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PLATELETS FUNCTIONS, ORGANIZATION, AND THEIR ASSOCIATED DISEASES: A BRIEF REVIEW

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ABSTRACT

In healthy hemostasis and pathological states like thrombosis, inflammation, and cancer, platelets a varied small nucleate blood cell types play a crucial role. New, vital information regarding platelet biology and platelet responses to different pathogenic pathways has been provided by recent advances in proteomic studies. Given their ubiquitous distribution and relative ease of isolation from human samples, platelets provide a prime candidate for proteomic analysis, which holds great promise for unraveling the intricate roles played by platelets in health and illness, identifying and evaluating prospective protein molecules derived from platelets as biomarkers, and developing new antiplatelet therapeutic targets. This review provides up-to-date information on platelet organization, platelet-related disorders, stimulation heterogeneity and its effects on diverse platelet functions, and numerous therapeutic targeting efforts involving platelets.

KEYWORDS: Proteomics, Inflammation, Cardiovascular Disease, Neurodegeneration, Platelets.

INTRODUCTION

Megakaryocytes in the lungs and bone marrow produce platelets, which are small blood cells without a nucleus (1). Platelets enter the bloodstream after being liberated by their megakaryocytic progenitor and stay in circulation for 7-10 days. After that, the liver and spleen get rid of them (2). Specialized cells called platelets play an important role in both regular and pathological blood coagulation. Platelets rapidly clump together to form a block when primary hemostasis occurs, attaching to the damaged vessel wall precisely where the injury occurred. Failure to create an adequate plug increases the danger of bleeding, while excessive platelet reactivity increases the chance of thrombosis. Platelets have a major impact on several processes, such as inflammatory reactions and innate immunological responses (3). Platelets' reactivity to the endothelium, circulating cells, and blood signals determine their roles. Human blood contains 150,000–400,000 platelets per microliter. Adhesion molecules and cell surface receptors allow cells to actively examine their surroundings. Other important receptors include integrins, selectins, toll-like, transmembrane, immunoglobulin superfamily, tyrosine kinase, and lipid receptors. (4). When a positive stimulus, platelets release bioactive compounds from α-granules, dense granules, and lysosomes to alter their environment. They also release extracellular vesicles and oxidize free fatty acids to create bioactive lipids (1,5). The chemicals produced affect blood coagulation and other physiological and pathological processes (6,7).

Platelet activation involves the participation of many signaling pathways, which are facilitated by local prothrombotic factors and the secretory products of platelets (8). Platelet glycoprotein receptors interact with exposed collagen to initiate the process of platelet adherence to the extracellular matrix. Platelets endure structural alterations and release their granule contents as a consequence of this interaction (9). The hemostatic plug contains a heterogeneous population of cells that display morphological diversity at rest, in response to agonist stimulation, and otherwise. There is a wide range of age, size, and reactivity among blood platelets (10). In recent years studies have begun to shed light on the functional differences between various types of platelets (6,8,9). While there is some evidence linking structural variety to variations in platelet reactivity, the mechanisms underlying platelet function diversity remain unclear.

It has been discovered that platelets contain RNAs, even

though they do not have a nucleus. This genetic material was not only a byproduct of the progenitor megakaryocyte; it is quite important. Rather, it is the product of thrombopoiesis, a carefully orchestrated sorting process in which megakaryocytes transport mRNA to platelets (11). Platelets are capable of not only producing new proteins but also modifying the platelet moiety in response to convey signals. In addition to this, they exhibit a wide variety of coding and noncoding RNAs, as well as a variety of pathways for the processing of RNA transcripts and specifically designed translation processes. Additionally, it is possible to change the expression of genes in platelets through the transfer of RNAs from megakaryocytes and other cells that are circulating in the blood (12,13). Platelets can change both their shape and their function, which is very remarkable. It has been shown that the platelet transcriptome is an important regulator of platelet function in both healthy and sick individuals (7,12,13). Platelet dysfunction mutations have been linked to several different genes, including those that encode for receptors, intracellular signaling, cytoskeletal proteins, and platelet granule-forming proteins (3,15,16).

Both fundamental and applied research are currently conducting extensive research on the genomes and transcriptomics of megakaryocytes and platelets. In addition, multiple recent studies have brought attention to the possibility of using platelet transcripts as biomarkers, even for disorders that do not appear to have a platelet origin. This is because platelet transcripts are easily acquired and circulate throughout the body without difficulty(5,10).

