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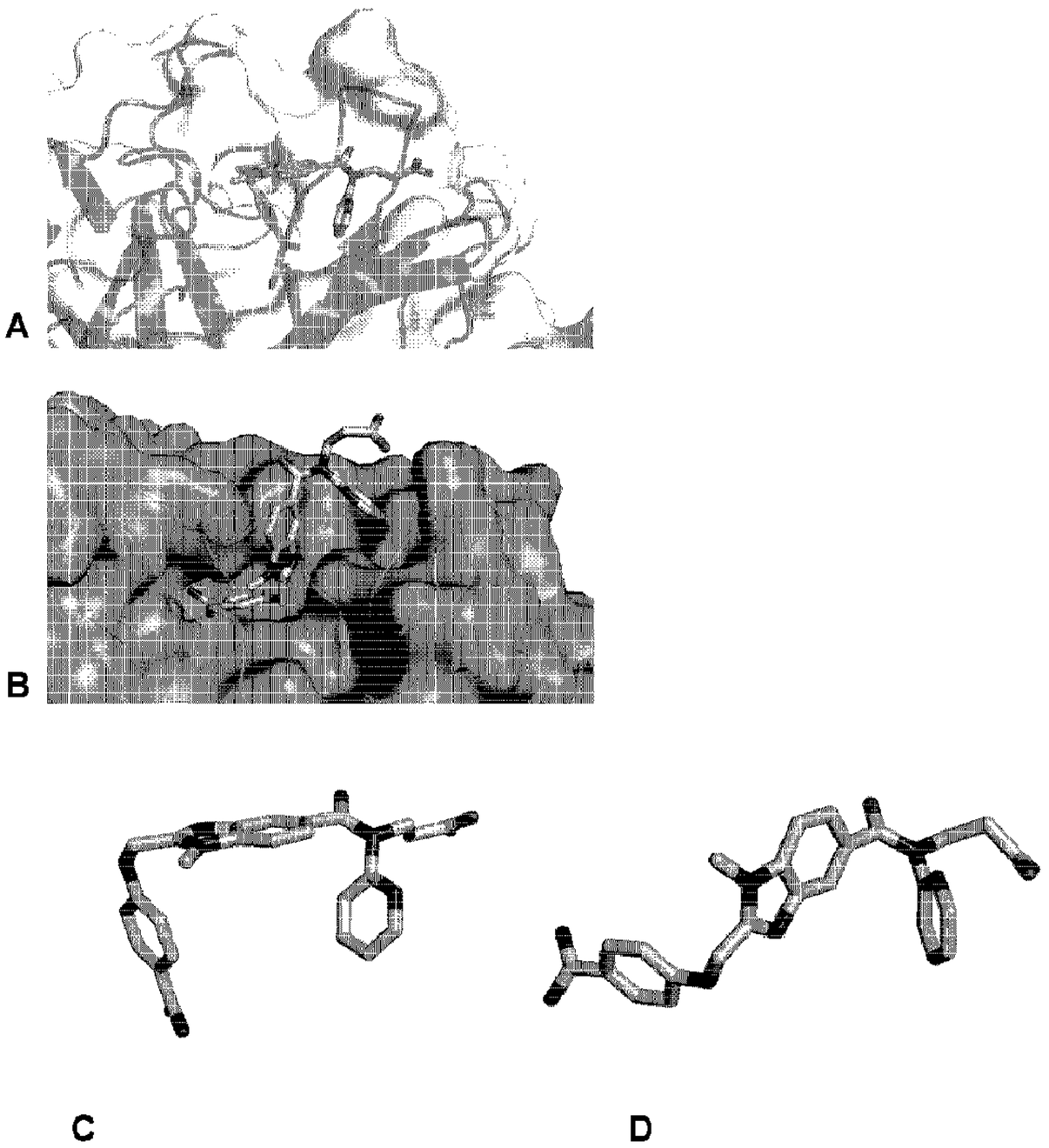

Figure 11

(57) Abrégé/Abstract:
The present invention relates to antibody molecules against anticoagulants, in particular dabigatran,and their use as antidotes of such anticoagulants.

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(54) Title: ANTICOAGULANT ANTIDOTES

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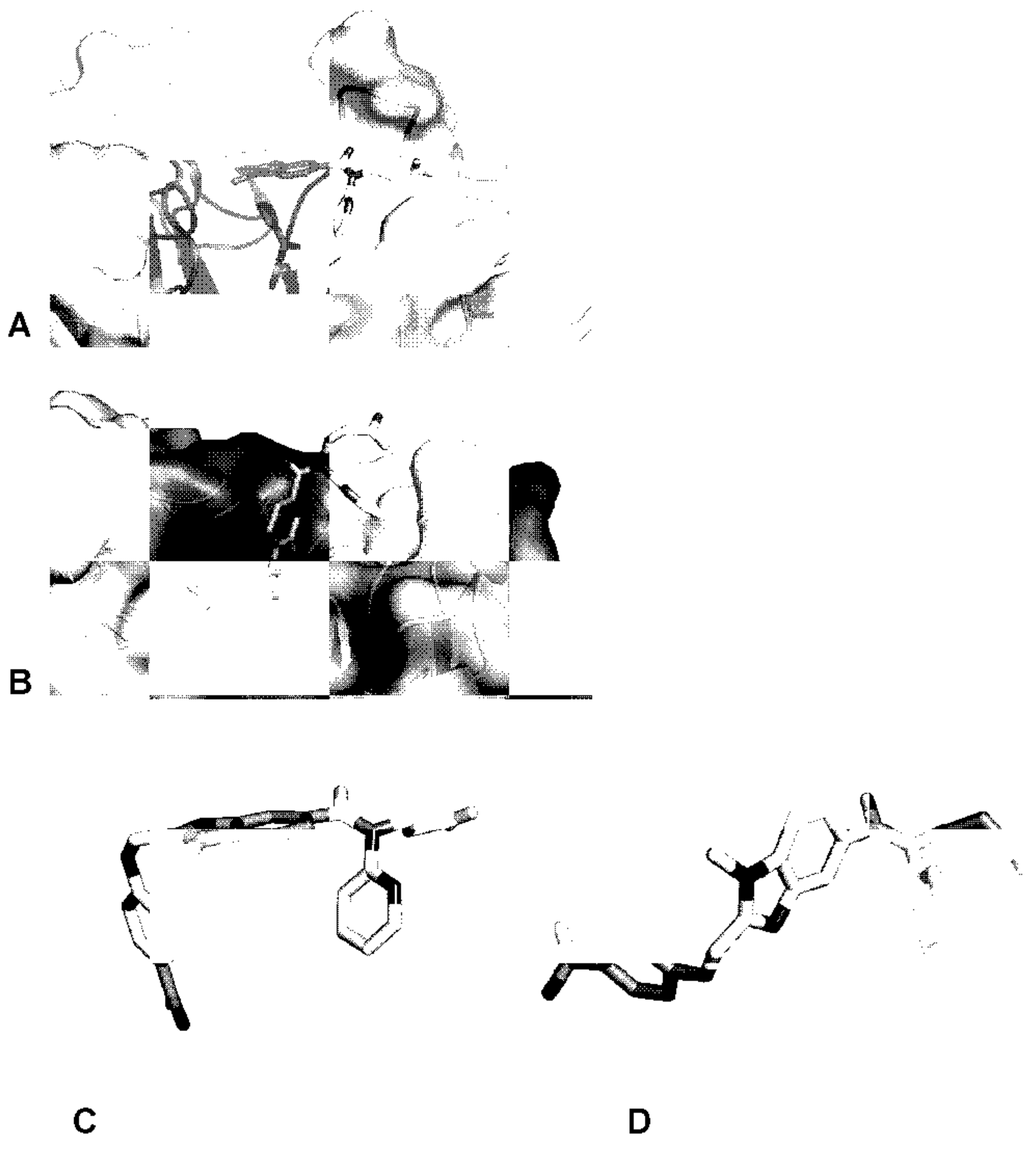

Figure 11

WO 2012/130834 A1

WO 2012/130834 A1

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ANTICOAGULANT ANTIDOTES

TECHNICAL FIELD

The present invention pertains to the field of medicine, in particular to the field of anticoagulant therapy.

BACKGROUND INFORMATION

Anticoagulants are substances that prevent coagulation; that is, they stop blood from clotting. Anticoagulants are widely used in human therapy as a medication for thrombotic disorders, for example primary and secondary prevention of deep vein thrombosis, pulmonary embolism, myocardial infarctions and strokes in those who are predisposed.

An important class of oral anticoagulants acts by antagonizing the effects of vitamin K, for example the coumarins which include warfarin. A second class of compounds inhibit coagulation indirectly via a cofactor such as antithrombin III or heparin cofactor II. This includes several low molecular weight heparin products which catalyse the inhibition of predominantly factor Xa (and to a lesser degree thrombin) via antithrombin III (bemiparin, certoparin, dalteparin, enoxaparin, nadroparin, parnaparin, reviparin, tinzaparin), Smaller chain oligosaccharides (fondaparinux, idraparinux) inhibit only factor Xa via antithrombin III. Heparinoids (danaparoid, sulodexide, dermatan sulfate) act via both cofactors and inhibit both factor Xa and thrombin. A third class represents the direct inhibitors of coagulation. Direct factor Xa inhibitors include apixaban, edoxaban, otamixaban, rivaroxaban, and direct thrombin inhibitors include the bivalent hirudins (bivalirudin, lepirudin, desirudin), and the monovalent compounds argatroban and dabigatran.

As blood clotting is a biological mechanism to stop bleeding, a side effect of anticoagulant therapy may be unwanted bleeding events. It is therefore desirable to provide an antidote to be able to stop such anticoagulant-related bleeding events when they occur (Zikria and Ansell, Current Opinion in Hematology 2009, 16(5): 347-356). One way to achieve this is by neutralizing the activity of the anticoagulant compound present in the patient after administration.

Currently available anticoagulant antidotes are protamine (for neutralization of heparin) and vitamin K for neutralization of vitamin K antagonists like warfarin. Fresh frozen plasma

and recombinant factor VIIa have also been used as non-specific antidotes in patients under low molecular weight heparin treatment, suffering from major trauma or severe hemorrhage (Lauritzen, B. et al, Blood, 2005, 607A-608A.). Also reported are protamine fragments (US Patent No. 6,624,141) and small synthetic peptides (US Patent No. 6,200,955) as heparin or low molecular weight heparin antidotes; and thrombin muteins (US Patent No. 6,060,300) as antidotes for thrombin inhibitor. Prothrombin intermediates and derivatives have been reported as antidotes to hirudin and synthetic thrombin inhibitors (US Patent Nos. 5,817,309 and 6,086,871). For direct factor Xa inhibitors, inactive factor Xa analogs have been proposed as antidotes (WO2009042962). Furthermore, recombinant factor VIIa has been used to reverse the effect of indirect antithrombin III dependent factor Xa inhibitors such as fondaparinux and idraparinux (Bijsterveld, NR et al, Circulation, 2002, 106: 2550-2554; Bijsterveld, NR et al, British J. of Haematology, 2004 (124): 653-658). A review of methods of anticoagulant reversal is provided in Schulman and Bijsterveld, Transfusion Medicine Reviews 2007, 21(1): 37-48.

International patent application WO2011089183 discloses antibodies that can bind and neutralize the activity of dabigatran.

There is a need to provide improved antidotes for anticoagulant therapy, and in particular to provide antidotes for direct thrombin inhibitors like dabigatran for which no specific antidotes have been disclosed so far.

BRIEF SUMMARY OF THE INVENTION

In one aspect, the present invention relates to an antibody molecule capable of neutralizing the activity of an anticoagulant.

In a further aspect, the antibody molecule has binding specificity for the anticoagulant.

In a further aspect, the anticoagulant is a direct thrombin inhibitor, a Factor Xa inhibitor, or a vitamin K antagonist.

In a further aspect, the anticoagulant is dabigatran, argatroban, melagatran, ximelagatran, hirudin, bivalirudin, lepirudin, desirudin, apixaban, otamixaban, edoxaban, rivaroxaban, defibrotide, ramatroban, antithrombin III, or drotrecogin alpha.

In another aspect, the present invention relates to an antibody molecule against dabigatran, dabigatran exetilate, and/or an O-acylglucuronide of dabigatran.

In a further aspect, the present invention relates to an antibody molecule against dabigatran, dabigatran exetilate, and/or an O-acylglucuronide of dabigatran with reduced immunogenicity in man.

In a further aspect, the present invention relates to an antibody molecule against dabigatran, dabigatran exetilate, and/or an O-acylglucuronide of dabigatran with improved physicochemical properties, in particular improved solubility in aqueous solvents.

In a further aspect, the present invention relates to an antibody molecule against dabigatran, dabigatran exetilate, and/or an O-acylglucuronide of dabigatran with improved produceability in host cells, in particular resulting in improved production yields.

In a further aspect, the antibody molecule is a polyclonal antibody, a monoclonal antibody, a human antibody, a humanized antibody, a chimeric antibody, a fragment of an antibody, in particular a Fab, Fab', or $F(ab')_2$ fragment, a single chain antibody, in particular a single chain variable fragment (scFv), a domain antibody, a nanobody, a diabody, or a DARPin.

In a further aspect, the present invention relates to an antibody molecule as described above for use in medicine.

In a further aspect, the present invention relates to an antibody molecule as described above for use in the therapy or prevention of side effects of anticoagulant therapy.

In a further aspect, the side effect is a bleeding event.

In a further aspect, the present invention relates to a method of treatment or prevention of side effects of anticoagulant therapy, comprising administering an effective amount of an antibody molecule as described above to a patient in need thereof.

In another aspect, the present invention relates to a kit comprising an antibody molecule as described, together with a container and a label.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1: Increased time to clotting seen with increased concentrations of dabigatran using the thrombin clotting time assay. The 200 nM concentration resulted in an ~5-fold elevation in clotting time over baseline and was used in the first and second set of experiments. The 500 nM concentration (supratherapeutic) was used in the last set of experiments.

Figure 2: Four different antibodies to dabigatran (A-D) all neutralized the prolonged clotting time of dabigatran in human plasma. Baseline clotting in human plasma was 10.9 seconds, when 200 nM dabigatran was preincubated with plasma, clotting was prolonged to 51 seconds. Each antibody was added to plasma preincubated with 200 nM of dabigatran and further incubated for 5 min. The thrombin clotting time was then initiated by addition of thrombin. Each antibody could reverse the clotting time of dabigatran to different degrees. The most concentrated solution resulted in the largest reversal of anticoagulant activity.

Figure 3: The effect of increasing concentrations of polyclonal antibody (antibody D) added to human plasma that had been preincubated with 200 nM dabigatran was measured. Baseline clotting time was 11 seconds, addition of dabigatran prolonged clotting to 63.7 seconds. The effect of increasing dilutions of antibody on reversing the prolonged thrombin clotting time with dabigatran was then tested. The lowest concentration reduced the thrombin clotting time to 43.9 seconds. Higher concentrations completely reduced the thrombin clotting time to baseline levels and resulted in complete neutralization of the anticoagulant effect of dabigatran. Addition of a non specific rabbit

polyclonal antibody (square) had no effect on reversing the anticoagulant effect of dabigatran.

Figure 4: The effect of increasing concentrations of polyclonal antibody (antibody D) added to human plasma that had been preincubated with 500 nM dabigatran was measured. Baseline clotting time was 10.9 seconds, addition of this higher concentration of dabigatran prolonged clotting to 111.7 seconds (~10-fold increase). The effect of a 1:2 dilution of antibody or stock solution reversed the prolonged thrombin clotting time with dabigatran in a concentration dependent manner. The highest concentration also completely reversed the thrombin clotting time to baseline levels and resulted in complete neutralization of the anticoagulant effect of even supratherapeutic concentrations of dabigatran.

Figure 5: A mouse monoclonal antibody (Clone 22) reverses the anticoagulant effect of dabigatran in human plasma and in human whole blood. Increasing concentrations of mouse antibody were added to human plasma or whole blood that had been preincubated with 30 nM dabigatran. The assay was initiated by the addition of 1.5 – 2 U/mL of thrombin and clotting time was measured. 100% dabigatran activity was defined as the difference in clotting time in the presence and absence of compound. The antibody dose dependently inhibited the dabigatran mediated prolongation of clotting time.

Figure 6: A mouse Fab generated from the Clone 22 antibody reverses the anticoagulant effect of dabigatran in human plasma. Increasing concentrations of mouse Fab were added to human plasma that had been preincubated with 7 nM dabigatran. The intact antibody was also tested as a positive control. The assay was initiated by the additon of 0.4 U/mL of thrombin and clotting time was measured. 100% inhibition was defined as the complete block of the dabigatran mediated increase in clotting time. The Fab dose dependently inhibited the dabigatran induced prolongation in clotting time in human plasma.

Figure 7: A mouse monoclonal antibody (Clone 22) reverses the anticoagulant effect of dabigatran acylglucuronide in human plasma. Increasing concentrations of mouse antibody were added to human plasma that had been preincubated with 7 nM of dabigatran acylglucuronide or dabigatran. The assay was initiated by the additon of 0.4

U/mL of thrombin and clotting time was measured. 100% inhibition was defined as the complete block of the compound mediated increase in clotting time. The antibody dose dependently inhibited the dabigatran acylglucuronide induced prolongation in clotting time in human plasma.

Figure 8: Selected chimeric antibodies inhibit dabigatran activity in the thrombin clotting time assay. Increasing concentrations of antibody were added to human plasma that had been preincubated with 7 nM dabigatran. The intact antibody was also tested as a positive control. The assay was initiated by the additon of 0.4 U/mL of thrombin and clotting time was measured. 100% inhibition was defined as the complete block of the dabigatran mediated increase in clotting time. The antibodies dose dependently inhibited the dabigatran induced prolongation in clotting time in human plasma.

Figure 9: Fab VH5c/Vk18 (SEQ ID NO: 99 and SEQ ID NO: 100) and VH5c/Vk21 (SEQ ID NO: 99 and SEQ ID NO: 101) inhibit dabigatran activity in the thrombin clotting time plasma assay. The assay was performed as described above.

Figure 10: Fab VH5c/Vk18 (SEQ ID NO: 99 and SEQ ID NO: 100) and VH5c/Vk21 (SEQ ID NO: 99 and SEQ ID NO: 101) inhibit dabigatran activity in the plasma and whole blood thrombin clotting time assay. The assay was performed as described above.

Figure 11: Crystal structure of the Fab-Dabigatran complexes. **A**: Crystal structure of Fab 18/15 (WO2011089183) in complex with dabigatran. **B**: Crystal structure of Fab VH5c/Vk18 (SEQ ID NO: 99 and SEQ ID NO: 100) in complex with dabigatran. **C**: Conformation of dabigatran as seen in the crystal structure with Fab 18/15. **D**: Extended conformation of dabigatran as seen in the crystal structure with VH5c/Vk18.

Figure 12: Spatial aggregation propensities (SAP) calculated for (A) Fab 18/15 (B) Fab VH5c/Vk18 and (C) Fab VH5c/Vk21 comprising the CDRs (left panels) or the whole Fv region (right panels).

Figure 13: Titers of (A) Fab 18/15 (B) Fab VH5c/Vk18 and (C) Fab VH5c/Vk21 from fed batch runs of CHO cells transfected with corresponding Fab expression constructs.

DETAILED DESCRIPTION OF THE INVENTION

In one aspect, the present invention relates to an antibody molecule capable of neutralizing the activity of an anticoagulant.

Antibodies (also known as immunoglobulins, abbreviated Ig) are gamma globulin proteins that can be found in blood or other bodily fluids of vertebrates, and are used by the immune system to identify and neutralize foreign objects, such as bacteria and viruses. They are typically made of basic structural units - each with two large heavy chains and two small light chains - to form, for example, monomers with one unit, dimers with two units or pentamers with five units. Antibodies can bind, by non-covalent interaction, to other molecules or structures known as antigens. This binding is specific in the sense that an antibody will only bind to a specific structure with high affinity. The unique part of the antigen recognized by an antibody is called an epitope, or antigenic determinant. The part of the antibody binding to the epitope is sometimes called paratope and resides in the so-called variable domain, or variable region (Fv) of the antibody. The variable domain comprises three so-called complementary-determining region (CDR's) spaced apart by framework regions (FR's).

Within the context of this invention, reference to CDR's is based on the definition of Chothia (Chothia and Lesk, J. Mol. Biol. 1987, 196: 901–917), together with Kabat (E.A. Kabat, T.T. Wu, H. Bilofsky, M. Reid-Miller and H. Perry, Sequence of Proteins of Immunological Interest, National Institutes of Health, Bethesda (1983)).

The art has further developed antibodies and made them versatile tools in medicine and technology. Thus, in the context of the present invention the terms "antibody molecule" or "antibody" (used synonymously herein) do not only include antibodies as they may be found in nature, comprising e.g. two light chains and two heavy chains, or just two heavy chains as in camelid species, but furthermore encompasses all molecules comprising at least one paratope with binding specificity to an antigen and structural similarity to a variable domain of an immunoglobulin.

Thus, an antibody molecule according to the invention may be a polyclonal antibody, a monoclonal antibody, a human antibody, a humanized antibody, a chimeric antibody, a

fragment of an antibody, in particular a Fv, Fab, Fab', or $F(ab')_2$ fragment, a single chain antibody, in particular a single chain variable fragment (scFv), a Small Modular Immunopharmaceutical (SMIP), a domain antibody, a nanobody, a diabody.

Polyclonal antibodies represent a collection of antibody molecules with different amino acid sequences and may be obtained from the blood of vertebrates after immunization with the antigen by processes well-known in the art.

Monoclonal antibodies (mAb or moAb) are monospecific antibodies that are identical in amino acid sequence. They may be produced by hybridoma technology from a hybrid cell line (called hybridoma) representing a clone of a fusion of a specific antibody-producing B cell with a myeloma (B cell cancer) cell (Kohler G, Milstein C. Continuous cultures of fused cells secreting antibody of predefined specificity. Nature 1975;256:495-7.). Alternatively, monoclonal antibodies may be produced by recombinant expression in host cells (Norderhaug L, Olafsen T, Michaelsen TE, Sandlie I. (May 1997). "Versatile vectors for transient and stable expression of recombinant antibody molecules in mammalian cells.". J Immunol Methods 204 (1): 77–87; see also below).

For application in man, it is often desirable to reduce immunogenicity of antibodies originally derived from other species, like mouse. This can be done by construction of chimeric antibodies, or by a process called “humanization”. In this context, a “chimeric antibody” is understood to be an antibody comprising a sequence part (e.g. a variable domain) derived from one species (e.g. mouse) fused to a sequence part (e.g. the constant domains) derived from a different species (e.g. human). A “humanized antibody” is an antibody comprising a variable domain originally derived from a non-human species, wherein certain amino acids have been mutated to resemble the overall sequence of that variable domain more closely to a sequence of a human variable domain. Methods of chimerisation and -humanization of antibodies are well-known in the art (Billetta R, Lobuglio AF. “Chimeric antibodies”. Int Rev Immunol. 1993;10(2-3):165-76; Riechmann L, Clark M, Waldmann H, Winter G (1988). "Reshaping human antibodies for therapy". *Nature*: 332:323.).

Furthermore, technologies have been developed for creating antibodies based on sequences derived from the human genome, for example by phage display or using

transgenic animals (WO 90/05144; D. Marks, H.R. Hoogenboom, T.P. Bonnert, J. McCafferty, A.D. Griffiths and G. Winter (1991) "By-passing immunisation. Human antibodies from V-gene libraries displayed on phage." J.Mol.Biol., 222, 581-597; Knappik et al., J. Mol. Biol. 296: 57-86, 2000; S. Carmen and L. Jermutus, "Concepts in antibody phage display". Briefings in Functional Genomics and Proteomics 2002 1(2):189-203; Lonberg N, Huszar D. "Human antibodies from transgenic mice". Int Rev Immunol. 1995;13(1):65-93.; Brüggemann M, Taussig MJ. "Production of human antibody repertoires in transgenic mice". Curr Opin Biotechnol. 1997 Aug;8(4):455-8.). Such antibodies are "human antibodies" in the context of the present invention.

