

Research article

Abduction paresis with rostral pontine and/or mesencephalic lesions: Pseudoabducens palsy and its relation to the so-called posterior internuclear ophthalmoplegia of Lutz

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Abstract

Background: The existence of a prenuclear abduction paresis is still debated.

Methods: In a retrospective design, we identified 22 patients with isolated unilateral (n = 20) or bilateral (n = 2) abduction paresis and electrophysiological abnormalities indicating rostral pontine and/or mesencephalic lesions. Another 11 patients had unilateral abduction paresis with additional ocular motor abnormalities indicating midbrain dysfunction. Eight of these 11 patients also had electrophysiological abnormalities supporting this location. Electrophysiological examinations in all patients included masseter and blink reflexes (MassR, BlinkR), brainstem auditory evoked potentials (BAEP), and direct current electro-oculography (EOG).

Results: Unilateral MassR abnormalities in patients with unilateral abduction paresis were seen in 17 patients and were almost always (in 16 of 17 patients) on the side of the abduction paresis. Another 11 patients had bilateral MassR abnormalities. BlinkR was always normal. EOG disclosed slowed abduction saccades in the non-paretic eye in 6 patients and slowed saccades to the side opposite to the abduction paresis in another 5 patients. Re-examinations were done in 27 patients showing normalization or improvement of masseter reflex abnormalities in 18 of 20 patients and in all patients with EOG abnormalities. This was always associated with clinical improvement.

Conclusions: Electrophysiologically documented or clinically evident rostral pontine and/or mesencephalic lesions in our patients exclude an infranuclear intrapontine 6th nerve lesion and indicate the existence of an abduction paresis of prenuclear origin. An increased tone of the antagonistic medial rectus muscle during lateral gaze either by abnormal convergence or impaired medial rectus inhibition seems most likely.

Background

In 1921, Anton Lutz postulated the existence of a prenuclear abduction paresis, the so-called "ophthalmoplegia internuclearis posterior" (posterior internuclear ophthalmoplegia, PINO) [1]. This concept, however, was

based on an erroneous neuroanatomical concept: Lutz thought that the supranuclear fibers mediating horizontal gaze divide within the pons into a descending branch to lateral rectus motoneurons on one side and an ascending branch to medial rectus motoneurons on the other

side. The PINO was attributed to a lesion of the descending branch thought to be followed by a reduced or absent excitation of lateral rectus motoneurons. Although Lutz's basic neuroanatomical assumption was wrong, the existence of a PINO remained controversial, as a PINO was repeatedly discussed in patients, whose abduction paresis was thought to differ from a 6th nerve palsy. This included absence of strabismus and diplopia in the primary position [2–5], adduction nystagmus of the contralateral, i.e. non-paretic eye on lateral gaze [3,4,6], isolated impairment of abduction saccades, i.e. unrestricted abduction with following eye movements [7], preserved abduction saccades with caloric testing, i.e. with vestibular (caloric) nystagmus [8,9], or preserved abduction with the vestibulo-ocular reflex [9]. There was little agreement on both, the location of the responsible lesion and the underlying mechanism. Some suggested impairment of the supranuclear pathways for lateral gaze running near the 3rd nerve nucleus [9]. Others postulated a decreased excitation of lateral rectus motoneurons due to a lesion of aberrant pyramidal tract fibers to the abducens nucleus [10], or an affection of the connection between the paramedian pontine reticular formation (PPRF) and the ipsilateral abducens nucleus [5,7]. An impaired inhibition of the antagonistic medial rectus muscle was discussed by Collard et al. [4] suggesting a medial longitudinal fasciculus (MLF) lesion contralateral to the paretic eye. Finally, some authors attributed such cases to a lesion of the intrapontine segment of the 6th nerve thereby rejecting a pre- or supranuclear origin of the abduction paresis [11–14].

We re-address this issue based on findings in 33 (including 8 previously reported [15] patients with unilateral or bilateral abduction paresis with electrophysiologically or clinically documented rostral pontine and/or mesencephalic lesions.

