money, used illegal stimulants, and repeatedly caused traffic accidents. Stereotypic behaviors also occurred. He was admitted to a psychiatric hospital at age 33. He had no relevant past medical or family history. Neurological examination revealed reduction of speech output, indifference, repetitive behaviors, emotional incontinence, sucking reflex, and urinary and fecal incontinence. Baseline blood, urine, and cerebrospinal examinations were unremarkable. Electromyography was within normal limits. Although he was initially suspected to have schizophrenia, the diagnosis was changed to early onset Pick's disease. Thereafter, forced grasping, sucking reflex, snout reflex, palmomental reflex, Babinski reflex, pica, utilizing behavior, and hypersexuality also developed. No muscle weakness, muscle atrophy, or impairment of spatial function was found. Electromyography and nerve conduction velocity testing were within normal limits. At age 36, flexion in all four extremities, swallowing difficulty, and bilateral ankle clonus developed. Rigidity and tremor were not observed during the course. He died of pneumonia at age 37 about 8 years after the onset.

Summary of clinical features of BIBD and NIFID

The clinical features in all BIBD and NIFID cases are summarized in Table 1. The mean age at onset was 46.8 ± 11.6 years in BIBD cases and 48.0 ± 26.9 years in NIFID cases. The mean disease duration was 7.8 ± 2.8 years in BIBD cases and 6.9 ± 1.6 years in NIFID cases. BIBD and NIFID cases shared several clinical features besides frontal symptoms. The onset symptoms were frontal syndrome in three BIBD and one NIFID cases. Other onset symptoms included muscle weakness (one BIBD case), dysarthria (one BIBD and one NIFID cases), and memory impairment (one BIBD case). Dementia developed more than 1 year after the onset in one BIBD and one NIFID cases, but did not exhibit frontal syndrome at onset. Dysarthria, dysphasia, upper and lower motor neuron signs, gait disturbance, parkinsonism, and parietal symptoms were noted in both diseases during the course. Memory impairment and involuntary movements like alien-hand sign, athetosis, and chorea were found only in BIBD cases in our series.

Radiological findings in BIBD and NIFID

The BIBD (case 4) and NIFID cases (cases 5 and 6) that were examined radiologically consistently showed rapidly progressive severe atrophy in the frontotemporal lobe and caudate nucleus. A flattened caudate nucleus was observed by 1–5 years after the onset (Figs. 1, 2). In both NIFID cases, the frontal atrophy was accentuated in the convexity, and the temporal base was relatively preserved in the early course. Positron emission tomography (PET) of a NIFID case (case 5) disclosed left side-predominant hypometabolism in the perisylvian region as well as frontal lobes, being compatible with the findings of corticobasal degeneration (CBD; data not shown).

Neuronal loss in BIBD and NIFID

The distribution of cerebral atrophy in BIBD and NIFID cases is shown in Table 2. The distribution of frontotemporal atrophy in our BIBD cases varied from case to case (Fig. 3a, b). However, in the NIFID cases, the frontal convexity was prominently affected, and the temporal base was relatively preserved (Fig. 3d, e, f). Atrophy of the frontal convexity was accentuated in the posterior portion rather than the anterior portion in one NIFID case (case 5; Fig. 3d). Evident atrophy in the precentral gyrus was found in two BIBD (cases 3 and 4) and both NIFID cases (Fig. 3a, b, d, e). All BIBD and NIFID cases showed severe caudate atrophy with a concavity of the ventricular surface (Fig. 3c, f).

Microscopically, BIBD and NIFID cases had similar topographical distributions and severities of neuronal loss (Table 2). Severe neuronal loss in the frontal and/or temporal cortex was frequently found in both diseases, and subcortical gliosis with loss of the myelin in the frontal lobes was evident in all BIBD and NIFID cases. No ischemic change was noted in the white matter in the frontotemporal lobe in any BIBD and NIFID case. Astrocytosis in the primary motor cortex was found in one NIFID and all BIBD cases, and severe neuronal loss was encountered in one BIBD case and one NIFID case. The corticospinal tract was degenerated in three BIBD and both NIFID cases (Fig. 4a, c). Various degrees of frontopontine tract degeneration were also noted in all BIBD and NIFID cases in which the cerebral peduncle was examined (Fig. 4e, f). Neurons in the hypoglossal nuclei were spared in number in all BIBD and one NIFID cases, although astrocyte proliferation in this site was frequently noted in both diseases. In two cases, one BIBD and one NIFID, which clinically exhibited lower motor neuron signs and for which spinal cord tissues were available, evident gliosis was found in the anterior horns; however, the anterior horn cells in these cases were spared in number (Fig. 4b, d). In the basal ganglia in both diseases, the caudate nucleus was consistently affected by severe neuronal loss (Fig. 5a). Severe degeneration was frequently found in the putamen also (Fig. 5b). Further, some of the BIBD and NIFID cases showed severe degeneration in the thalamus and globus pallidus. In both BIBD and NIFID, the neurons in the nucleus basalis of Meynert were relatively spared in number despite the presence of evident glial proliferation. The substantia nigra was affected by severe neuronal loss in all of our subjects, except for one

Table 1 Clinical features of BIBD and NIFID

	BIBD				NIFID	
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Sex	Male	Male	Female	Male	Female	Male
Age at onset (years)	34	57	56	40	67	29
Duration (years)	6.3	6	12	7	5.7	8
Initial symptoms	Weakness in the left hand, dysarthria	Obsessive behaviors	Behavioral change memory impairment, altered eating habits	Disinhibition	Dysarthria	Disinhibition
Prominent features	Motor neuron disease	Dementia	Dementia	Dementia	Dysarthria, aphasia	Dementia
Clinical diagnosis	ALS with dementia	Pick's disease	Pick's disease	Pick's disease	Slowly progressive aphasia	Early-onset Pick's disease
Oculomotor abnormalities					+	
Dysarthria	+				+	
Dysphasia	+			+	+	
Primitive reflex[a]		+		+	+	+
Gait disturbance	+	+	+	+	+	+
Upper motor neuron signs	+				+	+
Lower motor neuron signs	+				+	
Parkinsonism	+	+		+	+	
Disinhibition				+		+
Apathy, indifference	+	+	+	+	+	+
Economy of effort[b]		+		+		+
Reduction of utterance	+	+		+		+
Stereotypy		+	+	+	+	+
Oral tendency		+				+
Hypersexuality				+		+
Altered dietary habits			+			+
Apraxia and other parietal signs	+	+			+	
Buccofacial apraxia					+	
Memory impairment		+	+			
Face recognition impairment		+	+			
Involuntary movements[c]	+		+			
Cerebellar signs	+					

[a] Palmomental reflex, grasp reflex, sucking reflex, and/or snout reflex

[b] Denkfaulheit

[c] Alien-hand sign (case 1), athetosis (case 3), or chorea (case 3)

BIBD case in which the degeneration was moderate (Fig. 5c). Moderate to severe neuronal loss in the insular and cingulate cortices, amygdala, ambient gyrus, subiculum, and parahippocampal gyrus was consistently found in both diseases. The hippocampal pyramidal neurons were strikingly reduced in number in three BIBD cases for which tissue was available, and one NIFID case also (Fig. 6a, b). Furthermore, marked reduction of the hippocampal granular cells was encountered in two of the three BIBD cases for which tissue was available, and in one NIFID case (Fig. 6a, b).

Inclusion bodies in BIBD and NIFID

All BIBD and NIFID cases had a varying number of round or oval intraneuronal cytoplasmic inclusions (Fig. 7a, b, c). The two diseases could not be distinguished by the morphological features of the inclusions as revealed by conven-

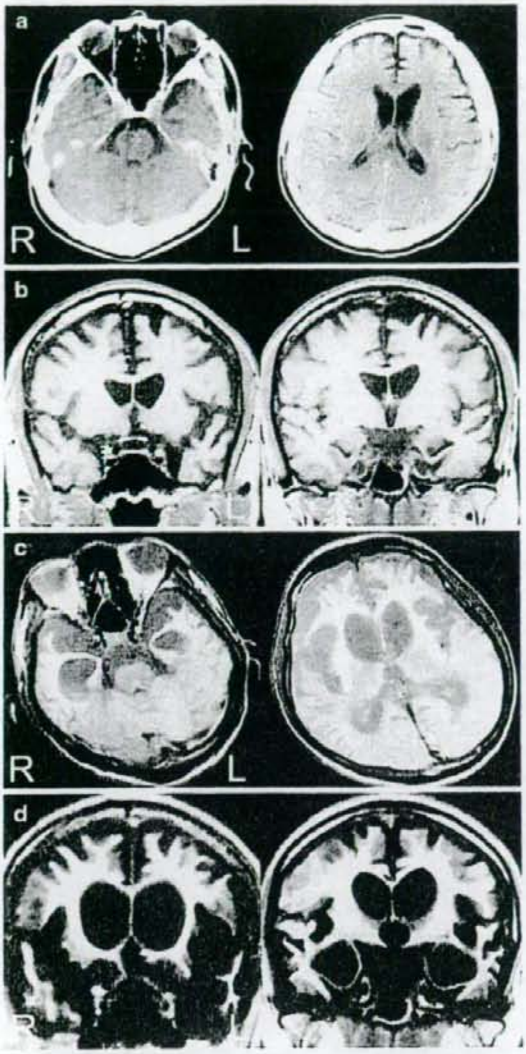

Fig. 1 Serial structural radiographic images of BIBD (case 4). Mild, but not negligible, atrophy in the frontal and temporal lobes and caudate nucleus is seen 2 years after the onset (**a**, **b**). The cortical atrophy is prominent in the frontal convexity and left superior temporal gyrus, and the temporal base is well spared at this time (**b**). Fluid attenuated inversion recovery (FLAIR) images 4 years after onset show severe atrophy in the basal ganglia including the caudate nucleus, frontal convexity, and temporal lobes (**c**, **d**)