Antibody molecules according to the present invention also include fragments of immunoglobulins which retain antigen binding properties, like Fab, Fab', or $F(ab')_2$ fragments. Such fragments may be obtained by fragmentation of immunoglobulins e.g. by proteolytic digestion, or by recombinant expression of such fragments. For example, immunoglobulin digestion can be accomplished by means of routine techniques, e.g. using papain or pepsin (WO 94/29348), or endoproteinase Lys-C (Kleemann, et al, Anal. Chem. 80, 2001-2009, 2008). Papain or Lys-C digestion of antibodies typically produces two identical antigen binding fragments, so-called Fab fragments, each with a single antigen binding site, and a residual Fc fragment. Pepsin treatment yields an $F(ab')_2$. Methods of producing Fab molecules by recombinant expression in host cells are outlined in more detail below.

A number of technologies have been developed for placing variable domains of immunoglobulins, or molecules derived from such variable domains, in a different molecular context. Those should be also considered as "antibody molecules" in accordance with the present invention. In general, these antibody molecules are smaller in size compared to immunoglobulins, and may comprise a single amino acid chain or be composed of several amino acid chains. For example, a single-chain variable fragment (scFv) is a fusion of the variable regions of the heavy and light chains of immunoglobulins, linked together with a short linker, usually serine (S) or glycine (G) (WO 88/01649; WO 91/17271; Huston et al; International Reviews of Immunology, Volume 10, 1993, 195 - 217). "Single domain antibodies" or „nanobodies" harbour an antigen-binding site in a single Ig-like domain (WO 94/04678; WO 03/050531, Ward et al., Nature. 1989 Oct 12;341(6242):544-6; Revets et al., Expert Opin Biol Ther. 5(1):111-24, 2005). One or

more single domain antibodies with binding specificity for the same or a different antigen may be linked together. Diabodies are bivalent antibody molecules consisting of two amino acid chains comprising two variable domains (WO 94/13804, Holliger et al., Proc Natl Acad Sci U S A. 1993 Jul 15;90(14):6444-8). Other examples for antibody-like molecules are immunoglobulin super family antibodies (IgSF; Srinivasan and Roeske, Current Protein Pept. Sci. 2005, 6(2): 185-96). A different concept leads to the so-called Small Modular Immunopharmaceutical (SMIP) which comprises a Fv domain linked to single-chain hinge and effector domains devoid of the constant domain CH1 (WO 02/056910).

In a further aspect, an antibody molecule of the invention may even only have remote structural relatedness to an immunoglobulin variable domain, or no such relation at all, as long as it has a certain binding specificity and affinity comparable to an immunoglobulin variable domain. Such non-immunoglobulin “antibody mimics”, sometimes called “scaffold proteins”, may be based on the genes of protein A, the lipocalins, a fibronectin domain, an ankyrin consensus repeat domain, and thioredoxin (Skerra, Current Opinion in Biotechnology 2007, 18(4): 295-304). A preferred embodiment in the context of the present invention are designed ankyrin repeat proteins (DARPin’s; Steiner et al., J Mol Biol. 2008 Oct 24;382(5): 1211-27; Stumpp MT, Amstutz P. Curr Opin Drug Discov Devel. 2007 Mar;10(2):153-9).

The antibody molecule may be fused (as a fusion protein) or otherwise linked (by covalent or non-covalent bonds) to other molecular entities having a desired impact on the properties of the antibody molecule. For example, it may be desirable to improve pharmacokinetic properties of antibody molecules, stability e.g. in body fluids such as blood, in particular in the case of single chain antibodies or domain antibodies. A number of technologies have been developed in this regard, in particular to prolong half-life of such antibody molecules in the circulation, such as pegylation (WO 98/25971; WO 98/48837; WO 2004081026), fusing or otherwise covalently attaching the antibody molecule to another antibody molecule having affinity to a serum protein like albumin (WO 2004041865; WO 2004003019), or expression of the antibody molecule as fusion protein with all or part of a serum protein like albumin or transferrin (WO 01/79258).

In a further aspect, the antibody molecule has binding specificity for the anticoagulant. "Binding specificity" means that the antibody molecule has a significantly higher binding affinity to the anticoagulant than to structurally unrelated molecules.

Affinity is the interaction between a single antigen-binding site on an antibody molecule and a single epitope. It is expressed by the association constant $K_A = k_{ass}/k_{diss}$, or the dissociation constant $K_D = k_{diss}/k_{ass}$.

In one aspect of the invention, the antibody binds to the anticoagulant with an affinity, as determined e.g. by surface plasmon resonance analysis (Malmqvist M., "Surface plasmon resonance for detection and measurement of antibody-antigen affinity and kinetics.", Curr Opin Immunol. 1993 Apr;5(2):282-6.), with a K_D value ranging from 0.1 pM to 100 µM, preferably 1 pM to 100 µM, preferably 1 pM to 1 µM. Antibody affinity can also be measured using kinetic exclusion assay (KinExA) technology (Darling, R.J., and Brault P-A., "Kinetic exclusion assay technology: Characterization of Molecular Interactions." ASSAY and Drug Development Technologies. 2004, Dec 2(6): 647-657).

The binding affinity of an antibody molecule may be enhanced by a process known as affinity maturation (Marks et al., 1992, Biotechnology 10:779-783; Barbas, et al., 1994, Proc. Nat. Acad. Sci, USA 91:3809-3813; Shier et al., 1995, Gene 169:147-155). Affinity matured antibodies are therefore also embraced in the present invention.

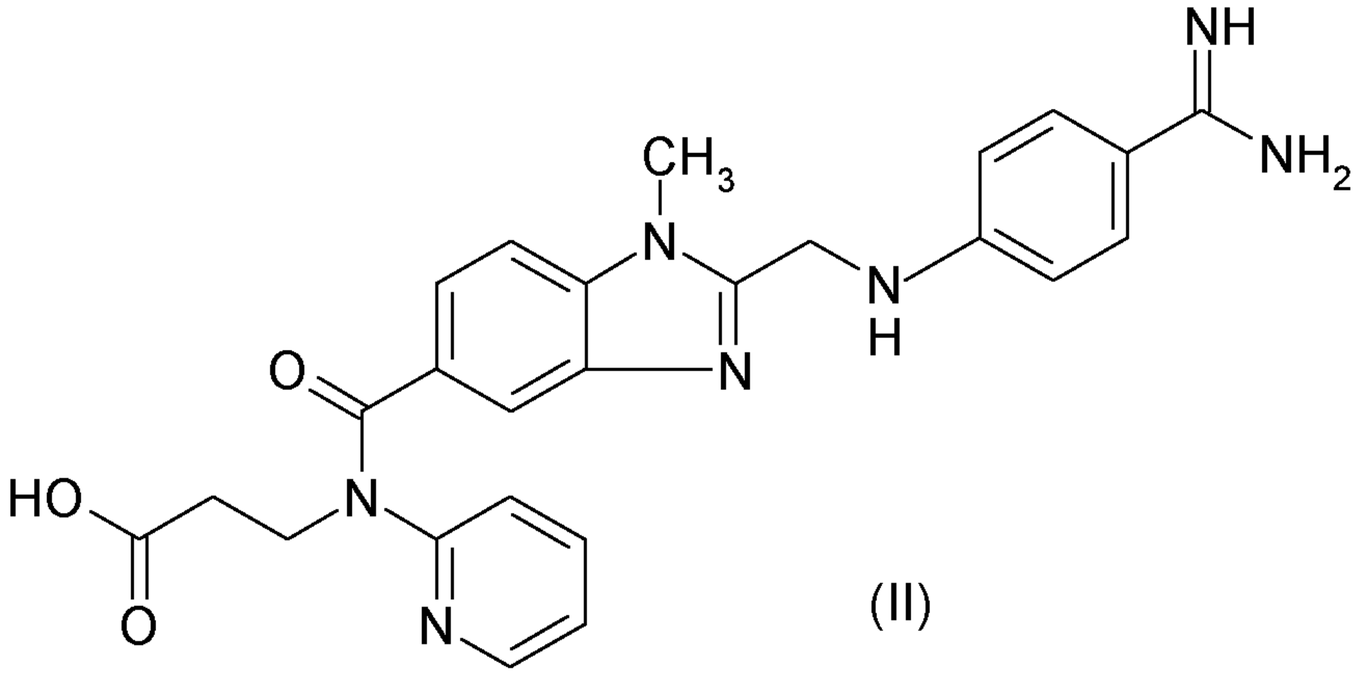
In a further aspect of the invention, the antibody molecule is capable of neutralizing the activity of the anticoagulant. That is, upon binding to the antibody molecule, the anticoagulant is no longer able to exert its anticoagulant activity, or exerts this activity at a significantly decreased magnitude. Preferably, the anticoagulant activity is decreased at least 2fold, 5fold, 10fold, or 100fold upon antibody binding, as determined in an activity assay which is appropriate for the anticoagulant at issue, particularly a clotting assay that is sensitive to thrombin, such as the ecarin clotting time or the thrombin clotting time (H. Bounameaux, Marbet GA, Lammle B, et al. "Monitoring of heparin treatment. Comparison of thrombin time, activated partial thromboplastin time, and plasma heparin concentration, and analysis of the behaviour of antithrombin III". American Journal of Clinical Pathology 1980 74(1): 68-72).

For manufacturing the antibody molecules of the invention, the skilled artisan may choose from a variety of methods well known in the art (Norderhaug et al., J Immunol Methods 1997, 204 (1): 77–87; Kipriyanow and Le Gall, Molecular Biotechnology 26: 39- 60, 2004; Shukla et al., 2007, J. Chromatography B, 848(1): 28-39).

Anticoagulants are well-known in the art, as outlined above. In a further aspect of the invention, the anticoagulant is a direct thrombin inhibitor, a Factor Xa inhibitor, or a vitamin K antagonist. Examples of vitamin K antagonists are the coumarins, which include warfarin. Examples of indirect predominantly factor Xa inhibitors are the heparin group of substances acting through activation of antithrombin III including several low molecular weight heparin products (bemiparin, certoparin, dalteparin, enoxaparin, nadroparin, parnaparin, reviparin, tinzaparin), certain oligosaccharides (fondaparinux, idraparinux), heparinoids (danaparoid, sulodexide, dermatan sulfate), and the direct factor Xa inhibitors (apixaban, otamixaban, rivaroxaban). Examples of thrombin inhibitors include the bivalent hirudins (bivalirudin, lepirudin, desirudin), and the monovalent compounds argatroban and dabigatran.

Thus, in a further aspect, the anticoagulant is dabigatran, argatroban, melagatran, ximelagatran, hirudin, bivalirudin, lepirudin, desirudin, apixaban, edoxaban, otamixaban, rivaroxaban, defibrotide, ramatroban, antithrombin III, or drotrecogin alpha.

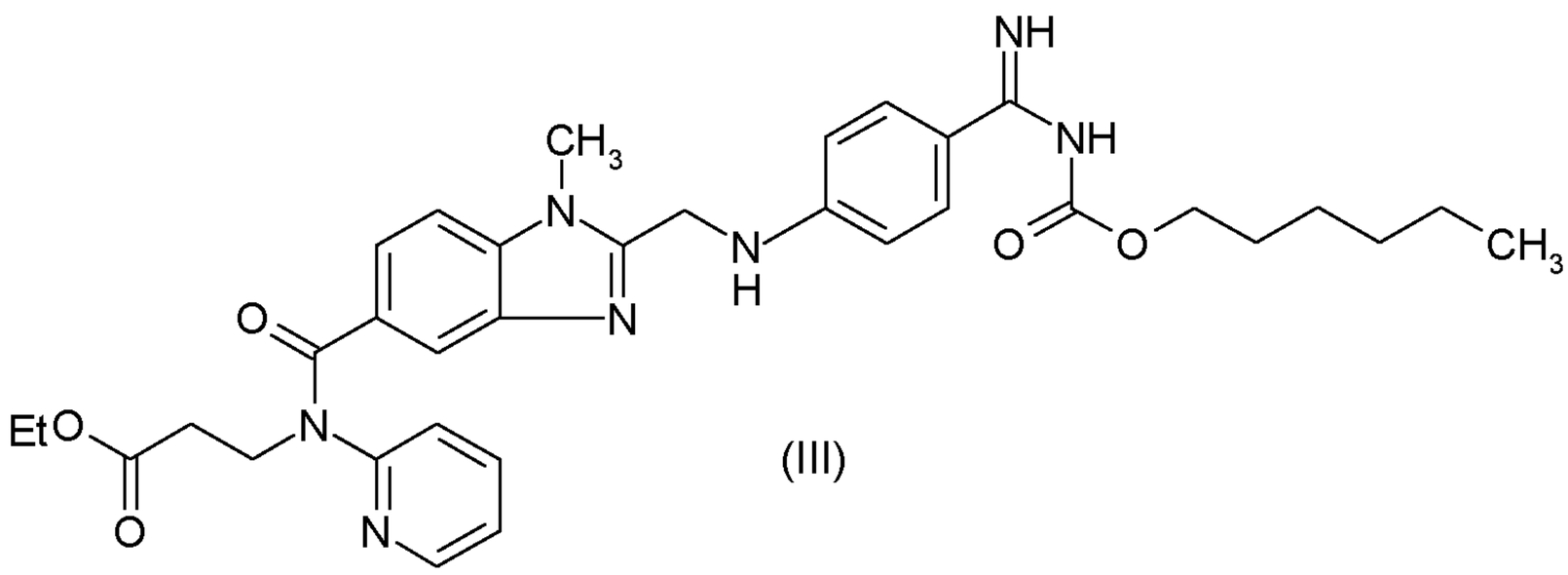
A preferred anticoagulant in the context of the present invention is dabigatran (CAS 211914-51-1, *N*-[2-(4-Amidinophenylaminomethyl)-1-methyl-1*H*-benzimidazol-5-ylcarbonyl]-*N*-(2-pyridyl)-beta-alanine) having the chemical formula (II):



(II)

Dabigatran is known from WO 98/37075, which discloses compounds with a thrombin-inhibiting effect and the effect of prolonging the thrombin time, under the name 1-Methyl-2-[N-(4-amidinophenyl)-aminomethyl]-benzimidazol-5-yl-carboxylic acid-N-(2-pyridyl)-N-(2-hydroxycarbonylethyl)-amide. See also Hauel et al. J Med Chem 2002, 45 (9): 1757–66.

Dabigatran is applied as a prodrug of formula (III):



(III)

The compound of formula III (named dabigatran etexilate, CAS 211915-06-9; ethyl 3-[(2-{[4-(hexyloxycarbonylamino-imino-methyl)-phenylamino]-methyl}-1-methyl-1*H*-benzimidazole-5-carbonyl)-pyridin-2-yl-amino]-propionate) is converted into the active compound (II) after entering the body. A preferred polymorph of dabigatran etexilate is dabigatran etexilate mesylate.

The main indications for dabigatran are the post-operative prevention of deep-vein thrombosis, the treatment of established deep vein thrombosis and the prevention of strokes in patients with atrial fibrillation (Eriksson et al., Lancet 2007, 370 (9591): 949–56; Schulman S et al, N Engl J Med 2009, 361 (24): 2342-52; Connolly S et al., N Engl J Med 2009, 361 (12): 1139–51; Wallentin et al., Lancet 2010, 376 (9745): 975-983).

In the human body, glucuronidation of the carboxylate moiety is the major human metabolic pathway of dabigatran (Ebner et al., Drug Metab. Dispos. 2010, 38(9):1567-75). It results in the formation of the 1-O-acylglucuronide (beta anomer). The 1-O-acylglucuronide, in addition to minor hydrolysis to the aglycon, may undergo

nonenzymatic acyl migration in aqueous solution, resulting in the formation of the 2-O-, 3-O-, and 4-O-acylglucuronides. Experiments with the purified 1-O-acylglucuronide and its isomeric rearrangement products revealed equipotent prolongation of the activated partial thromboplastin time compared with dabigatran.

In another aspect of the invention, the antibody molecule binds both to dabigatran and dabigatran etexilate.

In another aspect of the invention, the antibody molecule binds both to dabigatran and O-acylglucuronides of dabigatran, in particular the 1-O-acylglucuronide of dabigatran.

In another aspect of the invention, the antibody molecule binds furthermore to the 2-O-, 3-O-, and 4-O-acylglucuronides of dabigatran.

In another aspect of the invention, the antibody molecule is capable of neutralizing the activity of dabigatran and O-acylglucuronides of dabigatran, in particular the 1-O-acylglucuronide of dabigatran.

In the following, references to SEQ ID NOs. refer to the sequences of Table 1 and the sequence listing which is part of this application, unless indicated otherwise.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 selected from the group consisting of SEQ ID NO: 1, 7, 13, 19, 25, 31, 37, 43, 49, 55, 61, and 67, a CDR2 selected from the group consisting of SEQ ID NO: 2, 8, 14, 20, 26, 32, 38, 44, 50, 56, 62, and 68, and a CDR3 selected from the group consisting of SEQ ID NO: 3, 9, 15, 21, 27, 33, 39, 45, 51, 57, and 63, and a light chain variable domain with a CDR1 selected from the group consisting of SEQ ID NO: 4, 10, 16, 22, 28, 34, 40, 46, 52, 58, and 64, a CDR2 selected from the group consisting of SEQ ID NO: 5, 11, 17, 23, 29, 35, 41, 47, 53, 59, and 65, and a CDR3 selected from the group consisting of SEQ ID NO: 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, and 69.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 1,

a CDR2 of SEQ ID NO: 2, and a CDR3 of SEQ ID NO: 3, and a light chain variable domain with a CDR1 of SEQ ID NO: 4, a CDR2 of SEQ ID NO: 5, and a CDR3 of SEQ ID NO: 6.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 7, a CDR2 of SEQ ID NO: 8, and a CDR3 of SEQ ID NO: 9, and a light chain variable domain with a CDR1 of SEQ ID NO: 10, a CDR2 of SEQ ID NO: 11, and a CDR3 of SEQ ID NO: 12.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 13, a CDR2 of SEQ ID NO: 14, and a CDR3 of SEQ ID NO: 15, and a light chain variable domain with a CDR1 of SEQ ID NO: 16, a CDR2 of SEQ ID NO: 17, and a CDR3 of SEQ ID NO: 18.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 19, a CDR2 of SEQ ID NO: 20, and a CDR3 of SEQ ID NO: 21, and a light chain variable domain with a CDR1 of SEQ ID NO: 22, a CDR2 of SEQ ID NO: 23, and a CDR3 of SEQ ID NO: 24.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 25, a CDR2 of SEQ ID NO: 26, and a CDR3 of SEQ ID NO: 27, and a light chain variable domain with a CDR1 of SEQ ID NO: 28, a CDR2 of SEQ ID NO: 29, and a CDR3 of SEQ ID NO: 30.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 31, a CDR2 of SEQ ID NO: 32, and a CDR3 of SEQ ID NO: 33, and a light chain variable domain with a CDR1 of SEQ ID NO: 34, a CDR2 of SEQ ID NO: 35, and a CDR3 of SEQ ID NO: 36.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 37, a CDR2 of SEQ ID NO: 38, and a CDR3 of SEQ ID NO: 39, and a light chain variable domain with a CDR1 of SEQ ID NO: 40, a CDR2 of SEQ ID NO: 41, and a CDR3 of SEQ ID NO: 42.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 43, a CDR2 of SEQ ID NO: 44, and a CDR3 of SEQ ID NO: 45, and a light chain variable domain with a CDR1 of SEQ ID NO: 46, a CDR2 of SEQ ID NO: 47, and a CDR3 of SEQ ID NO: 48.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 49, a CDR2 of SEQ ID NO: 50, and a CDR3 of SEQ ID NO: 51, and a light chain variable domain with a CDR1 of SEQ ID NO: 52, a CDR2 of SEQ ID NO: 53, and a CDR3 of SEQ ID NO: 54.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 55, a CDR2 of SEQ ID NO: 56, and a CDR3 of SEQ ID NO: 57, and a light chain variable domain with a CDR1 of SEQ ID NO: 58, a CDR2 of SEQ ID NO: 59, and a CDR3 of SEQ ID NO: 60.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 61, a CDR2 of SEQ ID NO: 62, and a CDR3 of SEQ ID NO: 63, and a light chain variable domain with a CDR1 of SEQ ID NO: 64, a CDR2 of SEQ ID NO: 65, and a CDR3 of SEQ ID NO: 66.

In another aspect of the invention, the antibody molecule has binding specificity for dabigatran and comprises a heavy chain variable domain with a CDR1 of SEQ ID NO: 67, a CDR2 of SEQ ID NO: 68, and a CDR3 of SEQ ID NO: 9, and a light chain variable

domain with a CDR1 of SEQ ID NO: 64, a CDR2 of SEQ ID NO: 65, and a CDR3 of SEQ ID NO: 69.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 70, and a light chain variable domain of SEQ ID No: 71.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 72, and a light chain variable domain of SEQ ID No: 73.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 74, and a light chain variable domain of SEQ ID No: 75.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 76, and a light chain variable domain of SEQ ID No: 77.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 78, and a light chain variable domain of SEQ ID No: 79.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 80, and a light chain variable domain of SEQ ID No: 81.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 82, and a light chain variable domain of SEQ ID No: 83.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 84, and a light chain variable domain of SEQ ID No: 85.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 86, and a light chain variable domain of SEQ ID No: 87.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 88, and a light chain variable domain of SEQ ID No: 89.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 90, and a light chain variable domain of SEQ ID No: 91.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 92, and a light chain variable domain of SEQ ID No: 93.

In another aspect of the invention, the antibody molecule comprises a heavy chain variable domain of SEQ ID NO: 92, and a light chain variable domain of SEQ ID No: 94.

In another aspect of the invention, any one of the aforementioned light chain variable domains is fused to a constant domain of SEQ ID NO: 97.

In another aspect of the invention, any one of the aforementioned heavy chain variable domains is fused to a constant domain of SEQ ID NO: 98.

In another aspect of the invention, the antibody molecule comprises a heavy chain of SEQ ID NO: 95, and a light chain of SEQ ID No: 96.

In certain aspects, the invention concerns antibodies against dabigatran which have a high solubility in aqeous media and a low tendency of aggregation.

In another aspect of the invention, the antibody molecule is a scFv molecule. In this format, the variable domains disclosed herein may be fused to each other with a suitable linker peptide. The construct may comprise these elements in the order, from N terminus to C terminus, (heavy chain variable domain)-(linker peptide)-(light chain variable domain), or (light chain variable domain)-(linker peptide)-(heavy chain variable domain).

Processes are known in the art which allow recombinant expression of nucleic acids encoding sFv constructs in host cells (like E. coli, Pichia pastoris, or mammalian cell lines, e.g. CHO or NS0), yielding functional scFv molecules (see e.g. Rippmann et al., Applied and Environmental Microbiology 1998, 64(12): 4862-4869; Yamawaki et al., J. Biosci. Bioeng. 2007, 104(5): 403-407; Sonoda et al., Protein Expr. Purif. 2010, 70(2): 248-253).

