did not reach statistical significance.

Pseudobulbar (bulbar upper motor neurone damage) scoring also had a direct correlation with the presence of an abnormal Bell's phenomenon, irrespective of the type of ALS at onset (Table 4), but not with the severity of LM in the progressive bulbar palsy group ($P > 0.05$). On the other hand, some relationship could be found between the degree of impairment of Bell's phenomenon and the severity of pseudobulbar palsy signs. So, even when there was no difference between the abolished (2.55) and the inverted (2.25) abnormal types of the phenomenon, the lowest scoring belonged to the attenuated Bell's phenomenon (1.66), which probably represented the mildest degree of abnormality.

All three cases showing disturbed oculopalpebral voluntary movements had clinical evidence of severe pseudobulbar damage, two cases being quadriparetic. In all of these cases Bell's phenomenon was absent.

Electrophysiologically, the normal Bell's

phenomenon consists in the activation of the orbicularis oculorum muscles after eyelid occlusion, with an immediate increase in basal activity of recti superiores (Björk, 1954). Soon after cessation of voluntary contraction, the overactivity of the latter disappears and the basal activity of the ocular muscles is recovered (Fig. 3). The abolished Bell's phenomenon is represented in the EMG as an absence of the physiological reinforcement of rectus superior activity during eyelid occlusion (Fig. 4). The attenuated type has either a small overactivity of rectus superior or, more frequently, a rapid decay before completion of forceful eyelid occlusion (Fig. 5). Finally, the inverted Bell's phenomenon is represented electrically by a decrease in the basal activity of rectus superior at the time of voluntary activation of the orbicularis oculi muscle (Fig. 6).

Discussion

An unexpectedly high incidence of abnormal Bell's phenomenon was the most striking feature found

Table 2 Peripheral and upper motor neurone involvement at bulbar and spinal levels in 24 cases of amyotrophic lateral sclerosis

Case	Bell's phenomenon	Bulbar motor involvement		Limb motor involvement		Other motor signs
		Lower motor neurone	Upper motor neurone	Lower motor neurone	Upper motor neurone	
1 CMR	Normal	+ <	+	+	+	No
	Abolished	++ <	+++ <	++	++	No
2 JRN	Attenuated	+	++	+++	++	No
3 LPP	Attenuated	0	+	+++	+	No
4 ASS	Abolished	++	+++	+++	+	Cervical and limbs rigidity
5 FAO	Normal	0	0	+	++	No
6 CJE	Normal	0	0	+	+++	No
	Abolished	+ <	++	++	+++	Spastic quadriplegia
7 ACE	Normal	0	0	+	++	No
8 MPM	Normal	0	0	+++	++	No
9 CGG	Abolished	+	++	++	++	No
10 MRR	Normal	+ <	+	+++	+	No
11 ABG	Normal	+ <	+ <	+++	++	No
12 JMV	Normal	0	0	++	+	No
	Abolished	+	+++	+++	++	No
13 MAN	Normal	0	0	++	++	No
14 JLZ	Normal	0	0	+	++	No
15 FAV	Abolished	+ <	+++	+ <	+++	Cervical spasticity; spastic quadriplegia
16 BCG	Normal	+++	+	+	+	No
17 OAG	Attenuated	+	++	++	++	No
18 PPT	Abolished	+++ <	+++	+	++	No
19 JSC	Abolished	+++	++	+	+	No
20 MIA	Inverted	+++	+++ <	++	+ <	No
21 TMN	Normal	+	++	+	+	No
	Abolished	++	+++	++	++	No
22 CTR	Inverted	++	+++	+++	+++	No
23 GAE	Abolished	++	++	+ <	++	No
24 JCP	Normal	0	0	+	++	No

0=no abnormality; + =mild abnormality; ++ =moderate abnormality; +++ =marked abnormality; < =intermediate between consecutive grades.

Table 3 Bulbar and spinal motor signs in amyotrophic lateral sclerosis related to Bell's phenomenon

Bell's phenomenon	Bulbar motor signs*		Limb motor signs*	
	LM	UM	LM	UM
Impaired (15 cases)**	1.36††	2.3†	2	1.9
Normal (13 cases)**	0.46††	0.5†	1.73	1.61

* = mean intensity (scale between 0 and 3); LM = lower motorneurone; ** = four cases included in both groups; UM = upper motorneurone; † = P < 0.01 (t = 8.18); †† = P < 0.05 (t = 2.72).

