PMP22 related congenital hypomyelination neuropathy

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Abstract
The peripheral myelin protein 22 (PMP22) is a tetraspan membrane protein which is localised in the compact myelin of the peripheral nerves. In fibroblasts, where it was originally identified as growth arrest related factor 3 (Gas3), PMP22 has been shown to modulate cell proliferation; in the peripheral nervous system its roles are still debated. The duplication of PMP22 is the most common cause of the demyelinating form of the autosomal dominant Charcot-Marie-Tooth neuropathy (CMT1A); rarer missense mutations of PMP22 also cause CMT1A or severe dehypomyelinating neuropathies of infancy grouped under the heading of Dejerine-Sottas syndrome (DSS). Here, a sporadic patient affected with DSS is described; nerve biopsy disclosed a picture of hypomyelination/amyelination with basal laminae onion bulbs and no florid demyelination and it was consistent with congenital hypomyelination neuropathy (CHN); molecular analysis disclosed a novel point mutation of PMP22 that causes a non-conservative arginine for cysteine substitution at codon 109, in the third transmembrane domain. CHN is the rarest and severest form of DSS and it is thought to reflect dysmyelination rather than demyelination. The reported case suggests that missense point mutations may alter a putative role of PMP22 in modulating Schwann cell growth and differentiation.

Keywords: Dejerine-Sottas syndrome; congenital hypomyelination neuropathy; PMP22

Case report
Our patient, a 14 year old girl, is the first child of healthy non-consanguineous parents; her 12 year old brother is healthy. Early motor milestones were delayed: she could sit at 9 months and walk with orthoses at 4 years. At the age of 3 years she could neither stand nor walk unaided; there were generalised hypotonia and weakness, mainly of the legs, and areflexia. At the median nerve, motor nerve conduction velocity (MNCV) was 3.6 m/s, distal latency (DL) 40 ms, and compound motor action potentials (cMAPs) 200 μV; MNCV at the peroneal nerve was 2.4 m/s. Sensory action potentials (SAPs) were diffusely not evokable. At the age of 7, examination disclosed an ataxic gait with bilateral foot drop, scoliosis, pes cavus, generalised muscle weakness, and wasting prevalent in the legs, areflexia, and distal sensory impairment. Nerve conduction studies...
showed no modifications compared with the previous examination. Brain stem acoustic evoked potentials (BAEPs) showed bilateral increase of the interpeak latency between waves I and III, indicating an involvement of the peripheral acoustic pathways. Brain MRI was normal.

A left sural nerve biopsy performed at the age of 3 was processed for light and electron microscopy as described elsewhere.5 The total transverse fascicular area was increased (1.25 mm²; age matched control=0.37 mm²). Myelinated fibres were markedly decreased (density=1690 fibres/mm²; normal values=10–13 000 fibres/mm²). The histogram of the presumptive myelinated fibres was skewed to the left, 94% of fibres having a diameter smaller than 6 µm. All fibres had no myelin or extremely thin myelin sheaths and were surrounded by Schwann cell processes made of empty basal membranes (fig 1). There was no evidence of active demyelination. The g ratio (axon diameter v total fibre diameter) was markedly increased (0.92; age matched control=0.73).

Genomic DNA was extracted from blood samples of the proband, parents, and 50 healthy controls. The duplication at chromosome 17p11.2-p12 encompassing the PMP22 gene was ruled out by PFGE analysis as described elsewhere.6 The automated direct sequencing of the PMP22 gene and of the myelin protein zero gene (MPZ/P0) was performed as done previously.7 In P0, we did not find any mutation. In PMP22, we detected a heterozygous T to C transition at nucleotide (nt) 374 (exon 4) that causes an arginine for cysteine109 substitution in the third transmembrane domain (TM3) (fig 2). Rapid detection of the mutation was performed by restriction fragment length polymorphism analysis because the T374C transition introduces a CfoI restriction site. Briefly, a 356 base pair (bp) long fragment spanning exon 4 was amplified by polymerase chain reaction (PCR) according to Roa et al,7 and digested with CfoI (New England Biolabs); restriction products were electrophoresed on a 12% acrylamide gel (acrylamide/bis-acrylamide=19/1). CfoI digestion of the 356 bp fragment generated two bands of 212 and 144 bp in the wild type allele and three bands of 161, 144, 51 bp in the mutant allele. The T374C transition was absent in the healthy parents as well as in the 50 healthy controls.

Discussion

In a sporadic patient who met the clinical criteria of DSS, we identified a novel heterozygous Cys109Arg substitution of PMP22. The mutation seemed to be originated de novo because it was absent in the healthy parents. Because the Cys109Arg substitution changes a neutral polar aminoacid into a basic hydrophilic aminoacid and it was absent in 50 healthy controls the mutation is pathogenic. Furthermore, cysteine 109 is likely crucial for the PMP22's structure and function(s) because it is conserved in rat and mouse orthologues, as well as in other growth arrest related molecules belonging to the same family of tetraspan membrane proteins— namely, the human epithelial membrane protein-1 (EMP1) and epithelial membrane protein-2 (EMP-2).8,9

