Original article

Molecular typing of human platelet antigens in immune thrombocytopenia patients in northern Brazil

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\textbf{Abstract}

Background: Immune thrombocytopenia is an immune disease characterized by thrombocytopenia and bleeding due to platelet antibodies against platelet membrane glycoproteins. Human platelet antigens are derived from polymorphisms of these glycoproteins. The aim of this study was to investigate human platelet antigen frequencies in immune thrombocytopenia patients from the state of Amazonas, Brazil and investigate the potential association between specific antigens and risk for immune thrombocytopenia.

Method: Human platelet antigen typing was performed by BeadChip technology to determine allelic variants of 11 systems (HPA-1 to HPA-9, HPA-11 and HPA-15). Thirty-six patients (8 male and 28 female) with a median age of 34 years (range: 9–69 years) were evaluated and compared with data from Amazonas blood donors.

Results: Platelet counts varied from 3 to 98 × 10\textsuperscript{9}/L. The allele frequencies were 0.944 for HPA-1a, 0.056 for HPA-1b, 0.847 for HPA-2a, 0.153 for HPA-2b, 0.555 for HPA-3a, 0.444 for HPA-3b, 0.805 for HPA-5a, 0.222 for HPA-5b, 0.9975 for HPA-9a, 0.025 for HPA-9b, 0.486 for HPA-15a and 0.513 for HPA-15b. Among immune thrombocytopenia individuals, no \textit{b} allele of the HPA-4, -6, -7, -8 and -11 were found.

Conclusions: The results suggest HPA-1a, HPA-3b and HPA-5b are immune thrombocytopenia-specific autoepitopes.

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Introduction

Immune thrombocytopenia (ITP) is an immune-mediated acquired disease characterized by transient or persistent decrease affecting platelet numbers and, depending upon the degree of thrombocytopenia, increased risk of bleeding, due to the presence of platelet autoantibodies. Platelet membrane glycoproteins (GPs) appear to be the principal binding sites of ITP serum antibodies. The polymorphisms of the human platelet alloantigens occur due to single nucleotide substitutions that result in the substitution of an amino acid.

The Immuno Polymorphism Database (IPD) of human platelet alloantigens (HPA) lists 35 platelet alloantigens, which are located in GPs (platelet receptors). The three major platelet receptors are GPIb-IIIa, GPIb-IX-V and GPA-Ila. GPIb/IIa is the most polymorphic complex and carries 19 antigens: HPA-1 (176T>C); HPA-3 (2621T>G); HPA-4 (506G>A); HPA-6 (1544G>A); HPA-7w (1297C>G); HPA-8w (1984C>T); HPA-9w (2602G>A); HPA-10w (263C>G); HPA-11w (1976G>A); HPA-14w (1909_1911delAAAG); HPA-16w (497C>T); HPA-17w (662C>T); HPA-19 (487A>C); HPA-20w (1949C>T); HPA-21w (1960G>A); HPA-22w (584A>G); HPA-23w (1942C>T); HPA-24w (1508G>A) and HPA-26w (1818G>T). The von Willebrand factor (vWF) receptor GPIb/IX carries two antigens HPA-2 (482C>T) and HPA-12w (119G>A). In addition, the GPA-Ila complex carries the HPA-5 (1600G>A), HPA-13w (2483C>T), HPA-18w (2235G>T) and HPA-25w (3347C>T) polymorphic systems.

Moreover, the HPA-15 (Gov) polymorphism is located in the CD109 molecule and its alleles differ at a single nucleotide polymorphism (C2108A) that causes a Tyr682Ser amino acid substitution.

Platelet genotyping by BeadChip microarray technology

Platelet genotyping was performed using a BeadChip assay. The BeadChip microarray method is capable of determining 22 allelic variants of 11 HPA systems (HPA-1 to HPA-9, HPA-11 and HPA-15). DNA amplification and post-polymerase chain reaction steps were performed according to the manufacturer’s instructions. The BeadChip slides were analyzed in a fluorescent system using the Bioarray Solutions software (Immucor, Warren, NJ) in the HEMOAM genomic laboratory.