Methods

We retrospectively identified 22 patients with isolated unilateral ($n = 20$) or bilateral ($n = 2$) abduction paresis, who also had electrophysiological abnormalities indicating rostral pontine and/or mesencephalic lesions. Another 11 patients with an unilateral abduction paresis as their main clinical symptom had additional clinical signs of midbrain dysfunction, which were supported by abnormal electrophysiological findings in 8 of them. None of the 33 patients had total abduction paresis. In most patients, abduction was limited to 20–30° from the mid-position with saccadic and following eye movements. Electrophysiologic testing in all patients included masseter and blink reflexes (MassR, BlinkR), brainstem auditory evoked potentials (BAEP), and direct current electro-oculography (EOG) as described previously [15,16]. Criteria of MassR and BlinkR abnormalities

were: (i) unilateral or bilateral delayed latency outside the age related mean + 2.5 standard deviations (SD), (ii) unilateral or bilateral loss (including partial MassR loss, i.e. loss of more than 4 responses out of 10 trials); (iii) right/left differences outside the age related mean + 2.5 SD; (iv) increase or shortening of the MassR latency at re-examination by 0.8 ms or more was interpreted in favor of deteriorating or improving acute lesions. [15,16]. Velocities of saccades outside the normal range were considered abnormal (normal ranges of our laboratory: 30°-abduction saccades: 320 to 640°/s; 30°-adduction saccades: 335 to 670°/s; interocular difference < 35°/s).

Magnetic resonance imaging (MRI) was done in 8 patients with 1.0 (Siemens Magnetom, Erlangen, Germany) or 1.5 Tesla (Philips S, Eindhoven, The Netherlands) superconducting systems before and after intravenous gadolinium. T1-weighted (repetition time: 500–750 ms, echo time: 20–50 ms) and T2-weighted (repetition time: 1800–2080 ms, echo time: 80–100 ms) images were obtained. Slice thickness was between 4 and 7 mm. CT was done in 19 patients with an EMI 1010 (London, United Kingdom) or Siemens Somatom ARP (Erlangen, Germany). Slice thickness was between 4 and 7 mm.

Diagnosis of brainstem infarction was based on (a) sudden onset, (b) presence of at least one relevant risk factor for the development of cerebrovascular diseases (diabetes, hypertension, previous strokes or transient ischemic attacks, atrial fibrillation, heavy smoking, hypercholesterolemia, signs of general arteriosclerosis), and (c) subsequent improvement or recovery. Multiple sclerosis was diagnosed according to the criteria given by Poser et al. [17] and Paty et al. [18].

Results

Brainstem ischemia was diagnosed in 24 and multiple sclerosis in 4 patients. One patient had an undiagnosed inflammatory disease. In the remaining 4 patients the etiology remained undetermined.

Abnormal electrophysiologic findings are given in detail in table 1. Seventeen patients with unilateral abduction paresis, which was the only clinical signs in 12 and associated with additional clinical signs of midbrain dysfunction in 5, had unilateral MassR abnormalities. These abnormalities were ipsilateral in 16 and contralateral in one patient. One of these patients (#9) also had a delayed BAEP wave V ipsilateral to the abduction paresis and the MassR abnormality. Another 11 patients with unilateral abduction paresis, which was the only clinical signs in 8 and associated with additional clinical signs of midbrain dysfunction in 3, had bilateral MassR abnormalities, which were more pronounced on the side of the abduction paresis in 3 and without a relevant side difference in

