Platelet Glycoproteins IIb and IIla as a Calcium Channel in Liposomes

By Mary Ellen Rybak, Lori A. Renzulli, Matthew J. Bruns, and Diann P. Cahaly

Human platelet membrane glycoproteins IIb and IIla (GPIIb and IIla) were incorporated into phospholipid vesicles by the reverse-phase technique to assess the ability of GPIIb and IIla to function as a Ca\(^{2+}\) channel. Movement of Ca\(^{2+}\) across the lipid bilayer was quantitated by injection of proteoliposomes with encapsulated Fura-2 into Ca\(^{2+}\) buffers and measurement of Fura-2 fluorescence as an indicator of Ca\(^{2+}\) influx. Reciprocally, to assess the function of proteins in an inside-out orientation, Ca\(^{2+}\)-loaded vesicles were injected into Ca\(^{2+}\)-free buffer and Ca\(^{2+}\) efflux monitored by a calcium electrode. Incorporation of the IIb-IIla complex produced significant facilitation of Ca\(^{2+}\) movement across the lipid bilayer. No net transmembrane Ca\(^{2+}\) movement was seen with dissociated IIb and IIla. Movement of Ca\(^{2+}\) was proportional to the transmembrane Ca\(^{2+}\) gradient. Ca\(^{2+}\) movement into the vesicles was inversely proportional to extravesicular NaCl from 25 to 150 mmol/L, analogous to several studies in the intact platelet. Adenosine triphosphate had no effect on Ca\(^{2+}\) movement into or out of the vesicles. Specific inhibition of a Ca\(^{2+}\) shift into the vesicles was seen with M148, a monoclonal antibody to IIb/Illa, while no inhibition was observed with a panel of other anti-IIb/IIla monoclonal antibodies. This suggests that a specific site on the complex or orientation of the complex is essential for calcium channel function. These data demonstrate that the GPIIb-IIla complex can serve as a passive Ca\(^{2+}\) channel across a phospholipid bilayer and has the potential to play a role in Ca\(^{2+}\) flux across the platelet plasma membrane.

Materials and Methods

IIb-IIla Preparation

GPIIb-IIla was prepared by modification of published methods\(^ {10,12,13}\) from Triton X-114-solubilized platelet membranes. Platelet concentrates in acid-citrate-dextrose anticoagulant were washed twice in citric acid buffer (0.013 mol/L citric acid, 0.013 mol/L sodium citrate, 0.033 mol/L D-glucose) and NaCl (150 mmol/L), pH 7.0, and washed twice in Tris buffer (0.01 mol/L Tris and 0.15 mol/L NaCl, pH 7.24). Washed platelets were resuspended in Tris buffer (0.01 mol/L, pH 7.4, with CaCl\(_2\) (0.5 mmol/L), NaCl (0.15 mol/L), phenylmethylsulfonylfluoride (PMSF) (0.4 mmol/L), and leupeptin (100 \(\mu\)g/mL). Platelets were sonicated on ice with a probe sonicator and centrifuged (1,000 g) to remove nondisrupted platelets. The supernatant was centrifuged at 78,000 g for one hour and the pellet from this centrifugation suspended 1% (vol/vol) in precondensed Triton X-114, 10 mmol/L Tris, NaCl (150 mmol/L) buffer, pH 7.4, with 0.4 mmol/L PMSF, incubated overnight at 4°C, and centrifuged at 78,000 g for one hour at 4°C. The detergent phase was then applied to a 6% sucrose cushion, heated at 37°C for five minutes, and centrifuged at 1,500 g for five minutes and the detergent micelle aggregate layer removed. Some variability of protein composition of Triton X-114 preparations was observed. Further purification of proteins was achieved by application of the detergent phase to lentil-lectin Sepharose and elution with 10% α-methyl-D-mannoside in Tris-HCl buffer, NaCl 150 mmol/L, 10⁻⁶ mol/L CaCl\(_2\), pH 7.4. Detergent was partially removed with Biobeads SM2. Each IIb-IIla preparation was assayed for total protein determination by a modified Lowry technique\(^ {23}\) and residual Triton X-114 determined spectrophotometrically (\(A_{280}\)) after reaction with ammonium cobaltii/oxyanate reagent and solubilization in ethylene chloride.\(^ {23}\) Preparations maximally contained 0.27 to 0.90 mg Triton/mg protein. Proteins were analyzed by sodium

From the University of Massachusetts Medical Center, Worcester.

