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COMPOUND HETEROZYGOUS INTERMEDIATE MJD ALLELES CAUSE CEREBELLAR ATAXIA WITH SENSORY NEUROPATHY

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Spinocerebellar degeneration (SCD) is a group of disorders characterized by progressive ataxia caused by dysfunction and atrophy of the cerebellum or its projections. Approximately one-third of SCD cases are familial SCD, the majority of which are attributed to CAG triplet repeat expansions including spinocerebellar ataxia (SCA)1, SCA2, Machado-Joseph disease (MJD)/SCA3, SCA6, SCA8, SCA12, SCA17, and dentate-rubro-pallido-luysian atrophy (DRPLA). The triplet repeat number of the alleles representing complete penetrance varies among diseases. Generally, there is a gap between the normal alleles and the complete penetrance alleles. Rarely, intermediate alleles with the repeat numbers between the abnormal and normal ranges are observed, although the implications of these intermediate alleles remain ambiguous.

MJD is one of the most frequent triplet repeat diseases worldwide. The number of CAG expansion repeats for complete penetrance alleles ranges from 60 to 87, whereas that for normal alleles ranges from 12 to 44.¹ Intermediate expansion alleles, with repeats ranging from 45 to 59, are reported to be rare,^{2,3} and their clinical implications have not been completely delineated. Herein, we describe a pedigree with compound heterozygous intermediate alleles in the MJD locus representing progressive cerebellar ataxia and sensory axonal neuropathy.

Cases. The proband (II-3) was a 67-year-old man presenting with slowly progressive cerebellar ataxia with sensory axonal neuropathy who developed unstable gait at age 56 (figure). No symptoms indicative of SCA were reported in their parents, who were deceased over age 80. His medical history was unremarkable. Neurologic examination at age 67 revealed saccadic eye movements in smooth pursuit, mild slurred and scanning speech, limb and truncal ataxia, wide-based gait, difficulty in maintaining Mann posture or performing tandem gait, absence of patellar and Achilles tendon reflex bilaterally, decreased vibration sensation on bilateral ankles, and positivity for Romberg sign. Brain MRIs at age

64 revealed moderate cerebellar and brain stem atrophy (figure). Nerve conduction study at age 65 revealed a decreased amplitude of sensory nerve action potentials (SNAPs) with retained sensory or motor conduction velocity and compound muscle action potentials (table e-1 at Neurology.org/ng).

His 62-year-old younger sister (II-5) developed unstable gait in her late fifties. Neurologic examination and nerve conduction study revealed similar findings as the proband including mild cerebellar ataxia and decreased amplitude of sural SNAP (table e-1). His 64-year-old younger brother (II-4) developed unstable gait at age 60 with a history of long-standing alcohol intoxication. Neurologic examination at age 64 revealed saccadic eye movement in smooth pursuit, very mild gait ataxia, and absence of Achilles tendon reflex. His 69-year-old elder sister (II-2) showed no neurologic symptoms or signs. His elder brother (II-1) did not undergo neurologic examination.

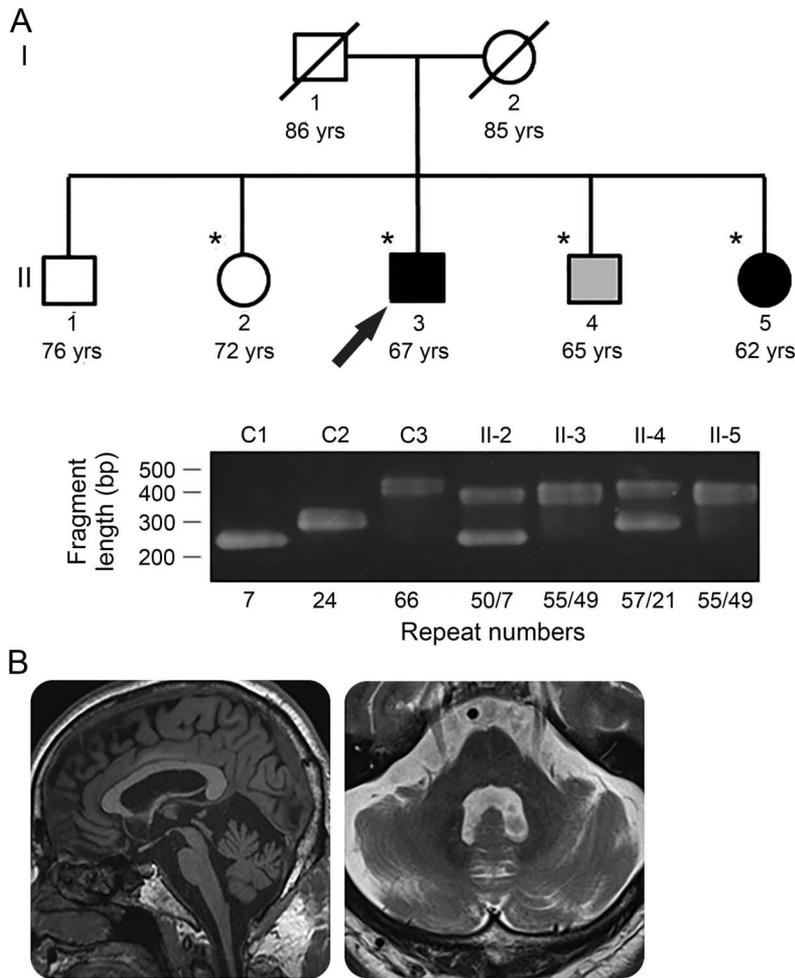
Methods. DNA samples were obtained from all the siblings except for individual II-1 with institutional review board–approved informed consent. PCR-based fragment analysis was performed to detect repeat expansions in SCA1, SCA2, MJD, SCA6, SCA8, SCA12, SCA17, SCA31, and DRPLA loci. Direct nucleotide sequencing method confirmed CAG expansions in the MJD locus (e-Methods).