In particular, the scFv antibody molecules of the invention can be produced as follows. The constructs can be expressed in different *E. coli* strains like W3110, TG1, BL21, BL21(DE3), HMS174, HMS174(DE3), MM294 under control of an inducible promoter. This promoter can be chosen from lacUV5, tac, T7, trp, trc, T5, araB. The cultivation media are preferably fully defined according to Wilms *et al.*, 2001(Wilms *et al.*, Biotechnology and Bioengineering 2001, 73(2): 95-103) , DeLisa *et al.*, 1999 (DeLisa *et al.*, Biotechnology and Bioengineering 1999, 65(1): 54-64) or equivalent. However, supplementation of the batch medium and / or feed medium with amino acids such as isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valin or complex media components such as soy peptone or yeast extract may be beneficial. The process for fermentation is performed in a fed-batch mode. Conditions: Temperature 20 – 40 °C, pH 5.5 – 7.5, DO is kept above 20%. After consumption of the initial carbon source the culture is fed with the feed media stated above (or equivalent). When a dry cell weight of 40 to 100 g/L is reached in the fermenter the culture is induced with an appropriate inducer corresponding to the used promoter system (e.g. IPTG, lactose, arabinose). The induction can either be performed as a pulsed full induction or as a partial induction by feeding the respective inducer into the fermenter over a prolonged time or a combination thereof. The production phase should last 4 hours at least. The cells are recovered by centrifugation in bowl centrifuges, tubular bowl centrifuges or disc stack centrifuges, the culture supernatant is discarded.

The *E. coli* cell mass is resuspended in 4- to 8-fold amount of lysis buffer (phosphate or Tris buffer, pH 7-8.5). Cell lysis is preferably performed by high pressure homogenization followed by recovery of the pellet by centrifugation in bowl, tubular bowl or disc stack centrifuges. Pellet containing scFv inclusion bodies is washed 2-3 times with 20 mM Tris, 150 mM NaCl, 5 mM EDTA, 2 M Urea, 0.5% Triton X-100, pH 8.0 followed by two wash steps using 20 mM Tris, 150 mM NaCl, 5 mM EDTA, pH 8.0. scFv inclusion bodies are finally recovered by centrifugation in bowl, tubular bowl or disc stack centrifuges. Solubilisation of scFv inclusion bodies can be performed in 100 mM Glycine/NaOH, 5 mM EDTA, 20 mM dithiothreitol, pH 9.5-10.5 containing chaotropic agents such as 6 M Guanidine-HCl or 8-10 mM Urea. After incubation for 30-60 minutes solution is centrifuged and supernatant containing the target protein recovered for subsequent refolding. Refolding is preferably performed in fed batch mode by diluting the protein solution 1:10-1:50 in refolding buffer to a final protein concentration of 0.1-0.5 mg/ml. Refolding buffer

can contain 50-100 mM Tris and/or 50-100 mM Glycine, 50-150 mM NaCl, 1-3 M urea, 0.5-1 M arginine, 2-6 mM of redox system such as e.g. cytein/ cystine or oxidized/reduced glutathione, pH 9.5-10.5. After incubation for 24-72 h at 4°C refolding solution is optionally filtrated using a 0.22 µm filter, diluted and pH adjusted to pH 7.0-8.0. Protein is separated via cation exchange chromatography in binding mode (e.g. Toyopearl GigaCap S-650M, SP Sepharose FF or S HyperCel™) at pH 7.0-8.5. Elution is performed by a linear increasing NaCl gradient. Fractions containing the target protein are pooled and subsequently separated on anion exchange column in non-binding mode (e.g. Toyopearl GigaCap Q-650M, Q-Sepharose FF, Q HyperCel™) followed by a cation exchange polishing step (eg. SP Sepharose HP). Fractions containing the target protein with a purity level of minimally 90% are pooled and formulated by diafiltration or size exclusion chromatography in PBS. Identity and product quality of the produced scFv molecule are analysed by reducing SDS-PAGE where the scFv can be detected in one major band of approx. 26 kDa. Further assays for characterization of the scFv include mass spectrometry, RP-HPLC and SE-HPLC.

In another aspect of the invention, the antibody molecule is a Fab molecule. In that format, the variable domains disclosed above may each be fused to an immunoglobulin constant domain, preferably of human origin. Thus, the heavy chain variable domain may be fused to a CH_1 domain (a so-called Fd fragment), and the light chain variable domain may be fused to a CL domain.

In another aspect of the invention, the antibody molecule comprises a heavy chain of SEQ ID NO: 99, and a light chain of SEQ ID No: 100. Preferably, the antibody molecule is a Fab molecule.

In another aspect of the invention, the antibody molecule comprises a heavy chain of SEQ ID NO: 99, and a light chain of SEQ ID No: 101. Preferably, the antibody molecule is a Fab molecule.

In another aspect of the invention, the antibody molecule is a Fab molecule which consists of a heavy chain of SEQ ID NO: 99, and a light chain of SEQ ID No: 100.

In another aspect of the invention, the antibody molecule is a Fab molecule which consists of a heavy chain of SEQ ID NO: 99, and a light chain of SEQ ID No: 101.

Nucleic acids encoding Fab constructs may be used to express such heavy and light chains in host cells, like E. coli, Pichia pastoris, or mammalian cell lines (e.g. CHO, or NS0). Processes are known in the art which allow proper folding, association, and disulfide bonding of these chains into functional Fab molecules comprising a Fd fragment and a light chain (Burtet et al., J. Biochem. 2007, 142(6), 665-669; Ning et al., Biochem. Mol. Biol. 2005, 38: 204-299; Quintero-Hernandez et al., Mol. Immunol. 2007, 44: 1307-1315; Willems et al. J. Chromatogr. B. Analyt. Technol. Biomed. Life Sci. 2003;786:161-176.).

In particular, Fab molecules of the invention can be produced in CHO cells as follows. CHO-DG44 cells (Urlaub,G., Kas,E., Carothers,A.M., and Chasin,L.A. (1983). Deletion of the diploid dihydrofolate reductase locus from cultured mammalian cells. Cell 33, 405-412.) growing in suspension in serum-free medium are transfected with expression constructs encoding heavy and light chain of the Fab molecule using Lipofectamine™ and Plus™ reagent (Invitrogen) according to the manufacturer's instructions. After 48 hours, the cells are subjected to selection in medium containing 200μg/mL of the antibiotic G418 and without hypoxanthine and thymidine to generate stably transfected cell populations. These stable transfectants are subsequently subjected to gene amplification by adding methotrexate (MTX) in increasing concentrations (up to 100 or 400 nM) into the culture medium. Once the cells have adapted, they are subjected to fed-batch fermentations over 10 to 11 days to produce Fab protein material.

Suspension cultures of CHO-DG44 cells and stable transfectants thereof are incubated in chemically defined, serum-free cultivation media. Seed stock cultures are sub-cultivated every 2–3 days with seeding densities of 3×10^5–2×10^5 cells/mL respectively. Cells are grown in shake flasks in Multitron HT incubators (Infors) at 5% CO_2, 37°C and 120rpm. For fed-batch experiments, cells are seeded at $3x10^5$ cells/mL into shake flasks in BI-proprietary production medium without antibiotics or MTX. The cultures are agitated at 120 rpm in 37°C and 5% CO_2 which is later reduced to 2% as cell numbers increase. Culture parameters including cell count, viability, pH, glucose and lactate concentrations are determined daily and pH is adjusted to pH 7.0 using carbonate as needed. BI-

proprietary feed solution is added every 24 hrs. Samples from the supernatant are taken at different time points to dermine the Fab product concentration by ELISA. After 10 to 11 days, the cell culture fluid is harvested by centrifugation and transferred to the purification labs.

The Fab molecule is purified from the supernatant of the fed-batch cultures by means of chromatography and filtration. As primary capture step affinity chromatography, e.g. Protein G or Protein L, are applied. Alternatively, in case of low binding affinities and capacities, the Fab is captured by cation exchange chromatography (CEX) exploiting the pI of the molecule. Host cell proteins and contaminants, e.g. DNA or viruses, are removed by additional orthogonal purification steps.

Identity and product quality of the produced Fab molecule are analysed by electrophoretic methods, e.g. SDS-PAGE, by which Fab can be detected as one major band of approx. 50 kDa. Further assays for characterization of the Fab product include mass spectrometry, isoelectric focusing and size exclusion chromatography. Binding activity is followed by BIAcore analysis.

Quantification of Fab or full-length IgG molecules in the supernatant of the cell cultures is performed via sandwich enzyme linked immunosorbent assay (ELISA). The full-length IgG can be detected using antibodies raised against human-Fc fragment (Jackson Immuno Research Laboratories) and human kappa light chain (peroxidase-conjugated, Sigma). The Fab fragment is immobilized by goat polyclonal anti-Human IgG (H and L, Novus) and detected by sheep polyclonal antibodies raised against human IgG (peroxidase-conjugated, The Binding Site).

Fab molecules can also be generated from full-length antibody molecules by enzymatic cleavage. The advantage of this approach is that platform processes for robust and efficient fermentation and purification are applicable which are amenable for up-scaling and high yields at the desired product quality. For purification affinity chromatography using a recombinant Protein A resin can be used as primary capture step which usually results in high purities.

For this purpose, the heavy chain encoding Fab sequences are fused to the Fc-region of a human IgG antibody molecule. The resulting expression constructs are then transfected into CHO-DG44 cells growing in suspension in serum-free medium using lipofection. After 48 hours, the cells are subjected to selection in medium containing 200μg/mL of the antibiotic G418 and without hypoxanthine and thymidine to generate stably transfected cell populations. These stable transfectants are subsequently subjected to gene amplification by adding methotrexate (MTX) in increasing concentrations (up to 100 or 400 nM) into the culture medium. Once the cells have adapted, they are subjected to fed-batch fermentations over 10 to 11 days to produce IgG protein material.

The IgG protein is purified from the culture supernatant by using recombinant Protein A-affinity chromatography. To obtain the desired neutralizing Fab fragment the full-length IgG is then incubated in the presence of papain which cleaves the IgG within the hinge region, thereby releasing two Fab fragments and the Fc-moiety.
The Fab molecule is isolated by affinity chromatography, e.g. Protein G or Protein L. Alternatively, in case of low binding affinities and capacities, the Fab is captured by cation exchange chromatography (CEX) exploiting the pI of the molecule. Host cell proteins and contaminants, e.g. Papain, DNA or viruses, are removed by additional orthogonal purification steps.

In another aspect of the invention, the antibody molecule is an amino acid sequence variant of an antibody molecule as described herein.

Amino acid sequence variants of antibodies can be prepared by introducing appropriate nucleotide changes into the antibody DNA, or by peptide synthesis. Such variants include, for example, deletions from, and/or insertions into and/or substitutions of, residues within the amino acid sequences of the antibodies of the examples herein. Any combination of deletions, insertions, and substitutions is made to arrive at the final construct, provided that the final construct possesses the desired characteristics. The amino acid changes also may alter post-translational processes of the humanized or variant antibody, such as changing the number or position of glycosylation sites.

A useful method for identification of certain residues or regions of the antibody that are preferred locations for mutagenesis is called "alanine scanning mutagenesis," as

described by Cunningham and Wells (Science, 244:1081-1085 (1989)). Here, a residue or group of target residues are identified (e.g., charged residues such as arg, asp, his, lys, and glu) and replaced by a neutral or negatively charged amino acid (typically alanine) to affect the interaction of the amino acids with antigen. Those amino acid locations demonstrating functional sensitivity to the substitutions then are refined by introducing further or other variants at, or for, the sites of substitution. Thus, while the site for introducing an amino acid sequence variation is predetermined, the nature of the mutation per se need not be predetermined. For example, to analyze the performance of a mutation at a given site, alanine scanning or random mutagenesis is conducted at the target codon or region and the expressed antibody variants are screened for the desired activity.

Amino acid sequence insertions include amino- and/or carboxyl-terminal fusions ranging in length from one residue to polypeptides containing a hundred or more residues, as well as intrasequence insertions of single or multiple amino acid residues. Examples of terminal insertions include an antibody fused to an epitope tag. Other insertional variants of the antibody molecule include a fusion to the N- or C-terminus of the antibody of an enzyme or a polypeptide which increases the serum half-life of the antibody.

Another type of variant is an amino acid substitution variant. These variants have at least one amino acid residue in the antibody molecule removed and a different residue inserted in its place. The sites of greatest interest for substitutional mutagenesis include the hypervariable regions, but FR alterations are also contemplated. Conservative substitutions are shown in the Table below under the heading of "preferred substitutions". If such substitutions result in a change in biological activity, then more substantial changes, denominated "exemplary substitutions", or as further described below in reference to amino acid classes, may be introduced and the products screened.

Original Residue	Exemplary Substitutions	Preferred Substitutions
Ala (A)	val; leu; ile	val
Arg (R)	lys; gln; asn	lys
Asn (N)	gln; his; asp, lys; arg	gln
Asp (D)	glu; asn	glu
Cys (C)	ser; ala	ser
Gln (Q)	asn; glu	asn
Glu (E)	asp; gln	asp
Gly (G)	ala	ala

His (H)	arg; asn; gln; lys;	arg
Ile (I)	leu; val; met; ala; phe; norleucine	leu
Leu (L)	ile; norleucine; val; met; ala; phe	ile
Lys (K)	arg; gln; asn	arg
Met (M)	leu; phe; ile	leu
Phe (F)	tyr; leu; val; ile; ala;	tyr
Pro (P)	ala	ala
Ser (S)	thr	thr
Thr (T)	ser	ser
Trp (W)	tyr; phe	tyr
Tyr (Y)	phe;trp; thr; ser	phe
Val (V)	leu; ile; met; phe ala; norleucine;	leu

In protein chemistry, it is generally accepted that the biological properties of the antibody can be accomplished by selecting substitutions that differ significantly in their effect on maintaining (a) the structure of the polypeptide backbone in the area of the substitution, for example, as a sheet or helical conformation, (b) the charge or hydrophobicity of the molecule at the target site, or (c) the bulk of the side chain. Naturally occurring residues are divided into groups based on common side-chain properties:

(1) hydrophobic: norleucine, met, ala, val, leu, ile;

(2) neutral hydrophilic: cys, ser, thr;

(3) acidic: asp, glu;

(4) basic: asn, gin, his, lys, arg;

(5) residues that influence chain orientation: gly, pro; and

(6) aromatic: trp, tyr, phe.

Non-conservative substitutions will entail exchanging a member of one of these classes for another class.

Any cysteine residue not involved in maintaining the proper conformation of the humanized or variant antibody also may be substituted, generally with serine, to improve the oxidative stability of the molecule, prevent aberrant crosslinking, or provide for established points of conjugation to a cytotoxic or cytostatic compound. Conversely, cysteine bond(s) may be added to the antibody to improve its stability (particularly where the antibody is an antibody fragment such as an Fv fragment).

A type of substitutional variant involves substituting one or more hypervariable region residues of a parent antibody (e.g., a humanized or human antibody). Generally, the resulting variant(s) selected for further development will have improved biological properties relative to the parent antibody from which they are generated. A convenient way for generating such substitutional variants is affinity maturation using phage display. Briefly, several hypervariable region sites (e.g., 6-7 sites) are mutated to generate all possible amino substitutions at each site. The antibody variants thus generated are displayed in a monovalent fashion from filamentous phage particles as fusions to the gene III product of M13 packaged within each particle. The phage-displayed variants are then screened for their biological activity (e.g., binding affinity). In order to identify candidate hypervariable region sites for modification, alanine scanning mutagenesis can be performed to identify hypervariable region residues contributing significantly to antigen binding. Alternatively, or in addition, it may be beneficial to analyze a crystal structure of the antigen-antibody complex to identify contact points between the antibody and human Dabigatran. Such contact residues and neighboring residues are candidates for substitution according to the techniques elaborated herein. Once such variants are generated, the panel of variants is subjected to screening as described herein and antibodies with superior properties in one or more relevant assays may be selected for further development.

Another type of amino acid variant of the antibody alters the original glycosylation pattern of the antibody. By "altering" is meant deleting one or more carbohydrate moieties found in the antibody, and/or adding one or more glycosylation sites that are not present in the antibody.

In some embodiments, it may be desirable to modify the antibodies of the invention to add glycosylations sites. Glycosylation of antibodies is typically either N-linked or O-linked. N-linked refers to the attachment of the carbohydrate moiety to the side chain of an asparagine residue. The tripeptide sequences asparagine-X-serine and asparagine-X-threonine, where X is any amino acid except proline, are the recognition sequences for enzymatic attachment of the carbohydrate moiety to the asparagine side chain. Thus, the presence of either of these tripeptide sequences in a polypeptide creates a potential glycosylation site. O-linked glycosylation refers to the attachment of one of the sugars N-aceylgalactosamine, galactose, or xylose to a hydroxyamino acid, most commonly serine

or threonine, although 5-hydroxyproline or 5-hydroxylysine may also be used. Thus, in order to glycosylate a given protein, e.g., an antibody, the amino acid sequence of the protein is engineered to contain one or more of the above-described tripeptide sequences (for N-linked glycosylation sites). The alteration may also be made by the addition of, or substitution by, one or more serine or threonine residues to the sequence of the original antibody (for O-linked glycosylation sites).

Nucleic acid molecules encoding amino acid sequence variants of the antibody are prepared by a variety of methods known in the art. These methods include, but are not limited to, isolation from a natural source (in the case of naturally occurring amino acid sequence variants) or preparation by oligonucleotide-mediated (or site-directed) mutagenesis, PCR mutagenesis, and cassette mutagenesis of an earlier prepared variant or a non-variant version of an antibody molecule as described herein. As outlined above, the antigen of the antibody molecule of the invention is an anticoagulant. The antigen is used to generate the antibody molecule, either by immunization of an animal, or by selecting antibody sequences from sequence libraries, as with phage display methods.

Immunization protocols for animals are well-known in the art. To achieve a proper immune response, it may be necessary to combine the antigen with an adjuvant, like aluminium phosphate, aluminium hydroxide, squalene, or Freund's complete/incomplete adjuvant. The antigens in the context of the present invention, like dabigatran, are mostly comparably small organic molecules, which sometimes do not stimulate antibody formation upon administration to an animal. It may therefore be necessary to attach the antigen to a macromolecule, as a hapten.

In a further aspect, the present invention relates to an antibody molecule as described above for use in medicine.

In a further aspect, the present invention relates to a pharmaceutical composition comprising an antibody molecule as described before, and a pharmaceutical carrier.

To be used in therapy, the antibody molecule is included into pharmaceutical compositions appropriate to facilitate administration to animals or humans. Typical formulations of the antibody molecule can be prepared by mixing the antibody molecule

with physiologically acceptable carriers, excipients or stabilizers, in the form of lyophilized or otherwise dried formulations or aqueous solutions or aqueous or non-aqueous suspensions. Carriers, excipients, modifiers or stabilizers are nontoxic at the dosages and concentrations employed. They include buffer systems such as phosphate, citrate, acetate and other anorganic or organic acids and their salts; antioxidants including ascorbic acid and methionine; preservatives such as octadecyldimethylbenzyl ammonium chloride; hexamethonium chloride; benzalkonium chloride, benzethonium chloride; phenol, butyl or benzyl alcohol; alkyl parabens such as methyl or propyl paraben; catechol; resorcinol; cyclohexanol; 3-pentanol; and m-cresol); proteins, such as serum albumin, gelatin, or immunoglobulins; hydrophilic polymers such as polyvinylpyrrolidone or polyethylene glycol (PEG); amino acids such as glycine, glutamine, asparagine, histidine, arginine, or lysine; monosaccharides, disaccharides, oligosaccharides or polysaccharides and other carbohydrates including glucose, mannose, sucrose, trehalose, dextrins or dextrans; chelating agents such as EDTA; sugar alcohols such as, mannitol or sorbitol; salt-forming counter-ions such as sodium; metal complexes (e.g., Zn-protein complexes); and/or ionic or non-ionic surfactants such as TWEEN™ (polysorbates), PLURONICS™ or fatty acid esters, fatty acid ethers or sugar esters. Also organic solvents can be contained in the antibody formulation such as ethanol or isopropanol. The excipients may also have a release-modifying or absorption-modifying function.

In one aspect, the pharmaceutical compositon comprises the antibody molecule in an aqueous, buffered solution at a concentration of 10-20 mg/ml, or a lyophilisate made from such a solution.

The preferred mode of application is parenteral, by infusion or injection (intraveneous, intramuscular, subcutaneous, intraperitoneal, intradermal), but other modes of application such as by inhalation, transdermal, intranasal, buccal, oral, may also be applicable.

In a further aspect, the present invention relates to an antibody molecule as described above for use in the therapy or prevention of side effects of anticoagulant therapy, in particular bleeding events.

In a further aspect, the present invention relates to the use of an antibody molecule as described herein for the manufacture of a medicament for the treatment or prevention of a

disease or disorder as described herein, in particular the side effects of anticoagulant therapy.

In a further aspect, the present invention relates to an antibody molecule as described above for use in the reversal of an overdosing of an anticoagulant, in particular dabigatran or dabigatran exetilate.

In a further aspect, the present invention relates to an antibody molecule as described above for use as an antidote of an anticoagulant, in particular dabigatran or dabigatran exetilate.

In a further aspect, the present invention relates to a method of treatment or prevention of side effects of anticoagulant therapy, comprising administering an effective amount of an antibody molecule as described above to a patient in need thereof.

In a further aspect, the present invention relates to a method of treatment of an overdosing event in anticoagulant therapy, comprising administering an effective amount of an antibody molecule as described above to a patient in need thereof.

In a further aspect, the present invention relates to a method for reducing the concentration of dabigatran or 1-O-acylglucuronide of dabigatran in plasma of a patient being treated with dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, comprising the step of administering a reversal agent that neutralizes the activity of dabigatran or 1-O-acylglucuronide in the patient.

In a further aspect, the present invention relates to a reversal agent that neutralizes the activity of dabigatran or 1-O-acylglucuronide for use in a patient being treated with dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, wherein the patient either has major bleeding considered life-threatening or leading to hemodynamic compromise, or wherein the patient requires emergency medical procedures.

In a further aspect, the present invention relates to a method for reducing the concentration of dabigatran or 1-O-acylglucuronide of dabigatran in plasma of a patient

being treated with dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, wherein the patient either has major bleeding considered life-threatening or leading to hemodynamic compromise, or wherein the patient requires emergency medical procedures, comprising the step of administering a reversal agent that neutralizes the activity of dabigatran or 1-O-acylglucuronide in the patient.

In a further aspect, the present invention relates to a method of reversal of the anticoagulant effect of dabigatran or 1-O-acylglucuronide of dabigatran in a patient being treated with dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, wherein the patient either has major bleeding considered life-threatening or leading to hemodynamic compromise, or wherein the patient requires emergency medical procedures, comprising the step of administering a reversal agent that neutralizes the activity of dabigatran or 1-O-acylglucuronide in the patient.

In a preferred embodiment, the reversal agent is an antibody molecule against dabigatran which is capable of neutralizing the anticoagulant activity of dabigatran, dabigatran etexilate, and/or 1-O-acylglucuronide. In another preferred embodiment, the reversal agent is an antibody molecule against dabigatran as described herein.

Preferably, the concentration of dabigatran or 1-O-acylglucuronide of dabigatran in plasma is greater than 0 nM but less than 1000 µM and wherein the reversal agent used to neutralize the activity of dabigatran or 1-O-acylglucuronide is present in a stoichiometric amount of dabigatran or 1-O-acylglucuronide of dabigatran to reversal agent.

In a further aspect, the concentration of dabigatran or 1-O-acylglucuronide of dabigatran in plasma is greater than 0 nM but less than 1000 µM, and wherein the reversal agent used to neutralize the activity of dabigatran or 1-O-acylglucuronide is present in a molar ratio of between 1:1 and 1:100 of dabigatran or 1-O-acylglucuronide of dabigatran to reversal agent.