Submitted September 3, 1987; accepted April 22, 1988.

Supported by the American Heart Association, Massachusetts Affiliate, Grant 13-515-856.

Address reprint requests to Mary Ellen Rybak, MD, University of Massachusetts Medical Center, 55 Lake Ave, North, Worcester, MA 01655.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "advertisement" in accordance with 18 U.S.C. section 1734 solely to indicate this fact.

© 1988 by Grune & Stratton, Inc.

0006-4971/88/7202-0035$3.00/0

Blood, Vol 72, No 2 (August), 1988; pp 714-720

From www.bloodjournal.org by guest on October 23, 2017. For personal use only.
dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE), reduced and nonreduced, using 7.5% gels (Fig 1B and C). While small amounts of contaminating proteins theoretically may have been present, they were not detectable by combined silver and Coomassie blue stains of gels of any protein preparation used. In addition, SDS-PAGE of the proteoliposome preparations revealed only two protein bands (Fig 1A). Proteins were then incubated in 10^{-4}/mol/L Ca^{2+} at 25°C for one hour prior to incorporation into vesicles to ensure consistent, albeit incomplete, association of the complex without excessive Ca^{2+} loading of vesicles. For dissociated complex studies, the proteins were incubated in Ca^{2+}-free buffer and initially prepared with EDTA (0.001 mol/L) in platelet membrane washing buffers and then maintained in Ca^{2+}-free buffer. This resulted in GPIIb that was 97% cleavable by thrombin, which is consistent with complex dissociation.

**Proteoliposome Preparation**

Large unilamellar vesicles were formed from egg lecithin (phosphatidylcholine) (Sigma Chemical Co, St Louis) by the reverse-phase method. Phosphatidylcholine vesicles permitted the use of varying Ca^{2+} concentrations without vesicle fusion or microscopic aggregate formation and limited intrinsic cation permeability. Phosphatidylcholine (25 mg in hexane at 100 mg/mL) was dried to a thin film on the bottom of a 50-mL round-bottomed flask in vacuo for three to 14 hours. The lipid film was resuspended in 1.5 mL of ether and then 0.250 mL of 10 mmol/L Tris-HCL or 10 mmol/L HEPES, 150 mmol/L NaCl buffer, pH 7.4, plus 30 mmol/L L Fura-2 pentapotassium salt (Molecular Probes, Inc, Eugene, OR) for influx studies. This mixture was then sonicated for two minutes in a bath-type sonicator containing double distilled H_{2}O (ddH_{2}O) with 0.01% Triton. Sonication was carried out at the point where the surface of the bath exhibited maximum agitation. The ether was removed by rotary evaporation under reduced pressure to form a lipidic gel. This gel was sonicated for one minute with 1 mL of buffer containing glycoproteins (50 to 700 μg/mL) with or without Fura 2 that had been kept at 4°C. For studies of adenosine triphosphate (ATP) effects, ATP, 2 mmol/L (Sigma), was added to the preparative buffers. Liposomes were washed twice by centrifugation at 14,000 g for ten minutes at 4°C. These liposomes were relatively homogenous in size and entrapped volume with a mean diameter of 5 μm as determined by laser light scattering with a Coulter N4 Submicron Particle Sizer (Coulter Electronics, Hialeah, FL). On average, 70% of the added protein was incorporated, with 48.6% ± 0.8% of protein in an outside-in orientation as determined by *Vibrio cholerae* neuraminidase cleavage of sialic acid residues. As previously reported, the GPIIb-IIIa complex incorporated onto the phosphatidylcholine lipid surface-bound fibrogenin with an approximate k_{d} of 10^{-7}. SDS-PAGE of proteins associated with SDS-solubilized liposome preparations revealed only two bands consistent with IIb and IIIa (Fig 1A). Studies of Ca^{2+} influx that involved the dissociated complex were performed at the equivalent protein-lipid ratio per liposome as the reassociated complex. To confirm that Fura-2 was retained in the liposomes following centrifugation, liposomes were gel filtered on a 6-mL Sephadex G-50 column. Fura-2 fluorescence (λ_{amin} 345 nm; λ_{max} 510 nm) was measured. An equivalent amount of Fura-2 remained within control and IIb-IIIa complex liposomes. This indicates that Fura-2 does not leak preferentially from the protein liposomes during the course of the experiment.

