Plasma and Platelet HLA in Normal Individuals: Quantitation by Competitive Enzyme-Linked Immunoassay

By K.J. Kao

Recent studies on platelet HLA indicate that >50% of platelet HLA antigens are adsorbed on the platelet surface and may be derived from plasma. It has been speculated that platelet HLA may be directly proportional to plasma HLA concentration. To determine the quantitative correlation between plasma and platelet HLA, a precise competitive enzyme-linked immunoassay (ELISA) for measurements of soluble and cellular HLA antigens was developed by using purified HLA antigens and W6/32 anti-HLA monoclonal antibody. The useful range of the standard curve for the assay was 0.01 to 5.0 μg/mL. The intrassay and interassay variations were 7% and 14%, respectively. The plasma HLA concentrations measured in 61 healthy adults ranged from 0.25 to 4.1 g/L. The mean plasma HLA concentration was 1.47 ± 0.87 μg/mL (± SD). Platelet HLA concentrations determined in the same 61 persons ranged from 4.7 to 17.33 fg/platelet, and the mean concentration was 9.3 ± 2.9 fg/platelet (± SD). Chloroquine-elutable platelet HLA concentrations were also determined in 42 of the 61 persons, with the mean value of 5.7 ± 2.1 fg/platelet (± SD). The plasma HLA concentration of each individual was then correlated with the same person’s total or chloroquine-elutable platelet HLA concentration. Linear regression analyses of the results revealed no significant correlation between platelet and plasma HLA concentrations. Thus, it is unlikely that chloroquine-elutable HLA are derived from plasma. The developed solid-phase assay for HLA will be useful for further study of the quantitative significance of plasma HLA antigens in allosensitization of transfused individuals.

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MATERIALS AND METHODS

Isolation of W6/32 anti-HLA monoclonal antibody. The W6/32 hybridoma, obtained from the American Type Culture Collection (Rockville, MD), was originally developed by Barnstable and coworkers and produces an IgG, monoclonal antibody that recognizes a common monomorphic determinant on HLA-A, B, and C molecules. W6/32 anti-HLA monoclonal antibody, and was applied to study the quantitative correlation between platelet and plasma HLA concentrations. The potential application of the assay to study plasma HLA immunogenicity is discussed.

Purification of HLA antigens. Sixty units of outdated platelet concentrates were obtained from the Citivan Regional Blood Center (Gainesville, FL). Platelets from each unit of platelet concentrate were washed twice with 50 mL of 0.02 mol/L of Tris-HCl, pH 7.4, containing 0.15 mol/L of NaCl and 2 mmol/L of EDTA (Tris-saline-EDTA). Washed platelets were pooled, centrifuged at 10,000 g for 10 minutes, and solubilized by resuspension in an equal volume of 2% NP-40 made in 0.02 mol/L of Tris-HCl, pH 7.4, containing 1 mmol/L of phenyl-methyl-sulfonyl fluoride (PMSF) and 1 mmol/L of ε-amino-ε-caproic acid (EACA). The resuspended platelets were incubated on ice for 60 minutes. Solubilized platelets were then centrifuged at 10,000 g for 10 minutes at 4°C. The supernatant was collected and centrifuged again at 50,000 g for 60 minutes at 4°C. Solubilized HLA antigens were then isolated from the final supernatant by column chromatography on the following three sequentially linked columns: (a) a Sepharose-4B column, (b) a normal mouse IgG-Sepharose-4B column, and (c) a W6/32 McAb-Sepharose 4B column. Details of preparing the columns have been described previously. The size of each column was 1.6 × 6 cm. After
extensive washing, HLA antigens were eluted by 0.05 mol/L of diethylamine, pH 11.5, containing 0.1% NP-40 and collected in 1-mL fractions. The eluted protein peak was pooled and dialyzed extensively against 0.01 mol/L of phosphate-buffered saline (PBS), pH 7.2, containing 0.05% Na$_2$O$_4$ and 0.1% NP-40. The concentration of HLA antigens was determined by a modified Lowry assay using bovine serum albumin (BSA) as the standard. Homogeneity of purified HLA antigens was evaluated by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE).