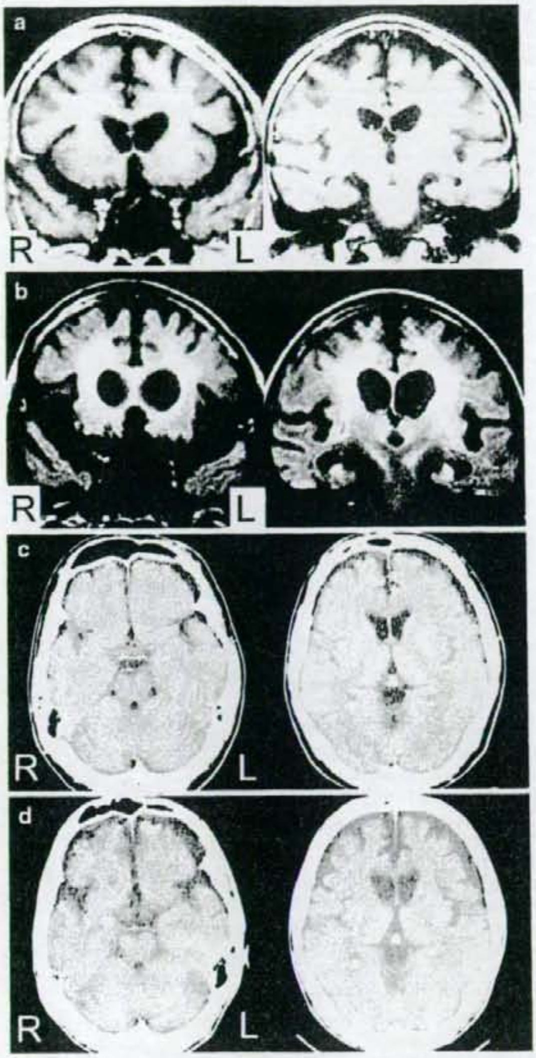

Fig. 2 Serial structural images of NIFID (cases 5 and 6). Coronal T1 images 16 months after the onset in case 5 clearly show the atrophy in the caudate nucleus (**a**). Five years after the onset, the severity of the frontal convexity in case 5 was more prominent in the posterior than in the anterior portion, and the temporal base appears to be spared (**b**). Serial CT images of NIFID in case 6 show mild atrophy in the frontal lobes and caudate nucleus 4 years after onset (**c**). The caudate nucleus is already flattened 5 years after onset, but the temporal lobes are relatively spared (**d**)

tional stains; however, intraneuronal cytoplasmic inclusions having distinct eosinophilic cores were noted only in one NIFID case (case 5, Fig. 7d).

In both NIFID cases, neurofilament-positive inclusions and α-internexin-positive inclusions were encountered in the affected cortex (Fig. 7e). Accumulations of neurofilaments as well as of α-internexin were seen in the hippocampal pyramidal neurons. These accumulations usually had a round or cap-like appearance. In contrast to these aggregates, the spherical inclusions with distinct eosinophilic cores observed in one NIFID case (case 5) were α-internexin-negative and neurofilament-negative (Fig. 7f, g, i, j). Inclusions with cores were frequently encountered in the CA3-4 of the hippocampus and pontine nucleus.

Table 2 Distribution of pathological changes in BIBD and NIFID

	BIBD				NIFID	
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Brain weight (g)	1,230	1,140	880	940	940	940
Cerebral atrophy	Ttip	Ftip, Fbase, Tbase	Ftip, Fbase, Tbase	F, Tbase	Fconv	Fconv, Ttip
Neuronal loss and astrocytosis						
Superior frontal gyrus	+++	+++	++	+++	+++	++
Medial frontal gyrus	+++	+	++	+++	++	+
Inferior frontal gyrus	+++	++	++	+++	++	+
Orbital gyrus	+++	+++	+	+++	+	++
Primary motor cortex	+++	+	+	+[a]	+++[a]	–[a]
Superior temporal gyrus	+++	+	++	+++	+	++
Medial temporal gyrus	+++	++	+++	+++	++	+
Inferior temporal gyrus	+++	+++	+++	+++	++	–
Parietal cortex	+	na	na	+	++	–
Insular cortex	+++	++	+++	+++	+++	++
Cingulate gyrus	+++	+++	+++	+++	++	++
Amygdala	+++	+++	na	+++	+++	++
Ambient gyrus	+++	++	+++	+++	+++	++
CA1 of hippocampus	+++	+++	+++	na	+++	–
Hippocampal dentate gyrus	+++	++	+++	na	++	–
Subiculum	+++	+++	+++	na	+++	+++
Entorhinal cortex	+++	+++	na	na	++	++
Parahippocampal gyrus	+++	++	+++	+++	++	++
Caudate nucleus	+++	+++	+++	+++	+++	+++
Putamen	+++	++	+++	+++	+++	+++
Globus pallidus	++	++	++	++	+++	++
Thalamus	+	++	±	+++	+++	+
Subthalamic nucleus	±	±	na	±	na	±
Nucleus basalis of Meynert	+	±	±	±	±	±
Dentate nucleus of Cerebellum	+	±	±	±	±	–
Trochlear nucleus	na	±	na	±	±	±
Oculomotor nucleus	na	na	na	na	±	±
Substantia nigra	+++	++	+++	+++	+++	+++
Red nucleus	±	na	±	na	±	±
Locus ceruleus	++	±	±	++	±	+
Pontine nucleus	±	±	±	±	±	±
Dorsal vagal nucleus	±	na	±	±	±	–
Hypoglossal nucleus	±	±	±	±	+	±
Inferior olivary nucleus	+	±	±	+	++	±
Frontopontine tract	na	+[b]	+[b]	+[b]	+	+
Corticospinal tract						
Cerebral peduncle	na	–	+	+	+[c]	+
Medulla oblongata	+	–	+	+	+	+
Anterior horn	±	na	na	na	±	na

F frontal, *Ftip* Frontal tip, *Fbase* frontal base, *Fconv* frontal convexity, *Ttip* temporal tip, *Tbase* temporal base. The severity of degeneration in the cerebral cortex, basal ganglia, and brainstem nuclei: -, no histopathological alteration; ±, no neuronal loss but gliosis; +, slight neuronal loss and gliosis; ++, moderate neuronal loss and gliosis; +++, severe neuronal loss and gliosis. Degeneration in the pyramidal tract and that in the frontopontine tract: +, present; –, absent. See details in the text. *na* not available

[a] Moderate astrocytosis was found in the deep cortical layer and adjacent white matter

[b] Degeneration was more evident in the frontopontine tract than in the corticospinal tract at the level of the cerebral peduncle

[c] Degeneration was more evident in the corticospinal tract than in the frontopontine tract at the level of the cerebral peduncle

Because the inclusions with cores were hematoxylin-positive, they were readily distinguished from α-internexin and neurofilament aggregates even in the single immunohistochemistry. Some of the inclusions with cores were surrounded by various amounts of α-internexin and neurofilament aggregates, ranging from a small accumulation (Fig. 7g) to

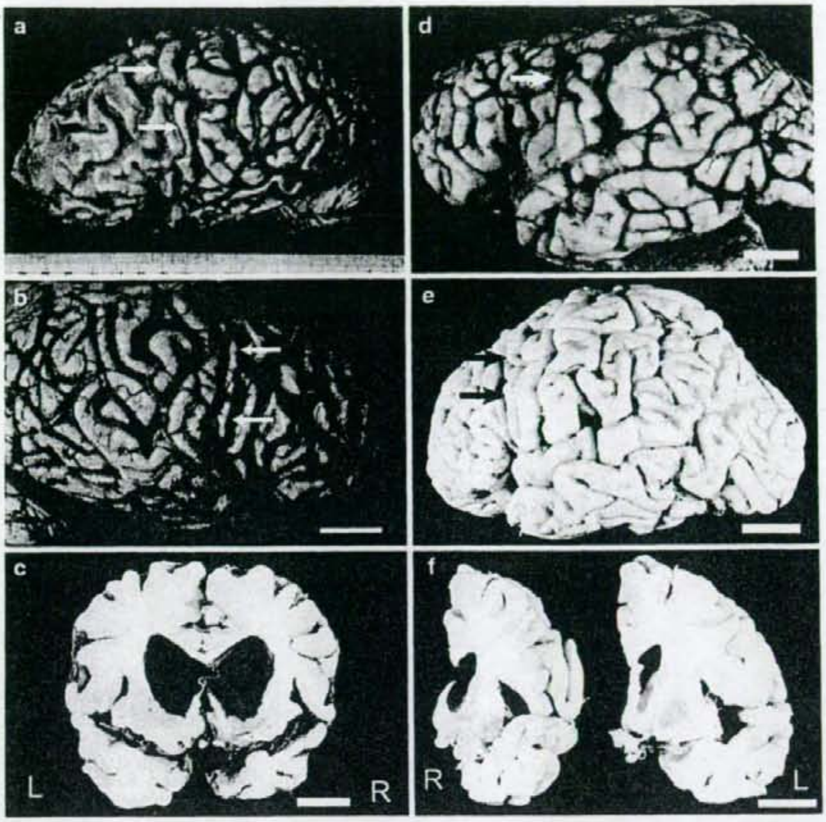

Fig. 3 Macroscopic findings in BIBD and NIFID. **a, b** Marked atrophy of the frontal and temporal lobes in BIBD (case 3). The bilateral precentral gyri are atrophic (*arrows*). **c** Severe atrophy in the basal ganglia as well as the right temporal lobe in BIBD (case 2). Severe dilation of the lateral ventricles with concavities of the ventricular surface is seen. **d** Severe atrophy in the frontal convexity in NIFID (case 5). The most severely affected region appears to be the precentral gyrus (*arrow*). The temporal cortices appear to be spared. **e** Severe atrophy in the frontal cortices including the precentral gyrus (*arrows*) in NIFID (case 6). **f** Although caudate atrophy is prominent, the frontotemporal cortices appear to be relatively spared in NIFID (case 6). All scale bars = 2 cm

