Acquired pendular nystagmus: its characteristics, localising value and pathophysiology

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SUMMARY Investigations were made of 16 patients with acquired pendular nystagmus and a further 32 cases reported in the literature were reviewed. Amongst our own patients two thirds had multiple sclerosis, almost one third a cerebrovascular accident or angioma and two had optic atrophy with squint. The nystagmus took forms which could be monocular or binocular, conjugate or disconjugate and could involve movements about single or multiple axes. Spectral analysis was used to characterise the amplitude and frequency of the movements and to estimate the degree of relationship (coherence) between movements of the two eyes or between movements of one eye about several axes. The oscillations ranged in frequency from 2·5 Hz to 6 Hz, with typical amplitudes between 3° and 5°. In a given patient all oscillations, regardless of plane, were highly synchronised. Somatic tremors of the upper limb, face and palate associated with the nystagmus were often at similar frequencies to the eye movement. The other ocular signs common to all our patients were the presence of squint with failure of convergence. Most patients also had skew deviation or internuclear ophthalmoplegia or both. The major oculomotor systems, that is, saccades, pursuit, optokinetic and vestibulo-ocular reflexes could be intact. It is inferred that the mechanism responsible for the pendular nystagmus lies at a level which is close to the oculomotor nuclei so that it can have monocular effects but is not part of the primary motor pathways. It is possible that this mechanism normally subserves maintenance of conjugate movement and posture of the eyes. The periodicity of the nystagmus is likely to arise from instability in a certain type(s) of neurone, for the associated somatic tremors have similar characteristics and yet involve very different neuronal muscular circuitry. Prognosis for cessation of the nystagmus is poor. In five patients with multiple sclerosis it was suppressed by intravenous hyoscine with, however, unacceptable subsequent side effects.

"These eyes that rowle in vain
To find thy piercing ray, and find no dawn."
    John Milton, *Paradise Lost*, III, 11/23–24

Pendular nystagmus is a sinusoidal, involuntary oscillation of the eyes which may be congenital or acquired in nervous diseases. Clinically, differentiation between congenital and acquired nystagmus is not difficult because of their distinct characteristics. Congenital pendular nystagmus is horizontal, binocular and conjugate, can have a variable wave

form and changes into a jerk nystagmus on lateral gaze. Acquired pendular nystagmus may be monocular or binocular, conjugate or disconjugate with a wave form which is largely independent of eye position. The movement of the eye may be vertical, horizontal or torsional in which case the globe rotates about the principal axis. An observed movement may be the result of combined oscillations about more than one axis as in "rotary" nystagmus (fig 1). Pendular nystagmus sometimes occurs in association with rhythmical movements at similar frequencies of other parts of the body, as in the syndrome of "oculo-palatal-myoclonus"[1] in which postmortem examination has confirmed a lesion in the brain stem. The nystagmus in this syn-
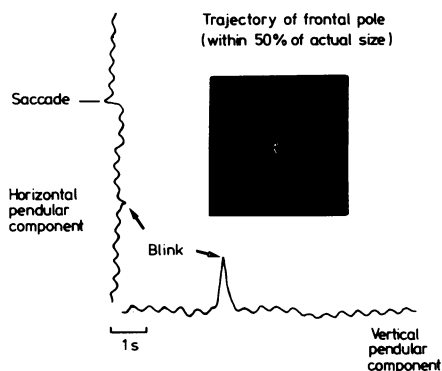
Fig 1 *An example of monocular rotatory nystagmus
recorded from a 25-year-old male patient with multiple
sclerosis. The rotation was the result of synchronous
pendular oscillations in both the vertical and horizontal
planes. The central figure indicating the trajectory was
produced by applying the horizontal and vertical
electro-oculographic recordings to the y and x amplifiers of
an oscilloscope. The maintenance of the unchanging
elliptical trajectory indicates the precision with which
horizontal and vertical components were synchronised.*

drome is always similar to the form which can occur
in isolation and there is no reason to suspect that
they have separate origins.

Although the planes in which the eyes move and
the phase relationships between the movements
show considerable variability from one case to
another there are features common to acquired
pendular nystagmus which lead us to suspect that
the movements should be classified together. Firstly,
both within and between patients the frequency and
amplitudes of the nystagmus are similar giving a clin-
ical appearance which is quite distinctive regardless
of the plane of movement. In addition, in any indi-
vidual, nystagmus which occurs in disconjugate
planes is synchronised indicating some form of yok-
ing between vertical, horizontal and torsional
oculomotor systems. These features suggest that a
unitary mechanism or at least similar types of
mechanisms sharing a common rhythm generator
are responsible for the various manifestations of
pendular nystagmus.