Table 1: Abnormal electrophysiological and/or clinical findings

No.	Age (years)	Sex	Etiology	Clinical findings	Electrophysiological findings
1	75	female	ischemia	abduction paresis right eye	MassR right loss ⇒ 8.3 ms left 8.0 ms ⇒ 7.9 ms EOG slowed abduction saccades left eye ^N
2	76	female	ischemia	abduction paresis right eye	MassR right 9.2 ms ⇒ 8.8 ms left 8.5 ms ⇒ 8.7 ms
3	51	Male	undetermined	abduction paresis right eye	MassR right 9.1 ms ⇒ 8.4 ms left 7.9 ms ⇒ 8.0 ms
4	58	female	ischemia	abduction paresis right eye	MassR right 8.9 ms ⇒ 8.0 ms left 8.2 ms ⇒ 7.9 ms EOG Slowed abduction saccades left eye ^N
5	33	female	Multiple sclerosis	abduction paresis left eye	MassR right 6.6 ms ⇒ 7.1 ms left 7.4 ms ⇒ 7.9 ms
6	74	Male	ischemia	abduction paresis right eye	EOG Slowed abduction saccades right eye ^N MassR right 7.3 ms ⇒ 7.2 ms left 6.6 ms ⇒ 7.2 ms
7	68	male	ischemia	abduction paresis right eye	MassR right 9.8 ms left 9.1 ms
8	78	female	ischemia	abduction paresis right eye	MassR right 9.6 ms left 8.9 ms
9	51	male	ischemia	abduction paresis left eye	EOG slowed saccades to the left ^N MassR right 7.4 ms left 9.0 ms BAEP right 5.8 ms ⇒ 5.9 ms left 6.1 ms ⇒ 5.9 ms
10	77	male	ischemia	abduction paresis right eye	EOG Slowed abduction saccades right eye ^N MassR right 8.6 ms left 8.0 ms
11	67	male	ischemia	abduction paresis right eye	MassR right 8.0 ms left 7.3 ms
12	39	female	inflammation	abduction paresis left eye	MassR right 6.9 ms left 6.1 ms
13	74	female	ischemia	abduction paresis right eye	EOG Slowed abduction saccades right eye ^N MassR right loss ⇒ loss left loss ⇒ 7.3 ms
14	34	female	Multiple sclerosis	abduction paresis right eye	MassR right 9.4 ms left 8.5 ms EOG Slowed saccades to the left ^N
15	26	male	Multiple sclerosis	abduction paresis right eye	MassR right 8.8>4 ms left 9.0 ms EOG Slowed saccades to the left ^N
16	68	female	ischemia	abduction paresis left eye	MassR right 9.4 ms ⇒ 8.0 ms left 9.2 ms ⇒ 8.0 ms
17	73	male	ischemia	abduction paresis right eye	MassR right 9,3 ms ⇒ 8.5 ms left 9.6 ms ⇒ 8.5 ms
18	68	female	ischemia	abduction paresis left eye	EOG Slowed abduction saccades left eye ^N MassR right 9.4 ms ⇒ 8.0 ms left 9.2 ms ⇒ 8.0 ms
19	73	male	ischemia	abduction paresis right eye	MassR right 9,3 ms ⇒ 8.5 ms left 9.6 ms ⇒ 8.5 ms
20	70	male	ischemia	abduction paresis right eye	MassR right 9.1>4 ms left 8.9>4 ms EOG Slowed saccades to the left ^N
21	65	male	ischemia	abduction paresis left > right eye	MassR right loss ⇒ 8.3 ms left 8.6 ms ⇒ 8.6 ms
22	55	male	undetermined	abduction paresis right > left eye	MassR right 11.8 ms ⇒ 10.3 ms left 9.4 ms ⇒ 9.0 ms
23	48	male	ischemia	abduction paresis plus	MassR right 7.9 ms ⇒ 8.1 ms

Table 1: Abnormal electrophysiological and/or clinical findings (Continued)

