Heterozygosity at Polymorphic Codon 219 in Variant Creutzfeldt-Jakob Disease

Ana Lukic, MD, MRCP; Jonathan Beck, Bsc; Susan Joiner, Bsc; Julian Fearnley, FRCP; Steve Sturman, FRCP; Sebastian Brandner, FRCP; Jonathan D. F. Wadsworth, PhD; John Collinge, FRS; Simon Mead, PhD, MRCP

Background: Genetic variants of the prion protein gene (PRNP) strongly determine susceptibility to prion diseases. All tested patients with definite variant Creutzfeldt-Jakob disease (vCJD) are homozygous for methionine at a common polymorphism at codon 129. A further genetic polymorphism at codon 219, a common variant in several Asian populations, is considered protective against sporadic CJD.

Objective: To report a finding of heterozygosity at codon 219 in 2 patients with vCJD.

Design: Case reports.

Setting: MRC (Medical Research Council) Prion Unit and Department of Neurodegenerative Disease, University College London Institute of Neurology, and National Prion Clinic, National Hospital for Neurology and Neurosurgery.

Patients: Two patients with clinical and investigation findings consistent with the diagnoses of probable vCJD.

Main Outcome Measures: Clinical and genetic findings.

Results: A 34-year-old man had a 15-month history of behavioral change progressing to ataxia, dysarthria, involuntary choreiform movements, and severe cognitive impairment. Cerebrospinal fluid analysis was positive for 14-3-3 protein, electroencephalography showed generalized slowing, and magnetic resonance imaging revealed thalamic high signal bilaterally, typical of vCJD. A 31-year-old woman had a 16-month history of cognitive decline, ataxia, involuntary choreiform movements, and myoclonic jerks. Magnetic resonance imaging showed bilateral pulvinar high signal. The diagnosis was confirmed by a tonsillar biopsy demonstrating abnormal prion protein deposition in a typical pattern for vCJD. PRNP sequencing showed a methionine homozygous codon 129 genotype and an E219K polymorphism in both patients.

Conclusions: The E219K polymorphism is neutral or may even confer susceptibility to vCJD. The observations are interpretable in the context of the conformational selection model of prion replication. A barrier to prion disease transmission depends on the degree to which permitted pathologic conformations of the prion protein overlap between the inoculum and the host.

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Prions are lethal human pathogens that cause neurodegenerative diseases with acquired, inherited, or unknown etiologies. Variant Creutzfeldt-Jakob disease (vCJD), an acquired prion disease transmitted by exposure to bovine spongiform encephalopathy prions, was first recognized in the mid-1990s. More than 200 cases have been identified worldwide, most in the United Kingdom. In neuropathologically confirmed vCJD, every patient who has undergone genotyping to date has been homozygous for methionine at a common polymorphism of the prion protein gene (PRNP) at codon 129. This genetic variant has profound susceptibility effects across all categories of prion disease. Studies modeling human susceptibility to bovine spongiform encephalopathy prion infection in transgenic mice have suggested that different clinicopathologic phenotypes may occur in individuals with other PRNP codon 129 genotypes.

A further genetic polymorphism has been reported at codon 219 in which guanine (G) is replaced by adenine (A) in the first position of codon 219, resulting in substitution from glutamic acid (E) to lysine (K). This polymorphism is common in Japan, with an allele frequency of 0.06 in the healthy population. It has not been reported in patients with sporadic CJD (sCJD) in the Korean and Japanese populations and is, therefore, considered strongly protective against this disease. Herein we report heterozygosity at codon 219 in 2 patients with diagnoses of vCJD and their clinical and investigation findings.
PATIENT 1

A 34-year-old British man presented in 2004 with a few months’ history of personality change and mild episodic memory impairment. He became obsessive, socially withdrawn, and apathetic, and he began to experience difficulty with managing finances. Several months later his gait was noted to be unsteady, and he was intermittently incontinent of urine. Subsequently, he developed clumsiness in the upper limbs and difficulty manipulating fine objects, and he could no longer use a knife and fork. His gait became increasingly unsteady, and he started to fall. His mood deteriorated significantly, and he began to demonstrate suicidal ideation. He was soon unable to perform his usual daily activities. He subsequently became doubly incontinent, he started to experience choreiform movements in the upper limbs, and he spoke less. He seemed to respond to visual hallucinations and experienced a disordered sleep-wake cycle. Physical examination revealed a bilateral grasp reflex. Involuntary choreiform limb movements were present, in addition to purposeful rubbing of his chest and hair. Spontaneous myoclonus of the lower limbs was present. His speech was hypophonic, mumbling, and monosyllabic. His gait was ataxic, with reduced arm swing, and he was unsteady on turning. There was increased tone and preserved power in all 4 limbs. His reflexes were symmetrical brisk, and the plantar responses were extensor bilaterally.