In the only extensive survey of acquired pendular
nystagmus to date[2] the authors postulated that the
ocular movements originated from the cerebellar
nuclei and their connections and were evidence of a
failure to maintain eye posture. The existence of
monocular pendular nystagmus throws doubt upon
this theory.[3] Accordingly we examined 16 patients
with acquired pendular nystagmus with a particular
view to determining the abnormalities of ocular
movements common to all which might provide
clues as to aetiology and pathophysiology.

Methods

Recordings of eye movements were taken using direct
coupled electro-oculography with a low pass cut off usually
set at 32 Hz. In cases of torsional pendular nystagmus two
small silver-silver chloride electrodes were placed on the
upper lid over the insertion of the superior oblique muscle
into the globe. The signals were amplified with a wide
bandpass in order to detect the EMG activity of the obli-
que muscle. Accelerometric recordings of head or limb
movements were taken using linear piezo resistive
accelerometers (Endevco 7265-10) mounted with their
sensitive axes oriented in the major plane of movement.
The device had a frequency response from steady state
acceleration up to a superimposed low pass cut off at
32 Hz.. Recordings of limb displacements were obtained
using a Schottky barrier photo-detector mounted with its
sensitive surface in the focal plane of a 35 mm camera
which was oriented to view the limb from a suitable angle.
A small pilot lamp was mounted on the limb, the move-
ment of which was registered by the photo-detector and
resolved into displacements in the vertical and horizontal
planes (after the method of Findley *et al*[4]).

The signals relating eye and body movements were sub-
jected to spectral analysis on a Hewlett Packard 5420A
digital signal analyser. The analyses employed to character-
ise the signals were the *Auto-spectrum*; used to measure
the amplitude and frequency of the dominant frequency of
a tremor, and *Coherence* (the average of square of the
cross spectra divided by product of the averages of the
auto-power spectra); which is a measure of the degree to
which two signals (that is, tremors) are related. Coherence
is expressed on a scale of 0 to 1 in which 0 indicates that
the signals are independent of each other and 1 indicates
that they are completely related. As a point of interpreta-
tion a coherence of 1 can be taken to indicate that the
signals are *causally* related. These functions derived from
the raw signals were averaged to improve the significance
of the measurements. The analyses were performed on
1025 point digitised 10·24 s samples of raw data producing
a maximum temporal resolution of 10 ms, a frequency
resolution of 0·05 Hz and bandwidth of DC to 25 Hz. The
data was digitally filtered to prevent aliasing of frequencies
in excess of 25 Hz and windowed with a Hanning window
appropriate for the analysis of sinusoidal signals.[5] Aver-
ages were made on spectra derived from overlapping sam-
ples of raw data. This compensates for the reduced con-
tribution of the data at the beginning and end of the data
samples which results from the application of a Hanning
window.

The validity of the raw data signals was established by
displaying the signals on a storage oscilloscope and making
a simultaneous comparison with an infra-red video record-
ing of the actual eye movement. Combined vertical and
horizontal movements were plotted in the form of a Lissaj-
ous figure using the x and y amplifiers of the oscilloscope
(fig 1).

Patients

Sixteen patients were referred for assessment by the con-
sultants at The National Hospital, Queen Square and

St Thomas' Hospital, London. In addition we include data derived from a further 27 patients with multiple sclerosis reported by Aschoff *et al*,[2] four patients described by Chokroverty and Barron[6] and one of Nathanson[7] and four taken from the case history records of the National Hospital who had had electro-oculographic recordings taken of their eye movements; a total of 52 patients with monocular and binocular pendular nystagmus. Congenital nystagmus of the pendular variety was excluded from the survey.

Amongst our patients 12 had clinically definite multiple sclerosis; four had had brain stem vascular accidents; one a brain stem angioma; there was one patient with congenital optic atrophy with strabismus and one with a unilateral amblyopia secondary to strabismus (both of these patients had a uniocular vertical pendular nystagmus in the affected eye); and one patient had a provisional diagnosis of brain stem encephalitis.