**Calcium Transit Studies**

In all cases liposomes were utilized the same day of preparation and kept on ice until use. For Fura-2 studies, liposomes were used within one hour of preparation. Temperature and pH were rigorously controlled in all experiments and double-distilled deionized 18-mL water utilized in all buffers.

**Ca^{2+} movement into vesicles.** For Ca^{2+} movement into vesicles, Fura-2 (30 μmol/L)-loaded liposomes (10^{-4} mol/L intravesicular Ca^{2+}) were injected into buffer (20 μL of liposomes suspension to 980 μL of Tris (10 mmol/L) and NaCl (150 mmol/L) buffer with or without Ca^{2+} (10^{-5} to 10^{-2} mol/L); this approximates infinite cis-entry conditions (saturating external calcium). The Fura-2 fluorescence was measured (λ_{amin} 345 nm; λ_{max} 510 nm) in a Perkin-Elmer 650-10S fluorescence spectrophotometer with a Perkin-Elmer 150 xenon power supply (Perkin-Elmer Corp, Norwalk, CT). These emission and excitation wavelengths minimized contribution from intrinsic liposomal fluorescence and beam dispersion by the liposomes. These factors precluded an accurate determination of F_{max} and F_{min} for Fura-2 in this system. A standard curve of fluorescence v intravesicular [Ca^{2+}] was established by using nonprotein liposomes that were loaded with 30 μmol/L Fura-2 and known Ca concentrations (10^{-4} to 10^{-1} mol/L) and the fluorescence measured. This is shown in Fig 2. The effect of extravesicular NaCl concentration was determined by measuring the Ca^{2+} influx as described earlier in buffers containing 10 to 150 mmol/L NaCl. Intravesicular NaCl

![Fig 1. Nickel-stained SDS-PAGE (5% stacking, 7.5% running gel) of glycoprotein preparation before liposome incorporation. Molecular weight standards are shown in the first lane; in the second (B) and third (C) lanes, a IIb/IIIa preparation reduced with 2% dithiothreitol and unreduced are shown, respectively.](image-url)
Fig 2. Calibration curve for change in Fura-2 fluorescence (λex, 345 nm; λem, 510 nm). Fura-2–loaded phosphatidylcholine liposomes that contained 10−6 to 10−3 mol/L Ca2+ were injected into Tris-HCl buffers of the same Ca2+ concentration as the intravesicular concentration [Ca2+]. The fluorescence was then measured.

Calcium movement from inside the vesicles to the extravesicular milieu was measured with an Orion calcium activity electrode and reference electrode (Orion Products, Cambridge, MA) in series with a Corning model 130 pH meter (Corning Glass Works, Corning, NY) and Kip and Zonen (The Netherlands) BO4D chart recorder. The calcium electrode was calibrated daily according to the manufacturer’s instructions with 4 mol/L KCl, which served as an ionic strength adjustor (ISA), and an Orion 0.1 mol/L CaCl2 standard in serial dilutions to establish a standard curve of millions of electron volts v log [Ca2+]. Efflux studies were performed on the linear portion of this standard curve.

Twenty microliters of calcium-loaded (0.001 to 0.25 mol/L CaCl2) liposomes (control, IIb-IIIa) washed in identical buffers were added by Hamilton syringe to 30 mL of Ca2+–free HEPS (10 mmol/L)-saline (10 to 150 mmol/L) plus 600 μL. ISA and stirred continuously with a magnetic stirrer. The change in electron volts over time was measured. Each individual experiment had ten replicates, and each set was repeated three times. Concentrations of calcium significantly higher than physiological were required for efflux studies because of limits of accurate detection with the Ca2+<sup>2+</sup> electrode.