Statistical analysis

The genotype and allele frequencies were estimated by direct counting, and the results were compared individually with the values published for healthy individuals from Amazonas. The 95% confidence interval (CI), chi square (X²) test or Fisher’s exact test were used for comparative analysis. The Hardy–Weinberg equilibrium of HPA system genotypes was evaluated using the Hardy–Weinberg calculator. p-Values lower than 0.05 were considered significant in all statistical analyses.
Table 1 – Clinical data and comparative analysis of allele frequencies between immune thrombocytopenia (ITP) patients and blood donors in the state of Amazonas.

<table>
<thead>
<tr>
<th>Clinical data</th>
<th>ITP patients</th>
<th>Blood donors&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>n&lt;sup&gt;a&lt;/sup&gt; patients</td>
<td>36</td>
<td>200</td>
</tr>
<tr>
<td>Gender (male:female)</td>
<td>8:28</td>
<td>140:60</td>
</tr>
<tr>
<td>Age (years)</td>
<td>34 (9–69)</td>
<td>36 (19–65)</td>
</tr>
<tr>
<td>Platelet count – x 10&lt;sup&gt;9&lt;/sup&gt;/L</td>
<td>41.5 (5–98)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>&gt;150&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

System                     | a    | b    | a    | b    | p-value<sup>d</sup> |
---------------------------|------|------|------|------|----------------------|
HPA-1                      | 0.944| 0.056| 0.86 | 0.137| <0.0001              |
HPA-2                      | 0.847| 0.153| 0.852| 0.147| 0.754                |
HPA-3                      | 0.555| 0.444| 0.665| 0.335| <0.0001              |
HPA-4                      | 1.00 | 0.00 | 0.995| 0.005| <0.0001              |
HPA-5                      | 0.805| 0.222| 0.892| 0.107| <0.0001              |
HPA-6                      | 1.00 | 0.00 | 1.00 | 0.00 | –                    |
HPA-7                      | 1.00 | 0.00 | 1.00 | 0.00 | –                    |
HPA-8                      | 1.00 | 0.00 | 1.00 | 0.00 | –                    |
HPA-9                      | 0.997| 0.025| 0.997| 0.005| –                    |
HPA-11                     | 1.00 | 0.00 | 1.00 | 0.00 | –                    |
HPA-15                     | 0.486| 0.513| 0.502| 0.497| 0.502                |

<sup>a</sup> Platelet count at diagnosis.

<sup>b</sup> Control includes blood donor samples published by Portela et al.<sup>19</sup>

<sup>c</sup> Platelet counts greater than 150 x 10<sup>9</sup>/L.

<sup>d</sup> Chi-square with Yates' correction calculated Fisher's exact p-value for comparisons of allele frequencies between ITP patients and Amazonas blood donors.

Table 2 – Genotype and allele frequencies for HPA-1 to HPA-9, HPA-11 and HPA-15 in chronic immune thrombocytopenia patients from the state of Amazonas.

<table>
<thead>
<tr>
<th>GP</th>
<th>SNP</th>
<th>Genotype frequency</th>
<th>Allele frequency</th>
<th>p-value Hardy-Weinberg</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPA-1</td>
<td>GPIIIa</td>
<td>AA</td>
<td>0.888</td>
<td>0.944</td>
</tr>
<tr>
<td>HPA-2</td>
<td>GPIIb</td>
<td>AB</td>
<td>0.111</td>
<td>0.056</td>
</tr>
<tr>
<td>HPA-3</td>
<td>GPIIIa</td>
<td>BB</td>
<td>0.00</td>
<td>0.847</td>
</tr>
<tr>
<td>HPA-4</td>
<td>GPIIIa</td>
<td>AA</td>
<td>0.694</td>
<td>0.555</td>
</tr>
<tr>
<td>HPA-5</td>
<td>GPIIa</td>
<td>AB</td>
<td>0.305</td>
<td>0.094</td>
</tr>
<tr>
<td>HPA-6</td>
<td>GPIIIa</td>
<td>BB</td>
<td>0.388</td>
<td>0.000</td>
</tr>
<tr>
<td>HPA-7</td>
<td>GPIIIa</td>
<td>BB</td>
<td>0.194</td>
<td>0.000</td>
</tr>
<tr>
<td>HPA-8</td>
<td>GPIIIa</td>
<td>BB</td>
<td>0.194</td>
<td>0.9975</td>
</tr>
<tr>
<td>HPA-9</td>
<td>GPIIb</td>
<td>AA</td>
<td>0.00</td>
<td>0.900</td>
</tr>
<tr>
<td>HPA-11</td>
<td>GPIIIa</td>
<td>AA</td>
<td>0.111</td>
<td>0.486</td>
</tr>
<tr>
<td>HPA-15</td>
<td>CD109</td>
<td>AB</td>
<td>0.638</td>
<td>0.513</td>
</tr>
</tbody>
</table>