A universal complaint amongst these patients was one of oscillopsia which was usually sufficiently marked to impair reading ability. The majority of our patients had severe neurological disability but in the few who were ambulant and active the oscillopsia caused difficulty with daily activities. The oculomotor impairment common to all patients was some form of failure of conjugate gaze or defect of voluntary convergence.

Results

The relevant findings in our patients which relate to the behavioural characteristics of their pendular nystagmus, associated oculomotor and visual disorders, tremor of parts of the body and diagnosis are presented in the table.

FREQUENCY OF PENDULAR NYSTAGMUS

The histogram of frequencies of pendular nystagmus as measured in our own patients and as reported by other authors is presented in fig 2. In the cases of nystagmus which varied in frequency the middle of the range of variability was used to plot the histogram. Because of the finding that in any one patient, regardless of the plane of movement, pendular nystagmus in more than one direction was phase locked, such compound nystagmus was characterised by only one frequency measurement. The frequency distribution was unimodal, skewed towards lower frequency values, with a mode at between 2·6 and 3 Hz with a mean at 3·6 Hz. There was no obvious relationship between frequency and direction of nystagmus and an underlying disease process.

In any given patient, whenever an episode of well defined binocular pendular nystagmus occurred, there was a precise phase lock between the movements of the right and left eye. The phase relationship was independent of the plane of movement, which could be different in the two eyes. This characteristic is illustrated in the case of a 28-year-old female with a presumed cerebrovascular accident which had left her with a binocular *convergent* pendular nystagmus which had remained unchanged in character for two years. An analysis of her eye movements is presented in fig 3. The raw data records in the lower part of the figure show a fluctuating pendular nystagmus of slightly greater amplitude in the left eye. The synchronisation arrow between the traces indicates that the nystagmus consisted of pendular movements of convergence and divergence. The auto-spectra of the movements of the left and right eye are averages of ten overlapping 10·24 s samples of eye movement recordings and indicates a frequency of 3·4 Hz in both eyes. The corresponding coherence function measured on the same data sample as the auto-spectra indicates a coherence of unity in the frequency band of the pendular eye movement (indicated by the single vertical arrow). The phase relationship between the right and left eye measured over the same data sample was 150° indicating that the movements were not perfectly convergent but slightly staggered (a phase of 180° would indicate perfect convergence). The most important of these measurements is the coherence function which increases its specificity and significance with successive averaging, unlike the other measurements in which averaging can hide the variability of the phenomena. The coherence of unity in the frequency band of the pendular movements proves that they are frequency locked.

Similar measurements on other patients with compound nystagmus revealed a similar degree of relationship between movements in the various planes. In the cases of combined horizontal and vertical oscillations the eye executes a rotation (as in fig 1) in which the circular or eilliptical pattern of the rotation is invariable indicating that frequency and phase relationships between the horizontal and vertical components of the movement are also invariable.

CONCURRENT TREMOR OF OTHER PARTS OF THE BODY

Eight patients with pendular nystagmus on whom we made measurements had tremor of other parts of the body including the head, neck and upper limbs. Of such tremors, some were similar in frequency to the pendular nystagmus and others dissimilar. Both similar and dissimilar tremor frequencies could coexist in the same person and in the same limb (depending upon whether the tremor was brought out by a posture of flexion or extension). The histogram of somatic tremor frequencies in our patients is presented in fig 3. It is evident that the distribution of frequencies is similar to that of the pendular nystagmus.

The degree of synchronisation which can coexist

Table *Classification of diseases, ocular signs and associated somatic tremor in patients with pendular nystagmus*