Table 4 Severity of bulbar motor signs and Bell's phenomenon

Type of ALS	Impairment of Bell's phenomenon		Normal Bell's phenomenon	
	BLM	BUM	BLM	BUM
Progressive bulbar palsy	1.87*	2.37**	1.66*	1.3**
Classical	0.87	2.1	0	0.3
Lumbar	1	2.5	0.14	0.2

BLM = Bulbar lower motorneurone signs; BUM = Bulbar upper motorneurone signs; * = P > 0.05 (t = 0.32); ** = P < 0.05 (t = 2.77).

when examining the oculomotor function in a series of 24 patients with ALS. Several degrees of impairment were suggested on clinical grounds, ranging from a short, unsustained upward dis-

placement of the eyeballs after forceful attempted closure of the eyelids, to abolition of the Bell's phenomenon, or even a downward, instead of upward, displacement of the eyes (here called inverted Bell's phenomenon). This range of abnormalities has been substantiated by ocular electromyography in all six cases so examined from the total 15 ALS cases with altered Bell's phenomenon. In 12 of them the altered sign was an isolated finding, so far representing the only abnormal oculomotor disturbance in ALS patients. This fails to confirm the previous statements that this ocular synkinetic movement is lost only in connection with severe supranuclear gaze disturbances (Bender, 1969; Cogan, 1970; Corin *et al.*, 1972), but rather suggests that it may become impaired in a highly selective manner. Some 10% of the normal healthy population may have no Bell's phenomenon (Bender, 1960), although we were unable to confirm this in our own normal control group where the phenomenon was constantly found to be normal. Accordingly, the incidence of 62.5% of impaired Bell's phenomenon found in our ALS series seems to be of significance.

The electrophysiological analysis of ocular muscles appeared to be an accurate way of con-

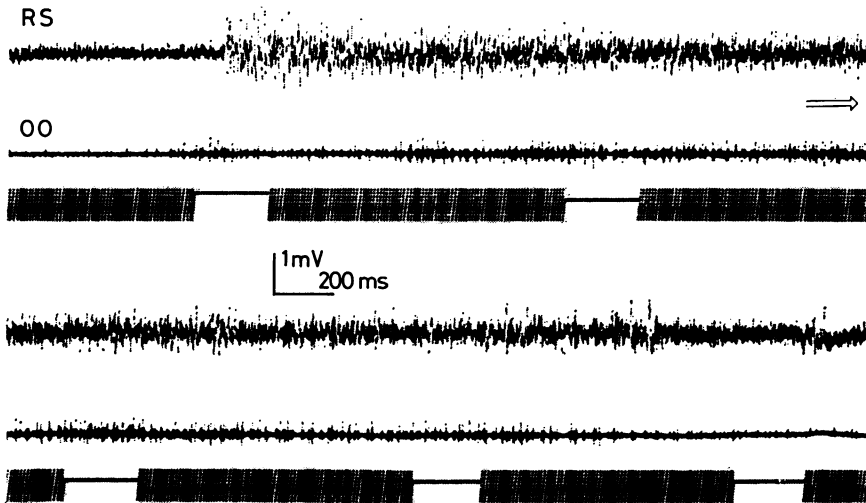


Fig. 3 *Electromyographic analysis of normal Bell's phenomenon. Simultaneous recordings from the rectus superior (RS) and orbicularis oculi (OO) muscles are shown in a case of myotonic dystrophy. During eyelid occlusion overactivity from the RS is seen to start later than OO muscle contraction, and to last until a little while after OO relaxation.*

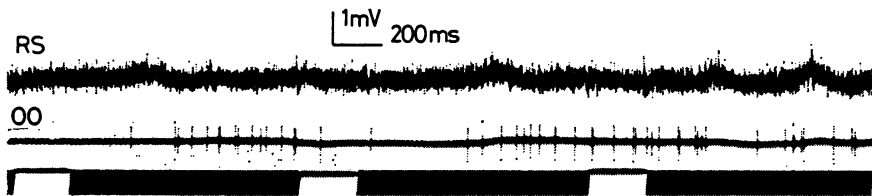


Fig. 4 *Ocular EMG in abolished Bell's phenomenon. There is no overactivity of rectus superior on closing the eyes. Weak voluntary contraction can be seen in this case.*

firming the range of abnormalities clinically observed in the Bell's phenomenon. For these purposes, the advantages of ocular EMG over the electro-oculogram are clear, since it was possible to obtain selective recordings from individual ocular muscles. For instance, the brief upward displacement of the eyeballs (which we define as attenuated Bell's phenomenon) was readily detected electromyographically as a rapid decay of the rectus superior muscle overactivity during voluntary contraction of orbicularis oculi, well before the eyelid occlusion was completed.

