RECOMBINANT PLATELET COLLAGEN RECEPTOR GLYCOPROTEIN VI AND ITS PHARMACEUTICAL USE

The invention relates to Glycoprotein VI (GPVI), its isolation, purification, and methods for recombinant production. Especially, the invention relates to the use of GPVI, preferably recombinant GPVI, in the treatment of disorders and pathological events correlated directly or indirectly to blood coagulation disorders such as thrombotic and cardiovascular diseases.The extracellular recombinant protein can also be used for establishing screening assays to find potential inhibitors of the membrane bound GPVI in order to inhibit interaction of platelets and collagen. GPVI on the platelet surface is modified during the platelet lifetime in vivo and can therefore be used as a marker of the platelet age profile.

Glycoprotein VI is a 62/65 kDa (non-reduced/reduced respectively) platelet membrane glycoprotein which forms a complex together with the Fcγ common subunit. The GPVI subunit contains the collagen binding site and the Fcγ subunit is responsible for signalling. The complex forms one of the major collagen receptors on the platelet surface, critical for platelet activation in response to collagen. The recognition sequence on collagen consists of $(GlyProHyp)_n$ sequences. Patients are known from Japan who have a genetic deficiency of GPVI. They have mild bleeding problems and their platelets respond only weakly to collagen, presumably via other receptors. A great deal has been learned about the signalling cascades originating at GPVI which strongly resemble those from immune receptors including T-cell receptors, B-cell receptors and natural killer cell receptors. These cascades involve src family tyrosine kinases such as Fyn and Lyn as well as $p72^{SYK}$ and many other tyrosine kinases and phosphatases and adaptor proteins such as LAT. A main target of these cascades is activation of phospholipase Cγ2 which splits phospholipids to give the second messengers diacylglycerol and IP_3. GPVI is thought to be involved in activation of the platelet integrin α2ß1 which has a major role in platelet adhesion to damaged vessel wall. Mice with the Fcγ subunit "knocked-out" have platelets which still show responses to collagen implying that the resting state of α2ß1 may also be regulated by the GPVI/Fcγ complex.

The platelet collagen receptor GPVI is closely related to the natural killer activatory receptors of the p58KAR family as well as to FcαR.

The adhesion and activation of resting, circulating platelets at a site of vascular injury is the first step in a process leading to the formation of a thrombus which is converted into a haemostatic plug. Collagen is one of the major components of the vessel wall responsible for platelet activation. Many types of collagen exist and seven of these are found in the subendothelial layers. Several different receptors for collagen have been identified on platelets but the major ones are now considered to be the integrin $\alpha_2\beta_1$ and the non-integrin GPVI. Although $\alpha_2\beta_1$ is well characterised and both subunits were cloned and sequenced several years ago, the structure of GPVI has remained elusive although several features have been identified. It was determined about twenty years ago that GPVI is a major platelet glycoprotein with a molecular mass in the 60-65 kDa range and an acid pI. Its role as a putative collagen receptor was established following the identification of a patient in Japan with a mild bleeding disorder whose platelets showed a specific defect of response to collagen and lacked this receptor. This patient had also developed autoantibodies to the deficient receptor and these were used to characterise the molecule further. More recently it was established that GPVI is associated non-covalently with the common Fcγ subunit which acts as the signalling part of the complex. It was also demonstrated that the recognition sequence on collagen for GPVI is a repeated Gly-Pro-Hyp triplet within the collagen triple helical structure and that synthetic peptides based on this structure could be used as specific GPVI directed agonists. The GPVI/ Fcγ complex was shown to signal to the platelet interior by an immune receptor-like mechanism, involving activation of $p72^{SYK}$ and leading by a cascade of kinase/phosphatase/adaptor protein interactions to activation of PLCγ2 and hence to release of granules and platelet aggregation. A further step in characterisation of this molecule was the demonstration that the snake C-type lectin, convulxin, from the Tropical Rattlesnake, Crotalus durissus terrificus was able to activate platelets by clustering GPVI through a multimeric interaction. Convuxin was shown to bind specifically to GPVI providing a method for purification of this receptor in conjunction with established approaches.