To assess the effect of MoAbs to GPIIb-IIIa on Ca2+ transit into vesicles, proteoliposomes were incubated in Tris-NaCl and 10−6 mol/L Ca2+ for 30 minutes at 4°C and 15 minutes at 25°C before influx studies. Fura-2–loaded liposomes that had been incubated with antibody were then added to 10−2 mol/L Ca2+ buffer and the influx quantitated. This incubation time, Ca2+<sup>2+</sup>, and dilution of antibodies used are adequate for platelet binding and inhibition of platelet function by their antibodies. The antibodies tested were M148 (1:10 dilution, generously provided by Dr Roger M. Hardisty<sup>33</sup>), antibodies 7E3 and 10E5 (100 μg/mL, generously provided by Dr B. Coller<sup>34</sup>), AP2 (1:100, generously provided by Dr T.J. Kunicki<sup>35</sup>), Tab (generously provided by Dr R.P. McEver<sup>36</sup>), antirotavirus antibody (an irrelevant antibody IgG2a, generously provided by Dr J. Herrmann), and mouse ascites. The antibodies were exhaustively dialyzed against 10−4 mol/L CaCl2 buffer prior to testing. Binding of MoAbs to GPIIb-IIIa liposomes and control liposomes was evaluated by fluorescein isothiocyanate (FITC)-conjugated second antibody. Liposomes (IIb-IIIa proteoliposomes or control liposomes) were incubated with antibody (30 minutes, 4°C, 10−4 mol/L, washed in Tris-saline, 10−4 mol/L CaCl2 buffer, and then incubated with conjugated FITC–goat antimurine antibody (Cooper Biomedical, Malvern, PA) for 45 minutes at 4°C. Liposomes were then washed and examined by fluorescence microscopy. In addition, the fluorescence of 10-μL aliquots of double-antibody–reacted liposomes (λex, 493 nm; λem, 525 nm) was measured. Statistical analysis was by Student’s t test except where indicated.

**RESULTS**

Ca2+ Movement Into Vesicles

Ca2+ movement was measured by absolute fluorescence (λex, 345 nm; λem, 510 nm) of Fura-2–loaded vesicles incubated in Ca2+ buffers. Kinetic studies, performed from 5 seconds to 15 minutes, demonstrated that the onset of influx was rapid and reached 83.6% of the maximum by five seconds with a minimal but detectable additional increase over the subsequent ten seconds (P = .0013 compared with five seconds), which represented the maximum Ca2+ movement into the vesicles (Fig 3). The precise onset of the influx could not be determined. No further influx occurred over 15 minutes. The change in fluorescence due to Ca2+ influx was dependent on extraliposomal [Ca2+] as shown in Table 1. Several controls were used initially; these included protein-free liposomes and purified erythrocyte glucose transporter.

After the observation that the dissociated IIb-IIIa complex failed to facilitate Ca2+ movement in excess of the influx observed in protein-free liposomes, the dissociated complex–containing liposomes were used as control. These data are shown in Table 1.

The Ca2+ influx was inversely related to the extravesicular NaCl concentration (25 to 150 mmol/L) as shown in Fig 4. This effect is parallel to that observed in the intact platelet

![Image](https://example.com/image.png)

**Fig 3.** Time course of Ca2+ influx into Fura-2 (30 μmol/L)–loaded IIb-IIIa liposomes. IIb-IIIa liposomes (1 μg protein/mg lipid) were injected into 10 mmol/L Tris-HCl (pH 7.40), 150 mmol/L NaCl, and 10−4 mol/L Ca2+. Fluorescence λex, 345 nm; λem, 525 nm was measured at the time points indicated. Each point is a mean of six replicates.
and was observed independently of replacement of intravesicular Na⁺ by N-methyl-D-glucamine. Identical data were observed if the intravesicular Na concentration remained at 150 mmol/L.

The addition of ionomycin, 1 μmol/L, to the liposome preparation resulted in a rapid increase in intravesicular Fura-2 fluorescence and complete and rapid equilibration with external calcium. Results for 10⁻² mol/L Ca²⁺, external, are shown on Table 1.