a dense and diffuse cytoplasmic pattern (Fig. 7h). In a few of the inclusions with cores that were surrounded by dense aggregates of α-internexin or neurofilament, weak to intense immunoreactivity of α-internexin or neurofilament, respectively, was noted. The inclusions with cores usually contained the epitope of p62 (Fig. 7k). Some of the inclusions with cores also showed weak ubiquitin immunoreactivity. In both NIFID cases, there were no lesions immunostained by anti-C-terminal-specific p62, TDP-43, or polyglutamine antibody. Double immunohistochemistry demonstrated that p62-positive spherical inclusions with cores frequently coexisted with α-internexin-positive inclusions in the cytoplasm of the hippocampal pyramidal neurons (Fig. 7l, m, n, o, p, q). The cores of the inclusions showed absent or only weak p62 immunoreactivity (Fig. 7l, m, n, o, p). α-Internexin aggregates often showed spicules or a tangle-like appearance (Fig. 7p, q). Both p62 and α-internexin aggregates were also found in the cytoplasm of the dentate granular cells, which were often intermingled (Fig. 7r). Although no inclusions with cores were seen in the other NIFID case, a small number of p62-positive inclusions were found in the hippocampus and pontine nucleus. No intranuclear inclusions immunopositive for neurofilament, α-internexin, or p62 were found in our NIFID cases.

In the BIBD cases, no immunoreactivity of tau, α-synuclein, ubiquitin, neurofilament, α-internexin, TDP-43, polyglutamine, or p62-C was seen in inclusions. However, some inclusions in the pontine nucleus in cases 1, 2, and 4 were labeled with anti-N-terminus of p62 antibody (Fig. 7s).

The distribution of basophilic inclusion bodies in BIBD cases was consistent with that reported previously [24]: the inclusions were most frequently found in the basal ganglia and brainstem nuclei. The inclusions were also found in the motor neurons in the hypoglossal nuclei in three BIBD cases (cases 1, 3, and 4) and in the spinal anterior horn cells in one BIBD case (case 1), who presented clinically with lower motor neuron signs. Although scant, the inclusions were noted in the hippocampus, subiculum, parahippocampal gyrus, amygdala, and cerebellar dentate nucleus. In NIFID cases, α-internexin-positive inclusions were frequently observed in the frontotemporal cortex, hippocampal pyramidal neurons, and dentate granular cells. Many inclusions were also encountered in the pontine nucleus (cases 5 and 6) and inferior olivary nucleus (case 5), and to

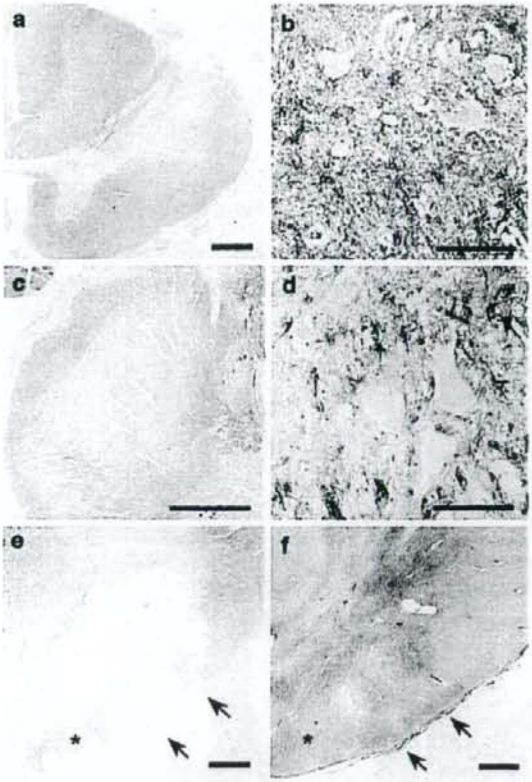

Fig. 4 Motor system involvement in BIBD and NIFID. **a** The cervical cord in BIBD (case 1). Evident loss of myelin in the corticospinal tract is seen. **b** The cervical cord in BIBD (case 1). Severe gliosis in the anterior horn is noted, although the anterior horn cells appear to be spared in number. **c** The cervical cord in NIFID (case 5). Severe loss of myelin in the corticospinal tract is observed. **d** The lumbar cord in NIFID (case 5). Evident gliosis in the anterior horn is seen, but neurons are spared. **e**, **f** Evident loss of myelin with gliosis in the corticospinal tract in the cerebral peduncle (*arrows*) in an NIFID case (case 5). The corticobulbar fibers appear to be involved also, but the degeneration in the frontopontine tract is relatively mild in this case (*asterisks*). **a**, **c**, **e** KB stain; **b**, **d**, **f** Holzer stain. Scale bars = (**a**, **c**, **e**, **f**) 1 mm, (**b**, **d**) 100 μm

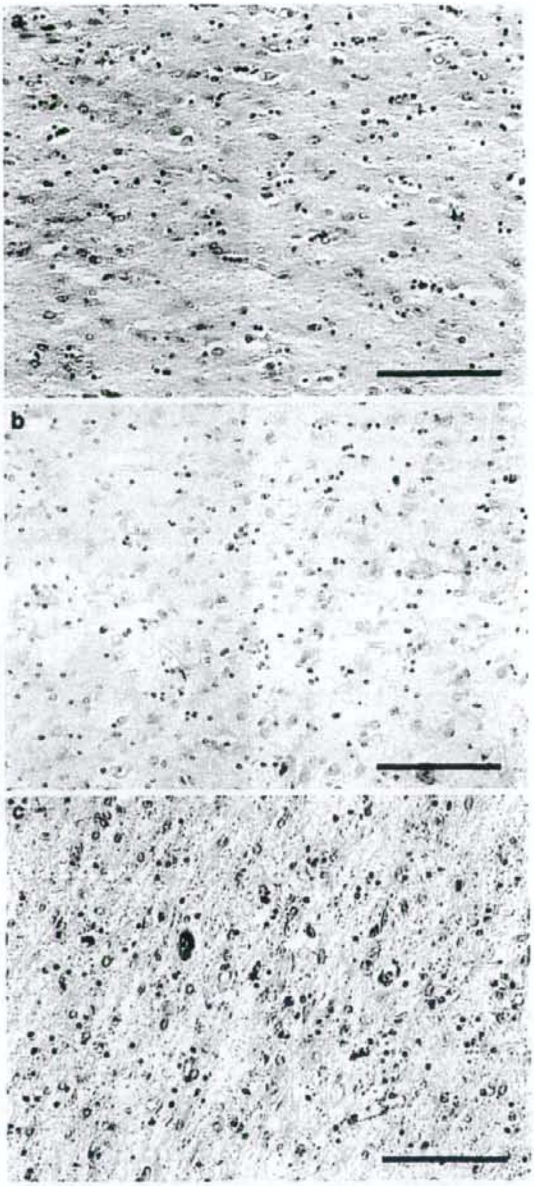

Fig. 5 The basal ganglia and substantia nigra in BIBD and NIFID. **a** Marked neuronal loss and astrocytosis with tissue rarefaction in the caudate nucleus in a BIBD case (case 2). **b** Severe neuronal loss with astrocytosis in the putamen in a BIBD case (case 3). **c** Severe neruonal loss and astrocytosis in the substantia nigra in a NIFID case (case 6). Free melanin was also scattered. **a**, **b**, **c** H&E stain. All scale bars = 100 μm

a lesser frequency, in the dentate nucleus in the cerebellum (case 5).

None of the cases showed neurofibrillary changes, argyrophilic grains, senile plaques, Lewy bodies, or Pick bodies on silver-stained or immunostained sections. No immunoreactivity of TDP-43 was noted in the spinal cord, hypoglossal nuclei, hippocampus, or frontotemporal cortices in BIBD and NIFID cases.