				superior oblique palsy left eye		left	9.3 ms ⇒ 8.5 m
24	69	male	ischemia	abduction paresis plus superior oblique left eye	MassR	right left	12.4>4 ms ⇒ 9.4 ms 10.2 ms ⇒ 9.2 ms
25	79	male	ischemia	aduction paresis plus elevation paresis left eye	MassR	right left	8.6 ms ⇒ 8.9 ms 9.2 ms ⇒ 9.5 ms
26	71	female	ischemia	abduction paresis plus elevation paresis right eye	MassR	right left	8.2 ms ⇒ 7.4 ms 10.0 ms ⇒ 8.4 ms
27	68	male	ischemia	abduction paresis plus elevation paresis right eye			
28	63	female	multiple sclerosis	abduction paresis right eye plus	EOG		slowed saccades to the left ^N
29	63	female	ischemia	upgaze palsy abduction paresis right eye plus	MassR	right left	8.9 ms ⇒ 8.0 ms 8.2 ms ⇒ 8.2 ms
30	40	male	undetermined	up- and downgaze palsy abduction paresis right eye plus	MassR	right left	8.2>4 ms 8.0 ms
31	21	male	undetermined	up- and downgaze palsy & gaze paresis to the left abduction paresis right eye plus			
32	75	female	ischemia	up- and downgaze palsy & convergence-retraction nystagmus Abduction paresis right eye plus	MassR	right left	loss ⇒ 8.1 ms 8.0 ms ⇒ 7.9 ms
33	73	male	ischemia	unsteady tandem walking with falling to the right abduction paresis right eye plus	MassR	right left	9.3 ms ⇒ 8.5 ms 9.6 ms ⇒ 8.5 ms
				unsteady tandem walking with falling to the right			

the remaining patients. Both patients with bilateral abduction paresis (#21 and #22) had unilateral MassR abnormalities. BlinkR was normal in all patients.

EOG disclosed slowed abduction saccades in the opposite eye in 6 patients with velocities ranging between 379 and 523°/s, which was by 123 to 199°/s slower than adduction saccades in the non-paretic eye. Another 5 patients had slowed saccades to the side opposite to the abduction paresis with velocities for 30°-saccades ranging between 323 and 478°/s, which was by 109 to 228°/s slower than adduction saccades in the non-paretic eye.

Re-examinations were done in 27 patients documenting normalized or improved MassR abnormalities in 18 and unchanged abnormal MassR findings in 2 patients. The delayed BAEP wave V latency (patient #9) was normal at re-examination. EOG documented saccadic slowing had improved or normalized in all patients.

MRI (8 patients) and CT (19 patients) revealed no brain-stem lesions except MRI documented bilateral symmetrical pontine hyperintensities without signs of acute infarctions in one patient with vertebrobasilar ischemia. (MRI disclosed multiple periventricular hyperintense lesions in two patients with multiple sclerosis and multiple

supratentorial white matter lesions in 6 patients with risk factors for cerebrovascular disease.

Discussion

Thirty of our patients had electrophysiologically documented rostral pontine and/or mesencephalic lesions. Unilateral MassR abnormalities were almost always on the side of the abduction paresis, which argues against a random association. Pre-existing electrophysiological abnormalities were unlikely, as almost all (19 of 21) re-examined patients showed improvement or normalization of abnormal MassR and BAEP findings, which strongly suggests acute lesions. This was always associated with improvement of the abduction paresis, which strongly indicates that both, clinical and electrophysiological abnormalities, were caused by the same actual lesion. Abnormal MassR findings in patients with normal trigeminal nerve sensory and motor function indicate lesions involving the ipsilateral trigeminal mesencephalic tract and nucleus [see for review [19,20]]. This corresponds to the rostral pons and mesencephalon between the level of the 5th nerve entry zone and the 3rd nerve nucleus level. An abnormal R1-component of the BlinkR (Blink-R1) with normal R2 components and normal trigeminal and facial nerve functions indicates an ipsilateral pontine lesion between the trigeminal nerve entry zone and the facial nucleus [see for review [19,20]]. Abnormal MassR findings with normal BlinkR-R1 as seen in 30 of our patients indicate rostral pontine and/or mesencephalic lesions [19,20]. Midbrain dysfunction was also evident from vertical gaze palsies and convergence nystagmus [21], which were seen in 4 of our patients. Such lesion location is clearly rostral to the intrapontine segment of the 6th nerve excluding an infranuclear intrapontine 6th nerve lesion in our patients.