**Preparation of platelet samples for HLA assay.** Platelets were isolated from freshly drawn venous blood by differential centrifugation and washed as described. Routinely, the venous blood was drawn into a 7-mL vacutainer containing EDTA as an anticoagulant. The washed platelets were suspended in 3 mL of Tris-saline-EDTA buffer and enumerated by a S-plus Coulter counter (Coulter Electronics, Hialeah, FL). The contamination of WBCs is always <0.01%. Ten to 40 million washed platelets were pipetted into a 1-mL conical polystyrene tube and pelleted by a Beckman Microfuge B (Beckman Instruments, Palo Alto, CA) at room temperature for 2 minutes. The supernatant was aspirated and discarded. Platelets were then resuspended in 100 μL 0.02 mol/L of Tris-HCl, pH 7.4, containing 0.05% NP-40, 5 mmol/L of EDTA and 1 mmol/L of PMSF, and left on ice for 60 minutes with occasional vortexing. After solubilization, all samples were stored at -70°C until assayed. The frozen samples were stable for at least 12 months at -70°C. Chloroquine-treated platelets were prepared as reported previously.

**Competitive ELISA for HLA antigens.** Each well of a 96-well Immunoplate (Nunc Inter-Med, Kamstrup, Denmark) was incubated overnight with 100 μL of purified HLA antigens (2 μg/ml) diluted in 0.01 mol/L of sodium phosphate buffer, pH 7.2, containing 0.15 mol/L of NaCl and 0.02% Na$_2$O$_4$ (PBS-azide) at 4°C. Subsequently, each well was washed three times with PBS-azide containing 0.5% Tween-20 (PBS-T) and then blocked with 300 μL 1% BSA in PBS-T for 30 minutes at room temperature. After the wells were washed three times, 50 μL of different concentrations of purified HLA standard (0.01 to 5 μg/ml), diluted plasma or solubilized platelet samples were added to wells in duplicate, followed by the addition of 50 μL W6/32 anti-HLA McAb (0.02 μg/mL). The incubations were mixed by placing plates on a MicroShaker II (Dynatech Laboratories, Alexandria, VA) for 15 seconds, and incubated at room temperature for 90 minutes. The plate was washed three times again, followed by addition of 100 μL of rabbit antimouse IgG alkaline phosphatase conjugate (1,000 × dilution (Sigma Chemical, St Louis)) into each well and incubated for 30 minutes.

Finally, 200 μL p-nitrophenyl phosphate disodium (1 mg/ml) prepared in 0.01 mol/L of sodium bicarbonate buffer, pH 9.6, containing 2 mmol/L of MgCl$_2$ was added to each well, and the plates were incubated at room temperature for 90 to 120 minutes in the dark. Fifty microliters of 3N NaOH was then added to each incubation to stop the reaction. Absorbance of each well at a wave length of 405 nm was measured in a BioRad ELISA plate reader (BioRad Laboratories Richmond, CA). All samples were diluted as needed in PBS-T containing 1% BSA and 5 mmol/L of EDTA and were assayed in duplicate. Plasma samples were also assayed at two different dilutions (5× and 10×) to ensure absence of interfering factors.

**RESULTS**

**Isolation of platelet HLA antigens.** HLA antigens isolated from solubilized platelets appeared to be homogeneous as judged by SDS-PAGE (Fig 1). The purified HLA antigens consist of a 44-kd heavy chain and a 12-kd noncovalently associated β$_2$-microglobulin. Routinely, 2 to 3 mg of HLA antigens were recovered from 60 U of outdated platelet concentrates. These purified HLA antigens were used to coat the wells and served as standards for the assay.

**Competitive ELISA for HLA antigens.** The quantitative assay for HLA antigens was developed based on the principle of competition for the binding of W6/32 anti-HLA McAb between plate-bound HLA antigens and unbound HLA antigens.
antigens in the standards or unknown samples. The concentrations of the HLA antigens used to coat the wells (2.0 μg/mL) and W6/32 anti-HLA McAb (0.02 μg/mL) used in the assay were found to be optimal to gain greater sensitivity and precision. As shown in Fig 2, the useful range of the standard curve was between 0.01 and 5.0 μg/mL.