2. PLATELET SIGNALING AND ACTIVATION

There are several different signaling systems involved in the intricate biological process of platelet activation. Due to the crucial role that they play in platelet functions, the cytoskeletal and signaling proteins are the primary targets of investigations into the platelet proteome(14).

Once attached to the extracellular matrix, platelets undergo a morphological change and discharge their granule contents. After that, they engage with platelet and collagen receptors that have been exposed (8,10,14). Three distinct kinds of granules are found in platelets, and granule exocytosis is critical for platelet function (6). For platelets to become activated, several variables must be present, such as tissue factor (TF) and other local prothrombotic factors. An important signaling receptor that activates platelets in reaction to exposed collagen is platelet membrane glycoprotein VI, or GPVI (2,13). Through G-protein-coupled receptor-mediated signaling, several soluble agonists, such as serotonin, TXA2, prostaglandin E2 (PGE2), thrombin, and adenosine diphosphate (ADP), can affect platelet responsiveness. Furthermore, platelet activation is mediated by the GPVI receptor via activation motif signaling based on immunoreceptor tyrosine (15). These compounds prolong the time that platelets clump together, making them more reactive to injury. No agonist can activate platelets more effectively than thrombin. It does this mostly through interacting with PARs. Research into the mechanisms by which thrombin activates human platelets PAR-1 and PAR-4 has had a major impact on the design of PAR antagonists capable of blocking thrombin-induced platelet activation (16). When the receptor for glycoprotein IIb/IIIa (GPIIb/IIIa) is overexpressed, platelet activation leads to aggregation. In doing so, the receptor becomes available for binding to fibrinogen or von Willebrand factor (vWF). Inflammation, thrombosis, and atherogenesis are caused by the interactions between activated platelets, circulating leukocytes, and the vascular endothelium when P-selectin is used (17). Furthermore, the transmembrane protein functional CD40 ligand (CD40L), also known as CD154, is an essential component of innate and adaptive immune cell signaling pathways (18). This protein is expressed by activated platelets. An upregulation of chemokine synthesis and adhesion molecule production occurs in endothelial cells when CD40L interacts with the receptor CD40. In response to stimuli such as matrix metalloproteinases (MMPs) release, interleukin 6 and 8 (IL-6 and IL-8), and cytokine-like soluble CD40L, activated platelets produce these factors (14,18). The production of matrix metalloproteinases (MMPs) is aided by platelets as well. It is possible to release CD40L in this state via cleavage. The progression of atherosclerosis and atherothrombosis is likely aided by SCD40L (19).

3. DISEASES IMPACT ON PLATELETS

The development, function, genetics, signaling, and communication of platelets, among other formerly unknown features of this biological component, have all been illuminated by recent breakthroughs in platelet research (20). The functional involvement of platelets in the pathophysiology of many diseases, not only coagulation disorders, has been extensively acknowledged with the identification of novel and unknown biological roles of platelets.

3.1 THE ROLE OF PLATELETS IN THROMBOSIS

Platelets are involved in every stage of atherothrombosis, including primary hemostasis and endothelium repair (21). The undamaged, non-activated endothelium prevents arterial plaque adhesion. Platelets can activate endothelial cell monolayers via GPIb and GPVI adhesion receptors in

inflammatory circumstances (22). Platelets activate the endothelium's chemotactic, adhesion, and proteolytic capabilities, which release inflammatory and mitogenic mediators into the environment. Platelets attract leukocytes into developing atherosclerotic plaques by altering endothelial-cell activity(22,23). Platelets send biochemical signals to monocytes, neutrophils, and lymphocyte subsets. In addition, they release several soluble mediators and sticky molecules like P-selectin. Leukocytes connect to activated platelets' P-selectin glycoprotein ligand 1 (PSGL-1) to increase their adhesion to active endothelial cells and prompt monocytes to release TF, which initiates contact. P-selectin signaling stimulates monocytes and macrophages to create chemoattractants or growth factors (24). When atherosclerotic lesions break or disintegrate, platelets cause arterial thrombosis and help them develop. After exposure to blood thrombogenic substrates, platelets "arrest" the exposed subendothelium, attract and activate more platelets by releasing major platelet agonists, and stabilize platelet aggregates (25). A platelet-fibrin thrombus will form after these processes. The fast production of occlusive coronary thrombi causes most ACS and, rarely, abrupt coronary death (22).