Our patients correspond to a number of previously reported patients, most of them with pathologically or radiologically proven midbrain or meso-diencephalic lesions, showing an abduction paresis with additional clinical signs of midbrain dysfunction like upgaze palsy, convergence paresis, or convergence nystagmus [3,7,9,22-29]. Such location was also obvious in another 2 patients with transient abduction paresis after ipsilateral mesencephalotomy [30]. These observations and our data leave no doubt on the existence of an abduction paresis with ipsilateral rostral pontine and/or mesencephalic lesions, even though we were unable to demonstrate CT or MRI documented brainstem lesions. Small brainstem lesions definitely escape observation by CT and "routine" MRI (=T1- and T2-weighted imaging with thick (4-7 mm) slices) as shown with pathologically documented brain stem infarctions [31,32], internuclear ophthalmoplegia [33-35], monocular elevation paresis [36], isolated 3rd, 4th, 6th, 7th, and 8th nerves palsies in

multiple sclerosis [37-41], and electrophysiologically documented brainstem lesions [15,36,39,42-49]. Thinner slicing and other recent techniques (e.g. diffusion weighted imaging, perfusion imaging, fluid attenuated inversion recovery) have increased MRI sensitivity [50-54]. Such techniques, however, were not applied to our patients. Moreover, lesions impairing the function of certain brainstem structures not necessarily impair the structural integrity and therefore may escape detection by MRI even with thinner slicing and diffusion weighted imaging [54,55]. Functional abnormalities, both clinical and electrophysiological, can be estimated equal reliable in indicating the location of a brainstem lesion if they have been correlated with imaging or pathologically documented lesion locations, which has been worked out for brainstem reflexes and clinical signs [see for review [19-21]].

Supranuclear excitatory connections mediating horizontal gaze simultaneously activate lateral rectus motoneurons and, via abducens nucleus internuclear neurons, medial rectus motoneurons [56,57]. Lesions of these fibres within the midbrain are followed by horizontal gaze disorders simultaneously affecting abduction in one and adduction in the other eye [56,57]. Abduction paresis in one without impaired adduction in the other eye as in our patients can not be attributed to a lesion of descending excitatory fibres mediating horizontal gaze, which excludes supranuclear impairment of lateral rectus activation as the working mechanism in our patients. Abduction paresis in our patients were most likely caused by abnormal convergence or impaired medial rectus inhibition during lateral gaze. Both conditions create an increased tone of the antagonistic medial rectus muscle causing abduction paresis despite normal lateral rectus activation.

Abduction paresis with organic and non-organic convergence spasm documents the functional significance of an abnormal convergence during lateral gaze [58-61]. Abduction paresis may also occur (not infrequently in association with convergence or convergence-retraction nystagmus as in patient #31) as one sign of the dorsal midbrain syndrome and is generally attributed to an abnormal convergence tone during lateral gaze [62,63]. Such mechanism was discussed as the most likely cause in patients with unilateral or bilateral abduction paresis with or without esotropia of the affected eye occurring with meso-diencephalic infarctions [24,26-29] and called "pseudo-sixth" [24] or "pseudoabducens palsy" [29]. Convergence neurons are located within the mesencephalic reticular formation. Their discharge is time-coupled to convergence eye movements and encodes their velocity [see for review [64]]. The supranuclear control of these neurons is not fully understood, but may

involve several connections. In primates, there is evidence for an excitatory projection from area 19 and 22 to the midbrain. Stimulation in these areas was followed by ipsilateral or ipsilaterally pronounced convergence movements with or without miosis depending on the intensity and exact location of the stimulation [65,66]. Another bilateral, mainly ipsilateral, projection from the frontal lobe to the midbrain was also shown in primates [67,68] and considered to exert direct inhibition of a subgroup of rectus medialis motoneurons (27), the group C of Büttner-Ennever und Akert, which is thought to be primarily involved in convergence eye movements [69]. A lesion of this connection within the midbrain would be followed by a disinhibition of convergence neurons creating an increased convergence tone during lateral gaze because of the preponderance of the excitatory projection from area 19 and 22 [27]. More recently, Pullicino et al. [29] provided convincing evidence, that the region of the interstitial nucleus of Cajal, which has a close proximity to convergence neurons in the monkey [70], may be critical for the occurrence of a "pseudoabducens palsy" due to a lesion of a descending pathway just before it reaches the convergence neurons.