Discussion

Among six cases previously diagnosed as having basophilic inclusions using conventional stains, the diagnosis of two cases (33%) was changed to NIFID. The clinical features of our NIFID cases were consistent with those reported previously. NIFID cases and BIBD cases shared several clinical

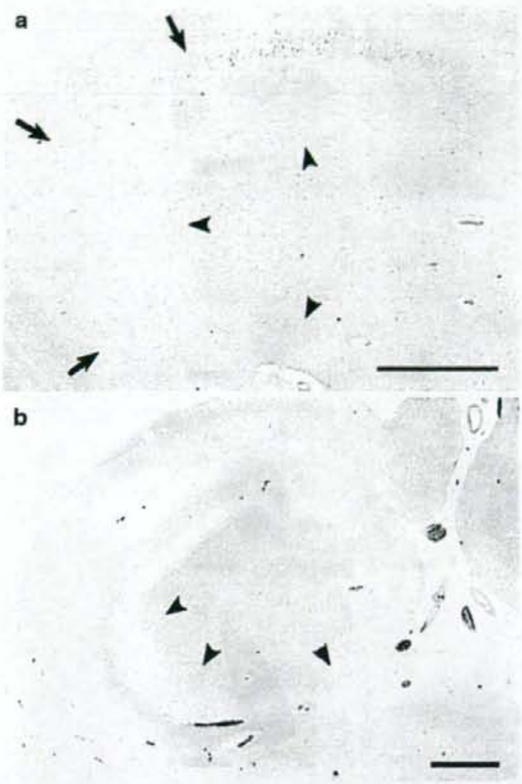

Fig. 6 Severe degeneration of the hippocampus in BIBD and NIFID. **a** BIBD (case 2). *Arrows* indicate severe loss of pyramidal neurons from the CA1 to the subiculum. In addition, the dentate granular cells have almost completely disappeared (*arrowheads*). **b** NIFID (case 5). The pyramidal neurons from the subiculum to CA4 have almost completely disappeared. The dentate granular cells are evidently reduced in number (*arrowheads*). **a**, **b** H&E stain. Scale bars = (**a**, **b**) 1 mm

features besides frontal symptoms, including dysarthria, motor neuron signs, parkinsonism, memory impairment, and parietal symptoms. Given these findings, it seemed to be difficult to clinically differentiate NIFID from BIBD. The distribution and severity of neuronal loss in BIBD cases also resembled those in NIFID cases: severe degeneration was frequently found in the caudate nucleus, putamen, substantia nigra, and pyramidal tract, as well as the frontotemporal cortex. Severe neuronal loss in the hippocampal pyramidal neurons was noted in all three BIBD cases for which the tissues were available and one NIFID case. Further, all of these cases had moderate to severe loss of the granular cells in the hippocampal dentate gyrus. The distribution corresponded to the clinical manifestations of both diseases.

In our BIBD and NIFID cases, the precentral gyrus and pyramidal tract were frequently affected, while the lower motor neurons tended to be spared in number. In previous BIBD cases, especially in MND cases with basophilic inclusions, clinical and pathological evidence of both upper and lower motor neuron involvement was often described. In previous NIFID cases also, the pyramidal tract degeneration was frequently noted, while the lower motor neuron degeneration in NIFID was frequently minimal [7, 17]. Although it is unusual, some of our BIBD and NIFID cases presented clinically with lower motor neuron signs, but did not have significant neuronal loss in the spinal anterior horn cells. The development of lower motor neuron signs in these cases may be explained by the formation of neuronal inclusions with evident astrocytosis in the corresponding sites. Although weakness was noted in some of the previous NIFID cases [7, 17], as far as we know, other lower motor neuron signs including fasciculation and muscle atrophy are rare in NIFID [4, 17, 21, 31]. These clinical findings also appear to support the view that the motor system involvement in NIFID tends to be restricted to the precentral gyrus and pyramidal tract. Further pathological findings need to be accumulated to clarify the histopathological profiles of motor system involvement in BIBD and NIFID.

TDP-43 accumulation is observed in several diseases with motor system involvement, including amyotrophic lateral sclerosis (ALS), FTLD with ubiquitin pathology (FTLD-U) [3, 29], Guamanian parkinsonism–dementia complex (PDC) [12], and Guamanian ALS [10], and to a lesser degree, in some diseases without motor neuron degeneration [2, 26]. In our BIBD and NIFID cases, TDP-43 immunoreactivity was not found in any inclusions, motor neurons, the hippocampal dentate gyrus, or the frontotemporal cortex, which are the preferred sites of TDP-43 accumulation in ALS and FTLD-U. In the consensus criteria recently reported by the Consortium for FTLD also [8], it was accepted that BIBD cases usually lack TDP-43 accumulation, although some of the neurons bearing basophilic inclusions in BIBD cases can show fine granular perikaryal immunoreactivity of TDP-43. Our results also support the view that TDP-43 is not a major pathogenic protein in BIBD and NIFID.

It is noteworthy that the cerebral atrophy in the NIFID cases was accentuated in the frontal convexity rather than the temporal base. Further, in one NIFID case, the frontal atrophy was more prominent in the posterior portion and extended to the parietal region. These findings are in accordance with the previous view that the parietal cortex in NIFID is often affected [7, 17], and that NIFID cases can exhibit CBD-like symptoms including apraxia [16, 17]. On the other hand, alien-hand sign and apraxia were also observed in our BIBD cases, suggesting that BIBD as well as NIFID should be included in the differential diagnosis of a patient presenting with CBD-like symptoms.

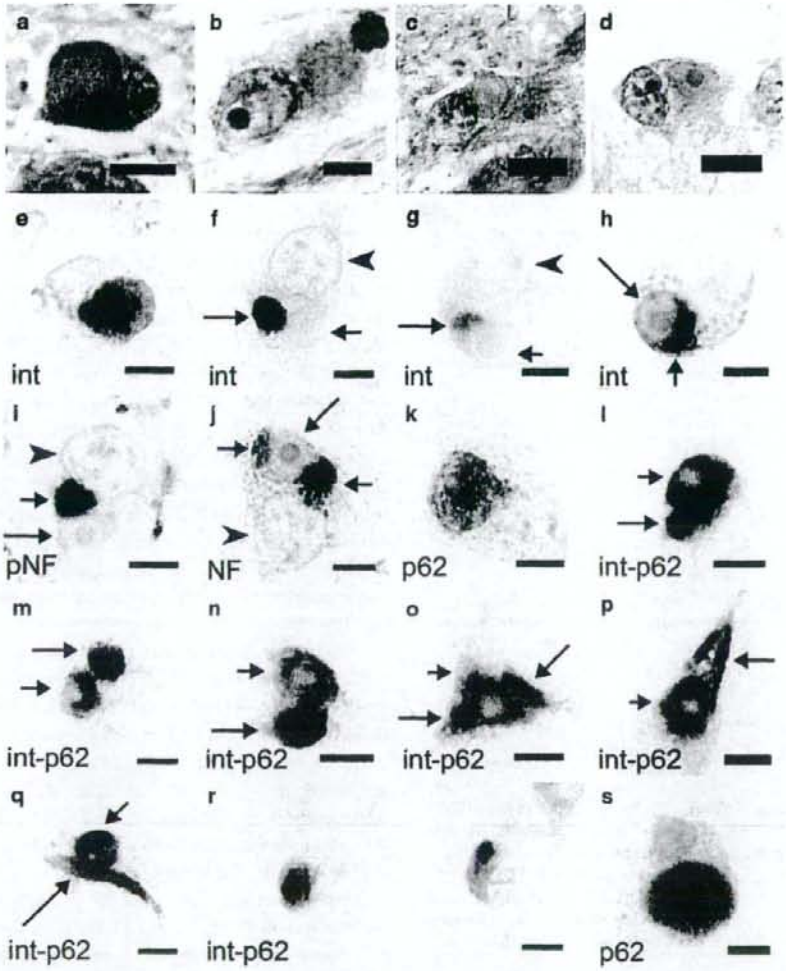

Fig. 7 Intraneuronal inclusions in BIBD (**a**, **b**, **s**) and NIFID (**c**, **d**, **e**, **f**, **g**, **h**, **i**, **j**, **k**, **l**, **m**, **n**, **o**, **p**, **q**, **r**). **a** An inclusion in the pontine nucleus in BIBD. **b** An inclusion in the nucleus basalis of Meynert in BIBD. **c** An inclusion without an eosinophilic core in the pontine nucleus in NIFID. **d** An inclusion with a distinct eosinophilic core (so-called cherry spot) in the CA4 in NIFID. **e** An α-internexin-positive inclusion in the frontal cortex in NIFID. **f** An α-internexin-positive inclusion in a hippocampal pyramidal neuron in NIFID (*long arrow*). The neuron also has an α-internexin-negative inclusion with a distinct core, which appears to correspond to the so-called cherry spot (*short arrow*). An *arrowhead* indicates a nucleus. **g** α-Internexin-negative inclusions with cores in NIFID (*short arrow*) were often accompanied by various amounts of α-internexin accumulation (*long arrow*). An *arrowhead* indicates a nucleus. The CA4. **h** Inclusions with cores in NIFID (*long arrow*) were often surrounded by a dense and diffuse cytoplasmic accumulation of α-internexin (*short arrow*). The pontine nucleus. **i**, **j** Most of the inclusions with cores in NIFID (*long arrows*) were hardly recognized by anti-neurofilament antibodies. *Short arrows* indicate neurofilament aggregates that contact the inclusions with cores. *Arrowheads* indicate nuclei. The CA4. **k** Inclusions with cores in NIFID usually show intense p62immunoreactivity. The CA4. **l**, **m**, **n**, **o** Inclusions with cores in NIFID were p62-positive, but the cores themselves were p62-negative (*black, short arrows*). α-Internexin aggregates frequently coexisted with the p62-positive inclusions with cores in the same neuron (*brown, long arrows*). The hippocampal CA4. **p** Two spicule-shaped neurofilament-positive inclusions (*brown, long arrow*) and a p62-positive spherical inclusion (*black, short arrow*) in a hippocampal neuron in NIFID. The core of the latter inclusion is p62-negative. **q** An α-internexin-positive inclusion showing a spicule-like appearance in NIFID (*brown, long arrow*). A p62-positive round inclusion with a hollow appearance is also present in the same neuron (*black, short arrow*). The CA3. **r** (α-Internexin (*brown*) and p62 (*black*) aggregates in the hippocampal dentate gyrus in NIFID. They were often intermingled. **s** Some inclusions in the pontine nucleus in BIBD cases are p62-positive. **a**, **c**, **d** H&E stain; **b** Klüver-Barrera stain; **e**, **f**, **g**, **h** (α-internexin immunohistochemistry. **i** SMI31 immunohistochemistry; **j** SMI32 immunohistochemistry; **k**, **s** p62-N immunohistochemistry; **l**, **m**, **n**, **o**, **p**, **q**, **r** double immunohistochemistry using anti-α-internexin antibody (*brown*) and anti-N-terminal specific p62 antibody (*black*). **a** Case 3; **e** case 6; **c**, **d**, **f**, **g**, **h**, **i**, **j**, **k**, **l**, **m**, **n**, **o**, **p**, **q**, **r** case 5; **b**, **s** case 2. Scale bar = (**a**, **b**, **c**, **d**) 10 μm, (**e**, **f**, **g**, **h**, **i**, **j**, **k**, **l**, **m**, **n**, **o**, **p**, **q**, **r**, **s**) 5 μm