3.2 BLOOD SUGAR AND PLATELETS

Diabetes mellitus is a complicated condition that includes microvascular and macrovascular complications, an increased risk of atherothrombotic events, and more (26). The role of platelets is critical in the development of diabetes. The abnormal activation of platelets, which is a hallmark of diabetes mellitus (DM) patients' platelets, is an early occurrence in the disease's natural history. Many believe that the detrimental metabolic state characterized by acute hyperglycemia, glycemic fluctuation, and insulin resistance that precedes and accompanies diabetes is responsible for the alterations in platelet function seen in DM (27). Through intermediary mediators such as oxidative stress, endothelial dysfunction, cellular cross-talk, and circulating microparticles that exchange microRNAs, metabolic abnormalities can impact platelet transcriptome and posttranscriptional regulation (28). Platelet hyperreactivity, a result of these impacts, is characterized by elevated levels of adhesion molecules such as P-selectin, elevated metabolism of arachidonic acid, and higher production of TXA2 (29). It is now well-established that hyperactivated platelets are the cells that amplify the vascular complications of diabetes mellitus (DM), contribute significantly to the development and maintenance of chronic inflammation within the disease, and raise the risk of atherothrombosis in the context of DM (30). It seems that platelets are involved in the pathophysiology of DM in two ways: as targets and as effectors. They transfer metabolic imbalance into vascular injury and then alter it (31). Future research should target particular disease-based mechanisms to lessen the thrombotic load in diabetes.

3.3 PLATELETS AND CANCER

The process of carcinogenesis requires simultaneous changes to both the cancer cells and the tumor microenvironment. From the early tumor formation and extravasation of cancer cells to metastasis, experimental data show that platelets are implicated in carcinogenesis (32). They penetrate the tumor milieu alongside cancer cells and activate the same proliferative pathways triggered by oncogenic mutations, which help the disease develop and progress. Because platelets inhibit cell death, tumor cells can endure hematological and solid tumor malignancies (33). Platelets not only promote angiogenesis by activating cancer cell proangiogenic factor expression, but they can also transport matrix metalloproteinases (MMPs), fibroblast growth factors, vascular endothelial growth factors, and platelet-derived growth factors to the tumor. Because they transport nutrients, waste materials, and oxygen, platelets enable neovascularization, which is critical for the tumor's blood supply (34). Circulating tumor cells can evade the immune system's deadly assault because platelets aggregate with tumor cells and transfer "normal" MHC I molecules onto tumor cell surfaces. This partially physically blocks natural killer cells from recognizing cancer cells (10,23,33). Platelets protect cancer cells from immune surveillance during metastasis (35). Platelets aid cancer cells in circulation in sticking to the endothelium, which in turn facilitates metastasis. Platelets may also signal the formation of a pre-metastatic sub-area and allow extravasation at a distant site. Finally, platelets influence the efficacy of targeted cancer treatments, such as chemotherapy, in patients (36). Platelets clump together and release growth and proangiogenic substances into the tumor milieu when they are activated by cancer cells. Because of the interaction between cancer cells and platelets, these substances can worsen the pro-coagulant milieu. There is growing evidence that tumors can exploit platelets' ability to perform a hemostatic role in cancerous settings to promote their growth, survival, and metastasis(37).

3.4 THE FUNCTION OF PLATELETS IN LUNG DISEASES

Lungs maintain a healthy hemostatic and inflammatory defense system by storing megakaryocytes and platelets, the components of blood clots. However, platelets have been implicated as possible damage

effectors in several lung diseases and disorders, according to both experimental and clinical findings (38). Platelet numbers and function can be affected by lung infections influenza and systemic infections such as bacterial sepsis (39). Platelets play a role in several lung diseases, including cystic fibrosis, asthma, COPD, and intermittent inflammatory lung illnesses. Acute respiratory distress syndrome (ARDS) is influenced by changes in platelet count and function. Platelets that are activated cause damage to alveoli(38,40). Additionally, platelets influence pulmonary embolism, pathological lymphangiogenesis, and pulmonary hypertensive disorders. In both experimental and clinical neoplasia, platelets affect the probability of lung metastasis. It is suggested that to understand the role of platelets in pulmonary pathophysiology, it is necessary to examine the changes that occur in their transcriptome, proteome, and metabolome as a result of lung diseases and the megakaryocytic pathways that precede them(41,42).