In a further aspect, the concentration of dabigatran or 1-O-acylglucuronide of dabigatran in plasma is between 30 nM and 1000 µM, and wherein the reversal agent used to

neutralize the activity of dabigatran or 1-O-acylglucuronide is present in a ratio of between 30 nM and 1000 µM of dabigatran or 1-O-acylglucuronide of dabigatran to reversal agent.

In another aspect, the present invention relates to a method for reversing or reducing the activity of dabigatran or 1-O-acylglucuronide of dabigatran in a patient experiencing bleeding or at risk for bleeding due to an impaired clotting ability or trauma, comprising the steps of:

(a) determining the amount of dabigatran or 1-O-acylglucuronide of dabigatran present in the patient;

(b) administering an effective amount of an agent to reverse or reduce the activity of dabigatran or 1-O-acylglucuronide of dabigatran determined in the patient; and

(c) monitoring a thrombin clotting time of the patient to ensure a reversal or reduction in activity of dabigatran or 1-O-acylglucuronide of dabigatran has been reached.

In a preferred aspect, the reversal of activity of dabigatran or 1-O-acylglucuronide of dabigatran is 100%. In a further preferred aspect, the reduction of activity of dabigatran or 1-O-acylglucuronide of dabigatran is between 10 and 99 % of dabigatran or 1-O-acylglucuronide of dabigatran in the patient.

The "therapeutically effective amount" of the antibody to be administered is the minimum amount necessary to prevent, ameliorate, or treat the side effects of anticoagulant therapy, in particular the minimum amount which is effective to stop bleeding. This can be achieved with stoichiometric amounts of antibody molecule.

Dabigatran, for example, may achieve a plasma concentration in the magnitude of 200 nM when given at the recommended dose. When a monovalent antibody molecule with a molecular weight of ca. 50 kD is used, neutralization may be achieved for example at a dose of about 1 mg/kg, when given intravenously as a bolus. In another embodiment, the dose of a Fab molecule applied to a human patient may be 50-1000 mg per application, for example 100, 200, 500, 750, or 1000 mg. Depending on the situation, e.g. when dabigatran has been overdosed in a patient, it may be adequate to apply an even higher dose, e.g. 1250, 1500, 1750 or 2000 mg per application. The appropriate dose may be different, depending on the type and dose of anticoagulant administered; the time elapsed since such administration, the nature of the antigen molecule, the condition of the patient,

and other factors. The skilled expert knows methods to establish doses which are both therapeutically effective and safe.

In a further aspect, the present invention relates to an antibody molecule with binding affinity to dabigatran and/or dabigatran etexilate. Preferably, the antibody molecule binds to the dabigatran and/or dabigatran etexilate with an affinity, as determined e.g. by surface plasmon resonance analysis (Malmqvist M., "Surface plasmon resonance for detection and measurement of antibody-antigen affinity and kinetics. "Curr Opin Immunol. 1993 Apr;5(2):282-6.) or kinetic exclusion assay (KinExA) technology (Darling, R.J., and Brault P-A., "Kinetic exclusion assay technology: Characterization of Molecular Interactions." ASSAY and Drug Development Technologies. 2004, Dec 2(6): 647-657), with a K_D value ranging from 0.1 pM to 100 µM, preferably 1 pM to 100 µM, more preferably 1 pM to 1 µM.

The antibody molecules of the invention can also be used for analytical and diagnostic procedures, for example to determine antigen concentration in samples such as plasma, serum, or other body fluids. For example, the antigen molecules may be used in an enzyme-linked immunoadsorbent assay (ELISA), like those described in the examples. Thus, in a further aspect, the present invention relates to analytical and diagnostic kits comprising antibody molecules a described herein, and to respective analytical and diagnostic methods.

In a further aspect, the present invention relates to a method of manufacturing an antibody molecule of any one of the preceding claims, comprising

(a) providing a host cell comprising one or more nucleic acids encoding said antibody molecule in functional association with an expression control sequence,
(b) cultivating said host cell, and
(c) recovering the antibody molecule from the cell culture.

The invention further provides an article of manufacture and kit containing materials useful for neutralization of oral anticoagulants, particularly direct thrombin inhibitors. The article of manufacture comprises a container with a label. Suitable containers include, for

example, bottles, vials, and test tubes. The containers may be formed from a variety of materials such as glass, metal, plastic or combinations thereof. The container holds a pharmaceutical composition comprising the antibody described herein or dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof. The active agent in the pharmaceutical composition is the particular antibody or dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof. The label on the container of the antibody indicates that the pharmaceutical composition is used for neutralizing or partially neutralizing dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof *in vivo*.

The kit of the invention comprises one or more of the containers described above. It may further include other materials desirable from a commercial and user standpoint, including other buffers, diluents, filters, needles, syringes, and package inserts with instructions for use.

In one embodiment of the invention, the kit comprises an antibody of any one the antibodies described herein or a pharmaceutical composition thereof. For example, the kit may comprise (1) any one the antibodies described herein or a pharmaceutical composition thereof, (2) a container and (3) a label.

In another embodiment, the kit comprises an antibody of any one the antibodies described herein or a pharmaceutical composition thereof, and dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof. The form of dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof may be in the form of a solid, liquid or gel. In a preferred embodiment, the pharmaceutically acceptable salt of dabigatran etexilate is a mesylate salt. In yet another preferred embodiment, the strength per doage unit of the dabigatran, dabigatran etexilate, prodrug of dabigatran or pharmaceutically acceptable salt thereof is between about 50 mg and about 400 mg, about 75 mg and about 300 mg, about 75 mg and 150 mg, or about 110 mg and about 150 mg, given once-a-day (QD) or twice-a-day (BID). For example, the kit may comprise (1) any one the antibodies described herein or a pharmaceutical composition thereof, (2) a pharmaceutical composition of dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, (3) a container and (4) a label.

In an alternate embodiment, the kit comprises (1) a first pharmaceutical composition comprising dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, (2) a second pharmaceutical composition comprising any one the antibodies described herein or combination thereof, (3) instructions for separate admininstration of said first and second pharmaceutical compositions to a patient, wherein said first and second pharmaceutical compositions are contained in separate containers and said second pharmaceutical composition is administered to a patient requiring neutralization or partial neutralization of dabigatran or 1-O-acylglucuronide of dabigatran.

The invention also provides a diagnostic method to neutralize or partially neutralize dabigatran or 1-O-acylglucuronide of dabigatran in a patient being treated with dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, comprising administering any one of the antibodies described herein, a combination thereof or a pharmaceutical composition thereof. Specifically, the invention provides a method for neutralizing or partially neutralizing dabigatran or 1-O-acylglucuronide of dabigatran in a patient comprising the steps of (a) confirming that a patient was being treated with dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, and the amount that was taken by the patient; (b) neutralizing dabigatran or 1-O-acylglucuronide with any one of the antibodies described herein or combination thereof prior to performing a clotting or coagulation test or assay wherein dabigatran or the 1-O-acylglucuronide of dabigatran would interfere with the accurate read out of the test or assay results; (c) performing the clotting or coagulation test or assay on a sample taken from the patient to determine the level of clot formation without dabigatran or 1-O-acylglucuronide of dabigatran present; and (d) adjusting an amount of dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof administered to the patient in order to achieve the appropriate balance between clot formation and degradation in a patient. The molar ratio of antibody to dabigatran or 1-O-acylglucuronide of dabigatran is in the molar ratio of between 0.1 and 100, preferably between 0.1 and 10. The accurate read out of the test or assay result may be an accurate read out of fibrinogen levels, activated protein C resistance or related tests.

EXAMPLES

I. PRODUCTION OF POLYCLONAL ANTI-DABIGATRAN ANTIBODIES

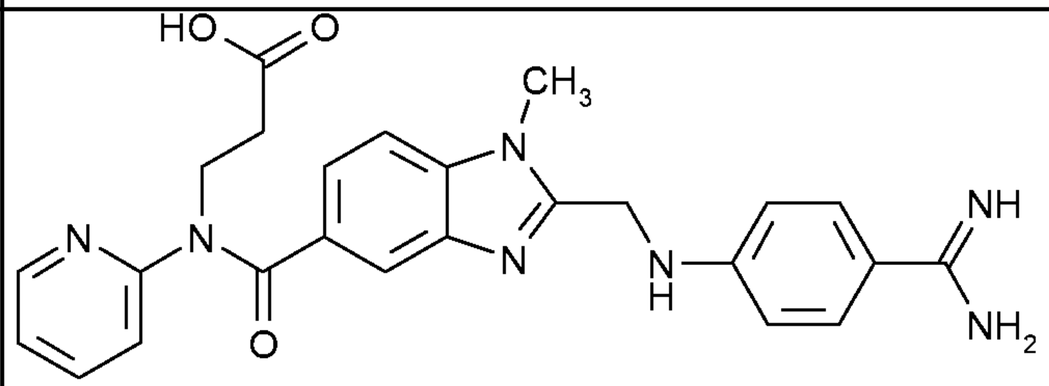
For the production of polyclonal anti-dabigatran antibodies, 3 different immunogens were produced with two different haptens and different molar input ratios of the hapten and the carrier protein (BSA).

For the screening, an enzyme horseradish peroxidase (HRP)-conjugate was produced and an enzyme-immunosorbent assay (ELISA) developed.

Further purification of the polyclonal antibodies was performed by affinity chromatography on protein A sepharose FF.

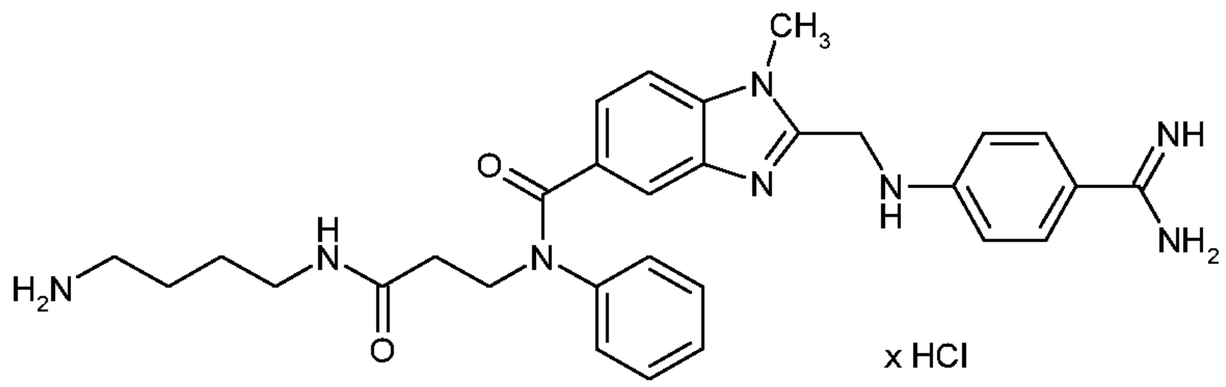
1. MATERIALS AND METHODS

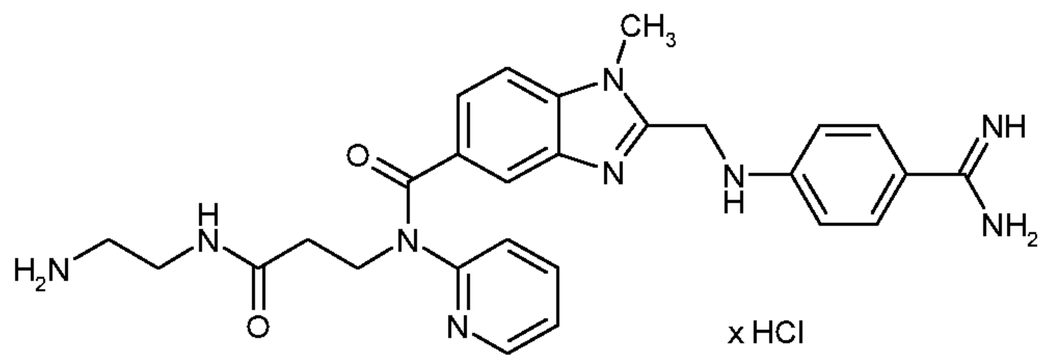
Test compound (dabigatran)

Code:	dabigatran, zwitter ion
Structural formula:	 $C_{25}H_{25}N_7O_3$ molecular weight: 471.5 g/mol

1.1 HAPTEN USED FOR SYNTHESIS OF IMMUNOGEN AND TRACER

Code:	Hapten1

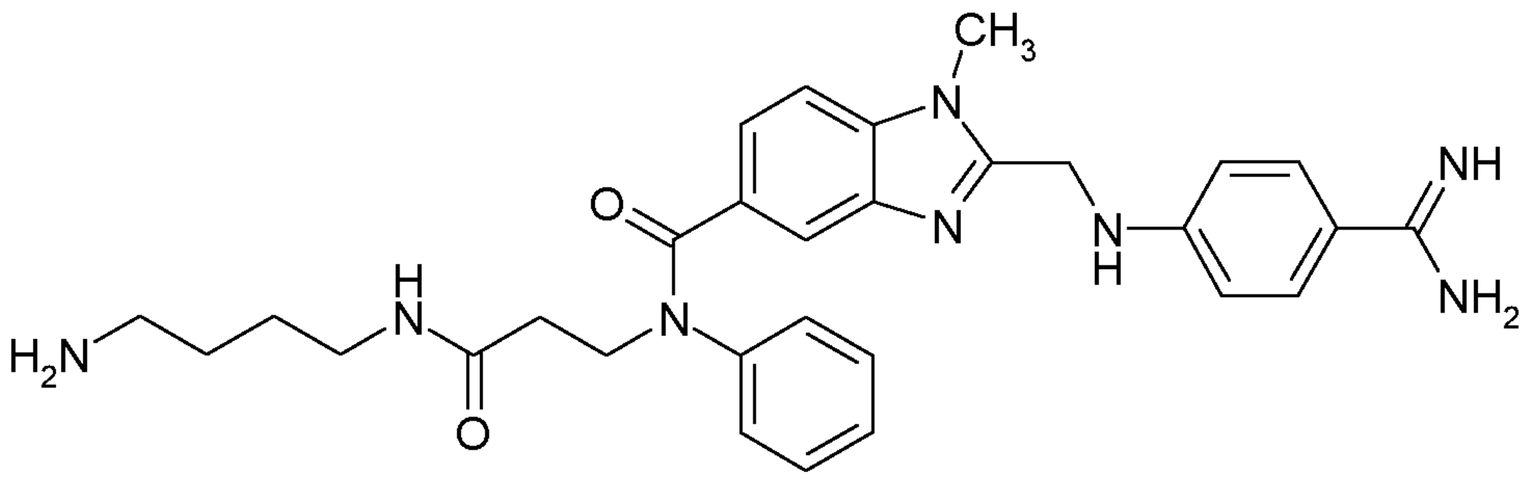
Structural formula of ligand:	 $C_{30}H_{36}N_8O_2$ * HCl molecular weight: 577.13 g/mol

Code:	Hapten2
Structural formula of ligand:	 $C_{27}H_{31}N_9O_2$ * HCl molecular weight: 550.07 g/mol

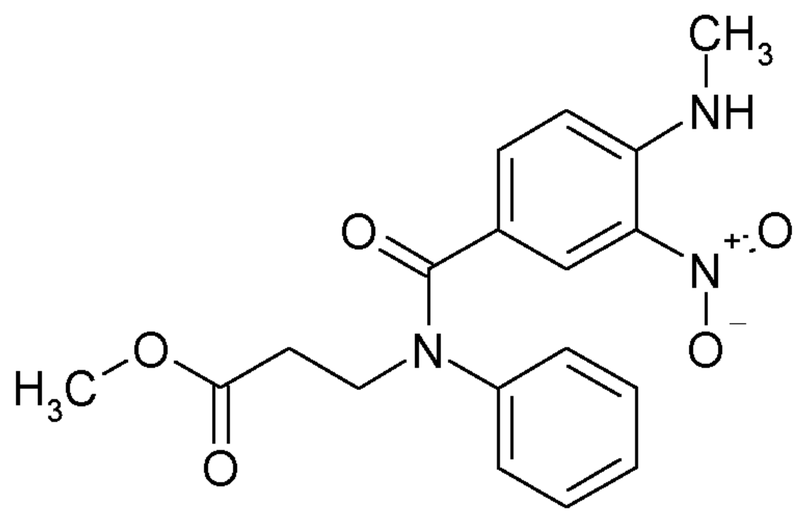
1.2 SYNTHESIS OF HAPTENS

The haptens Hapten1 and Hapten2 were synthesized as follows:

Hapten1 2-[(4-Carbamimidoyl-phenylamino)-methyl]-1-methyl-1H-benzoimidazole-5-carboxylic acid [2-(4-amino-butylcarbamoyl)-ethyl]-phenyl-amide



1a 3-[(4-Methylamino-3-nitro-benzoyl)-phenyl-amino]-propionic acid methyl ester



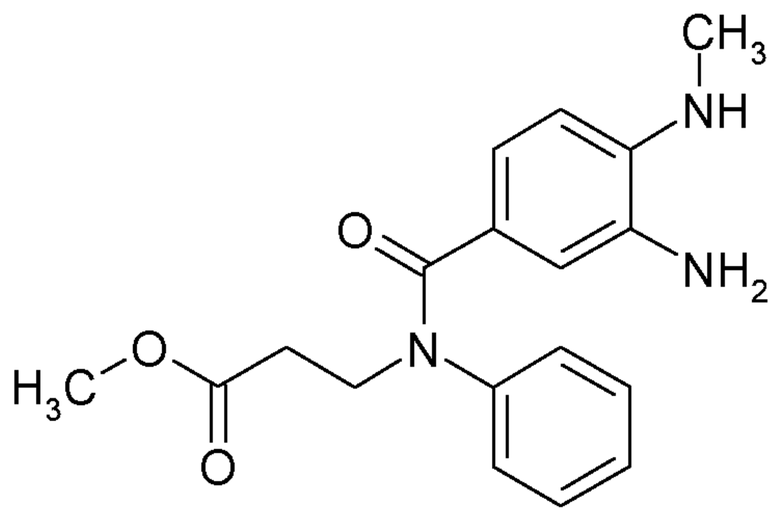
To a solution of 4-methylamino-3-nitro-benzoic acid chloride (23.3 mmol) and 3-phenyl-amino-propionic acid methyl ester (23.3 mmol) in 80 mL dry tetrahydrofuran (THF) triethylamine (50.2 mmol) was added dropwise under stirring at room temperature. After three hours the rection mixture was evaporated to dryness, the remaining solid triturated with water and the solid product isolated through filtration.

Yield: 99%

$C_{18}H_{19}N_3O_5$ (357.36)

TLC (silica gel; Dichloromethane/ethanol 19:1): R_f = 0.48

1b 3-[(3-Amino-4-methylamino-benzoyl)-phenyl-amino]-propionic acid methyl ester



The nitro group of product 1a was reduced by hydrogenation at room temperature in ethanol with Pd (10% on charcoal) as catalyst.

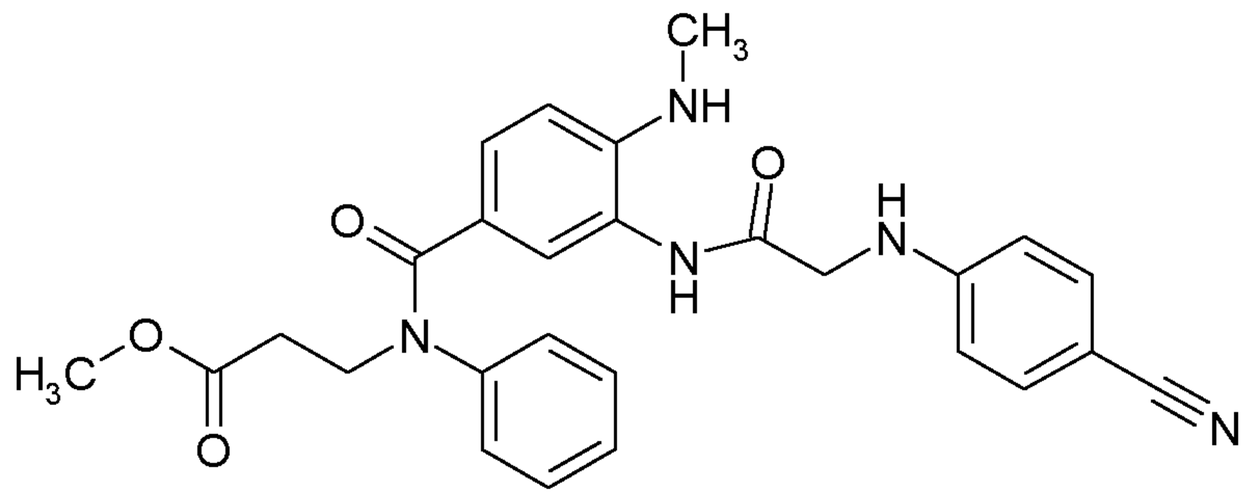
Yield: 99%

$C_{18}H_{21}N_3O_3$ (327.38)

TLC (silica gel; Dichloromethane/ethanol 9:1): R_f = 0.23

Mass spectrum (ESI): $[M+H]^+$ = 328

1c 3-({3-[2-(4-Cyano-phenylamino)-acetylamino]-4-methylamino-benzoyl}-phenyl-amino)-propionic acid methyl ester



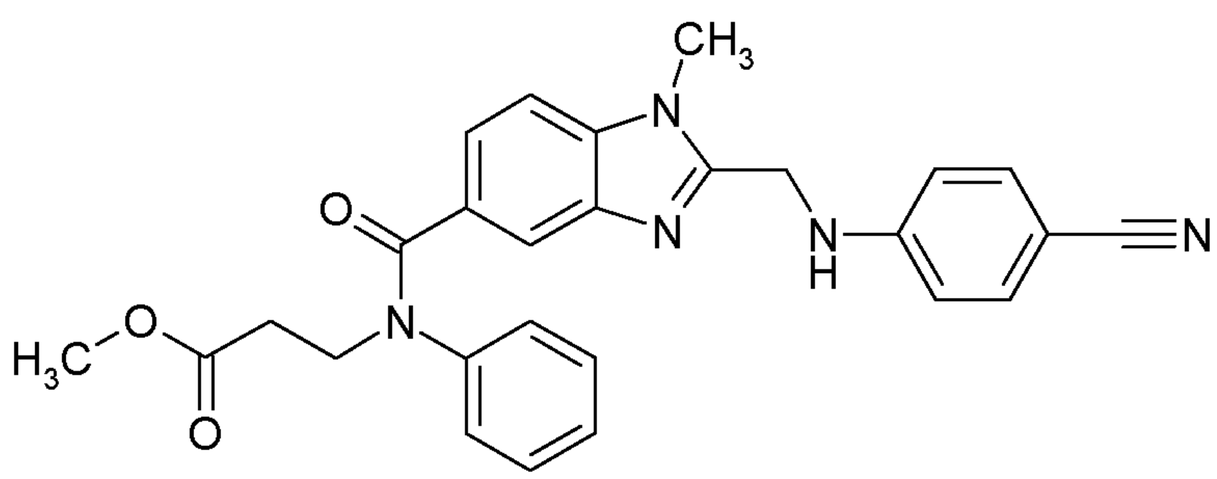
The product of 1b (23.2 mmol) and N-(4-cyano-phenyl)-glycine (23.2 mmol) were coupled with CDI (23.2 mmol) in dry THF at room temperature. After completion of the reaction the mixture was evaporated to dryness and the crude product was used without further purification.