The degeneration of the basal ganglia in the BIBD and NIFID cases, which did not differ between the two diseases, was more severe and extensive than that in CBD. In our previous semiquantitative study, the globus pallidus and substantia nigra in CBD cases usually showed severe degeneration with fibrous gliosis, but unlike BIBD and NIFID, the putamen and caudate nucleus did not [38]. The development of involuntary movements observed in our BIBD cases might be associated with the severe alteration in the striatum.

All of our BIBD cases for which the tissue was available had severe neuronal loss with gliosis in the hippocampus, although this site was originally reported to be spared in BIBD [24]. Further, all these cases also showed evident loss of dentate granular cells with severe astrocytosis. Loss of neurons in the hippocampus including the dentate gyrus was also observed in one NIFID case. As far as we know, although a varying degree of neuronal loss in the hippocampal pyramidal neurons in NIFID has been described, a reduction in the number of dentate granular cells has not been noted in any previous NIFID case [4, 7, 16, 21, 27]. Whether the severity of the hippocampal lesion differs in NIFID and BIBD remains to be elucidated.

The NIFID cases examined in this study had two types of intraneuronal cytoplasmic inclusions that were differentiated immunohistochemically: (1) neurofilament- and α-internexin-positive round, cap-like, or spicule-shaped inclusions lacking cores and (2) p62-positive but neurofilament- or α-internexin-negative spherical inclusions bearing distinct eosinophilic cores. The morphological features of the latter inclusions were quite similar to those of the "compound intraneuronal inclusion bodies" described by Schochet and Earle in 1970 [35]. At least three cases with compound intraneuronal inclusion bodies have been reported, and interestingly, they were young-onset dementia or MND, and often showed remarkable frontotemporal and caudate atrophy and pyramidal tract degeneration [11, 33, 35]. More recently, Josephs et al. [16] called the eosinophilic core a "cherry spot". Several previous studies demonstrated the morphological and immunohistochemical heterogeneity of inclusions in NIFID. Bigio et al. [4] noted three different morphologic types of intracytoplasmic inclusions in a NIFID case: Pick-like bodies, pleomorphic inclusions, and hyaline conglomerate-like inclusions. They noted that a small number of Pick-like bodies were faintly neurofilament-positive, but the latter two inclusions showed intense neurofilament immunoreactivity. Mackenzie and Feldman [21] described two types of inclusions in an NIFID case: Pick body-like inclusions and hyaline conglomerate inclusions. They described Pick body-like inclusions as round or oval, consistently ubiquitin-positive, rarely neurofilament-positive, and often surrounded by diffuse cytoplasmic immunoreactivity of the neurofilament. They also noted that the center of some hyaline conglomerate inclusions had small, round or elongated eosinophilic masses, but the inclusions appeared to be irregular, sometimes multilobulated, and neurofilament-positive. Thus, the characteristics of the inclusions were not in accordance with those of the inclusions with eosinophilic cores that we observed. Uchikado et al. [40] also noted the presence of α-internexin-negative inclusions in NIFID. Like our results, they observed p62-positive and α-internexin-positive inclusions within the same neuron. However, they noted that round, p62-positive inclusions often occupied a central core of larger α-internexin inclusions, being inconsistent with our results that inclusions with eosinophilic cores were α-internexin-negative. Uchikado et al. further demonstrated electron microscopically that inclusions in NIFID contain two types of components. Based on the presence of neurofilament-negative inclusions, Mackenzie and Feldman [21] speculated that whether NIFID is a single disease entity remains to be elucidated. Indeed, our results led us to speculate that an unknown protein besides neurofilament and α-internexin may play a pivotal pathogenic role at least in some NIFID cases, and possibly, neurofilaments and α-internexin accumulate secondarily in NIFID cases having inclusions with eosinophilic cores. To understand the histopathological heterogeneity in NIFID, further immunohistochemical and biochemical findings need to be accumulated.

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Brief Report

A Large Family with Spinocerebellar Ataxia Type 6 in Iran: A Clinical and Genetic Study

Haruo Shimazaki MD PhD*[‡], Reza Vazifehmand MSc**[‡], Mohhamad-Hassan Heidari PhD**,
Hamid-Reza Khorram-Khorshid MD PhD***, Sassan Saber MD**, Shamsodin Hejazi MD[†],
Fatemeh Aghakhani-Moghadam BSc***, Yi Ouyang MD PhD*, Junko Honda PhD*,
Imaharu Nakano MD PhD*, Yoshihisa Takiyama MD PhD[•]*

The authors describe a large Iranian family with autosomal dominant cerebellar ataxia, which included 14 patients in four generations. We examined seven patients who had expanded CAG repeats in the CACNA1A gene with repeat instability (24 and 25 repeats). Although all patients showed cerebellar ataxia, each patient exhibited peripheral neuropathy or spasticity indicating intrafamilial phenotypic variability.

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Keywords: CAG repeats • Iran • peripheral neuropathy • SCA6 • spasticity

Introduction

Spinocerebellar ataxia type 6 (SCA6) is an autosomal dominant neurodegenerative disorder characterized by late-onset and slowly progressive pure cerebellar ataxia. Patients with SCA6, however, less frequently manifest non-cerebellar symptoms including peripheral neuropathy and pyramidal signs.[1, 2] SCA6 is caused by a CAG repeat expansion in the *CACNA1A* gene that encodes the α_{1A} voltage-dependent calcium channel subunit.[3] To date, SCA6 has been reported from North,[4] and South America,[5] Europe,[1] South Africa,[6] Australia,[7] and East Asia.[8 – 10] We report here a large Iranian family with SCA6 with probable intergenerational instability of CAG repeats in the *CACNA1A* gene and intrafamilial phenotypic variability.

Materials and Methods

The family tree was consistent with autosomal dominant transmission (Figure 1). Four patients with ataxia (II-2, III-7, III-9, and III-21) were thoroughly examined in this family. Information on deceased family members was obtained from senior members of the family. Brain Magnetic Resonance Imaging (MRI) was performed in four patients (II-2, III-7, III-9, and III-21), and a nerve conduction study was performed in one patient (II-2).

Blood samples were obtained with informed consent from nine members, including seven patients (II-2, II-4, II-8, III-7, III-9, III-13, and III-21). DNA was extracted from peripheral blood leukocytes. Polymerase chain reaction (PCR) was performed to amplify the fragment of the *CACNA1A* gene containing the CAG repeat with a primer set (S-5-F1 and R1) as described previously.[9] The PCR-produced fragment was electrophoresed in a capillary on an automated ABI PRISM 310 genetic analyzer (Applied Biosystems, USA). Analysis was performed by use of GenScan analysis software version 3.1.2

Authors' affiliations: *Division of Neurology, Department of Internal Medicine, Jichi Medical University, Tochigi, Japan, **Department of Anatomical Sciences, School of Medicine, Shaheed Beheshti University of Medical Sciences, ***Genetic Research Center, The Social Welfare and Rehabilitation Sciences University, Tehran, †Department of Neurologic Sciences, Qom University of Medical Sciences, Qom, Iran, ‡These authors equally contributed to this work.

•**Corresponding author and reprints:** Yoshihisa Takiyama MD PhD, Department of Neurology, Jichi Medical University, Tochigi 329-0498, Japan.
Tel: +81-285-58-73-52, Fax: +81-285-44-51-18,
E-mail: ytakiya@jichi.ac.jp
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(Applied Biosystems). The CAG repeat sizes were determined by using size markers derived from plasmid DNAs containing 17 and 21 CAG repeats, and a GenScan-500 TAMRA.

This study was approved by the Medical Ethical Committee of Jichi Medical University.