Thus, it is clear from the prior art that GPVI seems to be a very interesting compound in many therapeutical fields above all concerning with applications which are related, directly or indirectly, to blood coagulation events which depend on collagen – platelet interaction. It was, therefore, the goal of the present invention is to provide GPVI in a recombinant form and to show its efficiency as direct therapeutical target or as tool for screening of short compounds, especially chemically synthesized or synthesizable compounds having the capability to inhibit or block the natural platelet-collagen interaction.
The invention relates also to portions or fragments of the GPVI protein which have maintained their biological activity which is the binding to collagen.

The invention was successful in purifying adequate amounts of GPVI for preliminary characterisation and for peptide sequencing. The sequences were used to design primers for PCR to identify a positive sequence in a DNA library. This DNA sequence was then used as a probe to isolate an almost complete cDNA sequence from the library and missing 5'-sequence was obtained using a RACE method from a platelet cDNA library.

The invention was also successful in showing the use of recombinant GPVI as therapeutically applicable compound which is capable, when administered in a patient with e.g. damaged blood vessels, to bind to collagen, thus preventing platelets bearing membrane-bound GPVI from binding to said collagen.
The recombinant soluble extracellular domain of GPVI contains the collagen binding site and can prevent platelet activation by collagen. It could therefore be applicable to treatment of disease conditions involving increased platelet activation with collagen, such as atherosclerotic plaque rupture, in diseases such as unstable angina or, during surgical treatment such as Percutaneous Transluminal Coronary Angioplasty (PTCA), where arteries are reopened by inflation of a balloon catheter causing considerable damage to the vessel wall and much platelet activation and often resulting in reclosure of the vessel later.
The advantage of recombinant GPVI fragments compared to present treatment methods is that they act at an earlier stage by preventing or reducing platelet activation rather than by suppressing events after platelet activation, such as

aggregation by GPIIb-IIIa antagonists. Thus, smaller amounts of platelet granule contents are released including growth factors and chemokines which are involved not only in wound repair but in the remodelling of the vessel wall by smooth muscle migration and in attraction of phagocytic cells such as monocytes known to contribute to atherosclerosis. Fab fragment of humanised mouse monoclonal antibodies against GPVI could be used with similar effect to block GPVI on the platelet surface with similar applications as above.

Recombinant GPVI according to this invention can also be used in a binding assay to collagen to screen for small molecules (in combinatory libraries for example) capable of inhibiting this interaction and which can be used to develop therapeutic compounds which are inhibitors of the collagen-platelet interaction . By suitable derivatisation these compounds are made orally available. Again the main objective is to prepare compounds reducing GPVI-collagen interactions and hence platelet activation in situations where platelets come into contact with collagen. The screening technology as such used in this invention is well established in the prior art. By such screening assays the invention enables finding and developing new targets which can inhibit the natural membrane-bound GPVI on the platelet surface as a collagen antagonist. Such targets which may be small chemical molecules may then be the basis for further inventions.

Another major application of GPVI and reagents that recognize specific domains of GPVI is as markers of platelet age and functionality. Young platelets are generally thought to be more active and functional than older ones. Young platelets bind to and are activated by the snake venom C-type lectin convulxin, which is specific for GPVI, and as they age both the binding and degree of activation decrease. This can be due to either proteolytic or conformational changes in GPVI or its association with Fcγ due to platelet activation or damage in the circulation. This can be a useful parameter to measure the age and function profile of platelets in patients as well as in normal persons during medical controls. The platelet age profile changes in many diseases affecting the bone marrow or the immune system and could be an important diagnostic criterion if better methods for its determination were available. For example, patients with

diseases involving increased platelet turnover will show more young platelets whereas patients on chemotherapy or radiation treatment will show a steadily aging population. Thus, such an age profile can be used for a precise monitoring of treatment. In a normal healthy population very little is known about the age profile distribution and its role as a predictor of changes in health. It is not known whether the changes in GPVI are due to the partial involvement of platelets in haemostatic events and whether changes might be more pronounced in patients with extensive cardiovascular disease. At present thiazole orange is used to detect young reticulated platelets containing mRNA. This mRNA soon decays, restricting the method to only the youngest platelets. Reagents which could be used in such an assay would include GPVI-specific snake venom proteins such as convulxin, or monoclonal or polyclonal antibodies recognising the N-terminal region of GPVI or monoclonal antibodies recognising new sites or conformations exposed by proteolysis of the N-terminal domain or specific conformations present either in the intact molecule and not in the aged one or vice versa or small chemical entities selected to recognise specifically intact GPVI or its modified form. These reagents would be labelled with a fluorescent marker, or together with a fluorescent labelled second antibody or affinity reagent and used in flow cytometry to measure the platelet binding profile. At a later stage alternative, less labour intensive measuring techniques based on automated measuring of platelet profiles could be adopted. Using cell sorting methods with flow cytometry or magnetic beads it should be possible to isolate young and old platelets to examine the factors involved in removal of old platelets from the circulation. Reagents recognizing specific forms of GPVI would be a key to such studies.