**MoAbs**

MoAbs to different epitopes on IIb-IIIa exerted different effects on Ca²⁺ influx. MoAb M148 maximally inhibited the influx by 58.5%, while MoAbs 7E3, 10E5, Tab, and AP2 had minimal inhibitory activity even at 100 μg/mL. MoAb 357, an irrelevant, antivirous antibody, had no significant effect on Ca²⁺ influx. The differences in inhibitory activity of specific MoAbs were not explained by significant differences in binding to IIb-IIIa liposomes. IIb-IIIa liposomes were incubated with specific or irrelevant antibody and examined by both fluorescence microscopy and total FITC-associated fluorescence. Binding was observed with 7E3, 10E5, AP2, and M148. This is shown in Table 2. Microscopically and by absolute fluorescence, 7E3 revealed binding identical to M148 despite the failure of 7E3 to inhibit Ca²⁺ influx. Irrelevant MoAb 357 showed no fluorescence above background. Specific MoAbs incubated with protein-free liposomes exhibited no fluorescence above background, which indicated no significant binding to the lipid moiety.

**Ca²⁺ Egress**

Ca²⁺ egress from vesicles was measured by incubation of Ca²⁺-loaded (10⁻² mol/L) liposomes in Ca²⁺-free buffer. The egress observed is presumably mediated by protein complexes in an inside-out orientation. In their experiments the extravascular compartment is analogous to the intracellular, cytoplasmic compartment in the intact platelet. Egress was immediate in onset and apparent equilibrium reached at five minutes. The egress was proportional to the amount of protein incorporated into the vesicles (Fig 5). The effect of increased protein on the initial rate (ie, within the first 15 seconds) could not be assessed. Incorporation of ATP (2 mmol/L) into the vesicles had no effect on Ca²⁺ egress, which was quantitatively identical to the non-ATP liposomes.

**DISCUSSION**

Reported data suggest that platelet GPIIb and IIIa may play a role in Ca²⁺ flux across the platelet plasma membrane; however, questions remain. While the results of Brass⁹ indicate that these glycoproteins may play a role in basal platelet Ca²⁺ flux, the data of Powling and Hardisty²⁴ suggest that IIb-IIIa may not play a role in Ca²⁺ influx into activated platelets. In the present study, the GPIIb-IIIa

| Table 1. Change in Intravesicular Fluorescence (ΔF) and Intravesicular Calcium ([Ca²⁺]) Due to Ca²⁺ Movement Into IIb-IIIa Complex, Dissociated IIb/IIIa, and Nonprotein Liposomes |
|-----------------|-----------------|-----------------|-----------------|
| External [Ca²⁺]mol/L | ΔF | [Ca²⁺]mol/L | ΔF | [Ca²⁺]mol/L |
| 10⁻⁴ | 4.1 ± 2.0 | 0.7 x 10⁻³ | 0.5 ± 0.1 | 0.4 x 10⁻⁴ |
| 10⁻³ | 8.2 ± 3.1 | 0.6 x 10⁻⁴ | 1.5 ± 0.2 | 0.6 x 10⁻⁴ |
| 10⁻² | 18.5 ± 4.2 | 2.0 x 10⁻⁵ | 1.0 ± 0.5 | 0.1 x 10⁻⁴ |
| 10⁻¹ | 19.6 ± 2.0 | 4.0 x 10⁻⁶ | 1.2 ± 0.5 | 0.1 x 10⁻⁴ |
| 10⁻² + ionomycin (1 μmol/L) | 23.4 ± 2.9 | 1 x 10⁻⁸ | 23.4 ± 2.1 | 1 x 10⁻⁵ |

Difference between complexed and dissociated proteins, P < .0001; difference between 10⁻⁴ and 10⁻⁵, P < .05; difference between 10⁻⁴ and 10⁻³, P < .0001; difference between 10⁻² and 10⁻¹, not significant.