Results

This large Iranian family included 14 patients with ataxia in four generations. We examined a 43-year-old man (III-9), a 53-year-old man (III-21), a 75-year-old woman (II-2), and a 45-year-old woman (III-7) in this family. The clinical findings in the four patients are summarized in Table 1. Other three patients (II-4, II-8, and III-13) were described as ataxic cases in the previous medical records. Cerebellar ataxia was found in all four patients. Patient II-2 showed hyporeflexia and decreased vibratory sensation without diabetes mellitus and vitamin B12 deficiency. A peripheral nerve conduction study of this patient disclosed mild reduction of motor nerve conduction velocities in the lower extremities and severe decrease of sensory nerve action potentials with moderately reduced conduction velocities, indicating peripheral neuropathy (data not shown). Patients III-21 and III-7 exhibited hyperreflexia with Babinski signs. Furthermore, the latter patient showed spasticity of the lower extremities. Brain MRI of all four patients revealed marked cerebellar atrophy without brainstem involvement (data not shown).

The CAG repeat numbers in the family members were as follows: patients II-2, II-8, III-7, and III-9 had 13/24 repeats, whereas II-4 had 13/25 repeats. Patients III-13 and III-21 had 11/24 repeats. Family members without ataxia (III-4 and III-5) had 11/13 repeats (Figure 1).

Discussion

SCA6 usually includes pure cerebellar ataxia including unsteadiness of gait, horizontal and vertical gaze nystagmus, and dysarthria.[9] In the present family, however, it is noteworthy that each patient exhibited peripheral neuropathy or spasticity in addition to cerebellar ataxia.

Peripheral neuropathy in patients with SCA6 has been reported in a few papers so far.[1,2] Regarding Japanese patients with SCA6, 15.2% of 140 patients showed hyporeflexia.[2] Nerve

Table 1. Clinical features of the patients in the Iranian SCA6 family.

Generation code number	III-9	II-2	III-21	III-7
Age (years)	44	76	54	46
Sex	Male	Female	Male	Female
Age at onset (years)	36	35	40	33
Age at examination (years)	43	75	53	45
Cerebellar				
Ataxic gait	+	+	+	+
Limb ataxia	+	+	+	+
Truncal ataxia	+	+	+	+
Vertigo	+	+	+	+
Gaze nystagmus	+	+	+	+
Dysarthria	+	+	+	+
Peripheral				
Depressed DTRs	-	+	-	-
Disturbance of pinprick and touch sensation	-	-	-	-
Decreased vibration sense	-	+	-	-
Pyramidal				
Spasticity	-	-	-	+
Brisk DTRs	-	-	+	+
Babinski sign	-	-	+	+
Extrapyramidal				
Rigidity	-	-	-	-
Tremor	-	-	-	-
External ophthalmoplegia				
Upward gaze paresis	-	-	-	-
Horizontal gaze paresis	-	-	-	-
Slow eye movement	-	-	-	-
Dementia	-	-	-	-

DTRs: deep tendon reflexes.

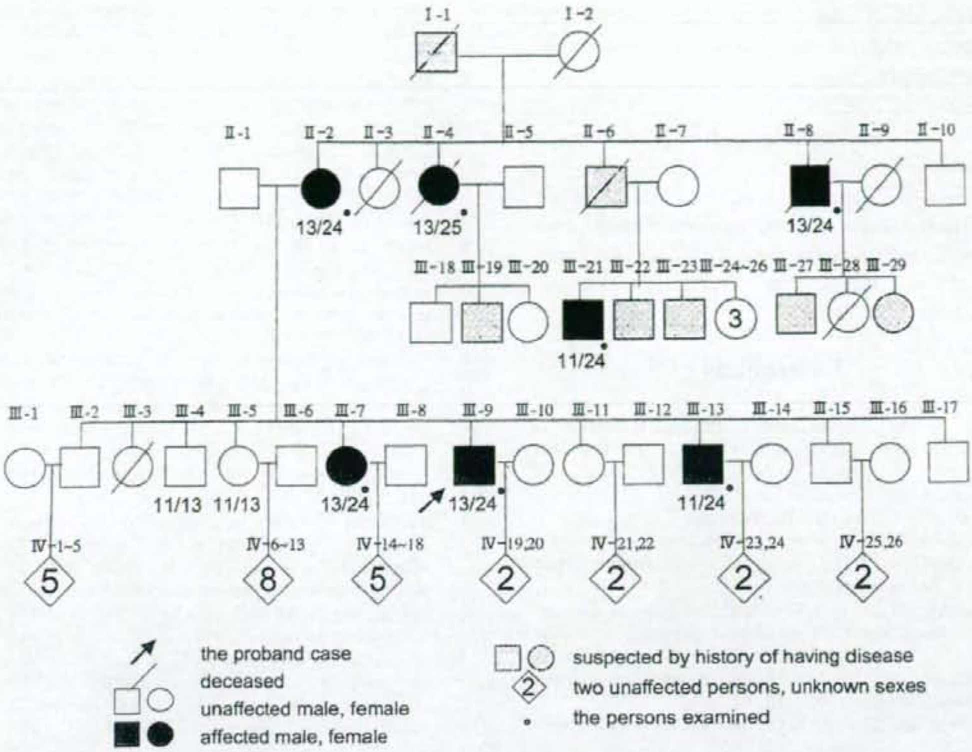

Figure 1. Family tree of the Iranian family with SCA6. The numbers below the symbols for the individuals are the CAG repeat numbers in the CACNA1A gene. The gender is unspecified for the fourth generation members, denoted by diamonds to maintain anonymity.

conduction studies showed normal findings even in patients with hyporeflexia.[2] In contrast, nerve conduction studies disclosed mild sensorimotor peripheral neuropathy with axonal and demyelinating elements in six of ten German patients with SCA6.[1] Thus, peripheral neuropathy appears to be more frequent in German patients than in Japanese ones.

Meanwhile, pyramidal signs including hyperreflexia, spasticity, and Babinski sign have been documented in 6%, 3.8%, and 1.4% of patients with SCA6, respectively.[2] In the present family, two of the four patients showed hyperreflexia and Babinski sign, and one patient showed spasticity in addition to hyperreflexia and Babinski sign.

Schöls et al. described that peripheral neuropathy and spasticity were uncorrelated with CAG repeat length, and that spasticity and neuropathy accompanied a duration of more than five years.[1] In the present family, all four patients examined had the same 24 CAG repeats in the *CACNA1A* gene in spite of phenotypic variability. Each patient with neuropathy or spasticity, however, exhibited a long disease duration, i.e., 40 or 12 years, respectively. Therefore, the disease duration might have influenced the phenotypic variability in our SCA6 patients. Further examinations are required to determine whether or not there is any genotype-phenotype correlation or some factors influence the phenotypic variability in SCA6.

The number of expanded CAG repeats in the *CACNA1A* gene is usually stable during transmission from a parent to an offspring, there being only a few exceptions.[10] Interestingly, patient II-4 had 25 CAG repeats, the other six patients (II-2, II-8, III-7, III-9, III-13, and III-21) having 24 CAG repeats in this family. Unfortunately, we could not obtain direct evidence of intergenerational instability of CAG repeats because of the death of patient I-1. However, there may be intergenerational instability of the CAG repeats in the *CACNA1A* gene in this family.

In conclusion, the present study shows the intrafamilial clinical variability and worldwide distribution of SCA6.

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老年医学の展望

本邦初のパーキンソン病の遺伝子治療

中野　今治

Key words：パーキンソン病，遺伝子治療，ウイルスベクター，アデノ随伴ウイルス，臨床研究

（日老医誌　2008：45：9-13）

はじめに

2007年5月7日（月），我々自治医科大学の遺伝子治療臨床研究グループ（神経内科，遺伝子治療研究部，脳神経外科）により，本邦初となるパーキンソン病の遺伝子治療が実施された．当日，手術の準備は早朝から始められ，無事終了したのは夕方であった．終了の後，チームの主なメンバーで記者会見を行い，その内容はマスメディアで報道された（図1）．

本稿では，我々が実施した遺伝子治療を主体にパーキンソン病の遺伝子治療の概要を述べることにする．

パーキンソン病と現在の治療法

パーキンソン病は，40～70歳で発病する進行性の神経変性疾患で，振戦，寡動，筋強剛と姿勢反射障害を主な症候とする（前三者を3大症候，これに姿勢反射障害を加えて4大症候という）．通常は発病10年前後で寝たきりとなるが，その期間は3～15年と症例によりかなりの幅がある．

中脳の黒質のドパミン合成細胞は，線条体に投射し，その軸索終末でドパミンを合成して線条体に放出する．健常人では，ドパミン合成の第一段階として内在性のチロシンから，チロシン水酸化酵素（tyrosine hydroxylase：TH）によってレボドパが合成される．この際，テトラヒドロビオプテリン（tetrahydrobiopterine：BH4）がTHの補酵素として働くが，BH4合成の律速酵素がGTPシクロヒドロキシラーゼI（GTP cyclohydroxylase I：GCH）である．こうして合成されたレボドパが芳香族Lアミノ酸脱炭酸酵素（aromatic L-amino acid decarboxylase：AADC）によってドパミンに変換されて放出される[1]（図2A）．ドパミンにより興奮する神経細胞の一部は視床下核を抑制して運動が滑らかに行われるように調整している．