Therefore, it is an object of the present invention to provide a DNA coding for Glycoprotein VI or biological active fragments thereof, especially the sequence of Fig. 2.

It is a further object of this invention to provide a DNA coding for Glycoprotein VI comprising the amino acid sequences of Fig. 1a and 1b.

It is another object of this invention to provide a pharmaceutical composition comprising recombinant GPVI together with a pharmaceutically acceptable diluent, carrier or excipient, and its use for the manufacture of a medicament in the therapeutical field of thrombotic and cardiovascular events and disorders related to platelet-collagen interactions

Another object of the invention is the use of recombinant GPVI in a screening tool for detecting specific inhibitors of platelet-collagen interactions.

Another object of the invention is the use of GPVI as a marker for platelet age and exposure to cardiovascular diseases.

Possible medical indications and applications, respectively, are, for example, unstable angina pectoris, PTCA, use of stents in this field, operations on coronary vessels, general operations on blood vessels, operations which may damage larger blood vessels such as hip joint operations. Moreover, all indications are included which relate to thromboembolic events caused by disorders of the interaction between the vessel wall and the coagulation system with a high risk of formation of thrombi and blocking of vessels.

As indicated above, the GPVI protein and fragments thereof according to the present invention are suitable as pharmaceutically effective compounds in pharmaceutical compositions and combinations.

The pharmaceutical formulations according to the invention optionally may comprise additional active incredients like anti-coagulants such as hirudin or heparin or thrombolytic agents such as plasminogen activator or hementin or antagonists to other platelet receptors such as GPIIb-IIIa antagonists like abciximab or eptifibatide or ADP-receptor antagonists such as clopidogrel.

The novel protein,and its biological active fragments respectively, according to the invention may form pharmaceutically acceptable salts with any non-toxic, organic or inorganic acid. Inorganic acids are, for example, hydrochloric, hydrobromic, sulphuric or phosphoric acid and acid metal salts such as sodium monohydrogen orthophosphate and potassium hydrogen sulfate. Examples for

organic acids are the mono, di and tri carboxylic acids such as acetic, glycolic, lactic, pyruvic, malonic, succinic, glutaric, fumaric, malic, tartaric, citric, ascorbic, maleic, hydroxymaleic, benzoic, hydroxybenzoic, phenylacetic, cinnamic, salicylic and sulfonic acids such as methane sulfonic acid. Salts of the carboxy terminal amino acid moiety include the non-toxic carboxylic acid salts formed with any suitable inorganic or organic bases. These salts include, for example, alkali metals such as sodium and potassium, alkaline earth metals such as calcium and magnesium, light metals of Group IIIA including aluminium, and organic primary, secondary and tertiary amines such as trialkylamines, including triethylamine, procaine, dibenzylamine, 1-ethenamine, N,N'-dibenzylethylene-diamine, dihydroabietylamine and N-alkylpiperidine.

As used herein, the term "pharmaceutically acceptable carrier" means an inert, non toxic solid or liquid filler, diluent or encapsulating material, not reacting adversely with the active compound or with the patient. Suitable, preferrably liquid carriers are well known in the art such as sterile water, saline, aqueous dextrose, sugar solutions, ethanol, glycols and oils, including those of petroleum, animal, vegetable, or synthetic origin, for example, peanut oil, soybean oil and mineral oil.

The formulations according to the invention may be administered as unit doses containing conventional non-toxic pharmaceutically acceptable carriers, diluents, adjuvants and vehicles which are typical for parenteral administration.

The term "parenteral" includes herein subcutaneous, intravenous, intra-articular and intratracheal injection and infusion techniques. Also other administrations such as oral administration and topical application are suitable. Parenteral compositions and combinations are most preferably adminstered intravenously either in a bolus form or as a constant fusion according to known procedures. Tablets and capsules for oral administration contain conventional excipients such as binding agents, fillers, diluents, tableting agents, lubricants, disintegrants, and wetting agents. The tablets may be coated according to methods well known in the art.