Yield: 97%

$C_{27}H_{27}N_5O_4$ (485.54)

Mass spectrum (ESI): $[M+H]^+$ = 486

1d 3-({2-[(4-Cyano-phenylamino)-methyl]-1-methyl-1H-benzoimidazole-5-carbonyl}-phenyl-amino)-propionic acid



A solution of the product of 1c (22.6 mmol) in 100 mL concentrated acetic acid was heated to reflux for one hour. The solution was then evaporated to dryness, the remaining solid triturated with water and under stirring the pH was adjusted to about 8-9. The crude product was isolated through extraction with ethyl acetate and purified by chromatography on silica gel (eluent: dichloromethane/ethanol 1:1).

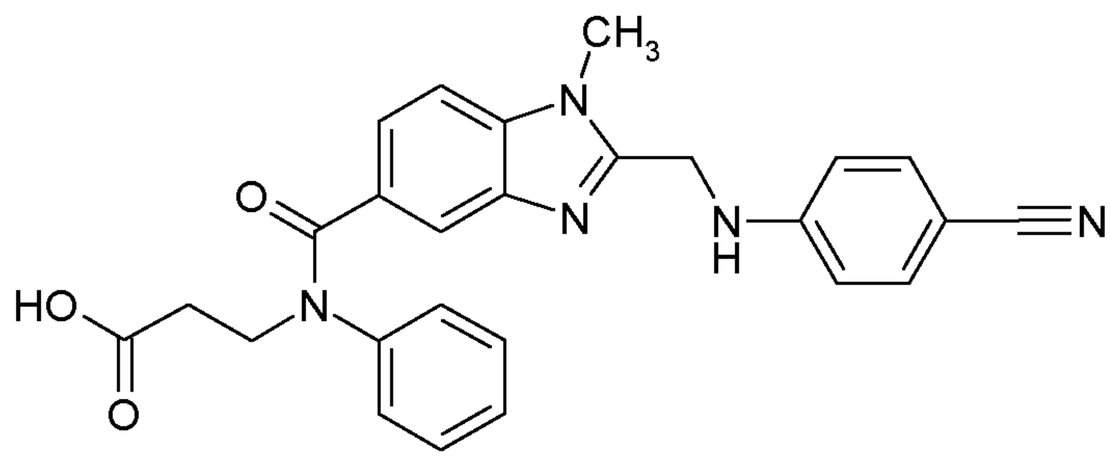
Yield: 58%

$C_{27}H_{25}N_5O_3$ (467.52)

TLC (silica gel; Dichloromethane/ethanol 9:1): R_f = 0.71

Mass spectrum (ESI): $[M+H]^+$ = 468

1e 3-({2-[(4-Cyano-phenylamino)-methyl]-1-methyl-1H-benzoimidazole-5-carbonyl}-phenyl-amino)-propionic acid



To a solution of the product of 1d (13.0 mmol) in 100mL methanol sodium hydroxide (20.0 mmol) was added. The mixture was stirred for 2.5 hours at 40°C and then evaporated to dryness. The remaining solid was stirred with 100 mL water and the pH was adjusted to

about 6 with concentrated acetic acid. The precipitated product was isolated by filtration, washed with water and dried at 60°C.

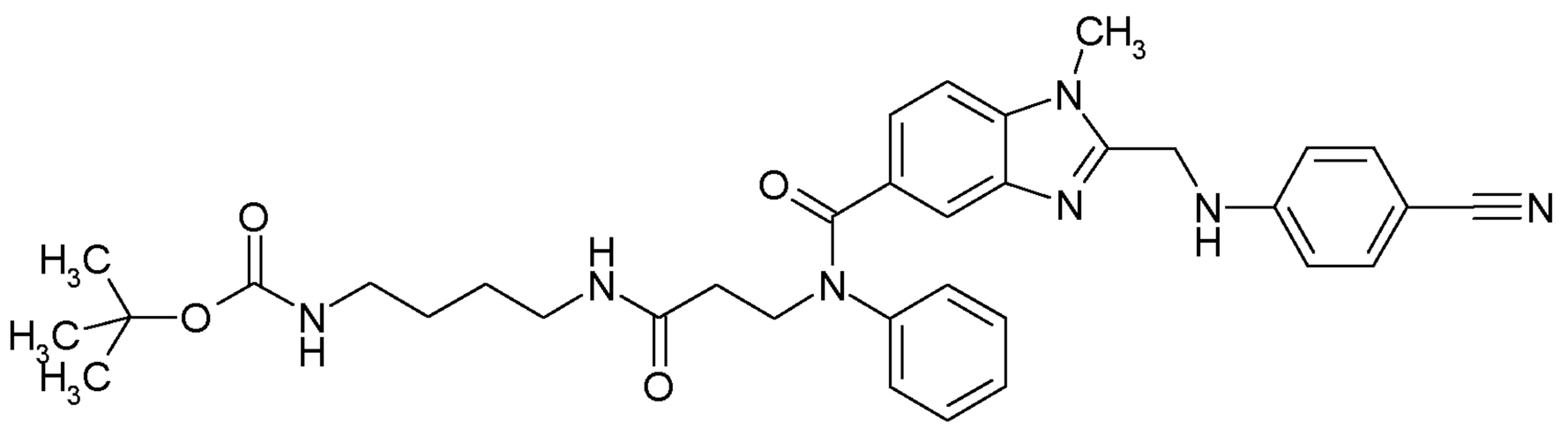
Yield: 88%

$C_{26}H_{23}N_5O_3$ (453.49)

TLC (silica gel; Dichloromethane/ethanol 9:1): R_f = 0.33

Mass spectrum (ESI): $[M+H]^+$ = 454

1f {4-[3-({2-[(4-Cyano-phenylamino)-methyl]-1-methyl-1H-benzoimidazole-5-carbonyl}-phenyl-amino)-propionylamino]-butyl}-carbamic acid tert-butyl ester



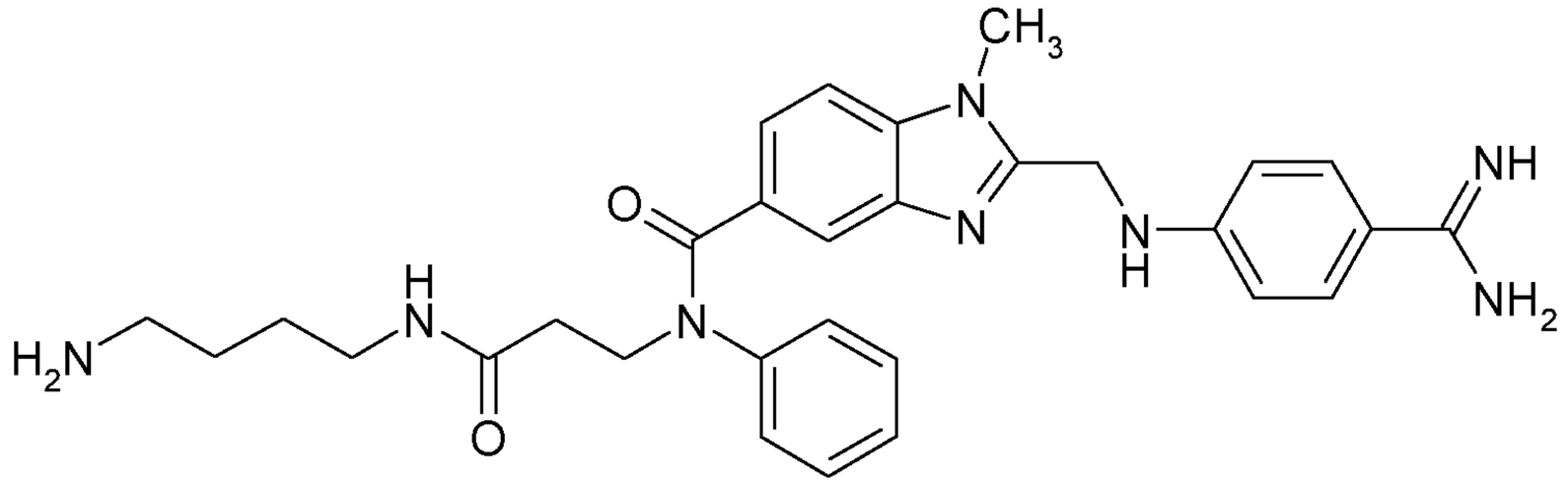
A solution of the product of 1e (5.23 mmol), 2-(1H-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium tetrafluoroborate (TBTU, 5.23 mmol) and N-methyl-morpholin (5.23 mmol) in 20 mL DMF was stirred at room temperature for 30 minutes. Then (4-amino-butyl)-carbamic acid tert-butyl ester (5.23 mmol) was added and the mixture stirred at room temperature for another 24 hours. The mixture was then diluted with water (100 mL) and the product was isolated through extraction with ethyl acetate.

Yield: 92%

$C_{35}H_{41}N_7O_4$ (623.75)

TLC (silica gel; Dichloromethane/ethanol 9:1): R_f = 0.51

1g 2-[(4-Carbamimidoyl-phenylamino)-methyl]-1-methyl-1H-benzoimidazole-5-carboxylic acid [2-(4-amino-butylcarbamoyl)-ethyl]-phenyl-amide



The product of 1f (4.81 mmol) was dissolved in a saturated solution of HCl in ethanol (250 mL), the mixture stirred at room temperature over night and then evaporated to dryness at 30°C. The remainig raw material was dissolved in 200 mL dry ethanol, then ammonium carbonate (48.1 mmol) was added and the mixture stirred at room temperature over night. After evaporation of the solvent the remaining raw material was triturated with ca. 5 mL ethanol, the undissolved material separated by filtration and the solvent evaporated at 30°C. The product was then dissolved in 30 mL water, the solution stirred with ca.2g charcoal, filtered and evaporated to dryness.

Yield: 90%

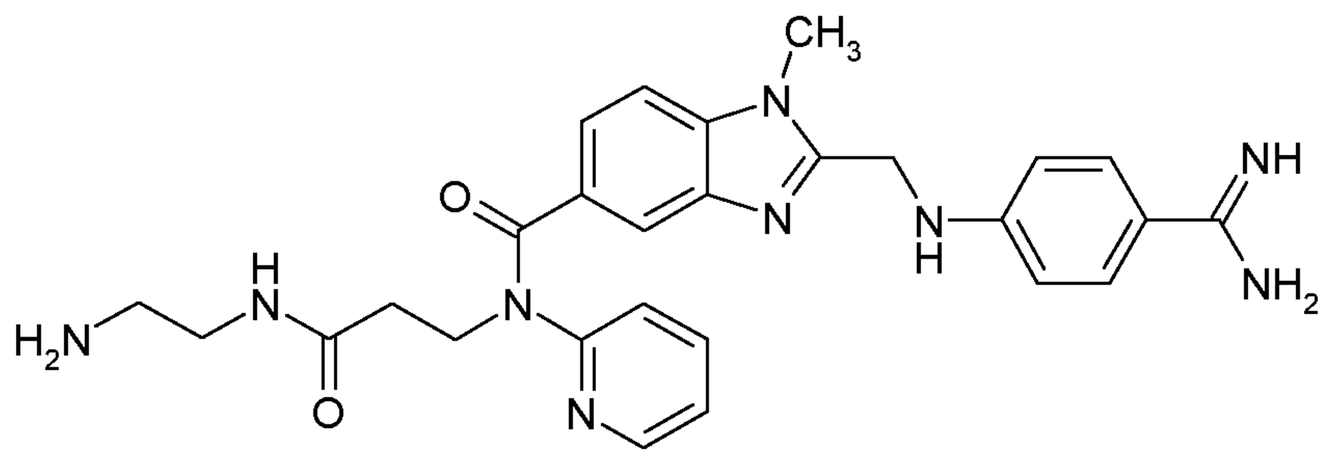
$C_{30}H_{36}N_8O_2$ (540.67)

TLC (reversed phase RP-8; methanol/5% aqueous NaCl solution 9:1): R_f = 0.79

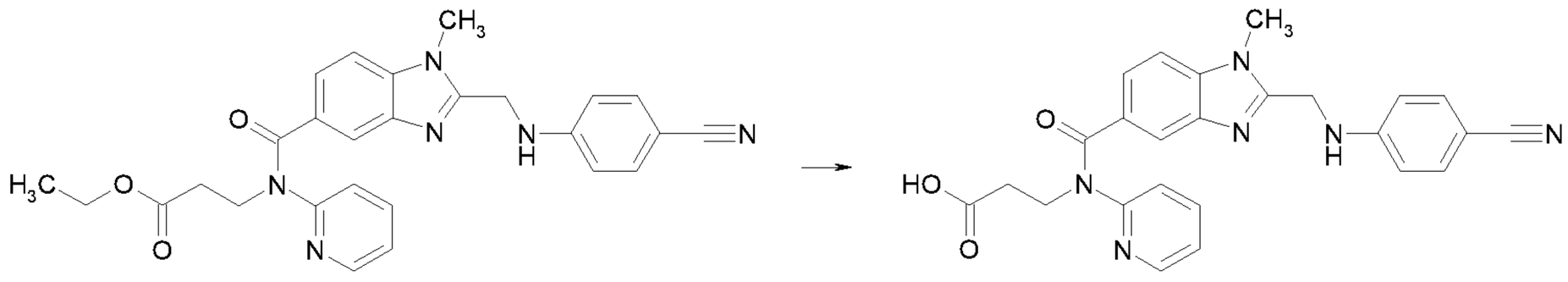
Mass spectrum (ESI): $[M+H]^+$ = 541

$[M+Cl]^-$ = 575/7

Hapten2 2-[(4-Carbamimidoyl-phenylamino)-methyl]-1-methyl-1H-benzoimidazole-5-carboxylic acid [2-(2-amino-ethylcarbamoyl)-ethyl]-pyridin-2-yl-amide



2a 3-({2-[(4-Cyano-phenylamino)-methyl]-1-methyl-1H-benzoimidazole-5-carbonyl}-pyridin-2-yl-amino)-propionic acid

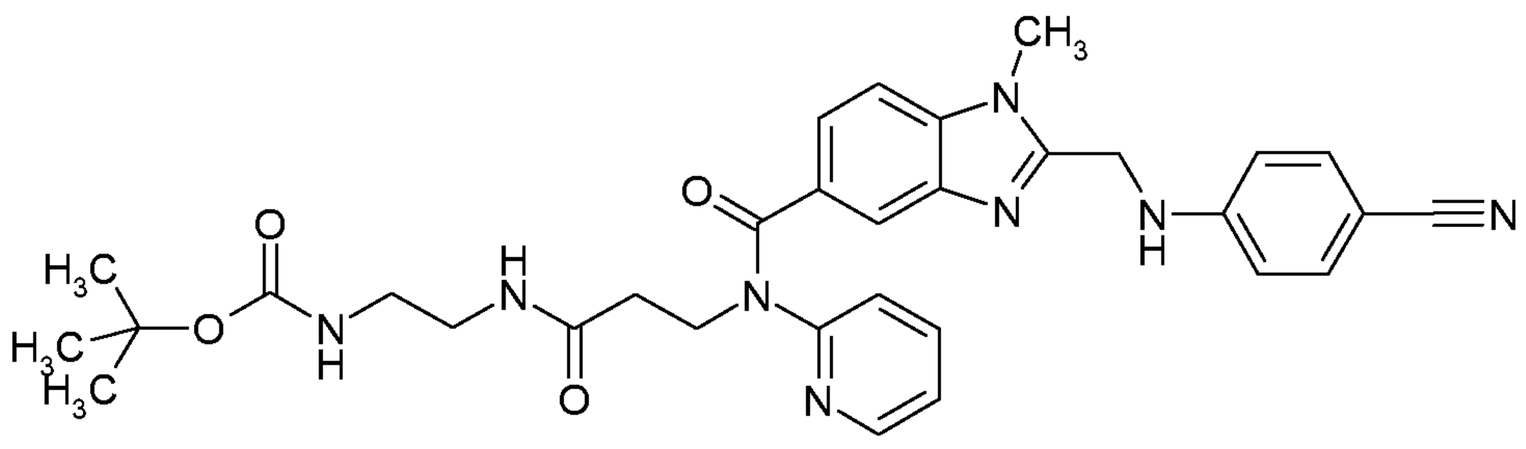


To a solution of sodium hydroxide (50.0 mmol) in 500 mL ethanol and 50 mL water was added 3-({2-[(4-Cyano-phenylamino)-methyl]-1-methyl-1H-benzoimidazole-5-carbonyl}-pyridin-2-yl-amino)-propionic acid ethyl ester (41.4 mmol). The mixture was stirred at room temperature for three hours, then ca. 350 mL ethanol were distilled off, ca. 100 mL water was added and the pH was adjusted to 6. Then diethylether (50 mL) was added and the mixture stirred over night. The product was isolated by filtration and used without further purification.

Yield: 78%

$C_{25}H_{22}N_6O_3$ (454.48)

2b {2-[3-({2-[(4-Cyano-phenylamino)-methyl]-1-methyl-1H-benzoimidazole-5-carbonyl}-pyridin-2-yl-amino)-propionylamino]-ethyl}-carbamic acid tert-butyl ester



A solution of the product of 2a (2.20 mmol), 2-(1H-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium tetrafluoroborate (TBTU, 2.20 mmol) and N-methyl-morpholin (2.20 mmol) in dry tetrahydrofuran (100 mL) was stirred at room temperature for 15 minutes. Then (2-amino-ethyl)-carbamic acid tert-butyl ester (2.20 mmol) was added and the mixture stirred at room temperature for another 24 hours. The mixture was then diluted with 40 mL water, the product was isolated through extraction with ethyl acetate and purified by chromatography (silica gel; dichloromethane/methanol 15:1).

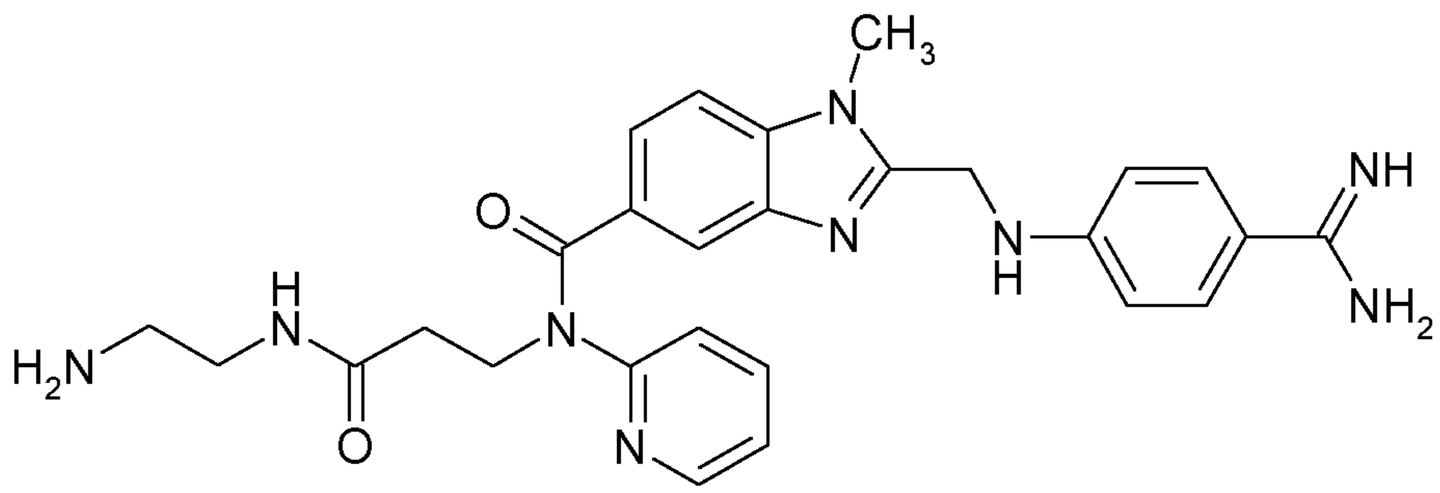
Yield: 61%

$C_{32}H_{36}N_8O_4$ (596.68)

Mass spectrum (ESI): $[M+H]^+$ = 597

$[M+H]^-$ = 595

2c 2-[(4-Carbamimidoyl-phenylamino)-methyl]-1-methyl-1H-benzoimidazole-5-carboxylic acid [2-(2-amino-ethylcarbamoyl)-ethyl]-pyridin-2-yl-amide



The product of 2b (1.34 mmol) was added to a saturated HCl solution in dry ethanol (30 mL). The solution was stirred at room temperature for 5 hours, then evaporated to dryness at 30°C. Ethanol (30 mL) and ammonium carbonate (13.0 mmol) were added and the mixture stirred at room temperature over night. The solvent was then evaporated, the residual material was triturated 5 times with ca. 4 mL of a mixture of dichloromethane/methanol (30:1), filtered and evaporated in order to separate the product from inorganic salts.

Yield: 27%

$C_{27}H_{31}N_9O_2$ (513.61)

Mass spectrum (ESI): $[M+Cl]^-$ = 548/50

$[M+HCl+Cl]^-$ = 584/6

$[M+H]^+$ = 514

2. CHEMICALS

2.1 CHEMICALS FOR REAGENT SYNTHESIS

name	specification	supplier	catalogue no.
1,4-Benzoquinone		Fluka	12309
Bovines Serum Albumin (BSA)		Serva	11920
1,1'-Carbonyl-di-(1,2,4-triazol)		Fluka	21861
Citric acid	analytical grade	Riedel-De Haën	33114
N,N- dimethylformamide (DMF)	for synthesis	Merck	822275
Ethanol	analytical grade	Baker	8006
Freund's adjuvant (CFA)	Complete	Sigma	F-5881
Freund's adjuvant (IFA)	Incomplete	Sigma	F-5506
Glycerine	Pure	Merck	104093
horseradish peroxidase HRP	25000 U / 100 mg	Boehringer Mannheim	108090
H_2SO_4	analytical grade	Riedel-De Haën	30743
KH_2PO_4	analytical grade	Merck	4873
$NaHCO_3$	analytical grade	Merck	106329
Na_2CO_3	analytical grade	Merck	106392
$(NH_4)_2SO_4$	analytical grade	Merck	101217
o-phenylene diamine	30 mg tablet	Sigma	P8412
Sodium perborate	Pure	Riedel-De Haën	11621
Thymol	Pure	Merck	8167

2.2 CHEMICALS FOR ELISA

Name	Specification	supplier	catalogue no.
Citric acid	analytical grade	Riedel-De Haën	33114
H_2SO_4	analytical grade	Riedel-De Haën	30743
KH_2PO_4	analytical grade	Merck	4873
$Na_2HPO_4 \cdot 2\ H_2O$	analytical grade	Merck	6580
NaCl	analytical grade	Merck	6404
NaOH	analytical grade	Merck	6498
o-phenylene diamine	30 mg tablet	Sigma	P8412
Sodium perborate	Pure	Riedel-De Haën	11621
Tween 20	Pure	Serva	37470

2.3 BUFFERS FOR ELISA

Name	Ingredients	use
buffer 1 stability:	0.05 M Na_2HPO_4 / KH_2PO_4 0.15 M NaCl, pH = 7.4 4 weeks at approximately +4°C	coating
buffer 2 stability:	as buffer 1, with 5 g/l BSA 10 days at approximately +4°C	assay buffer
buffer 3 stability:	as buffer 1, with 5 g/l BSA and 0.1 g/L thimerosal 4 weeks at approximately +4°C	microplate blocking; storage
buffer 4 stability:	0.1 M citric acid, adjusted to pH 5.0 with NaOH, 6.5 mmol/L sodium perborate citric acid: 6 months at approximately +4°C with perborate: 10 days at approximately +4°C	substrate buffer for o-phenylene diamine

wash solution stability:	water, 0.5 g/L Tween 20 10 days at ambient temperature	microplate washing
stop reagent stability:	2.25 M H_2SO_4 5 years at ambient temperature	arrests o-phenylene diamine colour development

Water from an Elgastat Maxima-HPLC ultra pure water processing system was used to prepare buffer solutions.