GP: glycoprotein; SNP: single nucleotide polymorphism.

ITP patients and comparative analysis are summarized in Table 1. The study sample was comprised of eight (22%) male and 28 (78%) female individuals. The participants' ages ranged from 9 to 69 years (mean age: 34 years) and the platelet count at diagnosis varied from 3 to 98 x 10<sup>9</sup>/L (median: 41.5 x 10<sup>9</sup>/L). The disease severity ranged between mild or moderate when correlated with the degree of thrombocytopenia. The genotype and allele frequencies and p-values of the Hardy–Weinberg test of samples employed in this study are shown in Table 2. The allele frequencies were 0.944 for HPA-1a, 0.056 for HPA-1b, 0.847 for HPA-2a, 0.153 for HPA-2b, 0.555 for HPA-3a, 0.444 for HPA-3b, 0.805 for HPA-5a, 0.222 for HPA-5b, 0.9975 for HPA-9a, 0.025 for HPA-9b, 0.486 for HPA-15a and 0.513 for HPA-15b. Of the ITP individuals, no b allele was identified for HPA-4, HPA-6, HPA-7, HPA-8 and HPA-11. Among these ITP individuals, the allele frequencies of the HPA system were consistent with the Hardy-Weinberg equilibrium.

In the comparative analysis, the allele frequencies for HPA-2 (p-value = 0.754) and HPA-15 systems (p-value = 0.502) were not significantly different between analyzed groups (ITP patients and healthy individuals). On the other hand, the ITP Group had higher incidences of HPA-1a (0.944), HPA-3b and HPA-5b alleles when compared to the Control Group.

Table 3 presents mismatch probabilities in homozygous chronic ITP patients (AA and BB) obtained considering the HPA genotype frequencies from Amazonas blood donors. Heterozygous patients, who present both alleles (a and b), have no post-transfusion mismatch development and this was not evaluated in this analysis.
Table 3 – Probability of mismatch in homozygous patients.

<table>
<thead>
<tr>
<th>Systems</th>
<th>GdAA</th>
<th>GdAB</th>
<th>GdBB</th>
<th>Mismatch in AA patients</th>
<th>95% confidence interval</th>
<th>Mismatch BB patients</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GdAA + GdBB (%)</td>
<td>Lower limit</td>
<td>Upper limit</td>
<td>GdAA + GdBB (%)</td>
<td>Lower limit</td>
<td>Upper limit</td>
<td></td>
</tr>
<tr>
<td>HPA-1</td>
<td>0.740</td>
<td>0.245</td>
<td>0.15</td>
<td>0.26 (26)</td>
<td>0.227</td>
<td>0.292</td>
<td>0.98 (98)</td>
</tr>
<tr>
<td>HPA-2</td>
<td>0.720</td>
<td>0.265</td>
<td>0.15</td>
<td>0.28 (28)</td>
<td>0.244</td>
<td>0.315</td>
<td>0.98 (98)</td>
</tr>
<tr>
<td>HPA-3</td>
<td>0.430</td>
<td>0.470</td>
<td>0.10</td>
<td>0.57 (57)</td>
<td>0.518</td>
<td>0.621</td>
<td>0.90 (90)</td>
</tr>
<tr>
<td>HPA-4</td>
<td>0.990</td>
<td>0.010</td>
<td>0.00</td>
<td>0.01 (1)</td>
<td>0.008</td>
<td>0.011</td>
<td>1.00 (100)</td>
</tr>
<tr>
<td>HPA-5</td>
<td>0.800</td>
<td>0.185</td>
<td>0.01</td>
<td>0.20 (20)</td>
<td>0.176</td>
<td>0.233</td>
<td>0.98 (98)</td>
</tr>
<tr>
<td>HPA-9</td>
<td>0.995</td>
<td>0.005</td>
<td>0.00</td>
<td>0.005 (0.5)</td>
<td>0.004</td>
<td>0.005</td>
<td>1.00 (100)</td>
</tr>
<tr>
<td>HPA-15</td>
<td>0.252</td>
<td>0.495</td>
<td>0.25</td>
<td>0.745 (75)</td>
<td>0.710</td>
<td>0.779</td>
<td>0.747 (75)</td>
</tr>
</tbody>
</table>

