Identification of four novel PMM2 mutations in congenital disorders of glycosylation (CDG) Ia French patients

Sandra Vuillaumier-Barrot, Gilles Hetet, Anne Barnier, Thierry Dupré, Maryvonne Cuer, Pascale de Lonlay, Valerie Cormier-Daire, Genevieve Durand, Bernard Grandchamp, Nathalie Seta

Abstract
We screened 11 unrelated French patients with congenital disorders of glycosylation (CDG) Ia for PMM2 mutations. Twenty one missense mutations on the 22 chromosomes (95%) including four novel mutations were identified: C9Y (G26A) in exon 1, L32R (T95GC) in exon 2, and T226S (C677G) and C241S (G722C) in exon 8. We studied the PMM activity of these four novel mutant proteins and of the R141H mutant protein in an E coli expression system. The T226S, C9Y, L32R, and C241S mutant proteins have decreased specific activity (23 to 41% of normal), are all more or less thermolabile, and R141H has no detectable activity. Our results indicate that the new mutations identified here are less severe than the inactive R141H mutant protein, conferring residual PMM activity compatible with life.

Keywords: CDG; phosphomannomutase; PMM2 mutations

Congenital disorder of glycosylation, previously called carbohydrate deficient glycoprotein involvement (CDG) Ia (OMIM 212065), is an autosomal recessive disorder characterised by central nervous system dysfunction and multigland failure owing to defective serum glycoprotein N-glycosylation, phosphomannomutase (PMM) deficiency, and mutations in the PMM2 gene. PMM2 gene mutations have been described in white CDG Ia patients and in two Japanese families. A total of 27 different missense mutations and a single base pair deletion have been reported. Most of the mutations are located in exons 5 and 8, and most of the patients are compound heterozygotes. We screened 11 previously unreported unrelated French patients with CDG Ia for mutations and studied the PMM activity of the new mutant proteins in an E coli expression system.

Methods
PATIENTS
Eleven unreported CDG Ia French patients were included in the study. Blood, cultured fibroblasts from forearm biopsy and/or lymphoblasts were referred to our laboratory for enzyme assay and molecular diagnosis.

SEQUENCING AND RESTRICTION ANALYSIS
RNA and DNA were isolated from fresh blood or cultured fibroblasts of CDG Ia patients. Two overlapping fragments were obtained from mRNA using RT-PCR were sequenced on both strands. The intron-exon junctions were sequenced in some patients after PCR from genomic DNA using available primers. Mutations were confirmed by restriction analysis of genomic DNA (excepted for C9Y, confirmed on cDNA) with mutagenic primers introducing diagnostic restriction sites, if necessary, and intronic primers.

CONSTRUCTS FOR EXPRESSION IN E COLI
Mutated cDNA was cloned into the expression plasmid pGEX-KG, thereby encoding a PMM-glutathione S-transferase (GST) fusion recombinant protein. The mutant and normal cDNAs were obtained by PCR from the cDNA

Table 1 PMM activities and PMM2 mutations in 11 unrelated French CDG Ia patients. Enzymatic activity is expressed in U/g protein. 1 U enzyme is the activity corresponding to the formation of 1 µmol NADPH/min under the assay conditions. Control activities were means (SD): leucocytes (le) 4.8 (1.5) U/g (n=93), fibroblasts (f) 4.54 (0.94) U/g protein. 1 U enzyme is the activity corresponding to the formation of 1 µmol NADPH/min under the assay conditions.