Results. The CAG repeat numbers in the MJD locus of individuals II-2, II-3, II-4, and II-5 were determined as 50/7, 55/49, 57/21, and 55/49, respectively (figure). The repeat numbers in other loci in the index patient were within the normal ranges.

Discussion. This study demonstrated that the compound heterozygous intermediate CAG expansions in the MJD locus were associated with cerebellar ataxia with sensory axonal neuropathy. The symptoms and signs identified in II-4 were probably due to alcohol intoxication, although the heterozygous intermediate allele might also contribute to the mild phenotype. The different length of intermediate alleles suggested repeat instability, PCR stuttering, or nonpaternity. A rare normal allele with 7 CAG repeat was observed.⁴ Clinical manifestations of the

Supplemental data
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Figure Genetic data of the index pedigree and brain MRI of the proband



(A) Pedigree chart of the index family and gel electrophoresis image of PCR products of MJD locus. Filled symbols represent the affected individuals and a shaded symbol represents the individual with a very mild phenotype. The arrow indicates the proband. The asterisks indicate individuals included in neurologic examination and linkage study. Age at the time of examination or age at the time of death is shown below each symbol. In the gel electrophoresis image, C1, C2, or C3 represents internal controls containing 7, 24, or 66 CAG repeat in MJD locus. Each repeat number is shown below the corresponding lane. (B) Brain MRIs of the proband. A T1-weighted sagittal image and a T2-weighted axial image represent mild atrophy of the cerebellum and brain stem.

patients with heterozygous MJD intermediate alleles in previous reports varied, including ataxia with autonomic dysfunction⁵ or restless leg syndrome with sensory axonal neuropathy without overt cerebellar ataxia.⁶ Thus, this study provides insight into the clinical implications of MJD intermediate alleles.

Of note, the intermediate alleles are assumed to have an additive effect considering that each intermediate allele by itself was unlikely to cause complete penetrant phenotypes in this pedigree. Homozygous complete penetrance alleles in MJD loci tended to cause more severe phenotypes with earlier onset than heterozygous complete penetrance alleles.⁷ The underlying mechanism was postulated as follows: homozygous expanded polyglutamine tracts in ataxin-3 proteins more likely aggregate than

heterozygous expanded tracts.⁷ Likewise, this study raises the possibility that 2 intermediate alleles together might confer the polyglutamine-derived cytotoxicity above the threshold, triggering multiple mechanisms for the development of MJD.

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- Costa Mdo C, Paulson HL. Toward understanding Machado-Joseph disease. *Prog Neurobiol* 2012;97:239–257.
- Lima M, Costa MC, Montiel R, et al. Population genetics of wild-type CAG repeats in the Machado-Joseph disease gene in Portugal. *Hum Hered* 2005;60:156–163.
- Gan SR, Ni W, Dong Y, Wang N, Wu ZY. Population genetics and new insight into range of CAG repeats of spinocerebellar ataxia type 3 in the Han Chinese population. *PLoS one* 2015;10:e0134405.
- Freund AA, Scola RH, Teive HAG, et al. Spinocerebellar ataxias: microsatellite and allele frequency in unaffected and affected individuals. *Arq Neuropsiquiatr* 2009;67:1124–1132.
- Gu W, Ma H, Wang K, et al. The shortest expanded allele of the MJD1 gene in a Chinese MJD kindred with autonomic dysfunction. *Eur Neurol* 2004;52:107–111.
- van Alfen N, Sinke RJ, Zwarts MJ, et al. Intermediate CAG repeat lengths (53,54) for MJD/SCA3 are associated with an abnormal phenotype. *Ann Neurol* 2001;49:805–807.
- Carvalho DR, La Rocque-Ferreira A, Rizzo IM, Imamura EU, Speck-Martins CE. Homozygosity enhances severity in spinocerebellar ataxia type 3. *Pediatr Neurol* 2008;38:296–299.

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