There was a clear correlation between abnormalities of Bell's phenomenon in any degree and the severity of involvement of the pyramidal tracts bilaterally at the supraspinal level. On the other hand, no correlation could be found with the type at onset of ALS in the individual patient, nor with the severity of lower motor neurone damage at the brainstem. Indeed, the preservation

of oculocephalic reflexes in the vertical plane in our patients points against a peripheral mechanism, in spite of the occasional pathological evidence of mild abnormalities of the neurones of the oculomotor nuclei (Mann and Yates, 1974). In this regard, it is of interest that our two cases with opercular syndrome secondary to bilateral infarction of the motor cortex, had a central type of facial diplegia together with vertical gaze palsy and abolished Bell's phenomenon, a finding similar to the reports of Alajouanine and Thurel (1933) and Bruyn and Gathier (1969). In one of these patients we observed identical EMG ocular findings to the ALS cases. This further suggests that, regardless of the aetiology, bilateral damage of the corticogeniculate tract is followed by impairment of Bell's phenomenon.

In addition to abnormal Bell's phenomenon of varying severity, three patients had an upward gaze palsy. In two of them a rather more com-

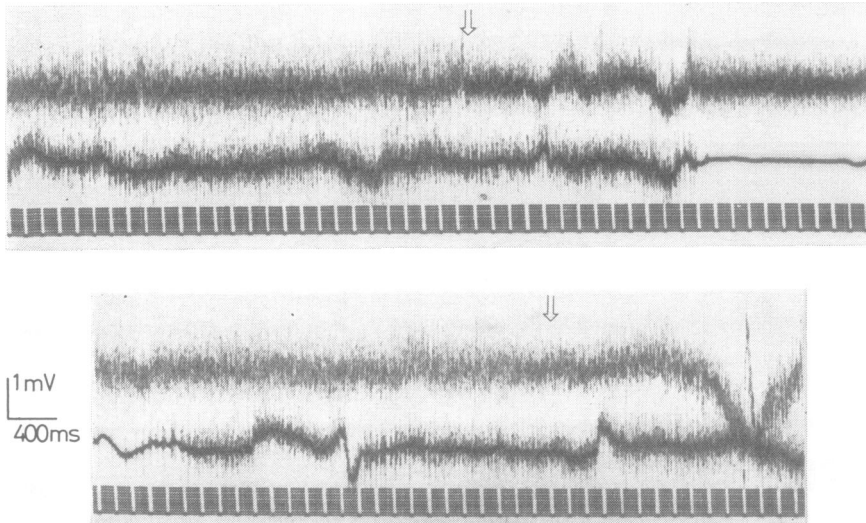


Fig. 5 Ocular EMG in attenuated Bell's phenomenon. In both examples overactivity in rectus superior is less marked than normally and decays before the completion of orbicularis contraction (arrows). Rectus superior in upper traces; orbicularis oculi in lower traces.

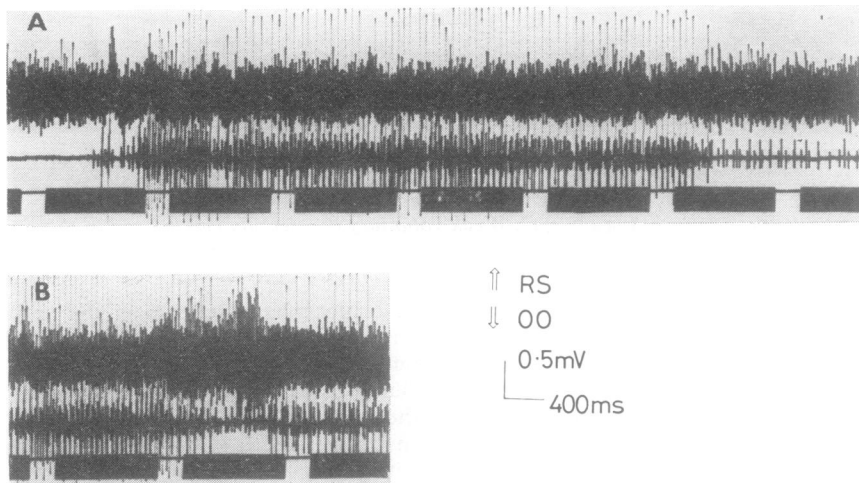


Fig. 6 Ocular EMG in inverted Bell's phenomenon. *A*: contraction of the orbicularis oculi (lower trace) induces a decrease of rectus superior basal activity (upper trace). *B*: inversely, relaxation of the orbicularis oculi is accompanied by an increase in rectus superior activity.

plex disturbed oculomotor function was found, with absent voluntary saccadic eye movements in the horizontal plane and spasmodic gaze fixation. Both patients were also unable to close their eyes voluntarily, in spite of preserved spontaneous and reflex blinking.