Oral liquid preparations may be in the form of aqueous or oily suspensions, solutions, emulsions, syrups or elixirs, or may be presented as a dry product for reconstitution with water or another suitable vehicle before use. Such liquid preparations may contain conventional additives like suspending agents, emulsifying agents, non-aqueous vehicles and preservatives.
Topical applications may be in the form of aqueous or oily suspensions, solutions, emulsions, jellies or preferably emulsion ointments.

Unit doses according to the invention may contain daily required amounts of the protein according to the invention, or sub-multiples thereof to make up the desired dose. The optimum therapeutically acceptable dosage and dose rate for a given patient (mammals, including humans) depends on a variety of factors, such as the activity of the specific active material employed, the age, body weight, general health, sex, diet, time and route of administration, rate of clearance. the object of the treatment, i.e., therapy or prophylaxis and the nature of the thrombotic desease to be treated, antiplatelet or anticoagulant activity.

Therefore, in compositions and combinations useful as anticoagulants in a treated patient (in vivo) a pharmaceutical effective daily dose of the peptides of this invention is between about 0.01 and 100 mg/kg body weight, preferably between 0.1 and 10 mg/kg body weight. According to the application form one single dose may contain between 0.5 and 10 mg of the collagen inhibitor To achieve an anticoagulant effect in extracorporeal blood a pharmaceutically effective amount of the inventive peptides is between 0.2 and 150 mg /l, preferably between 1mg and 20 mg/l extracorporeal blood.

Short Description of the Figures:

Fig. 1: Protein sequence of GPVI (one-letter-code)

1a: Leader sequence

1b: Mature protein

Open reading frame: 339 amino acids

Asterisk: Glycosylation site

Double underline: Transmembrane domain

Underline: Sequenced peptides

Fig. 2: GPVI nucleotide sequence covering open reading frame of 1017 bp plus 3' and 5' regions total 1249 bp

Detailed description of the invention

Two sequences of 7 amino acids showing the least degeneracy in the genetic code were chosen for the synthesis of DNA primers in order to amplify part of the of GPVI cDNA by PCR. As the location of both peptides in the protein were totally unknown, for each of them, two degenerate primers, one sense and one antisense were prepared. These primers were used to amplify a human bone-marrow library. The combination of the sense 5' TYA THC CNG CNA TGA ARMG 3' primer coding for the sequence PAMKRSL with the antisense 5' TTR TAN ARN GCR AAY TGR TC 3' one corresponding to DQFALYK amplified a DNA fragment of 221 bp. In addition to the selected peptides, the amplified DNA coded for the LysC/AspN peptide DQLELVATGVFAKPSLSAQPGPAVSS, clearly linking the sequence to the cDNA for GPVI.

Screening 600.000 pfu from a bone marrow library with this 221 bp DNA fragment produced 4 positive pfu. Three had inserts of 1350 bp whether cut by the restriction enzymes Sal I or EcoR I and belonged to the IgG superfamily. The fourth one had an 4.6 kb insert by Sal I digestion and gave two fragments of 2300 bp and 1300 bp respectively when treated by EcoRI. Its DNA encoded the sequence for the 10 peptides derived from amino acid sequencing of GPVI but stopped short of the amino terminal. No starting methionine or leader sequence could be found but more than 2000 bp of previously sequenced non-reading frame DNA terminating in an Alu sequence were present. The 5' end RACE experiment was completed on platelet poly A RNA with primers located in a part of the GPVI sequence which had been corroborated by that of the peptides. A fragment of 348 bp including 278 bp on the sequence of the fourth clone and 70 bp new from bp 1987 corresponding to 14 amino acids including the first

methionine were found before falling back on the established GPVI sequence. Thus, a cDNA containing a total of 1249 bp, a 25 bp 5' sequence upstream of the start codon, an open reading frame of 1017 bp coding for a protein, including leader sequence, with 339 amino acids, and a 3' region of 207 bp including the stop codon could be sequenced.