Lesions involving rostral parts of the central MassR arc may extend beyond this level reaching the meso-diencephalic junction thereby involving the region of the interstitial nucleus of Cajal. Such localized lesions were likely in a number of our patients because of additional clinical signs such as vertical gaze palsies (patients #29–31), monocular elevation paresis (patients #25–27), and convergence retraction nystagmus (patient #31), which was associated with ipsilateral MassR abnormalities in 4 of them. All previously described patients with an abduction paresis due to upper brainstem infarcts had additional clinical signs of rostral midbrain dysfunction (e.g. vertical gaze palsies, convergence retraction nystagmus) [24,26–29]. Such signs, however, were not seen in most of our patients indicating either more restricted rostral midbrain lesions involving descending fibres to convergence neurons with sparing of adjacent structures, or more caudally located, rostral pontine and/or pontomesencephalic lesions. Such lesion location is caudal to the level of the convergence neurons, which excludes damage of descending fibres involved in the control of convergence thereby also excluding abnormal convergence as the underlying mechanism of the abduction paresis in these patients.

Inhibition of antagonistic eye muscles may cause paresis of vertical and horizontal eye movements despite normal excitation of agonistic eye muscles [23,71–73]. Impaired medial rectus inhibition may occur with midbrain lesions as documented in a patient with an unilateral convergence paresis as a clinical sign of an ipsilateral

midbrain dysfunction, who also had an ipsilateral abduction paresis with grossly impaired medial rectus inhibition and normal lateral rectus excitation [23]. Medial rectus inhibition was attributed to several different mechanisms. Pola and Robinson [74] proposed the existence of inhibitory fibres ascending within the medial longitudinal fasciculus (MLF). As MLF fibre activity is always associated with contraversive eye movements, i.e. ipsilateral to the adducting eye [74,75], inhibitory MLF fibers would have to cross at the 3rd nerve nucleus level to reach the medial rectus motoneurons on the side of the abducting eye [74]. Such crossing of MLF fibres, however, has not been demonstrated so far [76,77].

Pierrot-Deseilligny [78] discussed an inhibition of excitatory abducens nucleus internuclear neurons ("disfacilitation") as the working mechanism of medial rectus inhibition. This inhibition was attributed to the activity of inhibitory burst neurons located within the dorsomedial pontine reticular formation, which receive afferents from the ipsilateral PPRF and project to contralateral abducens nucleus neurons [79,80]. Bilateral interruption of this connection and of both MLF, however, was followed by bilateral INO and bilateral loss of lateral rectus inhibition but only mild impairment of medial rectus inhibition [71]. Moreover, loss of excitatory MLF fibre activity is not associated with a reduced tonic resting activity of the medial rectus muscle [81–83]. These findings do not support the concept that inhibition of excitatory abducens nucleus internuclear neurons is important for medial rectus inhibition.

There is some experimental data supporting the concept of an inhibitory projection to medial rectus motoneurons: Fibre degeneration studies in rabbits [84] and primates [85] and autoradiographic studies in cats [86] and primates [76,87] demonstrated an uncrossed connection between the pontine reticular formation and the 3rd nerve nucleus. This projection originates from neurons in the pontine reticular formation between the level of the 4th and 6th cranial nerve nuclei [88] ascending adjacent but separate from the MLF [76,85], and approaching medial rectus motoneurons [87]. Stimulation of these neurons in animals with bilaterally destructed MLFs was followed by monosynaptic inhibitory potentials in ipsilateral 3rd nerve nucleus neurons and ipsilateral medial rectus motoneurons [88–90]. If this connection mediates medial rectus inhibition, its lesion would be followed by an abduction paresis with normal lateral rectus activation but impaired medial rectus inhibition.