3. SYNTHESIS OF IMMUNOGENS

In order to stimulate the immune system of rabbits to produce polyclonal antibodies against dabigatran, three immunogens (lot. nos. **GL256, GL258,** and **GL262,**) were synthesized by coupling the haptens HAPTEN1 and HAPTEN2 to the carrier protein bovine serum albumin (BSA) using 1,4-benzoquinone or 1,1'-carbonyl-di-(1,2,4-triazol) as coupling reagent.

For the synthesis of **GL256,** 1,4-benzoquinone was used as a homobifunctional compound with two reactive sites. First it reacts at an acidic pH with amino groups at only one of the two sites and at an alkaline pH at the other site with minimal polymerization.

GL258 and **GL262** were synthesized using 1,1'-carbonyl-di-(1,2,4-triazol) as coupling reagent with different input ratios of the hapten to the carrier protein.

3.1 SYNTHESIS OF GL256

To the solution of 0.75 µMol BSA in 8.5 mL 0.1 M KH_2PO_4-buffer (pH = 4.5), 0.416 mMol 1,4-benzoquinone (in 1.5 mL ethanol) was added and incubated for 1.5 h in the dark at room temperature. Afterwards the solution passed a sephadex G25 column equilibrated in 0.15 M NaCl to eliminate the excess of 1,4-benzoquinone (final volume 12.5 mL).

2.5 mL (0.15 µMol) of the purified BSA-solution were added slowly under stirring to a solution of the 525 µMol hapten HAPTEN1 dissolved in 2 mL 0.1 M $NaHCO_3$/Na_2CO_3-buffer (pH=8.5). During addition of the BSA solution the pH was adjusted to approximately 8.0. The molar input ratio of the hapten and the carrier protein was 3500:1.

After incubation at room temperature over night the immunogen was dialysed 6 times against 1 litre of aqua. dest. Thin-layer chromatography showed that no spots of unbound hapten remained in the hapten-carrier conjugates.

The immunogen was stored frozen in aliquots at -20°C. The degree of substitution of BSA with hapten in the supernatant of the immunogen was about 1:18 as determined by UV absorption spectrometry at 302 nm. The content of immunogen in the final solution was 0.75 mg GL256 / mL

3.2 SYNTHESIS OF GL258

A solution of 158 µMol HAPTEN2 in 6.3 mL N,N-dimethylformamide (DMF) was prepared at room temperature. 158 µMol 1,1'-carbonyl-di-(1,2,4-triazol) was added and incubated first for 4 hours at 10°C and afterwards for 30 min at room temperature. The chemical reaction was checked with thin-layer chromatography and was about 20-25%.

Then 0.75 µMol BSA were dissolved in 2 mL 0.13 M $NaHCO_3$ and 1 mL N,N-dimethylformamide (DMF) was added dropwise under stirring. The pH was adjusted to approximately 8.3. Afterwards the hapten solution (6.3 mL) and 4 mL 0.13 M $NaHCO_3$ were added dropwise to the BSA solution under stirring and the pH was adjusted to 8.4. The molar input ratio of the hapten and the carrier protein was 210:1 for the immunogen GL258.

After incubation at room temperature over night under stirring conditions, the immunogen was dialysed 6 times against 1 litre of aqua. dest. Thin-layer chromatography showed that no spots of unbound hapten remained in the hapten-carrier conjugates.

The immunogen was stored frozen in aliquots at -20°C. The degree of substitution of BSA with hapten in the supernatant of the immunogen was about 1:5 as determined by UV absorption spectrometry at 302 nm. The content of immunogen in the final solution was 0.28 mg GL258 / mL.

3.3 SYNTHESIS OF GL262

A solution of 225 µMol HAPTEN2 in 8.75 mL N,N-dimethylformamide (DMF) was prepared at room temperature. 225 µMol 1,1'-carbonyl-di-(1,2,4-triazol) was added and incubated for 4 hours at 10°C. The chemical reaction was checked with thin-layer chromatography and was about 20-25%.

Then 0.49 µMol BSA were dissolved in 2 mL 0.13 M $NaHCO_3$ and 1 mL N,N-dimethylformamide (DMF) was added dropwise under stirring. The pH was adjusted to approximately 8.2. Afterwards the hapten solution (8.75 mL) and 6 mL 0.13 M $NaHCO_3$ were added dropwise to the BSA solution under stirring and the pH was adjusted to 8.3. The molar input ratio of the hapten and the carrier protein was 460:1 for the immunogen GL262.

After incubation at room temperature over night under stirring conditions, the immunogen was dialysed 6 times against 1 litre of aqua. dest. Thin-layer chromatography showed that no spots of unbound hapten remained in the hapten-carrier conjugates.

The immunogen was stored frozen in aliquots at -20°C. The degree of substitution of BSA with hapten in the supernatant of the immunogen was about 1:32 as determined by UV absorption spectrometry at 302 nm. The content of immunogen in the final solution was 0.71 mg GL262 / mL

4. SYNTHESIS OF CONJUGATE

4.1 SYNTHESIS OF GL261

A solution of 37.4 µMol HAPTEN2 in 1.5 mL N,N-dimethylformamide (DMF) was prepared at room temperature. 37.5 µMol 1,1'-carbonyl-di-(1,2,4-triazol) was added and incubated first for 4 hours at 10°C and afterwards for 30 min at room temperature. The chemical reaction was checked with thin-layer chromatography and was about 20-25%.

Then 1.125 µMol enzyme horseradish peroxidase (HRP) were dissolved in 0.4 mL 0.13 M $NaHCO_3$ and 0.267 mL N,N- dimethylformamide (DMF) was added dropwise under stirring. The pH was adjusted to approximately 8.2. Afterwards 0.9 mL of the hapten solution (22.5 µMol) and 0.57 mL 0.13 M $NaHCO_3$ were added dropwise to the HRP solution under stirring and the pH was adjusted to 8.4. The molar input ratio of the hapten and the HRP was 20:1 for the HRP conjugate GL261.

After incubation at room temperature over night under stirring conditions, the HRP conjugate was separated from organic solvents and the excess of hapten by gel chromatography. The solution passed a sephadex G25 column equilibrated with 0.1 M phosphate buffer pH 7.0.

The final concentration of hapten-HRP conjugate (tracer, 5.64 mg/mL) was spiked with BSA yielding a concentration of about 10 mg/mL, an equal volume of glycerine to prevent freezing and a thymol crystal to prevent bacterial growth. The tracer solution was labelled as lot no. GL261 and stored in aliquots at -20°C.

The degree of substitution of HRP with hapten was 1:0.2 as determined by UV spectroscopy at 302 nm.

The specific activity of the tracer was measured in BSA-blocked microtiter plates using o-phenylene-diamine (OPD) as substrate and native HRP as reference material. The mixture of diluted HRP standards or the hapten-HRP conjugate and substrate solution were incubated for 30 min in the dark, stopped with sulphuric acid and absorption measured at 490 nm. The remaining activity was 94 % of the native HRP and the specific activity of the conjugate formulation in glycerine was 611 U/mL.

Summary of tracer specifications:

type:	HAPTEN2 - horseradish peroxidase (lot no. GL 261)
protein content:	5.64 mg/mL
specific activity:	108 U/mg 611 U/ml (substrate Guajacol and H_2O_2, 25°C)
storage:	at approximately -20°C
working dilution:	1:40000

5. IMMUNIZATION AND PRODUCTION OF ANTIBODIES

5.1 IMMUNIZATION OF RABBITS

Twelve female chinchilla rabbits, 3 months old, were immunized with an emulsion of 100 µg immunogen GL256, GL258 and GL262 in 0.5 mL 0.9 % NaCl solution and 0.5 mL of complete Freund's adjuvant (CFA). Several booster immunizations followed in the next month. For the third immunization 0.5 mL of incomplete Freund's adjuvant (IFA) was used. Each immunization was performed at four subcutaneous and four intramuscular sites.

Group A – immunogen GL256

Rabbit 1 #50

Rabbit 2 #51

Rabbit 3 #52

Rabbit 4 #53

Group B – immunogen GL258

Rabbit 5 #54

Rabbit 6 #55

Rabbit 7 #56

Rabbit 8 #57

Group C – immunogen GL262

Rabbit 9 #46

Rabbit 10 #47

Rabbit 11 #48

Rabbit 12 #49

Immunization scheme

Day	1	First immunization with 100 µg immunogen / mL per animal in CFA
Day	29	Second immunization with 100 µg immunogen / mL per animal in CFA
Day	57	Third immunization with 100 µg immunogen / mL per animal in IFA the rabbit's state of the healthy might change for the worse by the use of immunogens GL256 and GL258 rabbit 7 #56 was not treated
Day	67	First bleeding (2 mL per animal)
Day	81	Fourth immunization with 100 µg immunogen / mL per animal in CFA
Day	91	Second bleeding (25 mL per animal)
Day	112	Fifth immunization with 100 µg immunogen /mL per animal in CFA
Day	122	Assignment of the animal numbers was mislaid Third final bleeding (Exsanguination)*

*Rabbit no. 1-12 were exsanguinated completely 10 days after the fifth immunization. Exsanguination was performed via a carotid artery under anesthesia with xylazin (Rompun®, Bayer, Leverkusen, Germany) and ketamine hydrochloride (Ketavet®, Parke-Davis, Freiburg, Germany).

5.2 ANALYSIS OF RABBIT SERA

Serum was prepared by centrifugation of the coagulated rabbit blood. A protein fraction was obtained by ammonium sulphate precipitation and desalting through a Sephadex G25 column.

The individual protein fractions from the rabbit sera were screened for anti-dabigatran titer by a standard ELISA procedure.

Screening-ELISA:

Step	Procedure
A	protein fractions from each bleeding were adsorbed overnight at ambient temperature onto microtiter plates (100 µL/well; 1, 2 or 4 µg/mL) in buffer 1. wash microplates 4 times, 450 µL each block with 250 µL buffer 3 for at least 1 hour
B	wash microplates 4 times, 450 µL each
C	add to each well of microtiter plate in triplicate: + 50 µL buffer 2 + 50 µL calibration standards in buffer 2 + 25 µL dabigatran-horseradish peroxidase (HRP) conjugate GL 261 (tracer) (1/40000)
D	seal microplates with adhesive foil, complete sample distribution for all microplates incubate for 4 h on a shaker at ambient temperature
E	wash microplates 4 times, 450 µL each
F	add to each well of microtiter plate 100 µL o-phenylene diamine HCl, 2.7 mg/mL (one 30 mg tablet in 11 mL buffer 4) incubate for 30 min in the dark at ambient temperature
G	add to each well of microtiter plate 100 µL H_2SO_4 (2.25 M) shake for 5 minutes
H	read absorbance; test-wavelength: 490 nm, reference-wavelength: 650 nm

5.3 DETECTION OF ANTI-DABIGATRAN ANTIBODIES IN RABBIT SERA

Last three columns: values are for dabigatran

bleeding 2

rabbit		immunogene	coating conc [µg/ml]	conc. [Mol]	[Ext]	[%]
1	#50	GL256	2	0	1.812	100%
				2.E-12	1.574	87%
				2.E-11	0.461	25%
				2.E-10	0.059	3%
2	#51	GL256	1	0	2.193	100%
				2.E-12	2.086	95%
				2.E-11	1.515	69%
				2.E-10	0.207	9%
3	#52	GL256	2	0	1.513	100%
				2.E-12	1.419	94%
				2.E-11	0.728	48%
				2.E-10	0.107	7%
4	#53	GL256	2	0	1.474	100%
				2.E-12	1.388	94%
				2.E-11	0.848	58%
				2.E-10	0.142	10%
5	#54	GL258	1	0	2.114	100%
				2.E-12	1.892	89%
				2.E-11	0.646	31%
				2.E-10	0.159	8%
6	#55	GL258	1	0	1.295	100%
				2.E-12	0.937	72%
				2.E-11	0.265	20%
				2.E-10	0.140	11%
7	#56	GL258	2	0	1.611	100%
				2.E-12	1.372	85%
				2.E-11	0.424	26%
				2.E-10	0.145	9%
8	#46	GL258	1	0	1.640	100%
				2.E-12	1.290	79%
				2.E-11	0.425	26%
				2.E-10	0.196	12%
9	#47	GL262	2	0	1.854	100%
				2.E-12	1.534	83%
				2.E-11	0.530	29%
				2.E-10	0.254	14%
10	#48	GL262	2	0	1.458	100%
				2.E-12	1.142	78%
				2.E-11	0.300	21%
				2.E-10	0.131	9%
11	#49	GL262	4	0	1.646	100%
				2.E-12	1.393	85%
				2.E-11	0.460	28%
				2.E-10	0.257	16%
12	#50	GL262	2	0	1.605	100%
				2.E-12	1.400	87%
				2.E-11	0.389	24%
				2.E-10	0.109	7%

Final bleeding

rabbit	immunogene	coating conc [µg/ml]	conc. [Mol]	[Ext]	[%]
1	?	1	0	1.589	100%
			2.E-12	1.442	91%
			2.E-11	0.491	31%
			2.E-10	0.130	8%
2	?	1	0	1.375	100%
			2.E-12	1.041	76%
			2.E-11	0.293	21%
			2.E-10	0.101	7%
3	?	1	0	1.400	100%
			2.E-12	1.081	77%
			2.E-11	0.288	21%
			2.E-10	0.097	7%
4	?	1	0	1.183	100%
			2.E-12	0.882	75%
			2.E-11	0.396	33%
			2.E-10	0.183	15%
5	?	1	0	1.335	100%
			2.E-12	1.066	80%
			2.E-11	0.183	14%
			2.E-10	0.057	4%
6	?	1	0	1.214	100%
			2.E-12	0.976	80%
			2.E-11	0.250	21%
			2.E-10	0.123	10%
7	?	2	0	1.822	100%
			2.E-12	1.702	93%
			2.E-11	0.661	36%
			2.E-10	0.189	10%
8	?	2	0	1.234	100%
			2.E-12	1.085	88%
			2.E-11	0.671	54%
			2.E-10	0.147	12%
9	?	1	0	1.911	100%
			2.E-12	1.862	97%
			2.E-11	0.980	51%
			2.E-10	0.292	15%
10	?	1	0	1.933	100%
			2.E-12	1.891	98%
			2.E-11	1.055	55%
			2.E-10	0.076	4%
11	?	1	0	1.874	100%
			2.E-12	1.817	97%
			2.E-11	1.539	82%
			2.E-10	0.181	10%
12	?	2	0	1.599	100%
			2.E-12	1.425	89%
			2.E-11	0.475	30%
			2.E-10	0.050	3%

After screening of the protein fractions of all rabbits from bleeding 2, it was obvious that rabbit no. 5 (#54) had the highest titre of anti-dabigatran antibodies with the preferred hapten HAPTEN2. Furthermore, it was possible to displace the tracer from the antibody binding sites with only low concentrations of analyte (dabigatran).

For the screening of the final bleeding 3, the displacement of the tracer from the antibody binding site with low concentrations of analyte (dabigatran) was used as main decision criteria, because of the missing information about the immunogen used. Therefore rabbits no. 2, 3 and 5 were used for the further purification.

5.4 PURIFICATION OF POLYCLONAL ANTIBODIES

The anti-serum of rabbit no. 5 (#54) bleeding no. 2 and rabbits no. 2, 3 and 5 bleeding no. 3 (final bleeding) was precipitated with ammonium sulphate. The precipitate was centrifuged for 30 min at 10°C at 4500 U/min, separated from the solution and re-dissolved in Tris buffer. This procedure was repeated. Further purification was performed by affinity chromatography on protein A sepharose FF. The column buffer was 0.01 M Tris pH = 7.5 and 0.1 M glycine pH = 3.0 was used for elution. Fractions containing the rabbit IgG were combined. Protein concentration was determined by UV spectroscopy at 280 nm.

Summary of antibody specifications:

immunogen:	HAPTEN2-BSA (lot no. GL258)
rabbit:	no. 5 (#54) serum (bleeding no. 2)
protein content:	1.85 mg/mL
storage:	at approximately -20°C

immunogen:	HAPTEN1-BSA (GL256) or HAPTEN2-BSA (lot no. GL258) or HAPTEN2-BSA (lot no. GL262)
rabbit:	no. 2 serum collected (final bleeding)
protein content:	3.9 mg/mL
storage:	at approximately -20°C

immunogen:	HAPTEN1-BSA (GL256) or HAPTEN2-BSA (lot no. GL258) or HAPTEN2-BSA (lot no. GL262)
rabbit:	no. 3 serum (final bleeding)
protein content:	9.96 mg/mL
storage:	at approximately -20°C

immunogen:	HAPTEN1-BSA (GL256) or HAPTEN2-BSA (lot no. GL258) or HAPTEN2-BSA (lot no. GL262)
rabbit:	no. 5 serum (final bleeding)
protein content:	5.72 mg/mL
storage:	at approximately -20°C

II. Neutralization of dabigatran

Two series of experiments were performed to show the effect of the antibodies against dabigatran anticoagulant activity *in vitro*. The four polyclonal antibodies were received in the laboratory and further tested in human plasma. This was tested in the functional assay, the thrombin clotting time.

Assay description:

Briefly human plasma is obtained by taking whole blood into 3.13% sodium citrate. This is then centrifuged to obtain platelet free plasma and transferred to a separate tube and frozen until required on the day of the assay. Plasma is thawed at 37°C on the day of the assay.

The thrombin clotting time is performed as follows. First thrombin is diluted to manufacturer's specification (3 IU/mL thrombin) in the buffer provided (Dade Behring Test kit) and prewarmed to 37°C. It is used within 2 hrs of being prepared. All assays were

performed on a commercially available CL4 clotting machine (Behnk Electronics, Norderstadt, Germany). Fifty µL of plasma is pipetted into provided cuvettes with a magnetic stirrer and allowed to stir for 2 min in the well preheated to 37°C in the CL4 machine. At this point 100 µL of the thrombin solution is added and the time required for the plasma sample to clot is recorded automatically by the CL4. Dabigatran is preincubated for 5 min in plasma in the provided cuvettes, before adding thrombin and starting the measurement. If antibody is also tested (up 50 µL of stock solution), there is a further 5 minute incubation at 37°C before beginning clotting (i.e. 10 min total incubation with dabigatran, 5 min total incubation with antibody and then clotting is initiated with thrombin).

Initially a dabigatran standard curve was performed by adding increasing concentrations of dabigatran to human plasma and measuring the time to clotting after addition of thrombin (Figure 1). There was a concentration-dependent increase in the thrombin clotting time with increasing concentrations of dabigatran.

For the first set of neutralization experiments, a clinically relevant concentration of 200 nM of dabigatran was added to all plasma samples for neutralization. All 4 antibody preparations were able to shorten the time to clotting in plasma containing dabigatran (Figure 2). The extent of neutralization was related to the concentration of protein in each antibody preparation. The antibody solution with the highest concentration (D) was then serially diluted and tested for the ability to neutralize 200 nM dabigatran anticoagulant activity in a separate set of experiments. It can be seen in Figure 3, there was a concentration dependent inhibition of dabigatran-induced anticoagulant activity with increasing concentrations of antibody. In addition when a non-specific rabbit polyclonal antibody (blue square) was added to plasma containing dabigatran, it had no ability to neutralise the anticoagulant activity. The concentration dependency and the lack of neutralization of a non specific antibody indicate the reversal of anticoagulation by the antibody is specific for dabigatran.

However, these concentrations of dabigatran are clinically relevant, and bleeding or overdoses will probably occur with higher concentrations. Thus the ability of an antibody to inhibit the anticoagulant activity of the highest concentration of dabigatran (500 nM) in

the standard curve in Figure 1 was also tested. Figure 4 illustrates that antibody D could also inhibit high concentrations of dabigatran.

III. PRODUCTION AND CHARACTERIZATION OF MONOCLONAL ANTI-DABIGATRAN ANTIBODIES

1. Production of monoclonal anti-dabigatran antibodies and Fabs

Mice were immunized with Hapten1 (see Example 1.1) conjugated to carrier proteins such as hemocyanin and immunoglobulin and hybridomas were generated according to standard procedures. Monoclonal antibodies purified from the culture supernatants bound to dabigatran-protein conjugates and this binding could be competed with dabigatran in solution with half-maximal inhibition at concentrations in the range of 1 to 10 nM. Fabs were generated by papain cleavage of the monoclonal antibodies with subsequent elimination of the Fc domain via Protein A.

The variable regions from the heavy and light chains of the mouse antibodies were cloned and sequenced using standard methods. The sequences were confirmed by protein analysis by mass spectrometry and N-terminal sequencing of the antibodies. DNA constructs encoding chimeric antibodies comprising the specific mouse variable regions and human IgG constant regions were generated and protein was expressed in HEK293 cells and purified.

In order to reduce potential immunogenicity, sequences of mouse monoclonal antibody clones 35E6 and 27A9 were humanized by standard methods described above. Humanized Fabs were produced by transient transfection in mammalian cells (e.g. HEK293; CHO cells) and purified by affinity chromatography with benzamidine sepharose followed by size exclusion chromatography.

2. Characterization of monoclonal anti-dabigatran antibodies and Fabs

The sequences of the variable domains of 9 monoclonal antibody clones DBG22 (clone 22), 35E6, 45B9, 48E1, 49F8, 6A7F1, 2F1E5, 3B4E7, 1F6G8, 2D2E3, and 27A9 are depicted in Table 1. SEQ ID NO's 67, 68, 69, 92, 93, 94, 99, 100 and 101 represent optimized and/or humanized sequences. The Fab compound VH5C/VK18 comprises HCVH5C (SEQ ID NO: 99) as heavy chain, and LCVK18 (SEQ ID NO: 100) as light chain. The Fab compound VH5C/VK21 comprises HCVH5C (SEQ ID NO: 99) as heavy chain, and LCVK21 (SEQ ID NO: 101) as light chain. Thus, both VH5C/VK18 and VH5C/VK21 comprise a heavy chain variable domain with a CDR1 of SEQ ID NO: 67, a CDR2 of SEQ ID NO: 68, and a CDR3 of SEQ ID NO: 9, and a light chain variable domain with a CDR1 of SEQ ID NO: 64, a CDR2 of SEQ ID NO: 65, and a CDR3 of SEQ ID NO: 69. Both Fabs share a variable region of the heavy chain of SEQ ID NO: 92 (VH5C). VH5C/VK18 comprises a variable region of the light chain of SEQ ID NO: 93 (VK18), and VH5C/VK21 comprises a variable region of the light chain of SEQ ID NO: 94 (VK21).

In Table 1, the letters "CDR" denote a complementarity determining region, "VH" denotes the variable region of a heavy chain, "VK" denotes the variable region of a kappa light chain, "CL" denotes the constant region of a light chain, and "CH" denotes the constant region of a heavy chain, "LC" denotes the light chain of an antibody molecule, and "HC" denotes the heavy chain of an antibody molecule. For example, "VHCDR1 DBG22" denotes the first CDR (CDR1) of the variable domain of the heavy chain of clone DBG22, and "DBG22VH" denotes the variable region of the heavy chain of clone DBG22.