**Table 2. Binding of MoAbs to GPIIb-IIIa Liposomes by FITC Fluorescence (λex 495; λem 525 nm) of Liposomes After Incubation With Specific MoAbs and Irrelevant Antibody Plus FITC-Antimurine Antibody or FITC Alone and Inhibition of Ca²⁺ (10⁻² mol/L) Movement Into Liposomes**

<table>
<thead>
<tr>
<th>Antibody</th>
<th>FITC</th>
<th>Inhibition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7E3</td>
<td>27.6 ± 4.0</td>
<td>0</td>
</tr>
<tr>
<td>10E5</td>
<td>19.4 ± 3.1</td>
<td>0</td>
</tr>
<tr>
<td>AP2</td>
<td>21.4 ± 2.1</td>
<td>0</td>
</tr>
<tr>
<td>148</td>
<td>35.8 ± 5.1</td>
<td>58.5</td>
</tr>
<tr>
<td>357</td>
<td>13.2 ± 1.0</td>
<td>0</td>
</tr>
<tr>
<td>FITC antimurine</td>
<td>15.5 ± 1.2</td>
<td>0</td>
</tr>
</tbody>
</table>

Specific antibody fluorescence compared with irrelevant antibody or FITC antimurine antibody was significant to P < .005.
complex was shown to permit passive Ca\(^{2+}\) movement across a phosphatidylcholine bilayer. This Ca\(^{2+}\) movement was not observed if the GPIIb-IIIa complex was completely dissociated. This suggests that an intact complex is required for Ca\(^{2+}\) to traverse the phospholipid bilayer. This study does not answer the question whether the complexes responsible for influx are in the fibrinogen binding configuration or in the configuration of the resting platelet membrane. Since previously reported data suggest that <30\% of the IIb-IIIa complexes incorporated into liposomes bind fibrinogen and the data of Brass indicate that IIb-IIIa in the unactivated platelet may participate in Ca\(^{2+}\) flux, it is probable that these complexes may not be in the activated-platelet configuration. However, the precise configuration and the influence of ligand binding to the complex on Ca\(^{2+}\) flux remain to be determined.

The observed time course of Ca\(^{2+}\) influx cannot be directly compared with the kinetics of change in platelet cytoplasmic Ca\(^{2+}\) concentrations following activation. While observed changes in intravesicular calcium are rapid, further studies will be required to determine whether the onset is in the millisecond range if different populations of IIb-IIIa vesicles are involved or if two kinetic phases, one within the first second and a slower phase over five to 15 seconds, are occurring.

The specificity of this influx for IIb/IIIa and not undetected contaminants in the preparation is supported by the observation that one of the MoAbs to IIb and IIIa, M148, but not irrelevant antibody or mouse ascites, inhibited Ca\(^{2+}\) influx. The observation that only M148 of a panel of MoAbs against IIb and IIIa inhibited Ca\(^{2+}\) may be important for understanding the mechanism of this Ca\(^{2+}\) channel. The different effects of the specific MoAb were not due to significant differences in binding of antibodies to the IIb-IIIa on the liposomes as determined by fluorescence of FITC-coupled second antibody. M148, 10E5, 7E3, Tab, and AP2 have each been shown to inhibit ADP-induced platelet aggregation. Several of these MoAbs have been shown to react with different epitopes on IIb and/or IIIa, eg, 7E3 and 10E5. For several other antibodies, definitive comparisons of epitope specificity need to be performed; however, they probably bind to different epitopes on IIb/IIIa. The differences in inhibition seen may be related to these differences in epitope specificity or differences in steric factors subsequent to binding of antibody to IIb and/or IIa. Whether these antibodies bind to the same IIb-IIla molecules on the liposome surface and the precise conformation of the molecules to which they bind remain to be determined. Since inhibition of influx was seen in the presence of a vast excess of extravascular Ca\(^{2+}\), it is unlikely that any nonspecific effects of M148, such as calcium chelation, were responsible for the differences in inhibition of Ca\(^{2+}\) influx.

The data indicate that Ca\(^{2+}\) enters the liposomes and does not simply bind to the surface; however, binding of the Ca\(^{2+}\) to IIb (or, less likely, IIIa) may be a prerequisite to Ca\(^{2+}\) influx. Inhibition of Ca\(^{2+}\) influx by M148 may be related to interference with this Ca\(^{2+}\) binding.