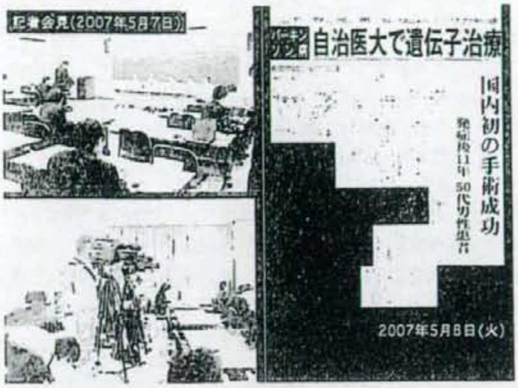

図1　本邦初のパーキンソン病遺伝子治療（2007年5月7日（月））の記者会見の様子と，翌日の新聞記事．

パーキンソン病では，黒質のドパミン合成細胞が進行性に変性脱落するために，線条体のドパミンが不足して発症する（図2B）．線条体でのドパミン不足により視床下核の神経細胞が異常に興奮し，随意運動の滑らかな遂行が阻害されると考えられている．

現在，パーキンソン病治療の原則は薬物療法であり，その主役はドパミンの前駆物質であるレボドパ（ドパ脱炭酸酵素阻害薬との合剤）である．そのほかにドパミン作動薬，放出されたドパミンの分解を防ぐモノアミン酸化酵素阻害薬（セレギリン），ドパミンと拮抗するアセチルコリンの作用を抑える抗コリン薬，ドパミンの放出を促すアマンタジンがある．服用したレボドパが血中で分解されるのを防ぐCOMT阻害薬（エンタカポン）も最近認可された．

パーキンソン病の手術療法として，破壊術や深部脳刺激術があり，現在の主流は視床下核や淡蒼球の電気刺激

A clinical research of AADC gene therapy for Parkinson's disease
Imaharu Nakano：自治医科大学神経内科

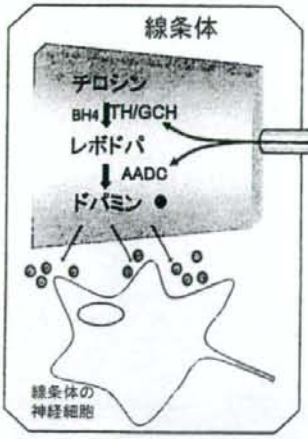

図 2A　健常人のドパミン合成細胞と線条体．黒質のドパミン合成細胞は，線条体に投射し，軸索終末でドパミンを合成して線条体に放出する．

である．また，細胞移植は，黒質のドパミン合成細胞と類似の働きを持つ交感神経節の神経細胞を線条体に移植する治療法である．この場合，患者自身の交感神経節細胞を用いるので拒絶反応は生じない．

これらの治療法はそれぞれ利点と共に，問題も有している．パーキンソン病治療薬の長期間服用により，①効果の減弱，②運動症状の変動，③不随意運動，④立ち直り反射の障害やすくみ足など，抗パーキンソン病薬が奏効しにくい症状，⑤幻覚妄想などの精神症状，が出現する．また，手術療法や細胞移植療法の効果も限られており，適応も限られてくる．このように，進行したパーキンソン病においては現在の治療法では満足すべき効果は得られていない状況であり，新しい治療法の開発が望まれている．遺伝子治療はそのような治療方法として期待される．

パーキンソン病では黒質のドパミン黒質の細胞は変性するが，線条体固有のニューロンは保持されている．我々の行っているパーキンソン病遺伝子治療では，この線条体ニューロンに遺伝子を導入するのである．我々の遺伝子治療の理解にはこのことの認識が必要である．

パーキンソン病の一般的な遺伝子治療戦略

パーキンソン病発症の主なメカニズムは，①黒質のドパミン合成細胞が脱落して，②線条体でドパミンが足りなくなり，③その結果，視床下核が異常に興奮した状態になることによると考えられる．従って，その遺伝子治療の戦略としては，それぞれのステップを阻止することを目指した3つの方法が考えられる．すなわち，黒質ドパミン合成細胞の保護，線条体でのドパミン合成，そして視床下核の興奮抑制である（図3）．ドパミン合成細胞の保護のためには，神経栄養因子の遺伝子を搭載したベクターを線条体に注入して発現させる[2)3)]．発現した神経栄養因子は，黒質からそこに投射しているドパミン合成細胞の軸索を逆行輸送されて細胞体に達し，神経保護作用を発揮することが期待される．第2の戦略は，線条体でのドパミン合成に関わっている3つの酵素（TH，AADC，GCH）の遺伝子を導入することである[4)]．3つめの方法は，視床下核の異常興奮の抑制である．これには，抑制性伝達物質であるガンマアミノ酪酸（GABA）を合成する酵素であるグルタミン酸脱炭酸酵素（glutamic acid decarboxylase：GAD）の遺伝子を視床下核に注入してGABAを合成させる．いずれの手法ともベクターとしてAAVを用い，定位脳手術により目的とする場所に注入する（図3）．

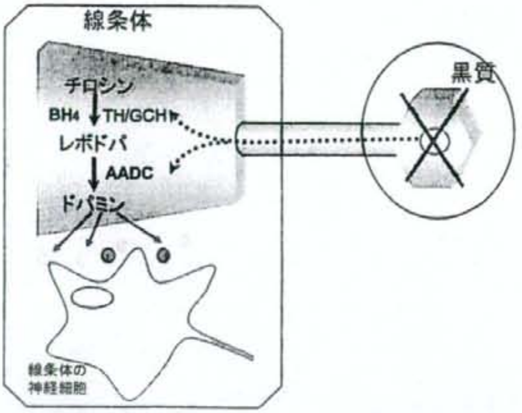

図 2B　パーキンソン病のドパミン合成細胞と線条体．パーキンソン病では黒質のドパミン合成細胞の変性のために線条体でドパミンが不足する．線条体の神経細胞は保全されている．TH：チロシン水酸化酵素，AADC：芳香族アミノ酸脱炭酸酵素，GCH：GTP シクロヒドラーゼ I，BH4：テトラヒドロビオプテリン

アデノ随伴ウイルス（adeno-associated virus：AAV）をベクターとして使用

ベクターとは，治療用遺伝子の運び屋の意味であり，いくつか種類がある．ウイルスベクターはこの運び屋としてウイルスを使った場合の名称である（図4）．

AAVは自然界に存在するウイルスのひとつで，それのみでは増殖できず，人に対しては病原性がなく，成人の多くは不顕性感染の状態にある[5)]．ウイルス由来のタンパク質の遺伝子を取り除き，空いた部分に治療用の遺

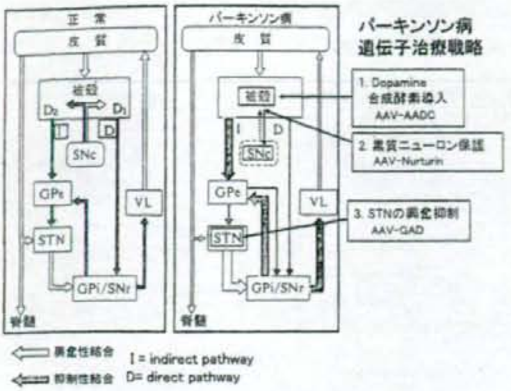

図3　健常人とパーキンソン病における大脳基底核運動系路の機能連関と遺伝子治療戦略

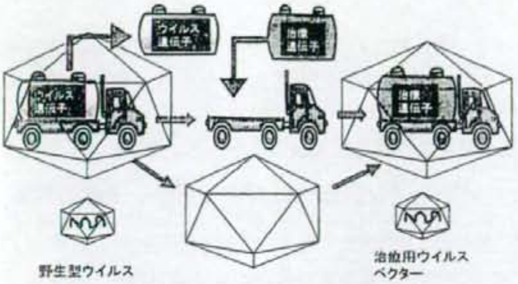

図4　ウイルスベクターの概念図．野生型ウイルスの増殖や蛋白合成に必要な遺伝子（荷台の積み荷）を治療用遺伝子に積み換え，再びウイルス粒子を作成する．遺伝子導入はこのウイルスベクターの感染によって行われる．

伝子を搭載したものが治療用ベクターである．我々の遺伝子治療では，この空いた部分にAADCの遺伝子を搭載している（図4）．

パーキンソン病に対する我々の遺伝子治療戦略

我々は，パーキンソン病のモデルサルで遺伝子治療実験を行って，安全で効果が有ることを確認した後に臨床研究を立案した．

サルの研究では，ドパミン合成に関わる3つの酵素（TH，GCH，AADC）の遺伝子を別々のAAVベクターに搭載して線条体に注入し，治療効果を挙げた[6]（図5）．しかし，臨床研究においては，最初から3種類の遺伝子を同時に注入するのは安全性の点で不安が有ることから，まずAADCの遺伝子のみを注入してAADCを合成させ，L-DOPAを服用することでドパミンを合成する戦略を採用した（図6）．

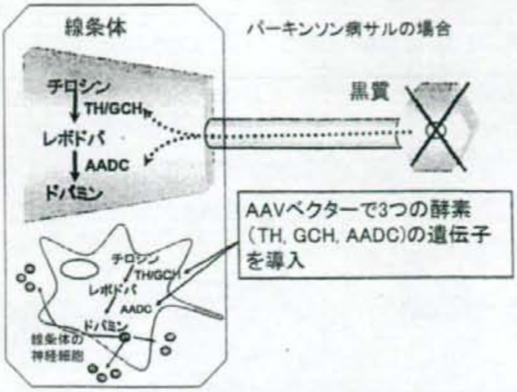

図5　パーキンソン病モデルサルの遺伝子治療実験．サルの場合には3つの酵素（TH：チロシン水酸化酵素，GCH：GTPシクロヒドラーゼI，AADC：芳香族アミノ酸脱炭酸酵素）の遺伝子を同時注入しても安全で奏効することが確認できた．