Gd: genotype of Amazonas blood donor.

Discussion

Studies have demonstrated relevant associations between GP polymorphisms and immune-mediated platelet disorders. The HPA allele frequencies were compared in 36 chronic ITP patients with published data of 200 healthy individuals from Amazonas.15 The ITP group presented higher incidences of the HPA-1a, HPA-3b and HPA-5b alleles, which could suggest an association of these alleles with ITP in this population. In addition, Castro et al.12 suggested that the presence of HPA-5b might be associated to increased risk for acute ITP in Brazilian patients. On the other hand, Thude et al.15 showed that allele frequencies of the HPA-1, HPA-3 and HPA-5 were identical between patients with refractory autoimmune thrombocytopenia and blood donors in the German population. While, the HPA-2b was related to a higher risk for chronic ITP in Macedonian patients.24 Therefore, we suppose that the diversity in the prevalence of autoepitopes among ITP individuals worldwide occurs in response to genetic inheritance of HPA polymorphisms.

There is evidence of clinical correlations between autoantibodies against extracellular GP epitopes and their pathogenic role in ITP.15 ITP T cells recognize epitopes generated from GPIb/IIa and probably other platelet proteins.21 Thus, the immune potentials of HPA-1, HPA-3 and HPA-5 alleles are very important, for example, GPIb/IIa, carrying HPA-1 and HPA-3 antigens, is the most abundant complex (50,000–80,000 copies per platelet). While, despite the low abundance of GPIIa/IIa on the platelet membrane (800–2000 copies per platelet), HPA-5 has been considered an important immunogenic factor linked to immune syndromes in Caucasians22 and has been associated with high predicted risk of inducing alloimmunization in the Amazonas population.19 Ghevaert et al.22 demonstrated that, most anti-platelet antibodies (95%) have specificity against HPA-1a or HPA-5b, while only 5% are specific to the other systems, such as HPA-2, HPA-3 and HPA-15. However, the pathogenesis of ITP is clearly heterogeneous due to the racial admixture among Brazilian individuals, a condition that can affect these findings. Antibody specificity was not evaluated in this study, making it impossible to speculate about this potential association.

Platelet membrane glycoproteins appear to be an important binding site for ITP serum antibodies. This study analyzed 36 patients with ITP from Amazonas, and described specific HPA antigens related to the occurrence of ITP. However, the relationship between immunization and its potential clinical consequences is not straightforward. Hence, the findings of this study represent just an attempt to amplify the knowledge about HPA and ITP and suggest a potential association as a risk factor for the development of ITP.

Finally, studies have discussed the feasibility of applying molecular typing in the routine of hospital transfusion services.23,24 Some authors have reported a correlation between the prevention of newly developed alloantibodies in previously immunized patients and reductions in transfusion rates. Thus, a simulation of platelet transfusion mismatch was performed considering the HPA genotype frequencies of Amazonas blood donors.19 The results suggest a higher risk of alloimmunization in homozygous BB patients, due to the high frequency of AA and AB genotypes in the Amazonas blood donor registry. Therefore, when transfusions are necessary in previously immunized patients, a future strategy could involve the recruitment of homozygous BB donors by HPA molecular typing.

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Authorship

JCC, PSK, RMP and SCC participated actively in all experiments and drafted the manuscript. CF and AMSF helped with data analysis and manuscript writing and provided suggestions during the course of the experiments. SSW designed the experiments, provided guidance during all parts of the work, including the preparation of the manuscript.

Conflicts of interest

The authors declare no conflicts of interest.
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All authors read and approved the final version of the manuscript.

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