3.5. PLATELETS FOR BRAIN DISORDERS

Platelets play a very crucial function with neurons, making them an interesting component in neurodegenerative disorders. The neurotransmitters serotonin, glutamate, and dopamine are stored and released by platelets, which also express proteins N-methyl-D-aspartate. Platelets have elevated levels of several proteins like tau protein and amyloid precursor protein which is mainly responsible for the development of Alzheimer's disease (AD) (40,43). Beyond that, platelets contain all the enzyme machinery needed to produce amyloid precursor proteins and have concentrations of 5-hydroxytryptamine isoforms that are comparable to those in the brain (44). Hence, amyloid precursor protein is produced by active platelets and adds to the buildup of amyloid in the blood vessels. One important source of this protein in the periphery is platelets. Early on in the course of Alzheimer's disease, there may be issues with platelet dysfunction and amyloid precursor protein processing(16,31,43).

Furthermore, certain diseases like Alzheimer's disease, Parkinson's, and multiple sclerosis may also depend on activated platelets when they adhere to the inner lining of blood vessels, leading to their complete blockage and an increase in the production of Aβ40 peptide(45). This, in turn, causes cerebral amyloid angiopathy, dementia, and, finally, the rapid progression of Alzheimer's disease. Platelets may represent alterations in the central nervous system that follow neurodegenerative clinical disorders; thus, they may be valuable as biomarkers for the early diagnosis of diseases.

4. PROTEOMICS AND PLATELETS

Given the central role that platelets play in the pathogenesis of many disorders, they have been the focus of intensive research for their activation, surface receptors, and possible targets (46). Despite ongoing worries about patients' wildly varying pharmacological reactions, several antiplatelet therapies have been successfully developed and put into clinical practice. To get around these limitations, new approaches have evolved that employ "omic" technology. When it comes to improving precision medicine through patient monitoring, the "omics" discipline is undeniably crucial(47). This innovative idea aims to determine the best ways to prevent and treat health problems by considering a person's specific genetic composition, lifestyle choices, environmental influences, and current health status. Because of its ability to profile individual proteins and shed light on cellular and molecular processes, proteomics has become an indispensable tool for tailoring patient care and developing novel therapeutic options. With the use of proteomics, new signaling proteins and receptors have been identified, which has substantially improved our understanding of the principal signaling pathways in platelets – (46,48). Because of their abundance of bioactive proteins in their granules and the large number of receptors they express, platelets are an excellent source of biomarkers that can help track the development of disease. Therefore, biomedical researchers are very interested in biomarkers derived from platelets because they may be able to use them to monitor the development of diseases and the success of treatments.

5. CONCLUSION

The significance of platelets in the pathophysiology of other diseases beyond coagulation disorders has been underscored by new insights on platelet shape, heterogeneity, signaling, interactions, and various roles that have arisen as a result of advancements in the area of platelet research. Due to the sensitivity, efficiency, and high throughput of proteomics methods, our knowledge of the platelet proteome has grown substantially, and numerous new proteins and alterations to them have been discovered. In particular, proteomics has proven to be a helpful approach for gaining an understanding of the myriad of roles that platelets perform in both healthy and diseased states. The proteomics studies that were conducted on platelets have enhanced our understanding of the role that lipid rafts and their function in platelet action. Therefore, it is very necessary for future studies of these membrane microdomains. Because of advancements in sample preparation techniques, increased familiarity with MS-based identification and quantification, and cutting-edge bioinformatics tools, the area of proteomics has contributed to an expansion of our understanding of platelet function and illness.