A cDNA coding for platelet GPVI was cloned and sequenced from a human bone marrow cDNA library using RACE with platelet mRNA to supply missing 5' sequence. The open reading frame of 1017 bp encodes 339 amino acids and a untranslated 3' region. Hydrophobicity analysis of the amino acid sequence revealed the presence of two putative transmembrane domains, a putative 20 amino acid signal sequence, and a 19 amino acid domain between residues 247 and 265 of the mature protein. The sequence and its amino acid translation are shown in Fig. 2 and Fig. 1. A comparison with the amino acid sequence of the most similar molecules found in a search of GenBank reveals clearly that it belongs to the immunoglobulin superfamily and the extracellular domain contains two Ig C2-domain loops formed by two disulphide bridges. It is a membrane crossing protein class one molecule with the N-terminus at the exterior and traverses the membrane once. The most closely related molecules belong to the natural killer receptor class which contains both inhibitory and activatory types. GPVI clearly belongs to the activatory subclass not only through its function but also because unlike the inhibitory class it does not contain ITIM sequences in its cytoplasmic domain. Neither does it contain any tyrosine residues which might be involved in phosphorylation. There are some threonine and serine residues in this domain but they do not match any criteria for kinase consensus sequences. Like the activatory class of NK receptors, GPVI contains an arginine residue as the third amino acid of the membrane crossing domain which is involved in the complex formation with the Fcγ subunit. The cytoplasmic domain contains 51 amino acids, showing only a minor similarity (in the region just below the membrane) to the cytoplasmic domains of other members of this family. This suggests that this domain in GPVI may associate with different types of cytoplasmic molecule than the other family members. GPVI contains only a single putative N-glycosylation site at Asn69. The domain just above the membrane

after the beta sheets of the Ig domains finish, however, is rich in theonine and serine residues which could provide O-glycosylation sites such as are found in GPIbα and GPV. The main function of this O-glycosylation seems to be to present the receptor structures well-extended from the platelet surface to facilitate the interactions with their bulky ligands. Since GPVI was earlier established as a sialoglycoprotein, the difference in molecular mass between the theoretical amino acid mass (37 kDa) and the mass determined by gel electrophoresis (65 kDa reduced) must be due to this glycosylation.

The structure of natural killer receptors of the two domain type has been established by X-ray crystallographic studies and the two Ig-domains were shown to form an acute angle with the receptor site for the peptide-carrying HLA antigens lying on the outside of the elbow. A direct comparison of the structure of the HLA peptide binding site with that of collagen immediately suggests why these receptors have a common origin because the multiple alpha-helical structures of the HLA binding site and the peptide it contains strongly resemble the triple helical structure of collagen. The natural killer receptors are postulated to work by a dimerisation mechanism with two receptors recognising two separate HLA sites on the cell which the natural killer cell is investigating. Possibly this dimerisation is part of the activation or deactivation mechanism, depending on the class of receptor. In the case of GPVI there may as well be the possibility for two GPVI molecules to associate with one Fcγ, since each monomer of the Fcγ dimer has a recognition sequence. However, the stoichiometry is not yet known, and based upon the structure of collagens, collagen-like peptides that act via GPVI and convulxin, it seems likely that the strength of the signal is related to the number of GPVI/Fcγ complexes that are clustered together. Other platelet receptors belonging to this Ig family include ICAM-2 (CD102)and PECAM (CD31).

All microorganisms, cell lines, expression systems, expression hosts, plasmids, promoters, resistance markers, replication origins, restriction sites or other fragments or parts of vectors which are mentioned in the description not directly in connection with the claimed invention are commercially or otherwise generally

available. Provided that no other hints are given, they are used only as examples and are not essential with respect to the invention, and can be replaced by other suitable tools and biological materials, respectively.

The techniques which are essential according to the invention are described in detail below and above. Other techniques which are not described in detail correspond to known standard methods which are well known to a person skilled in the art, or are described mor in detail in the cited references and patent applications and in the standard literature (e.g. Sambrook et al., 1989, Molecular Cloning: A Laboratory Manual, 2nd Edition, Cold Spring Harbor; Harlow, Lane, 1988, Antibodies: A Laboratory Manual, Cold Spring Harbor).

EXAMPLES

Example 1: *Materials*–Protein A-Sepharose, peroxidase-conjugated goat anti-mouse and anti-rabbit antibodies, bovine serum albumin, *Crotalus durissus terrificus* venom, wheat germ aggulutinin (WGA), N-hydroxysuccinimidyl chloroformate-activated cross-linked 4% beaded agarose and Triton X-114 were from Sigma Chemical Co. (St Louis, MO), Octanoyl-N-methyl-glucamide (ONMG) and nonanoyl-N-methyl-glucamide (NNMG) were from Oxyl Chemie (Bobingen, Germany).