His Mini-Mental State Examination score was 12 of 30 at the time of investigation, 12 months after symptom onset. Investigation findings were positive for cerebrospinal fluid 14-3-3 protein and a raised S-100B protein level of 0.38 ng/mL, with a cerebrospinal fluid protein concentration of 0.07 g/dL (reference range, <0.38 ng/mL), with a cerebrospinal fluid protein concentration of 0.07 g/dL (reference range, 0.02-0.05 g/dL [to convert to grams per liter, multiply by 10]) and otherwise normal cerebrospinal fluid constituents and no oligoclonal bands. Electroencephalography revealed nonspecific slow wave activity. Diffusion-weighted magnetic resonance imaging showed increased thalamic signal bilaterally, consistent with the pulvinar sign. There was increased tone and preserved power in all 4 limbs. His reflexes were symmetrical brisk, and the plantar responses were extensor bilaterally.

Histopathology showed a bilateral grasp reflex bilaterally and brisk finger jerks. The patient had abnormal movements of her upper and lower limbs and a rocking movement of the body, which were suppressible only for a short period. Tone and power were normal. Her reflexes were symmetrical, and the plantar response was flexor. She was disorientated in time and place. She had evidence of frontotemporal and parietal lobe cognitive dysfunction demonstrated by dyspraxia with difficulty miming, substitution of body parts as tools, and problems with motor sequencing. Investigation findings were positive for cerebrospinal fluid 14-3-3 protein. Magnetic resonance imaging showed bilateral pulvinar high signal. Electroencephalography was unremarkable. A tonsillar biopsy demonstrated abnormal prion protein (PrP) typical of vCJD on Western blotting (type 4t PrPSc using the London classification) (Figure). PRNP sequencing revealed a methionine homozygous codon 129 genotype and an E219K polymorphism. The patient deteriorated further and became bed bound and mute. She died 16 months after the onset of symptoms. An autopsy was not performed.

**COMMENT**

Heterozygosity at codon 219 is a common polymorphism in the healthy Japanese population and in populations in Oceania, South Asia, and the Middle East, but it has not been detected in Africans or Europeans. Eleven patients and controls with E219K all had Asian ethnicity or ancestry based on a heterogenous diagnostic referral series totaling more than 1800 samples at the MRC (Medical Research Council) Prion Unit.

Recent data from a transgenic animal knock-in model suggest that the 219E and 219K proteins can convert to PrPSc when challenged with sCJD or vCJD prions. Human PrP 219K–expressing mice succumbed to vCJD with a shorter incubation time compared with human PrP 219E–expressing mice. The E219K heterozygous mice had a longer incubation time to vCJD than did either homozygous mouse. However, the present patients suggest that the heterozygous genotype at codon 219 is not protective against vCJD and may even confer increased...
risk. We do not know whether the PrP30 seen on Western blot of tonsillar tissue in patient 2 includes PrP with 219K or whether this is solely derived from the 219E PrP. The E219K polymorphism occurs as a result of a substitution of negatively charged E by the positively charged K. Further studies are necessary to establish whether this charge change may be critical in permitting the conversion of PrP to its abnormal isoform in vCJD but not sCJD. Our seemingly paradoxical observations may be interpreted in the context of the conformational selection model of prion transmission proposed by Collinge14 in 1999 and Collinge and Clark15 in 2007. This model proposes that prion transmission occurs efficiently when there is an overlap between the infectious prion and the permissible conformations of the host PrP. In this circumstance, the 219K protein may not adopt the molecular conformations found in sCJD, resulting in strong resistance to this disease. However, in vCJD, the model proposes that the 219K protein permits or even favors the bovine spongiform encephalopathy strain, resulting in no resistance to disease or even increased susceptibility.

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Correspondence: Simon Mead, MRCP, National Prion Clinic and Prion Unit, University College London Institute of Neurology, Queen Square, London WCIN 3BG, United Kingdom (s.mead@prion.ucl.ac.uk).

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Study concept and design: Lukic. Acquisition of data: Lukic, Beck, Joiner, Fearnley, Sturman, and Wadsworth. Analysis and interpretation of data: Lukic, Beck, Joiner, Brandner, Wadsworth, Collinge, and Mead. Drafting of the manuscript: Lukic. Joiner, and Wadsworth. Critical revision of the manuscript for important intellectual content: Beck, Fearnley, Sturman, Brandner, Wadsworth, Collinge, and Mead.

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REFERENCES