Table 1

SEQ ID NO	Designation	Sequence
1	VHCDR1 DBG22	GFSLTSYIVD
2	VHCDR2 DBG22	VIWAGGSTNYNSALRS
3	VHCDR3 DBG22	AAYYSYYNYDGFAY
4	VKCDR1	KSSQSLLYTNGKTYLY

	DBG22	
5	VKCDR2 DBG22	LVSKLDS
6	VKCDR3 DBG22	LQSTHFPHT
7	VHCDR1 35E6	GYTFTNYWMH
8	VHCDR2 35E6	ETNPRNGGTNYNEKFKR
9	VHCDR3 35E6	GTSGYDYFDY
10	VKCDR1 35E6	RSSQTIVHSNGNTYLE
11	VKCDR2 35E6	KVSNRFS
12	VKCDR3 35E6	FQASHFPYT
13	VHCDR1 45B9	GVSLFTYDVD
14	VHCDR2 45B9	VMWSGGTTNYNSALKS
15	VHCDR3 45B9	DRWSPGGFAY
16	VKCDR1 45B9	QSSQSLLYTNGKTYLH
17	VKCDR2 45B9	LVSKLDS
18	VKCDR3 45B9	LQSTHFPHT
19	VHCDR1 48E1	GFSLTSYDVD
20	VHCDR2 48E1	VIWAGGSTNYNSALKS
21	VHCDR3 48E1	DRWSPGGFAY
22	VKCDR1 48E1	KSSQSLLYTNGKTYLI
23	VKCDR2 48E1	LVSKLDS
24	VKCDR3 48E1	LQTTHFPHT
25	VHCDR1 49F8	GFSLSTYGVD
26	VHCDR2 49F8	LIWAGGSTTYNSAFKS
27	VHCDR3 49F8	ERSGDSPFGY
28	VKCDR1 49F8	KSSQSLLYTNGKTYLN

29	VKCDR2 49F8	LVSKLDS
30	VKCDR3 49F8	LQNSHFPHT
31	VHCDR1 6A7F1	GFTFSTYGMS
32	VHCDR2 6A7F1	SVTRGGNTYYPDSM
33	VHCDR3 6A7F1	DYSGWYFDV
34	VKCDR1 6A7F1	RSSQSIVHSNGDTFLE
35	VKCDR2 6A7F1	KVSNRFS
36	VKCDR3 6A7F1	FQGSRIPYT
37	VHCDR1 2F1E5	GFTLTNYGMN
38	VHCDR2 2F1E5	WINTYTGEPTYADDFKG
39	VHCDR3 2F1E5	SAGTDYFDY
40	VKCDR1 2F1E5	RASESVDSYGNSFMH
41	VKCDR2 2F1E5	LASNLES
42	VKCDR3 2F1E5	QQNNEDPWT
43	VHCDR1 3B4E7	GYTFTYYTIH
44	VHCDR2 3B4E7	YINPASSYTNYIQKFKD
45	VHCDR3 3B4E7	GANWDYFDY
46	VKCDR1 3B4E7	RSSQNIIQSNGNTYLE
47	VKCDR2 3B4E7	KVSNRFS
48	VKCDR3 3B4E7	FQGSHVPYT
49	VHCDR1 1F6G8	GYTFTSYTIH
50	VHCDR2 1F6G8	YINPSSGYTYYIQNFKD
51	VHCDR3 1F6G8	GANWDYFDY
52	VKCDR1 1F6G8	RSSQNIVQTNGNTYLE
53	VKCDR2	KVSSRFS

	1F6G8	
54	VKCDR3 1F6G8	FQGSHVPFT
55	VHCDR1 2D2E3	GYTFTHSGMN
56	VHCDR2 2D2E3	WINTNTGEPTYAEEFNGR
57	VHCDR3 2D2E3	SWWTDYFDY
58	VKCDR1 2D2F8	RSSQSIVHSNGNTYLE
59	VKCDR2 2D2E3	KVSNRFS
60	VKCDR3 2D2E3	FQGSHFPYT
61	VHCDR1 27A9	GYTFTNCYMH
62	VHCDR2 27A9	ETNPRNGGTNYNEKFKR
63	VHCDR3 27A9	GTSGYEYFDY
64	VKCDR1 27A9	RSSQSIVHSDGNIYLE
65	VKCDR2 27A9	KVSYRFS
66	VKCDR3 27A9	FQGSHVPYT
67	VHCDR1 5C	GYTFTDYYMH
68	VHCDR2 5C	ETNPRNGGTTYNEKFKG
69	VKCDR3 18	FQASHVPYT
70	DBG22VH	QVQLEQSGPG LVAPSQRLSI TCTVSGFSLT SYIVDWVRQS PGKGLEWLGV IWAGGSTNYN SALRSRLSIT KSNSKSQVFL QMNSLQTDDT AIYYCASAAY YSYYNYDGFA YWGQGTLVTV SA
71	DBG22VK	DVVMTQTPLT LSVTIGQPAS ISCKSSQSLL YTNGKTYLYW LLQRPGQSPK RLIYLVSKLD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGI YYCLQSTHFP HTFGGGTKLE IK
72	35E6VH	QVQLQQPGAE LVKPGASVKL SCKTSGYTFT NYWMHWVRQR PGQGLEWIGE TNPRNGGTNY NEKFKRKATL TVDKSSNTAY MQLSSLTFGD SAVYYCTIGT SGYDYFDYWG QGTTLTVSS
73	35E6VK	DVLMTQTPLS LPVSLGDQAS ISCRSSQTIV HSNGNTYLEW YLQKPGQSPK LLIYKVSNRF SGVPDRFSGS GSGTGFTLKI SRVEAEDLGV YFCFQASHFP YTFGGGTKLE IK
74	45B9VH	QVQLKQSGPG LVAPSQSLSI TCTVSGVSLF TYDVDWVRQS PGKDLEWLGV MWSGGTTNYN SALKSRLNIM KDSSKSQVFL KMSGLQTDDT GIYYCATDRW SPGGFAYWGQ GTLVTVSA
75	45B9VK	DVVMTQTPLT LSVLIGQPAS ISCQSSQSLL YTNGKTYLHW LLQRPGQSPK RLIYLVSKLD SGVPDRFSGS GSGTDFTLKI

		SRVEAEDLGV YYCLQSTHFP HTFGGGTKLE IR
76	48E1VH	QVQLKQSGPG LVAPSQSLSI TCTVSGFSLT SYDVDWVRQS PGKGLEWLGV IWAGGSTNYN SALKSRLIIS KDNSKNQVFL RMNSLQTDDT AMYYCASDRW SPGGFAYWGQ GTLVTVSA
77	48E1VK	DVVMTQTPLT LSVTIGQPAS ISCKSSQSLL YTNGKTYLIW LLQRPGQSPK RLIHLVSKLD SGVPDRFSGS GSGTDFTLKI SRVEAEDLGV FYCLQTTHFP HTFGGGTKLE IR
78	49F8VH	QVQLKQSGPG LVAPSQSLSI TCTVSGFSLS TYGVDWVRQS PKKGLEWLGL IWAGGSTTYN SAFKSRLSIS KDNSKSQVFL KMNSLQTDDT AMYYCASERS GDSPFGYWGQ GTLVTVSA
79	49F8VK	DVVMTQSPLI LSVTIGQPAS ISCKSSQSLL YTNGKTYLNW LLQRPGQSPE RLIHLVSKLD SGVPDRFSGS GSGTDFTLKI SRVEAEDLGV YYCLQNSHFP HTFGSGTKLE IK
80	6A7F1VH	EVKLVESGGD LVRPGGSLKL SCAASGFTFS TYGMSWVRQS PEKRLEWVAS VTRGGNTYYP DSMRGRFTIS RDNVGNILYL HLRSLRSEDT AIYFCARDYS GWYFDVWGAG TTVTVSS
81	6A7F1VK	DVLMTQIPLS LPVSLGDQAS ISCRSSQSIV HSNGDTFLEW YLQKSGQSPK LLIYKVSNRF SGVPDRFSGS GSGTDFTLKI SRVEAEDLGV YYCFQGSRIP YTFGGGTKLE IK
82	3B4E7VH	QVQLQQSGAE LARPGASVKM SCKASGYTFT YYTIHWVKQR PGQGLEWIGY INPASSYTNY IQKFKDRATL TADKSSSTAY MQLSSLTSED SAVFYCARGA NWDYFDYWGQ GTTLTVSS
83	3B4E7VK	DVLMTQTPLS LPVSLGDQAS ISCRSSQNII QSNGNTYLEW YLQKPGQSPK LLIYKVSNRF SGVPDRFSGS GSGTDFTLKI SRVEAEDLGV YYCFQGSHVP YTFGGGTNLE IK
84	2F1E5VH	QIQLVQSGPE LKKPGETVKI SCKSSGFTLT NYGMNWVKQV PGKGLRWMGW INTYTGEPTY ADDFKGRFAF SLETSARTAY LQINNLKNED AATYFCARSA GTDYFDYWGQ GTTLTVSS
85	2F1E5VK	NFVLTQSPAS LAVSLGQRAT ISCRASESVD SYGNSFMHWC QQKPGQPPKL LIYLASNLES GVPARFSGSG SRTDFTLTID PVEADDAATY YCQQNNEDPW TFGGGTKLEI K
86	1F6G8VH	QIQLVQSGPE LKKPGETVKI SCKSSGFTLT NYGMNWVKQV PGKGLRWMGW INTYTGEPTY ADDFKGRFAF SLETSARTAY LQINNLKNED AATYFCARSA GTDYFDYWGQ GTTLTVSS
87	1F6G8VK	DVLMTQTPLS LPVSLGDQAS ISCRSSQNIV QTNGNTYLEW YLQKPGQSPN LLIYKVSSRF SGVPDRFSGS GSGTDFTLKI SRVEAEDLGV YYCFQGSHVP FTFGGGTKLE IK
88	2D2E3VH	QAQIHLVQSG PELKKPGETV KISCKASGYT FTHSGMNWMK QTPGKDLKWM GWINTNTGEP TYAEEFNGRF AFSLEASANT AYLQINNLKN EDTATYFCAR SWWTDYFDYW GQGTTLTVSS
89	2D2E3VK	DVLMTQTPLS LPVSLGDQTS ISCRSSQSIV HSNGNTYLEW YLQKPGQSPE LLIYKVSNRF SGVPDRISGS GSGTDFTLKI SRVEAEDLGV YYCFQGSHFP YTFGGGTKLE IT
90	27A9VH	QVQLQQPGAE LVKPGASVKL SCKASGYTFT NCYMHWVKQR PGQGLEWIGE TNPRNGGTNY NEKFKRKATL TVNKYSSTAY MQLSSLTSED SAVYYCTIGT SGYEYFDYWG QGTTLTVSS

91	27A9VK	NILMTQTPLS LPVSLGDQAS ISCRSSQSIV HSDGNIYLEW YLQKPGQSPK VLIYKVSYRF SGVPDRFSGS GSGTYFTLKI SRVEAEDLGV YFCFQGSHVP YTFGGGTKLE IK
92	VH5C	QVQLVQSGAE VKKPGASVKV SCKASGYTFT DYYMHWVRQA PGQGLEWMGE TNPRNGGTTY NEKFKGKATM TRDTSTSTAY MELSSLRSED TAVYYCTIGT SGYDYFDYWG QGTLVTVSS
93	VK18	DIVMTQTPLS LSVTPGQPAS ISCRSSQSIV HSDGNIYLEW YLQKPGQSPK LLIYKVSYRF SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCFQASHVP YTFGQGTKLE IK
94	VK21	DIVMTQTPLS LSVTPGQPAS ISCRSSQSIV HSDGNIYLEW YLQKPGQSPK LLIYKVSYRF SGVPDRFSGS GSGTGFTLKI SRVEAEDVGV YYCFQASHVP YTFGGGTKLE IK
95	Clone 22 chimeric HC	QVQLEQSGPG LVAPSQRLSI TCTVSGFSLT SYIVDWVRQS PGKGLEWLGV IWAGGSTNYN SALRSRLSIT KSNSKSQVFL QMNSLQTDDT AIYYCASAAY YSYYNYDGFA YWGQGTLVTV SAASTKGPSV FPLAPSSKST SGGTAALGCL VKDYFPEPVT VSWNSGALTS GVHTFPAVLQ SSGLYSLSSV VTVPSSSLGT QTYICNVNHK PSNTKVDKRV EPKSCDKTHT CPPCPAPEAA GGPSVFLFPP KPKDTLMISR TPEVTCVVVD VSHEDPEVKF NWYVDGVEVH NAKTKPREEQ YNSTYRVVSV LTVLHQDWLN GKEYKCKVSN KALPAPIEKT ISKAKGQPRE PQVYTLPPSR EEMTKNQVSL TCLVKGFYPS DIAVEWESNG QPENNYKTTP PVLDSDGSFF LYSKLTVDKS RWQQGNVFSC SVMHEALHNH YTQKSLSLSP GK
96	Clone 22 chimeric LC	DVVMTQTPLT LSVTIGQPAS ISCKSSQSLL YTNGKTYLYW LLQRPGQSPK RLIYLVSKLD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGI YYCLQSTHFP HTFGGGTKLE IKRTVAAPSV FIFPPSDEQL KSGTASVVCL LNNFYPREAK VQWKVDNALQ SGNSQESVTE QDSKDSTYSL SSTLTLSKAD YEKHKVYACE VTHQGLSSPV TKSFNRGEC
97	hCL Domain	RTVAAPSVFI FPPSDEQLKS GTASVVCLLN NFYPREAKVQ WKVDNALQSG NSQESVTEQD SKDSTYSLSS TLTLSKADYE KHKVYACEVT HQGLSSPVTK SFNRGEC
98	hCH Domain	ASTKGPSVFP LAPSSKSTSG GTAALGCLVK DYFPEPVTVS WNSGALTSGV HTFPAVLQSS GLYSLSSVVT VPSSSLGTQT YICNVNHKPS NTKVDKRVEP KSCDKTHTCP PCPAPEAAGG PSVFLFPPKP KDTLMISRTP EVTCVVVDVS HEDPEVKFNW YVDGVEVHNA KTKPREEQYN STYRVVSVLT VLHQDWLNGK EYKCKVSNKA LPAPIEKTIS KAKGQPREPQ VYTLPPSREE MTKNQVSLTC LVKGFYPSDI AVEWESNGQP ENNYKTTPPV LDSDGSFFLY SKLTVDKSRW QQGNVFSCSV MHEALHNHYT QKSLSLSPGK
99	HCVH5C	QVQLVQSGAE VKKPGASVKV SCKASGYTFT DYYMHWVRQA PGQGLEWMGE TNPRNGGTTY NEKFKGKATM TRDTSTSTAY MELSSLRSED TAVYYCTIGT SGYDYFDYWG QGTLVTVSSA STKGPSVFPL APSSKSTSGG TAALGCLVKD YFPEPVTVSW

		NSGALTSGVH TFPAVLQSSG LYSLSSVVTV PSSSLGTQTY ICNVNHKPSN TKVDKKVEPK SC
100	LCVK18	DIVMTQTPLS LSVTPGQPAS ISCRSSQSIV HSDGNIYLEW YLQKPGQSPK LLIYKVSYRF SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCFQASHVP YTFGQGTKLE IKRTVAAPSV FIFPPSDEQL KSGTASVVCL LNNFYPREAK VQWKVDNALQ SGNSQESVTE QDSKDSTYSL SSTLTLSKAD YEKHKVYACE VTHQGLSSPV TKSFNRGEC
101	LCVK21	DIVMTQTPLS LSVTPGQPAS ISCRSSQSIV HSDGNIYLEW YLQKPGQSPK LLIYKVSYRF SGVPDRFSGS GSGTGFTLKI SRVEAEDVGV YYCFQASHVP YTFGGGTKLE IKRTVAAPSV FIFPPSDEQL KSGTASVVCL LNNFYPREAK VQWKVDNALQ SGNSQESVTE QDSKDSTYSL SSTLTLSKAD YEKHKVYACE VTHQGLSSPV TKSFNRGEC

The mouse monoclonal antibody clone 22 was tested for its ability to neutralize dabigatran anticoagulant activity in human plasma in the thrombin clotting time assay outlined in Example II. The antibody completely reversed the dabigatran-mediated prolongation of thrombin dependent clotting in human plasma in a dose dependent manner (Figure 5). The antibody also effectively inhibited dabigatran function in human whole blood. A Fab generated from this antibody blocked dabigatran activity in human plasma demonstrating that monovalent antigen binding domains can neutralize compound anticoagulant activity. (Figure 6).

The major metabolic pathway of dabigatran in humans is through the glucuronidation of the carboxylate moiety. Dabigatran acylglucuronides have been shown to be pharmacologically active (Ebner et al., Drug Metab. Dispos. 2010, 38(9):1567-75). To test whether the mouse monoclonal antibody clone 22 could neutralize these metabolites, dabigatran acylglucuronides were purified from the urine of rhesus monkeys treated with dabigatran and evalulated in the thrombin clotting time assay. The antibody dose dependently reversed the dabigatran acylglucuronide-mediated prolongation of thrombin dependent clotting in human plasma with similar potency to that seen with dabigatran (Figure 7). Thus the antibody is effective in blocking the anticoagulant activity of dabigatran metabolites found in humans.

The affinities of the Fab and the mouse-human chimeric antibodies comprising the variable domains of clone 22 were determined using Kinexa technology. A constant

concentration of Fab or chimeric antibody was incubated with various concentrations of dabigatran until equilibrium was reached. After this incubation the concentration of free antibody was determined by capturing the antibody on Neutravidin beads coupled with a Biotin-conjugated dabigatran analog. The captured Fab was detected with an anti-Mouse IgG (Fab specific) F(ab')2 fragment labeled with FITC. The captured chimeric antibodies were detected with an anti-human IgG conjugated with Cy5. The dissociation constants were calculated using a 1:1 binding model. The results from these experiments are summarized in the table below.

Affinity of anti-dabigatran antibodies

Antibody	Apparent K_d
Clone 22 Fab	48 pM
Clone 22 Chimeric Ab	34 pM

Both the Fab and the chimeric antibodies bind dabigatran with high affinity.

Thrombin clotting time assay

Briefly human plasma is obtained by taking whole blood into 3.13% sodium citrate. This is then centrifuged to obtain platelet free plasma and transferred to a separate tube and frozen until required on the day of the assay. Plasma is thawed at 37°C on the day of the assay.

The thrombin clotting time is performed as follows. First thrombin is diluted to manufacturer's specification (3 IU/mL thrombin) in the buffer provided (Dade Behring Test kit) and prewarmed to 37°C. It is used within 2 hrs of being prepared. All assays were performed on a commercially available CL4 clotting machine (Behnk Electronics, Norderstadt, Germany). Fifty µL of plasma is pipetted into provided cuvettes with a magnetic stirrer and allowed to stir for 2 min in the well preheated to 37°C in the CL4 machine. At this point 100 µL of the thrombin solution is added and the time required for the plasma sample to clot is recorded automatically by the CL4. Dabigatran is preincubated for 5 min in plasma in the provided cuvettes, before adding thrombin and starting the measurement. If antibody is also tested (up 50 µL of stock solution), there is a

further 5 minute incubation at 37°C before beginning clotting (i.e. 10 min total incubation with dabigatran, 5 min total incubation with antibody and then clotting is initiated with thrombin).

Activity of chimeric antibodies and humanized Fabs in the thrombin time assay is shown in Figures 8 -10, respectively.

Affinity determinations (Kinexa Method)

The affinities of Fab and mouse-human chimeric antibodies were determined using KinExA® technology. A constant concentration of Fab or chimeric antibody was incubated with various concentrations of dabigatran until equilibrium was reached. After this incubation the concentration of free antibody was determined by capturing the antibody on Neutravidin beads coupled with a Biotin-conjugated dabigatran analog. The captured Fab was detected with an anti-human IgG (Fab specific) F(ab')2 fragment labeled with FITC. The captured chimeric antibodies were detected with an anti-human IgG conjugated with Cy5. The dissociation constants (K_D) were calculated using a 1:1 binding model.

To measure rate constants (k_{on} and k_{off}) with the KinExA® instrument, the Kinetics Direct method was used. In this method, the binding partners are mixed in solution, and the concentration of free active binding sites is probed over time as active binding sites are depleted due to the formation of complexes. Data points are collected at specified time intervals and the signals are analyzed. In this way, k_{on} is measured directly and the off-rate k_{off} is calculated as $k_{off} = K_D \times k_{on}$.

Table: K_D values of chimeric antibodies determined using KinExA® technology.

Chimeric Ab	K_D (pM)
45B6	545
48E1	281
35E6	52
49F8	40
27A9	120

Table: K_D values, k_{on} and k_{off} of humanized Fabs VH5C/VK18 and VH5C/VK21

Fab	**K_D**	**k_{on}**	**k_{off} (calculated)**
VH5C/VK18	133 pM	9.38e+005/Ms	1.25e-004 /s
VH5C/VK21	147 pM	1.377e+006/Ms	2.02e-004 /s

Fab-dabigatran complex formation and crystallization

The Fabs were concentrated to 10 mg/ml, mixed with a 2 molar excess of dabigatran and incubated for 1 h at 4 °C. Complex and crystallization solution were mixed 1:1. The complex crystallizes in 25 % PEG 1500, 0.1 M SPG buffer (pH7).

Data collection and structure determination

Datasets for all crystals were collected on the Swiss light Source beamline PXI - X06SA of the Paul Scherrer Institut. All datasets were processed with the autoPROC package (Vonrhein, C., Flensburg, C., Keller, P., Sharff, A., Smart, O., Paciorek, W., Womack, T. & Bricogne, G. (2011). Data processing and analysis with the autoPROC toolbox. Acta Cryst. D67, 293-302.).

Fab VH5C/VK21:Dabigatran crystals grew in space group P212121 with unit cell dimensions a=59.97 Å, b=78.39 Å, c= 87,67 Å and diffract to 2.2 Å resolution. The complex structure was solved by molecular replacement with the program phaser (Collaborative Computational Project, number 4. 1994. "The CCP4 Suite: Programs for Protein Crystallography". Acta Cryst. D50, 760-763. Phaser crystallographic software. McCoy AJ, Grosse-Kunstleve RW, Adams PD, Winn MD, Storoni LC, Read RJ. J. Appl. Cryst. (2007). 40, 658-674.) using a homologous Fab structure (PDB-ID 1C1E) as the starting search model. Analysis of the electron density map showed clear electron density for dabigatran. The complete structure was improved with multiple rounds of model building with Coot and refinement with autoBUSTER (Coot: model-building tools for molecular graphics" Emsley P, Cowtan K *Acta Crystallographica Section D-Biological Crystallography* **60**: 2126-2132 Part 12 Sp. Iss. 1 DEC 2004. Bricogne G., Blanc E.,

Brandl M., Flensburg C., Keller P., Paciorek W., Roversi P, Sharff A., Smart O.S., Vonrhein C., Womack T.O. (2011). BUSTER version 2.11.2. Cambridge, United Kingdom: Global Phasing Ltd).

Fab VH5C/VK18:Dabigatran crystals grew in space group P21 and P212121, respectively. Crystals with space group P21 showed unit cell dimensions of a=51.81 Å, b=128.92 Å, c= 60.26 Å and diffract to 1.9 Å resolution. Crystals with space group P212121 showed unit cell dimensions of a=48.20 Å, b=59.74 Å, c= 127.69 Å and diffract to 2.2 Å resolution. Both complex structures were solved by molecular replacement with the program phaser using the structure of Fab VH5C/VK21 as the starting search model. Analysis of the electron density maps showed clear electron density for dabigatran. The complete structures were improved with multiple rounds of model building with Coot and refinement with autoBUSTER.

In silico analysis of Spatial Aggregation Propensity (SAP)

The spatial aggregation propensities (SAP) for each atom and each residue was calculated as described in (1) with the exception that residue hydrophobicity parameters where taken from (2). The Fv SAP is calculated as the sum over all positive residue SAP values in the variable domains of the antibody. The CDR SAP is calculated as the sum over all positive residue SAP values in the complementary determining regions of the antibody. Fv SAP and CDR SAP have been calculated for 850 different antibody structures from the protein data bank (PDB), yielding a mean (μ_{Fv} and μ_{CDR}) and standard deviation values (σ_{Fv} and σ_{CDR}) for both properties.