<table>
<thead>
<tr>
<th>Identification</th>
<th>PMM activity</th>
<th>Mutation 1 nucleotide</th>
<th>Mutation 1 amino acid</th>
<th>Mutation 2 nucleotide</th>
<th>Mutation 2 amino acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL</td>
<td>0.9 (le), 2.3 (ly)</td>
<td>G26A (exon 1)</td>
<td>C9Y</td>
<td>G245A (exon 5)</td>
<td>R141H</td>
</tr>
<tr>
<td>Co A</td>
<td>0.1 (f)</td>
<td>T95GC (exon 2)</td>
<td>L32R</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>MT</td>
<td>&lt;0.1 (f)</td>
<td>G385A (exon 5)</td>
<td>Y129M</td>
<td>G425A (exon 5)</td>
<td>R141H</td>
</tr>
<tr>
<td>HA</td>
<td>&lt;0.1 (f)</td>
<td>T95GC (exon 5)</td>
<td>I132T</td>
<td>G425A (exon 5)</td>
<td>R141H</td>
</tr>
<tr>
<td>DL</td>
<td>&lt;0.1 (f), &lt;0.1 (le)</td>
<td>T95GC (exon 5)</td>
<td>I132T</td>
<td>G425A (exon 5)</td>
<td>R141H</td>
</tr>
<tr>
<td>PA</td>
<td>ND</td>
<td>T95GC (exon 5)</td>
<td>I132T</td>
<td>G425A (exon 5)</td>
<td>R141H</td>
</tr>
<tr>
<td>SD</td>
<td>0.5 (f), &lt;0.1 (le)</td>
<td>C677G (exon 8)</td>
<td>T226S</td>
<td>G425A (exon 5)</td>
<td>R141H</td>
</tr>
<tr>
<td>GL</td>
<td>&gt;0.1 (f)</td>
<td>G691A (exon 8)</td>
<td>V231M</td>
<td>G425A (exon 5)</td>
<td>R141H</td>
</tr>
<tr>
<td>PJ</td>
<td>&lt;0.1 (f)</td>
<td>G691A (exon 8)</td>
<td>V231M</td>
<td>G425A (exon 5)</td>
<td>R141H</td>
</tr>
<tr>
<td>Ch A</td>
<td>0.5 (f)</td>
<td>G691A (exon 8)</td>
<td>V231M</td>
<td>G425A (exon 5)</td>
<td>R141H</td>
</tr>
<tr>
<td>RN</td>
<td>&gt;0.1 (f)</td>
<td>G722C (exon 8)</td>
<td>C241S</td>
<td>G425A (exon 5)</td>
<td>R141H</td>
</tr>
</tbody>
</table>

ND = not determined.
? = no mutations found in cDNA and intron-exon junctions.

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of heterozygous patients, using the Boehringer Expand High Fidelity PCR.

PHOSPHOMANNOMUTASE ASSAY
Clones were grown at 37°C overnight and bacterial cells were lysed by osmotic and mechanical shock. Expression of PMM2 protein in the cell lysate was checked by western blot analysis. The PMM activity of the recombinant proteins was assayed in the cell lysate, as described elsewhere.6 Thermolability was assessed by treating the lysates at 46°C for five minutes before determining activity. All assays were done at least in triplicate.

Results and discussion
Twenty one missense mutations were identified on the 22 chromosomes (95%) (table 1). The most frequent mutation, R141H in exon 5, was found in nine (41%) of the 22 chromosomes in keeping with previous data.2 3

Mutations I132T in exon 5 and V231M in exon 8 were each found three times (14%). We did not find the F119L mutation, which was present in 16% of CDG Ia alleles from the 56 patients of different geographical origins5 and in 44% of CDG Ia alleles from the 18 Danish patients.1 This mutation thus seems to be more prevalent in northern Europe than in France. Furthermore, we observed a variety of mutations in this French population in contrast to the Scandinavian countries, where two mutations, R141H and F119L, accounted for 88% of all mutations, indicating a founder effect.

Four new mutations from living patients were identified: C9Y (G26A) in exon 1, L32R (T95GC) in exon 2, and T226S (C677G) and C241S (G722C) in exon 8, which corresponds to the C-terminal portion of the protein. All described mutations are located in exons distant from exon 5. The C9Y mutation was found in exon 1, in which no mutations have previously been described, in two adult sibs.

We studied the PMM activity of the four novel mutant proteins and of the R141H mutant protein in an E coli expression system. All the clones expressed the recombinant PMM-GST protein to the same degree and with no change in the apparent molecular weight on western blotting (data not shown). The activity of the R141H mutant protein was undetectable, with values no different from the control clone without PMM2 cDNA (fig 1). This result confirms the absence of residual PMM activity for the most frequent mutant protein, R141H, which would explain the lack of homozygotes for this mutation, as it is probably lethal.1

The C241S, C9Y, L32R, and T226S mutant proteins exhibited 23 to 41% of the normal protein activity (fig 1). They were all more thermodenaturable than the control as they lost from 26 to 56% activity after heating at 46°C for five minutes, compared to 7% for the normal protein (fig 1).

Expression studies indicate that all the new mutations that we described in this paper affect PMM2 activity but are less severe than R141H. These results may be related to the corresponding mutation localisation on the gene, distant from exon 5. Studies of the functional domain of phosphomannomutase are required to understand exactly how these mutations affect PMM2 protein function.

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References
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