previous data from the same group. In Marjanovich et al (Figure 7) the same thrombin concentration (0.05 U/mL, 5 minutes) increased cGMP content in WT mouse platelets only 3-fold (from 300 to 900 fmol/10^8 platelets), whereas in Zhang et al, it increased the cGMP content 13-fold (from 10 to 1300 fmol/10^8 platelets), which is comparable with the cGMP increase induced by 10 μM sodium nitroprusside (SNP; Figure 1D). Second, if these data are correct, then the authors should also be able to show sGC/cGMP-induced VASP phosphorylation induced by thrombin stimulation. However, in all 3 of the papers mentioned above, the authors did not present any data on sGC/cGMP-induced VASP phosphorylation. Therefore, we decided to reproduce exactly this key experiment using the same platelet-specific sGC KO mouse model. Moreover, we used 3 different methods for cGMP determination (2 ELISAs, including one from the same supplier used by Zhang et al, and a cGMP RIA). The data in Figure 1 summarize the changes in cGMP content and VASP phosphorylation in platelets induced by thrombin and SNP in WT and platelet-specific sGC KO mouse platelets. Our experiments clearly show no detectable thrombin-induced increase in cGMP; moreover, VASP phosphorylation is even slightly decreased in thrombin-stimulated platelets (Figure 1).

Response

Yes, cGMP plays a stimulatory role in platelet activation

We are grateful for the opportunity to reply to Gambaryan et al who dispute conclusions of our recent publication. In our study, we have shown that soluble guanylyl cyclase (sGC) plays biphasic roles in platelet activation, a stimulatory role during platelet activation induced by low-dose platelet agonists and an inhibitory role when stimulated with high or pharmacologic concentrations of NO donors. Our finding extends our previous discoveries that the NO/cGMP/PKG pathway plays exclusively inhibitory roles in platelets.

In their discussion, Zhang et al state that the 2 major findings in their recent study are: first, that sGC plays a stimulatory role in platelet activation. This does not agree with several other studies as mentioned previously. Second, they reported that millimolar concentrations of SNP can mediate sGC-independent platelet inhibition. This was already described for human platelets by Marcondes et al in 2006, which was even cited by Zhang et al (reference 43 in Zhang et al), but for other reasons.

In summary, in our experiments we show that thrombin neither increases cGMP nor the subsequent cGMP-dependent VASP phosphorylation in platelets. Our data and those of many other groups do not support a “sGC platelet stimulatory concept.” In contrast, our present data and that of many other authors confirm the concept that the NO/sGC/cGMP/PKG pathway plays exclusively inhibitory roles in platelets.

Stepan Gambaryan
Institute of Clinical Biochemistry and Pathobiochemistry, University of Wuerzburg, Wuerzburg, Germany

Andreas Friebe
Institute of Physiology, University of Wuerzburg, Wuerzburg, Germany

Ulrich Walter
Centrum for Thrombosis and Hemostasis, University of Mainz, Mainz, Germany

Contribution: S.G. and A.F. performed the research and analyzed the data; and S.G. and U.W. wrote the final version of the letter.

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Correspondence: Stepan Gambaryan, Institut für Klinische Biochemie & Pathobiochemie, University of Wuerzburg, Grombuehlstr 12, D-97080 Wuerzburg, Germany; e-mail: gambaryan@klin-biochem.uni-wuerzburg.de; or Ulrich Walter, Centrum for Thrombosis and Hemostasis, University of Mainz, D-55131 Mainz, Germany; e-mail: ulrich.walter@unimedizin-mainz.de.

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activation, and challenges the concept that NO/cGMP solely plays an inhibitory role in platelets. Gambaryan et al claim that they “have never obtained evidence for any ‘stimulatory’ role of sGC in platelets” and conclude that “...the NO/sGC/cGMP/PKG pathway plays exclusively inhibitory roles in platelets.”

With due respect, we wish to point out that inability of some or several groups to see something does not prove its nonexistence. Thus, Gambaryan et al are logically incorrect in making the conclusion. Furthermore, there has been extensive data support from the Du laboratory, the Li laboratory, and others that the NO/sGC/cGMP/PKG pathway plays a stimulatory role in platelets (in addition to its inhibitory role), and there is a PI3K/Akt1/eNOS/sGC/cGMP/PKG signaling pathway that stimulates platelet granule secretion.1–10 Nevertheless, we are happy to discuss with Gambaryan et al to resolve the possible technical issues that prevent them from observing the stimulatory role of cGMP.

There is a labeling error in Figure 2A in our Blood article.2 The unit of cGMP concentration should be “fmol,” but was inadvertently labeled as “pmol.” We apologize for this error. However, there is an increase in cGMP levels in platelets stimulated with thrombin, which is consistent with previous results,5,6 and with the well-established concept that platelet activation leads to cGMP elevation.11 Previously we reported that VWF induces cGMP elevation in platelets.2 Gambaryan et al disputed our data and reported that they could not stably detect platelet cGMP elevation.12 However, with some apparent adjustment in techniques, Gambaryan et al have recently been able to show the elevation of cGMP in response to VWF.13 Similarly, we believe that detection of thrombin-induced cGMP elevation is a technical issue associated with their assay sensitivity.

VASP (vasodilator-stimulated phosphoprotein) phosphorylation in platelets is not a reliable indicator of platelet cGMP levels. VASP phosphorylation in human platelets can be mediated by cAMP-dependent protein kinase.14 It is true that Marcondes et al reported data supporting cGMP-independent inhibition of platelets by NO donors in 2006.15 However, this conclusion was disputed by Friebe, a coauthor of the Gambaryan letter, who reported that inhibition of platelets by NO donors is solely dependent on sGC.16 Our results show that sGC knockout did not affect platelet inhibition by high concentrations of NO donors. Therefore, we feel that it is necessary to report our findings, which support the conclusion of Marcondes et al. It is good to know that authors of this letter including Dr. Friebe now agree that high concentrations of NO donors can inhibit platelets via sGC-independent mechanisms.

Zhenyu Li
Department of Medicine, University of Kentucky, Lexington, KY

To the editor:

Extra-platelet NO and NO+ containing drugs are potent inhibitors of platelet aggregation in humans by cGMP-dependent and cGMP-independent mechanisms

Zhang and colleagues stated in their recent article1 that it was unknown until their study whether NO donors inhibit platelet function by cGMP-dependent and cGMP-independent mechanisms. Yet we2 and others3 reported several years ago that S-nitrosocysteine (CSNO) and sodium nitroprusside (SNP; Na2[Fe(CN)6NO]) inhibit platelet function by cGMP-dependent and cGMP-independent mechanisms. CSNO is a potent NO and NO+ donor,4 a crucially important extra- and intra-cellular S-nitrating species,5 and a potent inhibitor (IC50, 100nM) of collagen-induced (1 μg/mL) aggregation of washed human platelets by different cGMP-independent mechanisms.6

Xiaoping Du
Department of Pharmacology, University of Illinois at Chicago, Chicago, IL

References

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Correspondence: Zhenyu Li, Saha Cardiovascular Center, 741 S Limestone St, BBSRB, Rm B251, Lexington, KY 40536-0200; e-mail: zhenyuli08@uky.edu; and Xiaoping Du, Department of Pharmacology, University of Illinois College of Medicine, 835 S Wolcott Ave, Chicago, IL 60612; e-mail: xdu@uic.edu.
Response: yes, cGMP plays a stimulatory role in platelet activation

Zhenyu Li and Xiaoping Du