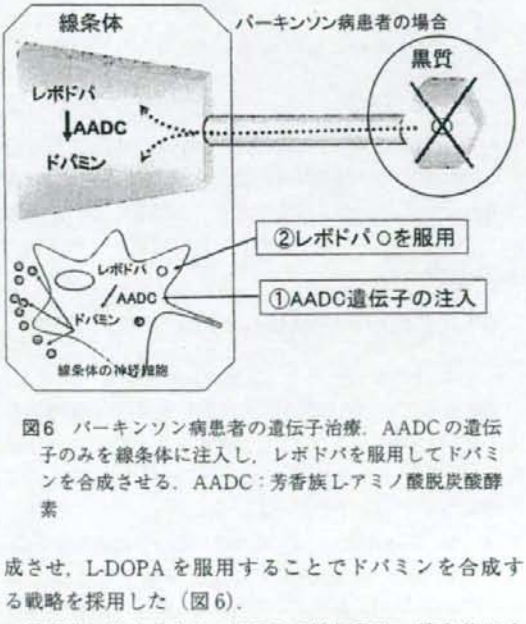

図6　パーキンソン病患者の遺伝子治療．AADCの遺伝子のみを線条体に注入し，レボドパを服用してドパミンを合成させる．AADC：芳香族L-アミノ酸脱炭酸酵素

線条体に注入されたAADCの遺伝子は，線条体固有細胞に入って発現し，AADCを産生する．次に服用した，レボドパがその細胞の中に入って，AADCによってドパミンに変換され，線条体に放出される．この方法であれば，仮にAADCが過剰に発現したとしても，服用するレボドパを減らせば産生されるドパミンの量も減るために副作用の心配もなくなる．

この計画に基づいて，パーキンソン病のモデルサルで

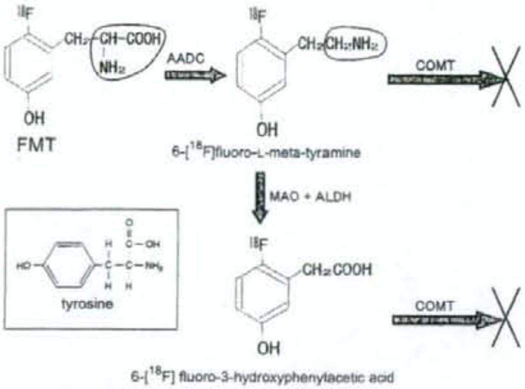

図7　6-[^{18}F]fluoro-L-meta-tyrosine（FMT）の代謝．F-dopamineはCOMTで代謝されるが，F-meta-tyramineは代謝されないため，FMTの方が代謝的に安定である．AADC：芳香族Lアミノ酸脱炭酸酵素，MAO：モノアミンオキシダーゼ，ALDH：アルデヒドデヒトロゲナーゼ，COMT：カテコールアミン—O—メチルトランスフェラーゼ　比較のためにtyrosineを示した．
（Applied Radiation and Isotopes 1990；41（5）pp.433-437より引用）

も人で行うのと同じ方法を試みた結果，AADCの遺伝子だけの注入では効果が無いこと，不随意運動などの副作用もないこと，そして，レボドパを投与することで初めてドパミンが作られて効果が現れ，症状が改善することが確認された．

6-[^{18}F] fluoro-L-meta-tyrosine（FMT）-PET

我々は，特発性パーキンソン病の診断をより確実にし，かつ線条体でのAADC遺伝子発現を視覚的・経時的に追跡するために，FMT-PETシステムを開発した（宇都宮セントラルクリニックで実施）．FMTはAADCにより代謝されて6-[^{18}F] fluoro-L-meta-tyramineになる．これは，F-dopamineと異なり，cathecolamine-o-methyltransferase（COMT）により分解されないために，代謝的に安定である（図7，8）．即ち，黒質ドパミン合成細胞の軸索終末であれ，AADC遺伝子を導入した被殻ニューロンであれ，AADCが存在する部位では，FMTが6-[^{18}F] fluoro-L-meta-tyramineに代謝されて貯留する．そして，そこで陽電子崩壊が生じて光子を放出して，その部位は高信号域として描出される．

パーキンソン病患者では，黒質ドパミン合成細胞の軸索終末が脱落しているために，FMT-PETでは被殻での信号が低下する．一方，AADC遺伝子を導入した患者では，注入部位の被殻ニューロンでAADCが発現するために，術前に減弱していた信号が増加する．PETは繰り返して検査できるために，AADCの発現を経時的に追跡できる利点を有する．

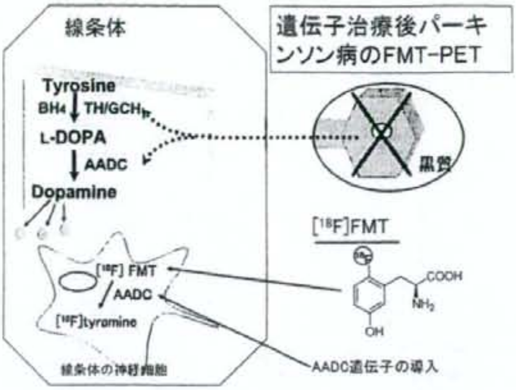

図8　AADC遺伝子導入後のFMT-PETの原理：線条体ニューロンに導入されたAADC遺伝子により，AADCが産生され，FMTがtyramineに代謝されて貯留し，18Fの陽電子崩壊が起こって光子が生じる．

パーキンソン病患者に対する遺伝子治療の実施

我々は，上のような考え方に立って，「AADC発現AAVベクター線条体内投与による進行期パーキンソン病遺伝子治療の臨床研究」という研究課題名で研究計画を策定した．AADC遺伝子を組み込んだ2型AAVベクターを進行したパーキンソン病患者の線条体（被殻）に定位脳手術的に注入し，その安全性を検証するとともに，経口投与するL-dopaによってドパミン産生を促し，パーキンソン症状を改善すること，およびドパミンの過剰合成に伴って生じ得るジスキネジアはL-dopaの投与量を減らすことにより予防することを狙った研究である．同時に，上述のように，導入したAADC遺伝子の発現をFMT-PETを用いて経時的に観察することも主要な課題とした．

この研究計画は，自治医科大学附属病院遺伝子治療臨床研究審査委員会に提出されて審議・承認され，ついで，厚生労働省の厚生科学審議会科学技術部会に申請された．そこでの審議を経た後に，「パーキンソン病遺伝子治療臨床研究作業委員会」で専門的な審議が行われ，2006年10月31日，厚生労働大臣から実施許可証が出た．

その後，様々の準備をし，本治療法の希望者を募集して，50歳代のパーキンソン病男性患者に対して，国内で初めての遺伝子治療を実施した（図9）．

図9　2007年5月7日に実施された遺伝子治療手術．注入ポンプ（→）によりAAV-AADCのベクター液を注入する．

パーキンソン病の遺伝子治療法に関する世界の現状（表1）

上述したように，パーキンソン病に対する遺伝子治療の基本的戦略には大きく3つ有る．米国では，そのそれぞれに従ったパーキンソン病の遺伝子治療が実際に行われている．3つの遺伝子治療ともベクターとしてAAVが用いられており，注入はいずれも定位脳手術で行われている．

我々と同じ方法で行っているのは，カリフォルニア大学サンフランシスコ医療センターで，ここでは既に9例で実施されている．

視床下核の異常興奮を抑える臨床研究では，一側の視床下核にのみGADの遺伝子を注入する．この方法は，2003年にコーネル大学で開始され，現在最初の12例が終了して2007年に論文が発表された[7]．治療側の手足（注射と反対側の手足）で1年後でも症状の改善が認められ，PETを使って遺伝子の働きが確認された．

3番目の臨床研究は，神経栄養因子の一つであるニュールトリン（NTN）の遺伝子を両側の線条体に注入する方法である．これまで12例が治療を受け，1年後の評価では症状が改善していたと報告されている．

おわりに

進行したパーキンソン病に対しては十分な治療法が無く，新規の治療法の開発が望まれている．遺伝子治療は緒に就いたばかりであるが，さらに改良され，期待に答えうる治療法となるものと思われる．

表1　パーキンソン病で現在行われている遺伝子治療（いずれもAAVを使用）

1）線条体でのドパミン合成
  AADC（aromatic L-amino acid decarboxylase）
    UCSF，自治医科大学
2）黒質ドパミンニューロンの保護
  Nurturin（CERE-120）
    UCSF
3）視床下核ニューロンの抑制[7]
  GAD-65, GAD-67（glutamic acid decarboxylase）
    Cornell University

今回の遺伝子治療臨床研究は，自治医科大学神経内科，遺伝子治療研究部，脳神経外科，宇都宮セントラルクリニックの共同研究として実施された．

また，実施に当たっては，自治医科大学附属病院看護部，中央手術部，麻酔科，治験推進室および関係事務部門から多大の支援を賜ったことに謝意を表する次第である．

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