Nerve biopsy was consistent with CHN, disclosing hypomyelination/amyelination and basal laminae onion bulbs in all fibres and no florid demyelination. Because of the pathological picture and the non-progressive evolution, CHN is envisaged as a defect of myelin formation rather than a disorder of myelin maintenance and stability.4

Although current reviews link CHN with rare mutations of the myelin protein zero (MPZ/P0) gene, which codes the major structural component in the compact myelin of peripheral nerves, or with the early growth response 2 (EGR2) gene, which codes a transcription factor crucial for the Schwann...
cell differentiation.\textsuperscript{1,7} We think that genetic lesions of PMP22 are a relevant cause of CHN. By reviewing the available pathological phenotypes of missense mutations of PMP22, seven mutations out of 25 (for a review of the mutations see Haites et al\textsuperscript{8}) actually seem to be associated with CHN no matter what the original diagnosis was. The seven mutations included His12Gln (TM1),\textsuperscript{10} Leu16Pro (TM1),\textsuperscript{10–13} Ser72Leu (TM2),\textsuperscript{5} 14 Ser72Trp (TM2),\textsuperscript{15} Ser76Ile (TM2),\textsuperscript{16} Gly100Glu (TM3),\textsuperscript{17} and Leu105Arg (TM3).\textsuperscript{4} 15 For instance, Leu16Pro was identified in three young patients belonging to the same family who were diagnosed as CMT1 because of autosomal dominant inheritance but who really met the clinical, electrophysiological, and pathological criteria of CHN.\textsuperscript{18–20} Furthermore, Vandenberghe et al\textsuperscript{21} communicated a patient with CHN who was a genetic compound for a nonsense mutation of PMP22 and the 7p11.2–p12 deletion.\textsuperscript{1} The relation between CHN and genetic lesions of PMP22 seems even stronger when animal models of inherited neuropathies are considered. The spontaneous murine mutants Trembler-J and Trembler that carry respectively the “human” mutations Leu16Pro (TM1) and Gly150Asp (TM4), also show a severe congenital deficiency of the myelin sheath.\textsuperscript{1}

Figure 2 Sense electropherogram encompassing the peripheral myelin protein 22 exon 4, in the patient (A) and in a healthy control (B). T=bold continuous curve; C=thin continuous curve; G=segmented curve. At nucleotide 374 of the complementary DNA (cDNA), the patient has a Y that indicates a T to C transition (arrow). The mutation is predicted to change a cysteine with an arginine at the amino acid residue 109 (Cys109Arg).

It is important to note that PMP22 has a structural role in the myelin sheath although it is a low-abundant component and has an unusual structure for an adhesive molecule.\textsuperscript{6} On the other hand, the association between CHN and missense mutations distributed in TM1–4 indicates that PMP22 is also involved in Schwann cell differentiation and myelin formation. Thus the pathological phenotypes of missense mutations suggest that PMP22 may have at least a dual function in the peripheral nervous system.

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Wilhelm Conrad Von Röntgen (1845–1923)

Röntgen’s parents, a German father and Dutch mother, were cousins. He was born in Lennep in Germany, but his family moved to Holland when he was 3 years old.

At the age of 17 he was enrolled as a student in the Technical School in Utrecht. He was expelled through no fault of his own without matriculating. Because of this he was unable to sit university examinations. One of his classmates is said to have drawn a caricature of a teacher and failed to own up. Röntgen seems to have been a troublemaker in class and probably the obvious person for the teacher to blame. All his school reports showed excellent marks, although, ironically, with the exception of physics.

Röntgen qualified at the age of 23 as a mechanical engineer from the Polytecnikum in Zurich. His experimental attitude and unusual qualities were noticed by August Kundt, Professor of Physics in Zurich. In 1869 he received his PhD. In 1870 Kundt became Professor of Physics in Würzburg in Bavaria. He wanted Röntgen, who was his assistant, to become a member of the faculty but the university refused because he lacked the requisite training in classical languages. In 1888 Röntgen became Professor of Physics at Würzburg. Before that there were professorships in other institutions. It is for discovery of x rays that he is most remembered and for which he received several honours including the first ever Nobel Prize for physics in 1901. He submitted his manuscript Eine neue Art von Strahlen—A new kind of ray (Vorläufige Mittheilung)—(preliminary communication) by von Dr W Röntgen to the Würzburg Physical Medical Society for publication in Sitzungsberichte der Physikalisch-Medizinischem Gesellschaft (Proceedings of the Society for Physical Medicine) on 28 December 1895. It was of great satisfaction to the Swedish Academy of Science that such an eminent achievement could be rewarded at the first distribution. The announcement to the world of one of the most dramatic events in the history of science, made on 6 January 1896, was greeted with universal enthusiasm. The first x ray photograph was of his wife’s hand. In the same year that he received the Nobel Prize Röntgen was appointed Professor of Physics in Munich. He continued to work at the University until 1920. After his wife died he lived in solitude and poverty amid the general economic collapse of Germany after the first world war.

There were many stamps issued in honour of Röntgen in 1995, a century after the discovery of x rays. Reproduced is a stamp from Belgium commemorating the event. This shows Wilhelm Röntgen and the hand of his wife Bertha. Her ring can be seen on the ring finger (Stanley Gibbons 3279, Scott B1124).