The oculocephalic manoeuvre readily elicited brisk doll's eye movements in both vertical and

horizontal planes, indicating the supranuclear nature of the gaze disturbance. All three cases suffered a severe pseudobulbar palsy, two cases being quadriparetic. Consequently, it appears appropriate to relate this form of disturbed oculomotor function in ALS to severe corticospinal tract degeneration. This dissociated paralysis of conjugate eye movements, sometimes referred to

as "pseudo-ophthalmoplegia" (Cogan, 1970), when reported in connection with ALS was always in cases associated with a severe degree of pseudobulbar palsy (Strumpell, 1894; Dereux, 1930; Hotz, 1956; Lapresle and Salisachs, 1976).

Abnormalities of vertical eyes movements have been observed in different experimental and pathological conditions involving the cerebral cortex. Unilateral hemispheric lesions induced an ipsilateral deviation of the eyes bearing some transitory upward component (Cogan, 1970). Longstanding unilateral lesions of the cerebral cortex do not impair elevation movements of the eyes, but during forced eyelid occlusion the eyes deviate in an oblique direction towards the hemiplegic side (Cogan, 1948; Troost *et al.*, 1972). Spiller (1905) stated that bilateral cortical lesions abolished upward eye movements, and there are extensive experimental data regarding conjugate ocular displacement in the vertical plane induced by simultaneous bilateral stimulation of the precentral cortex (Bender, 1960).

Alajouanine and Thurel (1931) were probably the first to relate disturbed vertical gaze function to bilateral supraspinal pyramidal tract damage. Most of their observations were made on patients with pseudobulbar palsy of vascular origin and with postencephalitic Parkinsonism. They also noted vertical gaze palsy associated with preserved oculocephalic reflexes and absence of Bell's phenomenon. In their series, one case was suffering from ALS and had been reported previously by Dereux (1930) as an example of Parinaud's syndrome in ALS. Contrary to this statement, Alajouanine and Thurel (1931) attributed the pathogenesis of this case to involvement of the pyramidal tract bilaterally.

Experimental lesions in the pretectal and posterior commissure regions abolished both upward eye movements and Bell's phenomenon (Pasik *et al.*, 1969), but this occurrence was far from constant. On the other hand, isolated lesions of these same structures in man may not modify the Bell's phenomenon (Alajouanine and Thurel, 1931; Bender, 1960; Lessell, 1975). This is unlikely to explain our findings in ALS as the pretectum and posterior commissure regions are not involved pathologically in this condition (Friedman and Freedman, 1950; Brownell *et al.*, 1970; Castaigne *et al.*, 1972; Bonduelle, 1975).

Fibres originating from the oculomotor frontal cortex run through the anterior limb of the internal capsule in proximity to the genu, and in close relationship with supranuclear facial fibres (Sachsenweger, 1969; Cogan, 1970; Laget, 1976). Fibres for upward gaze traverse the pretectum and

posterior commissure (Pasik *et al.*, 1969), where they may connect (Szentagothai, 1950), before reaching more caudal regions at the brainstem. Fibres separating from the main oculomotor pathway probably join the rectus superior nuclei while maintaining a connection with the facial nerve motor nucleus, holding the anatomical basis for the synergistic upward movement of the eyeballs which accompanies forced eyelid occlusion. It is plausible that selective involvement of these fibres might occur in ALS accompanying the corticospinal tract degeneration found in this illness.

A spectrum of supranuclear ocular motor disorders, ranging from an altered Bell's phenomenon of varying severity to impairment of upward gaze and spasmodic fixation can be observed in connection with bilateral damage to the corticogeniculate tract. This pathway is commonly involved in ALS, and may well explain the high relative incidence of these abnormalities, but this is non-specific and lesions from other causes may be found as well. Corticogeniculate lesions of mild degree may produce a disturbance of Bell's phenomenon as an isolated oculomotor impairment. Massive degeneration of the corticogeniculate tracts likely to accompany a severe supranuclear palsy of the pontine and bulbar muscles can be followed by impaired gaze movements of the vertical and horizontal plane with preserved ocular reflexes elicited by vestibular or retinal stimulation.

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