REFERENCES

1. Patel SR, Hartwig JH, Italiano JE. The biogenesis of platelets from megakaryocyte proplatelets. J Clin Invest 2005;115:3348-3354.
2. Josefsson EC, Vainchenker W, James C. Regulation of Platelet Production and Life Span: Role of Bcl-xL and Potential Implications for Human Platelet Diseases. Int J Mol Sci 2020;21:7591.
3. Sang Y, Roest M, de Laat B, et al. Interplay between platelets and coagulation. Blood Rev 2021;46:100733.
4. Cognasse F, Hamzeh H, Chavarin P, et al. Evidence of Toll-like receptor molecules on human platelets. Immunol Cell Biol 2005;83:196–198.
5. Gianazza E, Brioschi M, Baetta R. et al. Platelets in Healthy and Disease States: From Biomarkers Discovery to Drug Targets Identification by Proteomics. Int J Mol Sci 2020;21:4541.
6. Gianazza E, Brioschi M, Baetta R, et al. Platelets in Healthy and Disease States: From Biomarkers Discovery to Drug Targets Identification by Proteomics. IJMS 2020;21:4541.
7. Gallo CG, Fiorino S, Posabella G, et al. The function of specialized pro-resolving endogenous lipid mediators, vitamins, and other micronutrients in the control of the inflammatory processes: Possible role in patients with SARS-CoV-2 related infection. Prostaglandins & Other Lipid Mediators 2022;159:106619.
8. Yun S-H, Sim E-H, Goh R-Y, et al. Platelet Activation: The Mechanisms and Potential Biomarkers. Biomed Res Int 2016; 2016: 9060143.
9. Stark K, Massberg S. Interplay between inflammation and thrombosis in cardiovascular pathology. Nat Rev Cardiol 2021;18:666–682.
10. Chen Y, Zhong H, Zhao Y, et al. Role of platelet biomarkers in inflammatory response. Biomark Res 2020;8:28.
11. De Wispelaere K, Freson K. The Analysis of the Human Megakaryocyte and Platelet Coding Transcriptome in Healthy and Diseased Subjects. IJMS 2022;23:7647.
12. Rondina MT, Weyrich AS. Regulation of the genetic code in megakaryocytes and platelets. J Thromb Haemost 2015;13 Suppl 1:S26-32.
13. Neu CT, Gutschner T, Haemmerle M. Post-Transcriptional Expression Control in Platelet Biogenesis and Function. Int J Mol Sci 2020; 21:7614.
14. Stalker TJ, Newman DK, Ma P, Wannemacher KM, Brass LF. Platelet signaling. Handb Exp Pharmacol 2012:59–85.
15. Offermanns S. Activation of platelet function through G protein-coupled receptors. Circ Res 2006;99:1293-1304.
16. Faria AVS, Andrade SS, Peppelenbosch et al. The role of phospho-tyrosine signaling in platelet biology and hemostasis. Biochimica et Biophysica Acta (BBA) - Molecular Cell Research 2021;1868:118927.
17. Yakushkin VV, Zyuryaev IT, Khaspekova SG, et al. Glycoprotein IIb-IIIa content and platelet aggregation in healthy volunteers and patients with acute coronary syndrome. Platelets 2011;22:243–251.
18. Elgueta R, Benson MJ, de Vries VC, et al. Molecular mechanism and function of CD40/CD40L engagement in the immune system. Immunol Rev 2009;229:152–172.
19. Kawabe T, Matsushima M, Hashimoto N, et al. CD40/CD40 ligand interactions in immune responses and pulmonary immunity. Nagoya J Med Sci 2011;73:69–78.
20. van der Meijden PEJ, Heemskerk JWM. Platelet biology and functions: new concepts and clinical perspectives. Nat Rev Cardiol 2019;16:166–79.
21. Kaplan ZS, Jackson SP. The Role of Platelets in Atherothrombosis. Hematology 2011;2011:51–61.
22. Scridon A. Platelets and Their Role in Hemostasis and Thrombosis-From Physiology to Pathophysiology and Therapeutic Implications. Int J Mol Sci 2022;23:12772.
23. Yun S-H, Sim E-H, Goh R-Y, et al. Platelet Activation: The Mechanisms and Potential Biomarkers. BioMed Research International 2016;2016:1–5.
24. Ma Y-Q, Plow EF, Geng J-G. P-selectin binding to P-selectin glycoprotein ligand-1 induces an intermediate state of αMβ2 activation and acts cooperatively with extracellular stimuli to support maximal adhesion of human neutrophils. Blood 2004;104:2549–56.
25. Badimon L, Padró T, Vilahur G. Atherosclerosis, platelets and thrombosis in acute ischaemic heart disease. Eur Heart J Acute Cardiovasc Care 2012;1:60–74.
26. Cade WT. Diabetes-related microvascular and macrovascular diseases in the physical therapy setting. Phys Ther 2008;88:1322–35.
27. Huang D, Refaat M, Mohammedi K, et al. Macrovascular Complications in Patients with

Diabetes and Prediabetes. Biomed Res Int 2017;2017:7839101.