The influx of Ca\(^{2+}\) into GPIIb-IIla vesicles was inversely related to the extravascular NaCl concentration from 150 mmol/L to 25 mmol/L in a manner similar to that reported by Brass\(^{40}\) for the intact platelet. Brass reported that, under non-steady-state conditions, replacement of extraplatelet Na\(^{+}\) with N-methyl-D-glucamine decreased Ca\(^{2+}\) efflux and, under steady-state conditions, replacement of extraplatelet Na\(^{+}\) increased the amount of Ca\(^{2+}\) that entered the cell. Since the intact platelet and liposome systems are different, it is not possible to determine whether the observed similarities are due to related biologic effects. The mechanism of the NaCl effect in the liposome system cannot be due to those proposed for the intact platelet such as Na\(^{+}/K\(^{+}\)-ATPase activity, "relatively unexchangeable" Ca\(^{2+}\) pools that can be affected by Na\(^{+}\), and competing transport processes. Non-specific effects of the NaCl or ionic strength on the lipid bilayer are unlikely mechanisms since any such effects are accounted for by control liposomes, persistence of the NaCl effect with or without replacement by N-methyl-D-glucamine, and maintenance of intravesicular NaCl at 150 mmol/L. Since this effect was observed even at a [Ca\(^{2+}\)] concentration of 10\(^{-2}\) mol/L, it is unlikely that an effect on Ca\(^{2+}\) molecules is responsible. It is possible that the NaCl concentration directly influences the steric configuration of IIb-IIIa or interaction of IIb-IIla with Ca\(^{2+}\). Egress data suggest that the internally oriented proteins may also mediate Ca\(^{2+}\) movement. The relationship between the amount of protein added to the liposome preparation and Ca\(^{2+}\) efflux may be explained by a relative enrichment of the liposome preparation for proteoliposomes rather than protein incorporated per liposome or that true equilibrium had not been reached and the proportionality is related to an increased rate of release.

The current data are in direct agreement with the studies of Brass, which indicate that IIb-IIla may play a role in Ca\(^{2+}\) flux across the platelet plasma membrane.\(^{5,8}\) However, this study and those of Brass appear to be in contrast to the data of Powling and Hardisty on quin-2–measured Ca\(^{2+}\) influx in
response to ADP, platelet-activating factor, thrombin, and sodium arachidonate.\textsuperscript{24} The latter authors observed normal Ca\textsuperscript{2+} influx into thromboplastin platelets but inhibition of influx by MoAbs to the IIb-IIIa complex. They concluded that this influx occurs via a channel closely adjacent to the GPIIb-IIIa complex but not the IIb-IIIa complex per se. While an apparent contrast does exist, the Powling study and the current study concern different phenomena and cannot be directly compared. The Powling study addresses stimulated Ca\textsuperscript{2+} influx into the intact platelet, which may involve a number of complex processes and equilibria. The current study exclusively addresses the ability of the IIb-IIIa complex to mediate Ca\textsuperscript{2+} transit across a lipid bilayer. An alternative possibility is that residual molecules of IIb/IIIa in the thrombasthenic patients’ platelets studied mediated some calcium influx.

This study demonstrates the ability of the GPIIb-IIIa complex to mediate Ca\textsuperscript{2+} transit across a phospholipid bilayer. It is possible that these glycoproteins could play a role in basal Ca\textsuperscript{2+} homeostasis, or they could also be involved in transmembrane Ca\textsuperscript{2+} flux during platelet activation, particularly in localized changes in Ca\textsuperscript{2+} concentration in close proximity to the platelet plasma membrane. Several questions remain to be answered including the configuration and topographical relationship of the complexes on the liposome required to mediate Ca\textsuperscript{2+} flux. Answers to these questions will clarify the relationship of GPIIb-IIIa channel function to other Ca\textsuperscript{2+} channels.

REFERENCES

17. Coller BS, Peerschke EI, Scudder LE, Sullivan CA: A murine monoclonal antibody that completely blocks the binding of fibrinogen to platelets produces a thrombasthenia-like state in normal platelets and binds to glycoprotein IIb and/or IIIa. J Clin Invest 72:325, 1983
Platelet glycoproteins IIb and IIIa as a calcium channel in liposomes

ME Rybak, LA Renzulli, MJ Bruns and DP Cahaly