Age	Sex	Pendular nystagmus direction and amplitude		Frequency phase		Modifying factors	Associated tremors	INO	Convergence	Other oculomotor signs
		Right eye	Left eye							
Multiple sclerosis										
37	F	H 4°	H 4°	3·6 Hz	33°				absent	Opsoclonus, 1st° nystagmus to right and left
43	F	H 2°	H 2°	3·5 Hz		Fluctuating amplitude provoked by saccades	Intention/postural arm tremor 3·5 Hz		absent	Exophoria, centering dysmetria upbeat nystagmus
24	M	H 5°	H 2°	3·5 Hz	50°			bilateral	absent	
60	M	H 4°	H 4°	4·3 Hz		Accentuated on near gaze		bilateral	poor	
23	M	V	V	2·8 to 3·6 Hz		Wide fluctuation in amplitude/frequency	Head, palate, labial 2·8–3·6 Hz	bilateral	absent	
28	M	H 3°	H 3° acuities 2/60	3·7 to 4·0 Hz		Wide fluctuations	Head 3·7 Hz		absent	Supranuclear palsy, up/down beat nystagmus, bilateral 6ths
25	M	R 4°	T 4°	3·2 Hz	85°	Absent on closure		bilateral	poor ?	Incomplete INO, 1st° nystagmus to right and left
24	M	R 3°	H 3°	3·7 Hz	102°	Episodic, provoked by saccades	Head 3·7 Hz		absent	Supranuclear palsy, up/down beat nystagmus
43	F	H	H	3·5 Hz			Postural arm tremor 3·5 Hz		absent	1st° nystagmus right and left, upbeat nystagmus
49	M		H 2°	3·8 Hz				bilateral	?	Records: incomplete data
45	F		F + H 4°	3·7 Hz				bilateral	?	Records: incomplete data
54	F	F 2°		6·0 Hz		Absent in darkness and on closure		?	?	Records: incomplete data
Cerebrovascular accident										
49	F	V	H	2·5 Hz	60°		Rubral tremor of right arm 2·5 Hz	bilateral	absent	Skew deviation, omni-directional gaze paretic nystagmus
56	M	V 8°	V 8°	2·4 Hz		Persisted through light anaesthesia			absent	Total horizontal gaze paresis, skew deviation, downbeat nystagmus
51	M	V + T 2·5° minimal?		2·8 Hz			Palate 2·5 Hz	unilateral	absent	
28	F	H 4°	H 4°	3·5 Hz	150°	Variable incidence			poor	Square wave jerks, monocular jerk nystagmus of right eye
Brain stem angioma										
51	F	V 4°	V 4°	2·2 Hz				bilateral	absent	Skew deviation
Brain stem encephalitis										
64	F	V 8°	V 8°	2·7 Hz		Enhanced with eye closure, variable	Thumb, palate 2·7 to 3·5 Hz	bilateral	absent	
Amblyopia/optic atrophy										
40	M	V 3° amblyopic right eye		2·9 Hz		Intermittent, absent in dark, provoked by fixation			poor	Right exotropia and skew deviation
9	M	V 7°	V 7°	3·5 Hz		Left eye nystagmus onset before right				Left eye optic atrophy esotropia of left eye until 8 year subsequently became exo

H=horizontal, V=vertical, T=torsional.

between pendular nystagmus and simultaneous tremor of other parts of the body is illustrated in fig 4 which presents raw data records from a 23-year-old male patient with multiple sclerosis. His nystagmus ranged in frequency from 2·8 to 3·6 Hz and was accompanied at various times by rhythmical movements of the head, upper lip or palate. When any combination of these occurred simultaneously they were approximately synchronous as indicated by the vertical synchronisation arrows in fig 4. Careful measurement of the traces, however, revealed that over several cycles the various tremors did not maintain a precise phase relationship.

EFFECT OF PENDULAR NYSTAGMUS ON VISUAL ACUITY

All patients were distressed by the oscillopsia which they experienced as a result of their pendular nystagmus and this was more or less proportional to the amplitude of the eye movement. We were, however, surprised that visual acuity in patients with pendular nystagmus did not seem to be particularly low when tested using a Snellen chart, as estimated by comparison of acuities measured before and after treatment with hyoscine to suppress the nystagmus, acuity was reduced by only one to two lines of the Snellen chart. The degree of visual impairment
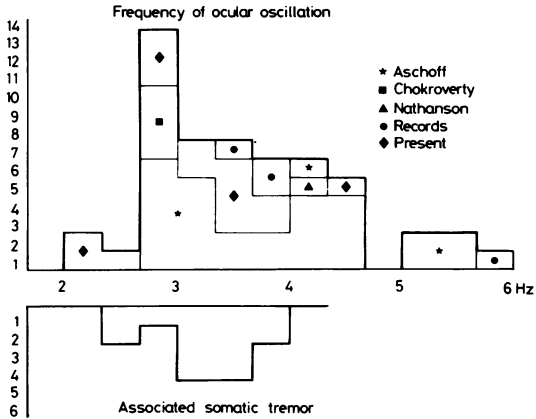
Fig 2 *Frequency histograms of the frequencies of pendular nystagmus and associated somatic tremor in our own patients and in patients reported by other authors and those documented in the records of the National Hospital.*

which our patients experienced seemed more the result of oscillopsia than of loss of acuity.