Example 2: *GPVI isolation from platelets* – Membrane glycoproteins were isolated from platelets as previously described. Briefly, platelets (from 40 buffy coats) were washed and lysed in 2% Triton X-114 in the presence of protease inhibitors. The Triton X-114 and aqueous phases were separated and the detergent phase was loaded on a column of wheat-germ agglutinin coupled to Sepharose 4B. The platelet glycoproteins were eluted with 10 mM Tris HCl, pH 7.4, 30 mM NaCl, 0.2% octanoyl-N-methylglucamide (ONMG) and 2% N-acetylglucosamine. After dialysis and concentration, the solution of glycoproteins was loaded on a column of convulxin bound to N-hydroxylsuccinamidyl–p-nitrophenyl chloroformate activated cross-linked 4% beaded agarose (1 mg/ml). The column was washed with 4 volumes of 10 mM Tris HCl, pH7.4, 30 mM NaCl,

0.2% nonanoyl-N-methylglucamide (NNMG), and then with 4 volumes of 10 mM Tris HCl, pH7.4, 30 mM NaCl and 2% NNMG. GPVI was eluted with 0.08% SDS in 10 mM Tris/HCl, pH 7.4. The solution was concentrated and loaded on a preparative gel of 8.5 % polyacrylamide using the Model 491 Prep Cell (BioRad, CA). The preparative electrophoresis was performed under non-reduced conditions following the manufacturer instructions. GPVI eluted as a single band at 65 kDa. The fractions were pooled, concentrated on Centricon-30 (Amicon, Beverly, MA) and resuspended in 10 mM Tris/HCl, pH7.4 and 0.1% ONMG.

Example 3: *Amino acid analysis of GPVI* - GPVI was digested with the endoproteinases LysC and AspN (Boehringer Mannheim, Germany). The 10 peptides generated were separated by reverse-phase HPLC and sequenced on an Applied Biosystem model 477A pulsed-liquid-phase protein sequencer with a model 120A on-line phenylthiohydantoin amino acid analyser.

Example 4: *Amplification of a 221 bp fragment coding for part of GPVI from a λgt11 cDNA library* -
A sample (10^{10} pfu) (plaque forming units) from a human bone marrow library (Clonetech, Palo Alto, CA) was amplified using 2 combinations of 4 degenerate primers. The final primer concentrations were 2 µM, the dNTP concentration was 200 µM and 2 U/100 µl reaction AmpliTaq Gold (Perkin Elmer, Rotkreuz, Switzerland) were used. The PCR conditions were 5 cycles at 37°C followed by 30 cycles at 44°C. The sense 19mer 5' TYATHCCNGCNATGAARMG 3' and the antisense 20mer 5' TTRTANARNGCRAAYTGRTC 3' amplified a 221 bp fragment which was subcloned in Bluescript KS^+ (Stratagene, La Jolla, CA) and sequenced using the T7 Sequenase kit (Amersham, Switzerland).

Example 5: *Screening the λgt11 cDNA library with the 221 bp GPVI probe*- The 221 bp fragment was cut from the plasmid, cleaned and labelled with α^{32}P-ATP (20MBq/50 µl, Hartmann Analytik, Braunschweig, Germany) using the High Prime Labelling kit (Boehringer Mannheim, Switzerland). The human bone marrow library was screened following the manufacturer.instructions. Positive phages were grown, their DNA isolated and subcloned in BlueScript using either EcoRI or

Sal I sites and sequenced. Sequencing was performed using the ABS system of *RACE*- Platelet poly A RNA was prepared as previously described (Power et al., Cytokine 7, 479-482, 1995). Reverse transcription (30 µl) was performed using 5 µg of poly A RNA with the primer 5'TGAATGAGACGGTCAGTTCAGC 3' (20 µM), dNTP (1mM), RNAsin (40 U), 1X AMV buffer and 20 U AMV reverse transcriptase for 20 min at 45°C followed by 20 min at 52°C. The reaction mixture was treated with 2 µl 6N NaOH at 65° C for 30 min, neutralised with 2µl 6N acetic acid, and concentrated in a Centricon 30 (Amicon). An anchor was ligated to the first strand DNA following the protocol of Aptes and Siebert (BioTechniques 15: 890-893, 1993). Nested PCR was performed using a primer complementary to the anchor and the primer 5' TTGTACAGAGCAAATTGGTC 3' (35 cycles, 55°C) and followed by the primer 5' GACCAGAGGCTTCCGTTCTG 3' (30 cycles at 53°C). The highest band (350 bp) was separated by agarose electrophoresis from the lower ones, subcloned into BlueScript, and sequenced.