When plasma pooled from six different healthy adults without history of previous blood transfusion or pregnancy was assayed at different dilutions, the values were in parallel with the standard curve (Fig 2). The result indicates that there was no factor(s) in plasma interfering with the assay. Next, the specificity of the assay was evaluated by assaying a HLA-depleted pooled plasma prepared by incubating pooled plasma with equal volumes of PA2.6 anti-HLA McAb-Sepharose 4B beads at 4°C for 4 hours. PA2.6 anti-HLA antibody was an IgG, monoclonal antibody developed by Brodsky and Parham. As expected, no significant amount was detected.

The intraassay and the interassay assay variations were evaluated by assaying a stock plasma sample with the standard curve (Fig 2). The intraassay result indicates that each of six different volunteer donors and frozen at -70°C. Plasma and serum HLA concentrations were 100 μL of 0.5% NP-40 was capable of solubilizing all the platelets and releasing all cellular HLA antigens, a linear correlation should be expected between HLA contents and the number of platelets solubilized. As shown in Fig 3, the amount of HLA indeed was linearly proportional to the number of platelets solubilized. Thus, 100 μL of 0.5% NP-40 was sufficient to release HLA from ≥4 x 10⁷ platelets.

The competitive ELISA was further evaluated by comparing this method with the surface binding assay in which ¹²⁵-I-labeled W6/32 Fab fragments were used. Concentrations of platelet HLA of four different individuals were determined by these two separate methods. As shown in Table 1, platelet HLA concentrations determined by either method yielded similar results.

### Quantitative correlation between plasma and platelet HLA concentrations.

After validation of the assay, plasma and platelet samples were collected from 61 healthy volunteers and assayed for their HLA concentrations. The plasma range of HLA concentrations was from 0.25 to 4.1 μg/mL, and the mean plasma HLA concentration was 1.47 ± 0.87 μg/mL (mean ± SD). Platelet HLA concentrations of the same 61 persons ranged from 4.7 to 17.33 fg/platelet, and the mean concentration was 9.3 ± 2.9 fg/platelet (mean ± SD). The plasma HLA concentration of each individual was then correlated with his or her own platelet HLA concentration. Linear regression analysis showed no significant correlation between the two parameters (r = 0.06 and P > 0.5) (Fig 4).

HLA concentrations of chloroquine-treated platelets were also determined in 42 of the 61 volunteer donors. The quantities of chloroquine-elicitable platelet HLA antigens were then calculated as the difference between HLA concentrations of platelets before and after the treatment of chloroquine. The range of chloroquine-elicitable platelet HLA antigens among the 42 individuals was 2.5 to 10.3 fg/platelet. The mean chloroquine-elicitable platelet HLA was 5.7 ± 2.1

### Table 1. Platelet HLA Concentrations Determined by EIA and SBA

<table>
<thead>
<tr>
<th>Case No.</th>
<th>EIA</th>
<th>SBA*</th>
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<tbody>
<tr>
<td>1</td>
<td>11.5</td>
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</tr>
<tr>
<td>2</td>
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<td>8.1</td>
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<td>8.6</td>
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<tr>
<td>4</td>
<td>6.7</td>
<td>6.5</td>
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EIA, enzyme-linked immunoassay; SBA, surface binding assay.