Severe problems were encountered when the patients attempted to read when it became evident that the nystagmus interfered with the generation of normometric scanning steps. The mechanism appeared to be one of simple summation. When the patient attempted to generate a saccade the amplitude was modified by the addition of the involuntary oscillation which could either reduce or augment the saccade depending upon the phase of the nystagmus.

BEHAVIOURAL CHARACTERISTICS
As can be seen from the column in the table listing modifying factors in the pendular nystagmus manifest in our patients there were no consistent behavioural characteristics which could be helpful in determining the underlying aetiology. In particular we did not observe any nystagmus to be inhibited following saccadic eye movements as reported by
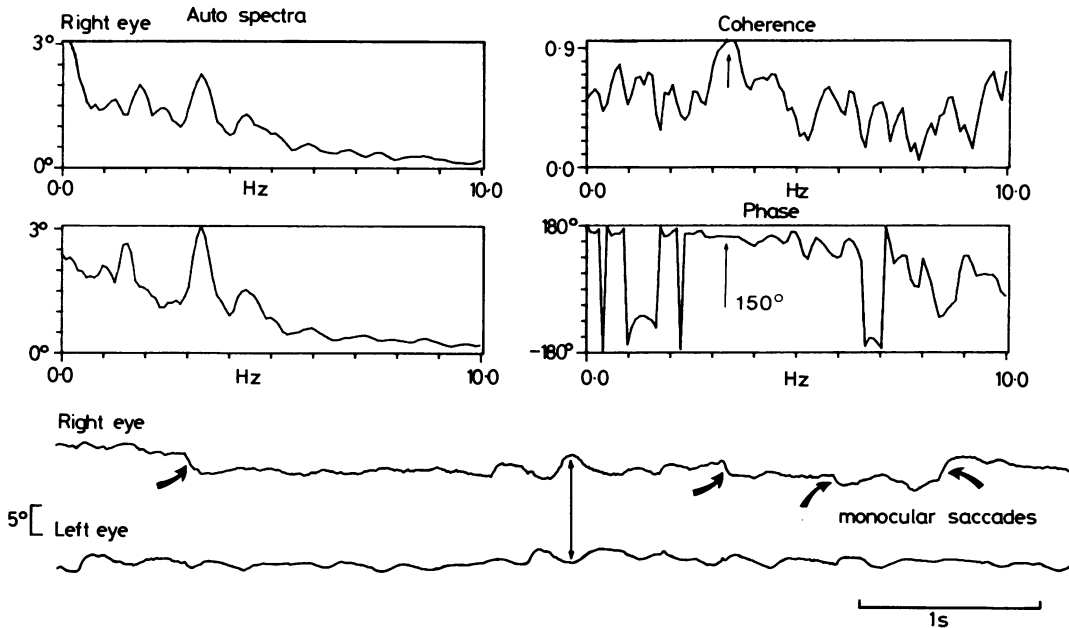

Fig 3 *Binocular pendular nystagmus in the horizontal plane recorded from a 28-year-old female patient with a presumed cerebrovascular accident. The movements of her eyes were in the direction of convergence and divergence. The auto spectra indicate the common dominant frequency of the pendular movements. The coherence and phase measurements at this frequency (indicated by small vertical arrows) show that the movements are completely synchronous with a phase difference of 150°. The raw data records show two types of spontaneous involuntary activity. The pendular nystagmus which is common to both eyes as indicated by the synchronisation arrow and monocular saccadic movements of the right eye. The spectral measurements were based on averages derived from ten 10·24 s samples of data. On this number of averages a coherence of 0·7 was significant at the 2% level.*
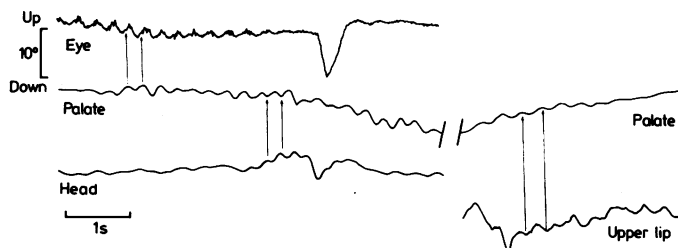
Fig 4   *Recordings of somatic tremor and pendular nystagmus taken from a 24-year-old male patient with multiple sclerosis. Synchronisation arrows between the traces indicate that the movements are similar in frequency in all body parts.*