Example 6: *Preparation of anti-GPVI Fab and F(ab')$_2$*—Polyclonal antisera against human GPVI were generated in rabbits. IgG from rabbit anti-GPVI antiserum was purified as described. Digestion of IgG with immobilized papain (Pierce) to generate Fab fragments was performed according to the standard protocol of the supplier. Fab fragments were separated from undigested IgG and Fc fragments using an immobilized Protein A (Sigma) column. The flowthrough was transfered to a dialysis tube, concentrated using solid polyethyleneglycol 20,000, thoroughly dialysed against 20 mM Hepes, 140 mM NaCl, 4 mM KCl, pH 7.4 and stored at 4°C until used. F(ab')$_2$ fragments were prepared by pepsin digestion of IgG, 1:50 enzyme to substrate ratio (w/w), in 0.5 M acetate buffer, pH 4.0, at 37°C for 18 hr. The pH was corrected to 7.4 with diluted NaOH and the sample was dialysed against 20 mM phosphate, pH 7.4. F(ab')$_2$ fragments were separated from undigested IgG and Fc fragments using Protein A chromatography. The flow-through was transferred to dialysis tube, concentrated using solid polyethyleneglycol 20 000, intensively dialysed against 20 mM Hepes, 140 mM NaCl, 4 mM KCl, pH 7.4 and stored in aliquots at -20°C. Washed platelets were lysed in Triton X-114 and phase separation was performed on the

soluble material before isolating the membrane glycoproteins associated with the Triton X-114 phase by affinity chromatography on wheat germ agglutinin-Sepharose 4B as described previously. As GPVI represents a very small fraction of the platelet membrane glycoprotein pool, we used the specificity of the snake C-type lectin convulxin for isolation of this receptor. Affinity chromatography on convulxin coupled to Sepharose 4B yielded a 65 kDa protein as major product. However, uncharacterized material of both higher and lower Mr co-eluted with GPVI and could not be removed by extensive washing of the column. Preparative gel electrophoresis on 8.5 % polyacrylamide was added as a final step of purification. Fractions containing GPVI were pooled and gave a single band on reanalysis. Purified GPVI was tested for its ability to block platelet aggregation by collagen. A slight inhibitory effect was observed when aliquots of GPVI solution were added to the platelet suspension. However, by preincubating GPVI with collagen before adding the mixture to the platelet suspension, aggregation could be inhibited in a dose-dependant manner. These platelets still aggregated when fresh collagen was added. Under non-reducing conditions, the isolated protein has a Mr of 62 kDa with a shift toward a slightly higher Mr (65 kDa) under reducing conditions. As the amino terminus of GPVI was found to be blocked, the protein was digested with the enzymes LysC and LysC/AspN which produced 4 and 6 peptides, respectively, from which sequence was obtained. The peptides were separated by reverse phase HPLC on a C4 column and sequenced using the Edman method. The amino acid sequences of these peptides are underlined in the translated cDNA sequence (Fig. 1).

Patent claims

1. DNA coding for Glycoprotein VI or biologically active fragments thereof.

2. DNA according to claim 1 comprising partially or completely the sequence of Fig. 2.

3. DNA having the sequence of Fig. 2

4. DNA according to claims 1 – 3 coding for Glycoprotein VI comprising the amino acid sequence of Fig. 1a and 1b.

5. Recombinant human Glycoprotein VI as medicament comprising the amino acid sequence of Fig. 1b.

6. Pharmaceutical composition comprising the protein of claim 5 and a pharmaceutically acceptable diluent, carrier or excipient therefor.

7. Pharmaceutical composition comprising additionally a pharmacologically active compound.

8. Use of recombinant GPVI in a screening tool for detecting specific inhibitors of platelet-collagen interactions.

9. Use of recombinant GPVI for the manufacture of a medicament in the therapeutical field of thrombotic and cardiovascular events and disorders related to platelet-collagen interactions.

10. Use of changes in GPVI as a marker for platelet age and platelet exposure to thrombotic and cardiovascular conditions or events.

* C L M S *