28. Santilli F, Simeone P, Liani R, et al. Platelets in Thrombotic and Non-Thrombotic Disorders, Cham: Springer International Publishing; 2017, p. 1225–38.
29. Vardon-Bounes F, Ruiz S, Gratacap M-P, et al. Platelets Are Critical Key Players in Sepsis. Int J Mol Sci 2019;20:3494.
30. Kakouros N, Rade JJ, Kourliouros A, et al. Platelet function in patients with diabetes mellitus: from a theoretical to a practical perspective. Int J Endocrinol 2011;2011:742719.
31. Carrizzo A, Izzo C, Oliveti M, et al. The Main Determinants of Diabetes Mellitus Vascular Complications: Endothelial Dysfunction and Platelet Hyperaggregation. Int J Mol Sci 2018;19:2968.
32. Van Zijl F, Krupitza G, Mikulits W. Initial steps of metastasis: cell invasion and endothelial transmigration. Mutat Res 2011;728:23–34.
33. Joyce JA, Pollard JW. Microenvironmental regulation of metastasis. Nat Rev Cancer 2009;9:239–252.
34. Fares J, Fares MY, Khachfe HH, et al. Molecular principles of metastasis: a hallmark of cancer revisited. Sig Transduct Target Ther 2020;5:28.
35. Labelle M, Begum S, Hynes RO. Direct signaling between platelets and cancer cells induces an epithelial-mesenchymal-like transition and promotes metastasis. Cancer Cell 2011;20:576–90.
36. Wang L, Wang X, Guo E, et al. Emerging roles of platelets in cancer biology and their potential as therapeutic targets. Front Oncol 2022;12:939089.
37. Ward MP, E. Kane L, A. Norris L, et al. Platelets, immune cells and the coagulation cascade; friend or foe of the circulating tumour cell? Mol Cancer 2021;20:59.
38. Weyrich AS, Zimmerman GA. Platelets in lung biology. Annu Rev Physiol 2013;75:569–591.
39. Middleton EA, Weyrich AS, Zimmerman GA. Platelets in Pulmonary Immune Responses and Inflammatory Lung Diseases. Physiol Rev 2016;96:1211–59.
40. Gianazza E, Brioschi M, Baetta R, Mallia A, Banfi C, Tremoli E. Platelets in Healthy and Disease States: From Biomarkers Discovery to Drug Targets Identification by Proteomics. Int J Mol Sci 2020;21:4541.
41. Gomez-Casado C, Villaseñor A, Rodriguez-Nogales A, et al. Understanding Platelets in Infectious and Allergic Lung Diseases. IJMS 2019;20:1730.
42. Takeda T, Morita H, Saito H, et al. Recent advances in understanding the roles of blood platelets in the pathogenesis of allergic inflammation and bronchial asthma. Allergology International 2018;67:326–33.
43. Leiter O, Walker TL. Platelets in Neurodegenerative Conditions-Friend or Foe? Front Immunol 2020;11:747.
44. Burnouf T, Walker TL. The multifaceted role of platelets in mediating brain function. Blood 2022;140:815–827.
45. Espinosa-Parrilla Y, Gonzalez-Billault C, Fuentes E, Pet al. Decoding the Role of Platelets and Related MicroRNAs in Aging and Neurodegenerative Disorders. Front Aging Neurosci 2019;11:151.
46. Shevchuk O, Begonja AJ, Gambaryan S, et al. Proteomics: A Tool to Study Platelet Function. Int J Mol Sci 2021;22:4776.
47. Senzel L, Gnatenko DV, Bahou WF. The platelet proteome. Curr Opin Hematol 2009;16:329–333.
48. Huang J, Swieringa F, Solari FA, et al. Assessment of a complete and classified platelet proteome from genome-wide transcripts of human platelets and megakaryocytes covering platelet functions. Sci Rep 2021;11:12358.

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