Aschoff *et al.*[2] On the contrary we found a curious instance of an episodic pendular nystagmus in a 24-year-old male patient with multiple sclerosis which was provoked by saccadic movements of small amplitude as illustrated in fig 5. With attempts to hold the eyes still there were short bursts of oscillatory eye movement. Whenever the patient made small saccades of about 5° to 10° in amplitude two or three cycles of nystagmus were initiated which decayed in the form of a damped oscillation. There was an accompanying tremor of the head with comparable behavioural characteristics. The crescendo-decrescendo appearance and the initiation by sudden movement of such rhythmical involuntary movements in this patient are reminiscent of "startle myoclonus" reported in children.[8]

It has been said that acquired pendular nystagmus in multiple sclerosis is present only during fixation and ceases with eye closure. We found this to be the case in only two of our multiple sclerosis patients.

PHARMACOLOGICAL SUPPRESSION OF PENDULAR NYSTAGMUS

On the basis of the observation that an intravenous dose of hyoscine can temporarily suppress low frequency somatic tremor in certain cases of multisystem degeneration,[9] we investigated the effect of this drug in five patients with pendular nystagmus. Four of these had multiple sclerosis and one a brain stem cerebrovascular accident. In all five, 10 minutes after a single intravenous dose of hyoscine 0·4 mg, the nystagmus was abolished (as judged by observation and electro-oculography). The patients themselves were aware of this and no longer experienced oscillopsia. In one case visual acuity improved from 6/12 to 6/6. The nystagmus recurred after approximately 15 minutes. The patients subsequently noted slight drowsiness but did not experience this during the period when the nystagmus was absent. The potential long term therapeutic application of hyoscine in such cases is being further investigated.
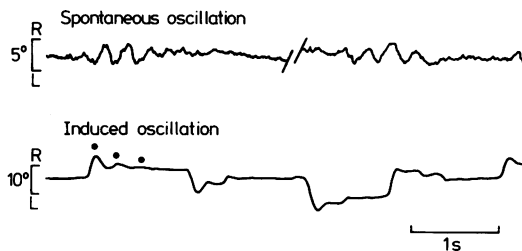

Fig 5   *Bursts of pendular nystagmus recorded from a 24-year-old male patient with multiple sclerosis. When the patient tried to keep his eyes still there were bursts of crescendo/decrescendo pendular oscillations as in the upper traces. Execution of small saccades appeared to trigger off two or three cycles of nystagmus as shown in the lower traces.*

In several other patients, a range of drugs including leva-dopa, baclofen, clonazepam, prochlorperazine, carbamazepine, tetrabenazine and a variety of major tranquillizers were administered to no avail. Informed consent following a full explanation of the procedure was obtained from all patients with whom pharmacological suppression of nystagmus was attempted.

ASYMMETRICAL FEATURES OF THE WAVE FORM OF PENDULAR NYSTAGMUS

The electro-oculographic technique which was the only eye movement recording method available to us is not sensitive enough to transduce the wave form of pendular nystagmus of small amplitude with a signal to noise ratio adequate to reveal the shape of the movement trajectory in detail. Information about precise trajectory would be useful because it would indicate whether the muscular activity responsible was reciprocally organised or asymmetrical in time or amplitude, which could give clues as to the origin of the oscillation. However, two observations derived from electro-oculographic recordings did suggest that in some cases the trajectory of the movement was asymmetrical indicating that

either the rhythm of the agonist/antagonist activity was iambic or that active myogenic displacement was occurring in only one direction with movement in the opposite direction being under the influence of the passive elastic properties of orbital tissue.

The first of these observations was that the shape of the wave form of the nystagmus tended to be "saw tooth" rather than sinusoidal; the second was that in some cases the pendular nystagmus exerted a directional bias on other oculomotor responses. This latter point is illustrated in fig 6(a). The recordings are taken from a 25-year-old male patient with a four year history of multiple sclerosis. He had a rotatory nystagmus of the right eye with a torsional pendular movement of the left. The movements of his right eye in response to optokinetic simulation (OKN) using a rotating drum which provided full field stimulation were markedly deranged with drum rotation to the right and relatively preserved with rotation to the left. His responses to caloric and rotational stopping stimuli were similarly affected. The movements of his left eye were normal. Smooth pursuit movements of the right eye were similarly asymmetrical with the oscillations tending to add to the pursuit movement in the rightwards direction giving a hypermetric appearance and to subtract from the pursuit in the leftwards direction giving a hypometric appearance. Corresponding movements

