A novel mutation (R218Q) at the boundary between the N-terminal and the first transmembrane domain of the glycine receptor in a case of sporadic hyperekplexia

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Hyperkplexia or startle disease (STHE, OMIM 149400) is a rare neurological disorder characterised by neonatal generalised muscular hypertonia followed by a period of generalised stiffness and by an exaggerated startle response to sudden external stimuli that persists throughout life. 

Hyperkplexia is usually inherited in an autosomal dominant manner although there is also evidence for a recessive form. 

Both forms are caused by mutations in the same gene, GLRA1, mapping on 5q31.2 and encoding for the α1 subunit of the inhibitory glycine receptor chloride channel. Recently, it has been shown that glycine receptor beta subunit mutations can also lead to hyperekplexia.

Glycine receptor (GlyR) belongs to the ligand gated ion channel receptor superfamily (LGICs), which includes α-aminobutyric acid, acetylcholine, and 5-hydroxytryptamine receptors and are localised in the postsynaptic membrane. All share a common pentameric structure that spans the membrane, comprising homologous subunits arranged in a ring to form a central ion conducting pore. In the case of GlyR, the α1-β complex is selective for chloride ions.

Each subunit is made up of a large glycosylated N-terminal extracellular domain, a short extracellular C-terminus, and four hydrophobic transmembrane spans (M1-M4), separated by two short hydrophilic loops M1-M2 (intracellular) and M2-M3 (extracellular) flanking the pore lining M2 domain, and by a long, extracellular, leucine rich M3-M4 loop.

Considering both dominant and recessive hyperekplexia cases, 15 mutations have been reported. Here we describe a novel GLRA1 mutation, occurring de novo in a patient with hyperekplexia, which results in the substitution of the arginine at position 218 with a glutamine (R218Q). It lies at the boundary between the N-terminal and the first transmembrane domain and could inhibit the transduction of allosteric coupling from glycine binding to channel activation.

The clinical diagnosis of hyperekplexia was made. Treatment with clonazepam did not result in an effective improvement of symptoms. Psychomotor development appeared moderately delayed at 12 months of age and at 6 years of age the boy received special education in school.

The parents denied similar problems and their neurological examination was unremarkable.

Collection and analysis of blood samples was performed after appropriate informed consent.

Molecular studies
DNA was extracted from the proband and his parents by the phenol-chloroform technique. The whole coding region of GLRA1 was amplified by nine sets of primers flanking all exons and PCR products were directly sequenced using an ABI PRISM 310 and the Big Dye Terminator Cycle Sequencing Ready Reaction Kit (Applied Biosystem, Foster City, CA). According to published reports amino acid numbering starts from the alanine at position 29.

RESULTS AND DISCUSSION
The sequence analysis showed a heterozygous G→A base transition (nt 1030 GenBank XM_032738) in GLRA1 exon 6 of the proband. This nucleotide change leads to an amino acid substitution at codon 218 (CGC→CAG) that replaces the highly conserved arginine at the boundary between the N-terminal and the M1 domain of the α1 subunit of the glycine receptor with a glutamine. This amino acid is invariant in glycine and GABAA receptor subunits from all species examined. The variation abolishes the restriction site AcI.
Using ActR, the mutation was not found in the patient’s parents or in 150 independent Italian controls. Paternity testing, performed in this patient according to Lynch, showed a paternity index of 100 that corresponds to a probability of paternity of 99.9%, suggesting the occurrence of a de novo mutational event.

Among patients with sporadic hyperekplexia, the present is the second case in which this phenotype has arisen from a de novo mutation rather than from the transmission of recessive alleles from unaffected heterozygous parents.

Seven missense mutations associated with dominant hyperekplexia have been described to date. They give rise to the substitution of amino acids located in the intracellular M1-M2 loop (one case), in the inner of the M2 domains (two cases), in the extracellular loop connecting segments M2-M3 (three cases), and within the large intracellular loop between M3 and M4 (one case) (fig 1). With the exception of the recent report of the Arg218Gln substitution in the GlyR, no further mutations have been described in this region. This mutation could inhibit the transduction of the allosteric signal transduction pathway from the glycine binding process to the channel activation gate.

Among the GLRA1 mutations associated with hyperekplexia in the heterozygous state, the R218Q substitution represents the first one which lies in the GlyR N-terminal region. Many studies have highlighted the role of this ectodomain for the ligand binding and the assembly properties of the glycine receptor. Disrupting a positive charge, R218Q might affect the correct protein folding and/or trafficking. More likely, considering the analogies of the arginine at position 218 with the arginine at position 271, the possibility exists that the R218Q substitution could inhibit the transduction of the allosteric coupling from glycine binding to channel activation, therefore suggesting that besides the M1-M2 and the M2-M3 loops the portion of the GlyR N-terminal region neighbouring to the M1 domain may also act as a structural component mediating this process.

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