The locations of the responsible lesions thought to be followed by an impaired medial rectus inhibition or abnormal convergence during lateral gaze are in accordance to

both, abnormal electrophysiological and clinical findings, and to an ischemic origin of the lesions as diagnosed in most of our patients. The regions in question, i.e. the midbrain area containing convergence neurons, the region of the uncrossed inhibitory connection, and the trigeminal mesencephalic tract and nucleus forms a watershed zone. It is supplied by long penetrating branches of the basilar artery with additional contributions from paramedian, lateral, and dorsolateral branches of the posterior cerebral artery and the superior cerebellar artery [91,92]. Occlusion of a long penetrating artery may cause unilateral or bilateral lesions, as these arteries often show an asymmetric termination [91,92], which explains bilateral MassR abnormalities in our patients. EOG documented slowed abduction saccades on non-paretic may also be attributed to asymmetric bilateral lesions. The close relation of the mesencephalic tract and nucleus of the trigeminal nerve to both, mesencephalic convergence neurons and the probably inhibitory connection between the pontine reticular formation and the medial rectus subnucleus, explains abnormal MassR findings in our patients. Slowed contraversive saccades (in 5 of our patients) may also occur with lesions near the 3rd nerve nucleus, if such lesions involve the descending excitatory fibres to the paramedian pontine reticular formation before its crossing at the 3rd/4th nerve nucleus level. A combined abduction and superior oblique palsy in the same eye and an ipsilateral MassR abnormality, which is caused by a single responsible lesion, can only be attributed to a midbrain lesion involving the intra-axial segment of the crossed 4th nerve, which runs closely related to the probably inhibitory connection and the trigeminal mesencephalic tract and nucleus. Monocular elevation paresis and abduction paresis in the same eye may also be caused by a single ipsilateral midbrain lesion involving the probably inhibitory connection and the intramesencephalic 3rd nerve, as monocular elevation paresis may also be caused by intra-axial 3rd nerve lesions [93].

Conclusions

Our data add further evidence on the existence of an abduction paresis with rostral pontine or mesencephalic lesions. With such locations, the most likely explanation is an increased tone of the antagonistic medial rectus muscle during lateral gaze, which may be due to abnormal convergence or impaired medial rectus inhibition. Both mechanisms are followed by "a failure of ocular abduction which is not due to dysfunction of the sixth nerve" [24]. Such ocular motor disorder resembles the ominous and unsettled "posterior internuclear ophthalmoplegia" of Lutz only with respect to its prenuclear origin, but not its mechanism. An impaired excitation of the lateral rectus muscle in one eye without impaired excitation of the medial rectus muscle in the other eye, as proposed by

Anton Lutz, is not compatible with the proven prenuclear organisation of horizontal eye movements. All kinds of horizontal eye movements (saccades, pursuit, vestibulo-ocular-reflex) are generated by an excitation of both, abducens nucleus motoneurons and internuclear neurons [see for review [57]]. This is followed by the simultaneous activation of the lateral rectus muscle in one eye (via projections of lateral rectus motoneurons) and the medial rectus muscle in the other eye (via the projections of abducens nucleus internuclear neurons, which cross at the abducens nucleus level and ascend in the medial longitudinal fasciculus to medial rectus motoneurons). Impaired excitation of the lateral rectus muscle without excitation of the medial rectus muscle in the opposite eye can not occur with lesions of prenuclear excitatory connections mediating horizontal gaze. This is only seen with infranuclear lesions of the 6th nerve. An increased tone of the antagonistic medial rectus muscle during lateral gaze is the only possible mechanism of an abduction paresis, which is not caused by a sixth nerve lesion. Such an ocular motor disorder should be called "pseudoabducens palsy" [29] or "pseudo-sixth" [24], because the term "posterior INO" was introduced on the basis of an erroneous neuroanatomical concept. Moreover, Cogan [94] had his own anterior and posterior types of internuclear ophthalmoplegia (INO) using the term "posterior INO" for the well known INO (= adduction paresis on lateral gaze and preserved adduction during convergence), and the term "anterior INO" for an INO with convergence paresis, which further confuses terminology [95].

Diagnosis of a pseudoabducens palsy should only be considered in patients with clinical, electrophysiological, or morphological evidence of an ipsilateral rostral pontine or mesencephalic lesion. In our experience, such an eye movement disorder is very rare with an incidence of less than one tenth as compared to the incidence of the well known internuclear ophthalmoplegia with adduction paresis on lateral gaze but usually preserved adduction during convergence.

Competing interests

None declared

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