Fig 6 *(a) recordings taken from a 25-year-old male patient with multiple sclerosis with a monocular pendular nystagmus of the right eye. The nystagmus interferes with optokinetic nystagmus to the right producing a deranged response. Nystagmus to the left and nystagmus in the good eye is unaffected. Smooth pursuit in the right eye was more affected with rightwards than with leftwards movements (arrow). (b) successive records taken at a 4 month interval from a 49-year-old female patient with a cerebrovascular accident showing an alteration in the nystagmus wave form from pendular to triangular.*

of the left eye showed a mild pursuit deficit. The shape of the pendular movements of the right eye when the patient was trying to keep his eyes still suggested that there was a stronger pull to the right than to the left. If there were such an asymmetry of muscle action then it would explain the directional characteristics of the patient's pursuit, vestibular and optokinetic responses.

Further evidence for asymmetry in the mechanism of some pendular nystagmus is derived from another of our patients; a 49-year-old woman with a brain stem cerebrovascular accident who presented originally with a pendular nystagmus and other signs of a brain stem lesion. Over the course of four months the signs in her upper limbs partially remitted. Concurrently the pendular nystagmus became a "jerk" nystagmus as illustrated in fig 6 (b).

The implications of these observations upon the interpretation of the results of caloric and rotational tests are important. The possibility of an asymmetrical wave form in pendular nystagmus should be taken into account in interpretation of such tests. Failure to do so could easily lead to a misleading clinical interpretation.

Discussion

PHYSIOLOGICAL AND ANATOMICAL CONSIDERATIONS CONCERNING THE NATURE OF PENDULAR NYSTAGMUS

Aschoff *et al*[2] postulated that a lesion in the cerebellar nuclei or their connections was the cause of acquired pendular nystagmus. Their reasons for this included the fact that amongst their patients with pendular nystagmus (all of whom had multiple sclerosis)', many had signs of cerebellar nuclear lesions in their upper limbs, for example postural or intention tremor. In addition they reviewed the evidence concerning the site of lesions in oculo-palatal myoclonus which consistently include the dentate and inferior olivary nuclei and brachium conjunctivum.[7][10] They interpreted the pendular eye movements as reflecting loss of postural control of the eyes by the cerebellar nuclei.[12] There are several reasons why this view is difficult to maintain. Firstly, as emphasised by Castaigne *et al*,[3] the existence of *monocular* pendular nystagmus (in the case of Castaigne's patient a monocular circumduction nystagmus, that is, rotatory nystagmus) implies that the mechanism responsible for generating the oscillation must have access to an oculomotor nucleus or nuclei which innervate only one eye. Although the interpretation of stimulation experiments is difficult because of the possibility of the excitation of axon collaterals, the evidence derived from animal and human studies indicates that electrical stimulation of
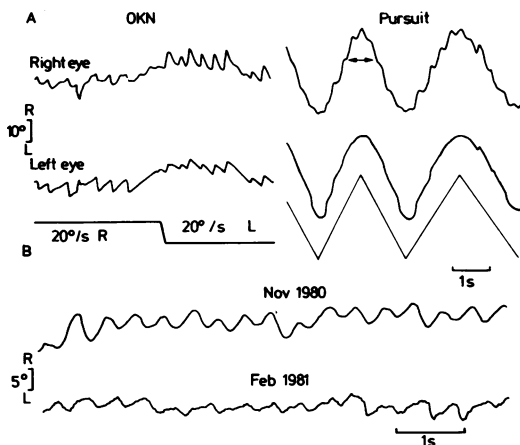
the cerebellum, its nuclei or efferent pathways results in *binocular* movements.[11][13][14] Secondly, it is imprudent to argue that the coexistence of pendular nystagmus and somatic tremor in diseases with multifocal lesions implies that these signs arise from the same anatomical lesion. This point is highlighted by the fact that amongst the patients in Aschoff's survey there was by no means a one to one correspondence between cerebellar signs in the upper limbs and the occurrence of pendular nystagmus and that of our own patients less than half had unequivocal signs of cerebellar disease.

The unique feature of pendular nystagmus which requires explanation is that it can be in any plane or combination of planes in either eye, simultaneously and at the same frequency. An important clue as to the nature of its mechanism is that all other saccadic and slow phase oculomotor mechanisms except those responsible for conjugate gaze and vergence may be intact.