* SBA was performed by using ¹²⁵-I-labeled W6/32 monoclonal Fab fragments and Scatchard analysis. The concentrations of platelets HLA were converted from molecules per platelet to femtograms per platelet. The mol wt of 56 kd for HLA antigens was used for calculation. There was no significant difference between HLA concentrations determined by the two assays (P > .5).
analysis did not reveal any significant correlation between the two parameters before and after chloroquine treatment. Forty-two subjects were available for the study. Linear regression analysis revealed no parameters that were determined by the competitive ELISA were comparable with those determined by the surface binding assay using 125I-labelled Fab fragments of W6/32 anti-HLA McAb and Scatchard analysis. The results indicate that all the platelet HLA antigens measured by the competitive ELISA were on the platelet surface, and there was no significant amount of HLA antigens in platelet cytoplasm. This finding is consistent with the absence of active protein synthesis in platelets. In contrast, the concentration of lymphocyte HLA antigens measured by the described competitive ELISA, was two to three times higher than that measured by the surface binding assay (data not shown). These differences are most likely due to the release of cytoplasmic HLA antigens from lymphocytes during solubilization. Thus, the HLA antigens measured in nucleated cells by the ELISA represent total cellular HLA antigens, which includes cytoplasmic and surface HLA antigens. The active synthesis of HLA antigens and the relatively fast turnover of membrane HLA antigens in lymphocytes are most likely responsible for the presence of high levels of HLA antigens in cytoplasm.

To test if the presence of anti-HLA antibodies in plasma samples from individuals with previous pregnancies or multiple blood transfusions might interfere with the assay, five of such plasma samples were assayed at 5x, 10x, and 20x dilutions. Due to the presence of anti-HLA antibodies that interfered with the assay, the values obtained were not in parallel with the standard curve of the assay (data not shown). Therefore, to obtain a valid measurement of plasma or serum HLA concentration, it is imperative to assay all plasma samples at least at two different dilutions to exclude those samples containing interfering factor(s). All the plasma HLA concentrations assayed in this report were measured at 5x and 10x dilutions. The results were all in parallel with the standard curve.

According to the present study, the average plasma HLA concentration in normal adults is 1.47 μg/mL. This number indicates that a significant amount of HLA antigens is present in the plasma of various blood components. Although the potential immunogenicity of plasma HLA antigens was reported, the clinical significance of the quantitative variation of plasma HLA in allosensitization of recipients of plasma containing blood products remains unclear. The precise quantitation of plasma HLA antigens by using the developed assay will facilitate the study of plasma HLA immunogenicity.

Because previously platelet HLA-B12 antigen concentrations was shown to be proportional to plasma HLA-B12 content, that platelets can acquire plasma HLA antigens and that most platelet HLA is probably adsorbed on platelet surface, it has been speculated that the amounts of platelet-surface HLA would be directly proportional to plasma HLA levels. Results of the present study showed that there was no significant quantitative correlation between total platelet

Fig 4. Quantitative correlation between plasma and total platelet HLA concentrations. Sixty-one normal adults were included in the study. Linear regression analysis revealed no significant correlation between the two parameters (r = .06, P > .5).

Fig 5. Quantitative correlation between plasma and chloroquine-elutable platelet HLA concentrations. Chloroquine-elutable platelet HLA was determined as the difference of HLA concentration between platelets before and after chloroquine treatment. Forty-two subjects were available for the study. Linear regression analysis did not reveal any significant correlation between the two parameters (r = .03, P > .8).
and plasma HLA (Fig 4). Because it is possible that only the adsorbed platelet HLA may derive from plasma and may correlate to plasma HLA, quantities of adsorbed platelet HLA were then determined in 42 individuals by subtracting HLA concentration left on chloroquine-treated platelets from total platelet HLA content. Nevertheless, no quantitative correlation between plasma and adsorbed platelet HLA was observed (Fig 5). The results of the present study differed from the earlier observation made by Liebert and Aster.8 They reported that serum HLA-B12 antigens were roughly proportional to HLA-B12 on platelets. The small number of subjects (N = 5) included in their study and the assay method used may account for the differences.

In conclusion, the results we report highly suggest that the chloroquine-elutable platelet HLA antigens may not be derived from plasma and that platelet HLA concentration is not in dynamic equilibrium with plasma HLA. Therefore, the quantitative expression of specific HLA antigens and the immunogenicity of platelets most likely could not be altered by incubating platelets with selected plasma. Although plasma HLA may not be the source of adsorbed platelet HLA, our results do not exclude the possibility that most platelet HLAs indeed may be adsorptive in nature. Further studies on the surface orientation and the physicochemical properties of chloroquine-elutable HLA antigens are needed to identify the origin and the adsorptive nature of platelet HLA antigens.

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REFERENCES

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