Because the generation of saccadic, pursuit, optokinetic and vestibulo-ocular reflex eye movements may be intact in the presence of pendular nystagmus the causal mechanism is unlikely to be related to these major oculomotor systems. The fact that a compound pendular nystagmus may exist in which the movements in various planes are perfectly synchronised (as indicated by a value of unity in the coherence function), implies that the nystagmus arises from disorder in a mechanism which is normally responsible for the co-ordination of eye movement in more than one plane.

In any one eye movement all extra-ocular muscles are involved.[15] In order to ensure accurate and conjugate gaze, corrections have to be made for deviations from the desired eye position or trajectory which arise from the secondary actions of muscles and changes in the passive visco-elastic properties of orbital tissue. Although not anatomically identified, it is accepted that a neuronal mechanism responsible for such corrections exists.[15] An important aspect of such a mechanism(s) is that it frequently has a different yet co-ordinated action on the two eyes, particularly as far as the secondary action of the muscles are concerned. This type of co-ordinating mechanism is a candidate for involvement in pendular nystagmus for the consequences of damage to such a structure could explain the variety and synchronicity of eye movements encountered in the disorder.

An anatomical localisation of the lesion responsible for pendular nystagmus in the proximity of the oculomotor nuclei is suggested by several features of the nystagmus and by frequently associated abnormalities of other ocular movements. Stimulation of most supra-nuclear oculomotor centres results in binocular movement and it is only close to or at the level of the oculomotor nuclei that a monocular response is evoked.[15] It is possible that the abnormal signals responsible for the oscillation have access to motor neurones innervating reciprocally related muscles because they produce a sinusoidal movement in the absence of globe retraction. In order for this to occur the signals must arise at a supranuclear level. However, in the case of a monocular movement this must be near the third nerve nucleus.

These arguments must almost necessarily hold for a monocular nystagmus; however, they have no application in the localisation of a lesion responsible for a conjugate binocular pendular nystagmus. Further evidence that the lesion responsible for pendular nystagmus is near the oculomotor complex is to be inferred from the universal occurrence amongst our patients of associated internuclear ophthalmoplegia or skew deviation, failure of convergence and squint, all of which are signs of derangement between or close to the level of the oculomotor nuclei.

The occurrence of pendular nystagmus in monocular amblyopia with strabismus requires further explanation because there is no evidence of structural damage in the brain stem. However, the character of the nystagmus in these patients is indistinguishable from that seen in multiple sclerosis, for example. The feature common to both is a marked failure in the vergence system and this may indicate that this is an aetiological factor. Certainly the similarity between nystagmus of an amblyopic eye and that resulting from structural lesions of the nervous system strongly suggests that they result from abnormalities of function of the same nervous mechanism. When pendular nystagmus arises in amblyopia we suspect there is additional, compounding insult to the nervous system, for example, migraine.

One can only speculate on the origin of the frequency characteristics of pendular nystagmus. Clues as to the origin of the rhythm come from the fact that associated somatic tremors sometimes have a similar periodicity. It is unlikely that such periodicity is caused by time delays around a form of control loop because the control parameters required for body parts with such diverse functions and physical properties as the eye, tongue or arm must be very different. The uniformity of frequency encountered in the syndrome of *oculo-palatal-laryngeal-diaphragmatic myoclonus* suggests that the rhythmicity derives from properties which are held in common by different types of neurones in different neuronal circuits. As such these properties must be fundamental to the function of the neurone, either in isolation or in the context of its local circuitry. Cycles of excitation and inhibition arising from the

properties of the neuronal membrane have been described for example in the inferior olive by Llinás and Yarom[16] and this structure is implicated in the syndrome of oculo-palatal myoclonus.[7 10] None of the tremulous movements in the syndrome are necessarily associated with weakness or ataxia of the affected part which implies that the primary motor pathway is intact so that the tremor must arise from an accessory pathway.

CLINICAL ASPECTS OF PENDULAR NYSTAGMUS
In general the prognosis for cessation of involuntary ocular movement and diminution of oscillopsia is poor. The results of pharmacological intervention so far have been discouraging. In those cases where the nystagmus has been modified by drug treatment (for example, with barbiturate and hyoscine) the subsequent level of impairment of concentration would be unacceptable for everyday life.

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