Z-scores for the Fv SAP and CDR SAP for the antibodies where then calculated according to

Z-score(Fv SAP) = (Fv SAP - μ_{Fv})/σ_{Fv} and

Z-score(CDR SAP) = (CDR SAP - μ_{CDR})/σ_{CDR}.

Results (Figure 11):

Humanized Fab 18/15:

Z-score(Fv SAP) = 1.06

Z-score(CDR SAP) = 1.00

Humanized Fab VH5C/VK18:

Z-score(Fv SAP) = -0.61

Z-score(CDR SAP) = -0.84

Humanized Fab VH5C/VK21:

Z-score(Fv SAP) = -0.61

Z-score(CDR SAP) = -0.78

Fab 18/15 (see WO2011089183) has more solvent-exposed hydrophobic surface than the average of known antibodies in the protein data bank.

Surprisingly, both VH5C/VK18 (SEQ ID NO: 99/SEQ ID NO: 100) and VH5C/VK21 comprises SEQ ID NO: 99/SEQ ID NO: 101) have less solvent-exposed hydrophobic surface than the average of known antibodies in the protein data bank (negative Z-scores). This means that these compounds have an increased solubility in aqueous media and a lower tendency for aggregation, making them more suitable for stable drug formulations with high antibody concentrations.

(1) Chennamsetty et. al., Proc Natl Acad Sci; **2009**, 106(29), pg 11937-11942
(2) Cowan and Whittaker, Pept Res; **1990**, 3(2), pg 75-80

Expression of Fab in CHO cells

Fabs were produced by transient transfection into CHO DG44 cells and subsequent selection and generation of stable cell pools. Figure 13 shows the titers of fed batch runs with Fab 18/15 (see WO2011089183), Fab VH5c/Vk18 and Fab VH5c/Vk21. Surprisingly, Fabs VH5c/Vk18 and VH5c/Vk21 show 5-10 fold higher titers as compared to Fab 18/15.

WHAT WE CLAIM

1. An antibody molecule against dabigatran comprising a heavy chain variable domain with a CDR1 selected from the group consisting of SEQ ID NO: 1, 7, 13, 19, 25, 31, 37, 43, 49, 55, 61, and 67, a CDR2 selected from the group consisting of SEQ ID NO: 2, 8, 14, 20, 26, 32, 38, 44, 50, 56, 62, and 68, and a CDR3 selected from the group consisting of SEQ ID NO: 3, 9, 15, 21, 27, 33, 39, 45, 51, 57, and 63, and a light chain variable domain with a CDR1 selected from the group consisting of SEQ ID NO: 4, 10, 16, 22, 28, 34, 40, 46, 52, 58, and 64, a CDR2 selected from the group consisting of SEQ ID NO: 5, 11, 17, 23, 29, 35, 41, 47, 53, 59, and 65, and a CDR3 selected from the group consisting of SEQ ID NO: 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, and 69.

2. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 1, a CDR2 of SEQ ID NO: 2, and a CDR3 of SEQ ID NO: 3, and a light chain variable domain with a CDR1 of SEQ ID NO: 4, a CDR2 of SEQ ID NO: 5, and a CDR3 of SEQ ID NO: 6.

3. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 7, a CDR2 of SEQ ID NO: 8, and a CDR3 of SEQ ID NO: 9, and a light chain variable domain with a CDR1 of SEQ ID NO: 10, a CDR2 of SEQ ID NO: 11, and a CDR3 of SEQ ID NO: 12.

4. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 13, a CDR2 of SEQ ID NO: 14, and a CDR3 of SEQ ID NO: 15, and a light chain variable domain with a CDR1 of SEQ ID NO: 16, a CDR2 of SEQ ID NO: 17, and a CDR3 of SEQ ID NO: 18.

5. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 19, a CDR2 of SEQ ID NO: 20, and a CDR3 of SEQ ID NO: 21, and a light chain variable domain with a CDR1 of SEQ ID NO: 22, a CDR2 of SEQ ID NO: 23, and a CDR3 of SEQ ID NO: 24.

6. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 25, a CDR2 of SEQ ID NO: 26, and a CDR3 of SEQ ID NO: 27, and a light chain variable domain with a CDR1 of SEQ ID NO: 28, a CDR2 of SEQ ID NO: 29, and a CDR3 of SEQ ID NO: 30.

7. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 31, a CDR2 of SEQ ID NO: 32, and a CDR3 of SEQ ID NO: 33, and a light chain variable domain with a CDR1 of SEQ ID NO: 34, a CDR2 of SEQ ID NO: 35, and a CDR3 of SEQ ID NO: 36.

8. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 37, a CDR2 of SEQ ID NO: 38, and a CDR3 of SEQ ID NO: 39, and a light chain variable domain with a CDR1 of SEQ ID NO: 40, a CDR2 of SEQ ID NO: 41, and a CDR3 of SEQ ID NO: 42.

9. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 43, a CDR2 of SEQ ID NO: 44, and a CDR3 of SEQ ID NO: 45, and a light chain variable domain with a CDR1 of SEQ ID NO: 46, a CDR2 of SEQ ID NO: 47, and a CDR3 of SEQ ID NO: 48.

10. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 49, a CDR2 of SEQ ID NO: 50, and a CDR3 of SEQ ID NO: 51, and a light chain variable domain with a CDR1 of SEQ ID NO: 52, a CDR2 of SEQ ID NO: 53, and a CDR3 of SEQ ID NO: 54.

11. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 55, a CDR2 of SEQ ID NO: 56, and a CDR3 of SEQ ID NO: 57, and a light chain variable domain with a CDR1 of SEQ ID NO: 58, a CDR2 of SEQ ID NO: 59, and a CDR3 of SEQ ID NO: 60.

12. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 61, a CDR2 of SEQ ID NO: 62, and a CDR3 of SEQ ID NO: 63, and a light chain variable domain with a CDR1 of SEQ ID NO: 64, a CDR2 of SEQ ID NO: 65, and a CDR3 of SEQ ID NO: 66.

13. The antibody molecule of claim 1 comprising a heavy chain variable domain with a CDR1 of SEQ ID NO: 67, a CDR2 of SEQ ID NO: 68, and a CDR3 of SEQ ID NO: 9, and a light chain variable domain with a CDR1 of SEQ ID NO: 64, a CDR2 of SEQ ID NO: 65, and a CDR3 of SEQ ID NO: 69.

14. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 70, and a light chain variable domain of SEQ ID No: 71.

15. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 72, and a light chain variable domain of SEQ ID No: 73.

16. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 74, and a light chain variable domain of SEQ ID No: 75.

17. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 76, and a light chain variable domain of SEQ ID No: 77.

18. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 78, and a light chain variable domain of SEQ ID No: 79.

19. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 80, and a light chain variable domain of SEQ ID No: 81.

20. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 82, and a light chain variable domain of SEQ ID No: 83.

21. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 84, and a light chain variable domain of SEQ ID No: 85.

22. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 86, and a light chain variable domain of SEQ ID No: 87.

23. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 88, and a light chain variable domain of SEQ ID No: 89.

24. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 90, and a light chain variable domain of SEQ ID No: 91.

25. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 92, and a light chain variable domain of SEQ ID NO: 93.

26. The antibody molecule of claim 1 comprising a heavy chain variable domain of SEQ ID NO: 92, and a light chain variable domain of SEQ ID NO: 94.

27. The antibody molecule of any one of claims 1 to 26, wherein the light chain variable domain is fused to a constant domain of SEQ ID NO: 97.

28. The antibody molecule of any one of claims 1 to 25, wherein the heavy chain variable domain is fused to a constant domain of SEQ ID NO: 98.

29. The antibody molecule of claim 1 comprising a heavy chain of SEQ ID NO: 95, and a light chain of SEQ ID No: 96.

30. The antibody molecule of claim 1 comprising a heavy chain of SEQ ID NO: 99, and a light chain of SEQ ID No: 100.

31. The antibody molecule of claim 1 comprising a heavy chain of SEQ ID NO: 99, and a light chain of SEQ ID No: 101.

32. The antibody molecule of any one of the preceding claims which is a polyclonal antibody, a monoclonal antibody, a human antibody, a humanized antibody, a chimeric antibody, a fragment of an antibody, in particular a Fab, Fab', or $F(ab')_2$ fragment, a single chain antibody, in particular a single chain variable fragment (scFv), a Small Modular Immunopharmaceutical (SMIP), a domain antibody, a nanobody, a diabody, or a Designed Ankyrin Repeat Protein (DARPin).

33. The antibody molecule of any one of the preceding claims for use in medicine.

34. Antibody molecule of any one of the preceding claims for use in the therapy or prevention of side effects of anticoagulant therapy, and/or for reversal of an overdosing of an anticoagulant.

35. Antibody molecule of claim 34, wherein the side effect is a bleeding event.

36. Method of treatment or prevention of side effects of anticoagulant therapy, or of an overdosing event in anticoagulant therapy, comprising administering an effective amount of an antibody molecule of any one of the preceding claims to a patient in need thereof.

37. Method of manufacturing an antibody molecule of any one of the preceding claims, comprising

(a) providing a host cell comprising one or more nucleic acids encoding said antibody molecule in functional association with an expression control sequence,

(b) cultivating said host cell, and

(c) recovering the antibody molecule from the cell culture.

38. A kit comprising an antibody of any one of claims 1 to 32, or a pharmaceutical composition thereof.

39. A kit comprising:

(a) an antibody of any one of claims 1 to 32, or a pharmaceutical composition thereof;

(b) a container; and

(c) a label.

40. A kit comprising an antibody of any one of claims 1 to 32, and dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof.

41. A method for neutralizing or partially neutralizing dabigatran or 1-O-acylglucuronide of dabigatran in a patient being treated with dabigatran, dabigatran etexilate, a

prodrug of dabigatran or a pharmaceutically acceptable salt thereof, comprising administering an antibody of any one of claims 1 to 32, or a pharmaceutical composition thereof.

42. A method for neutralizing or partially neutralizing dabigatran or 1-O-acylglucuronide of dabigatran in a patient comprising:

(a) confirming that a patient was being treated with dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, and the amount that was taken by the patient;

(b) neutralizing dabigatran or 1-O-acylglucuronide with an antibody of any one of claims 1 to 32 prior to performing a clotting or coagulation test or assay wherein dabigatran or the 1-O-acylglucuronide of dabigatran would interfere with the accurate read out of the test or assay results;

(c) performing the clotting or coagulation test or assay on a sample taken from the patient to determine the level of clot formation without dabigatran or 1-O-acylglucuronide of dabigatran present; and

(d) adjusting an amount of dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof administered to the patient in order to achieve the appropriate balance between clot formation and degradation in a patient.

43. A method for reducing the concentration of dabigatran or 1-O-acylglucuronide of dabigatran in plasma of a patient being treated with dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, comprising the step of administering a reversal agent that neutralizes the activity of dabigatran or 1-O-acylglucuronide in the patient.

44. A method of reversal of the anticoagulant effect of dabigatran or 1-O-acylglucuronide of dabigatran in a patient being treated with dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, wherein the patient either has major bleeding considered life-threatening or leading to hemodynamic compromise, or wherein the patient requires emergency medical procedures, comprising the step of administering a reversal agent that neutralizes the activity of dabigatran or 1-O-acylglucuronide in the patient.

45. A method for reversing or reducing the activity of dabigatran or 1-O-acylglucuronide of dabigatran in a patient experiencing bleeding or at risk for bleeding due to an impaired clotting ability or trauma, comprising the steps of:

(a) determining the amount of dabigatran or 1-O-acylglucuronide of dabigatran present in the patient;

(b) administering an effective amount of an agent to reverse or reduce the activity of dabigatran or 1-O-acylglucuronide of dabigatran determined in the patient; and

(c) monitoring a thrombin clotting time of the patient to ensure a reversal or reduction in activity of dabigatran or 1-O-acylglucuronide of dabigatran has been reached.

46. Method of any one of claims 43 to 45, wherein the reversal agent is an antibody molecule against dabigatran.

47. Reversal agent that neutralizes the activity of dabigatran or the 1-O-acylglucuronide of dabigatran, for use in a patient being treated with dabigatran, dabigatran etexilate, a prodrug of dabigatran or a pharmaceutically acceptable salt thereof, wherein the patient either has major bleeding considered life-threatening or leading to hemodynamic compromise, or wherein the patient requires emergency medical procedures.

48. Reversal agent of claim 47 which is an antibody molecule against dabigatran.

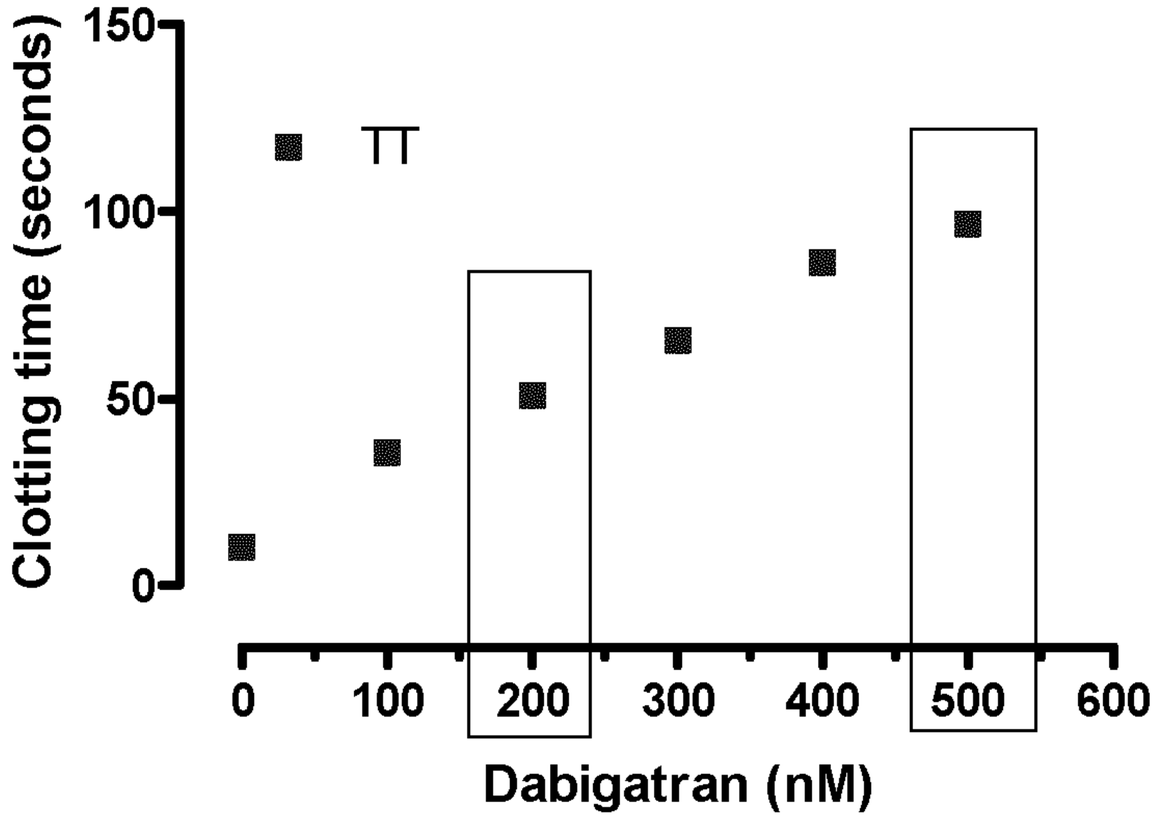

Clotting time (seconds)
150
100
50
0
TT
0
100
200
300
400
500
600
Dabigatran (nM)

Figure 1

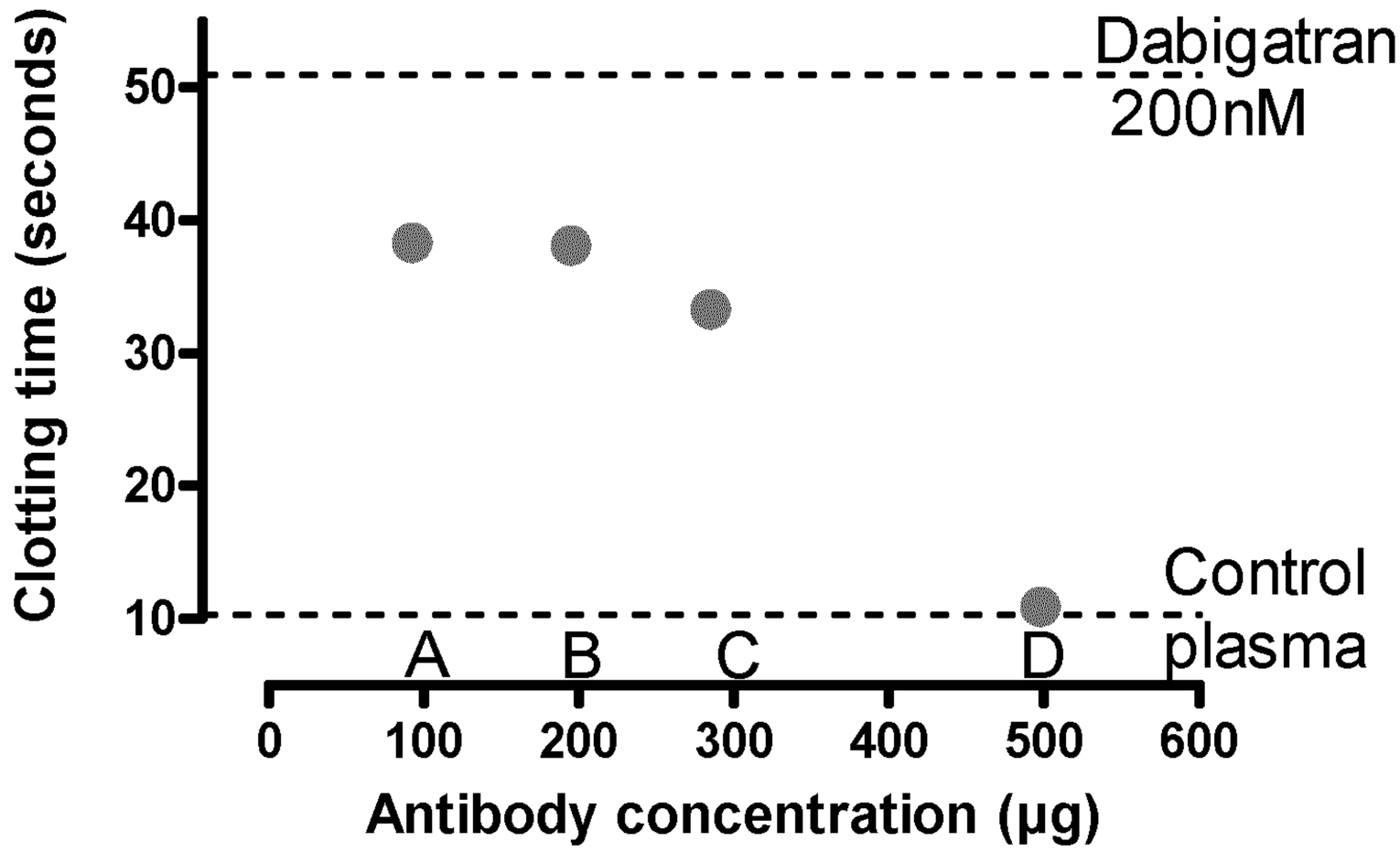

Clotting time (seconds)
50
40
30
20
10
Dabigatran
200nM
Control
plasma
A
B
C
D
0
100
200
300
400
500
600
Antibody concentration (µg)

Figure 2

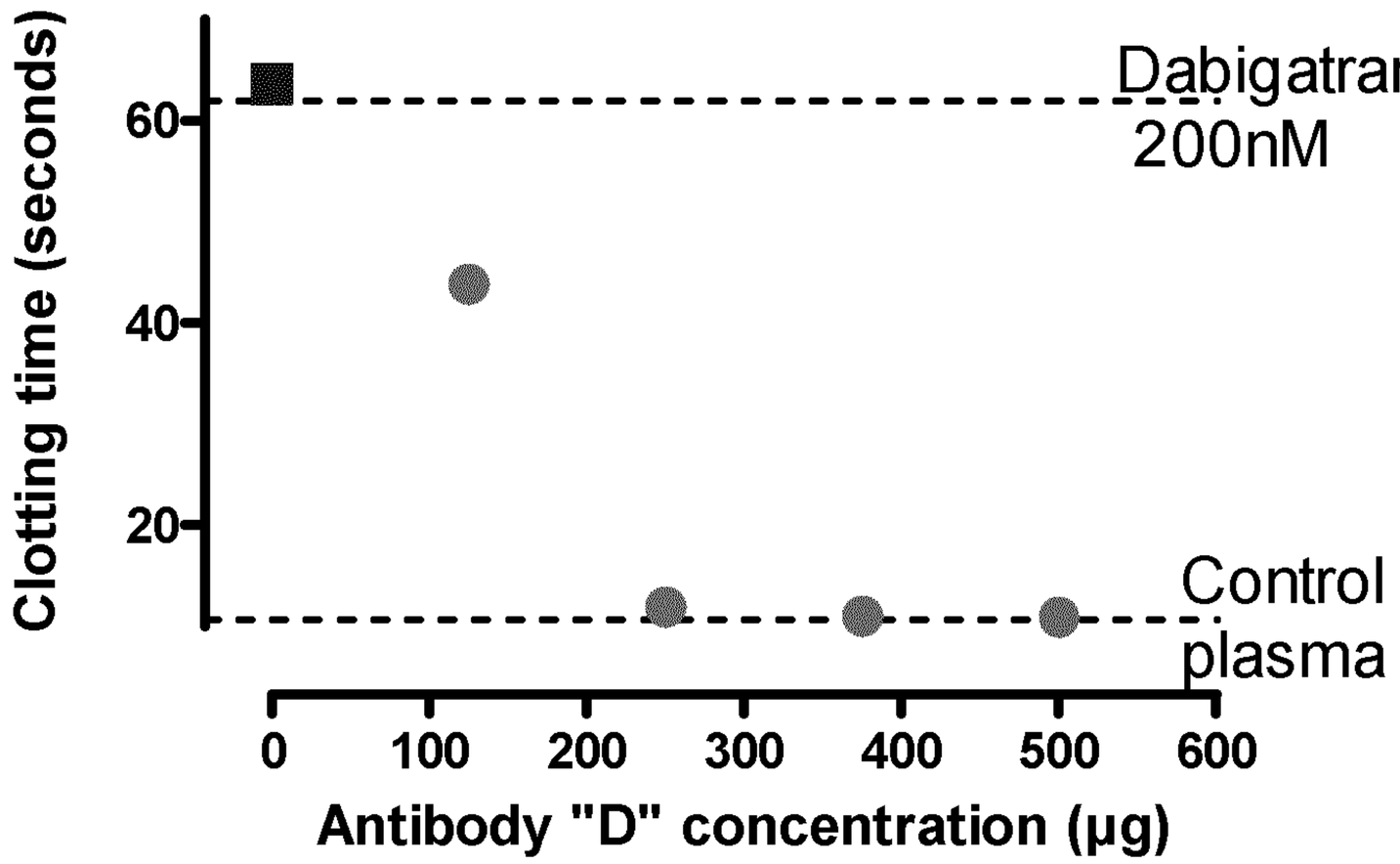

Clotting time (seconds)
60
40
20
Dabigatran
200nM
Control
plasma
0
100
200
300
400
500
600
Antibody "D" concentration (µg)
Nonspecific polyclonal Ab (167µg) + 200 nM dabigatran

Figure 3

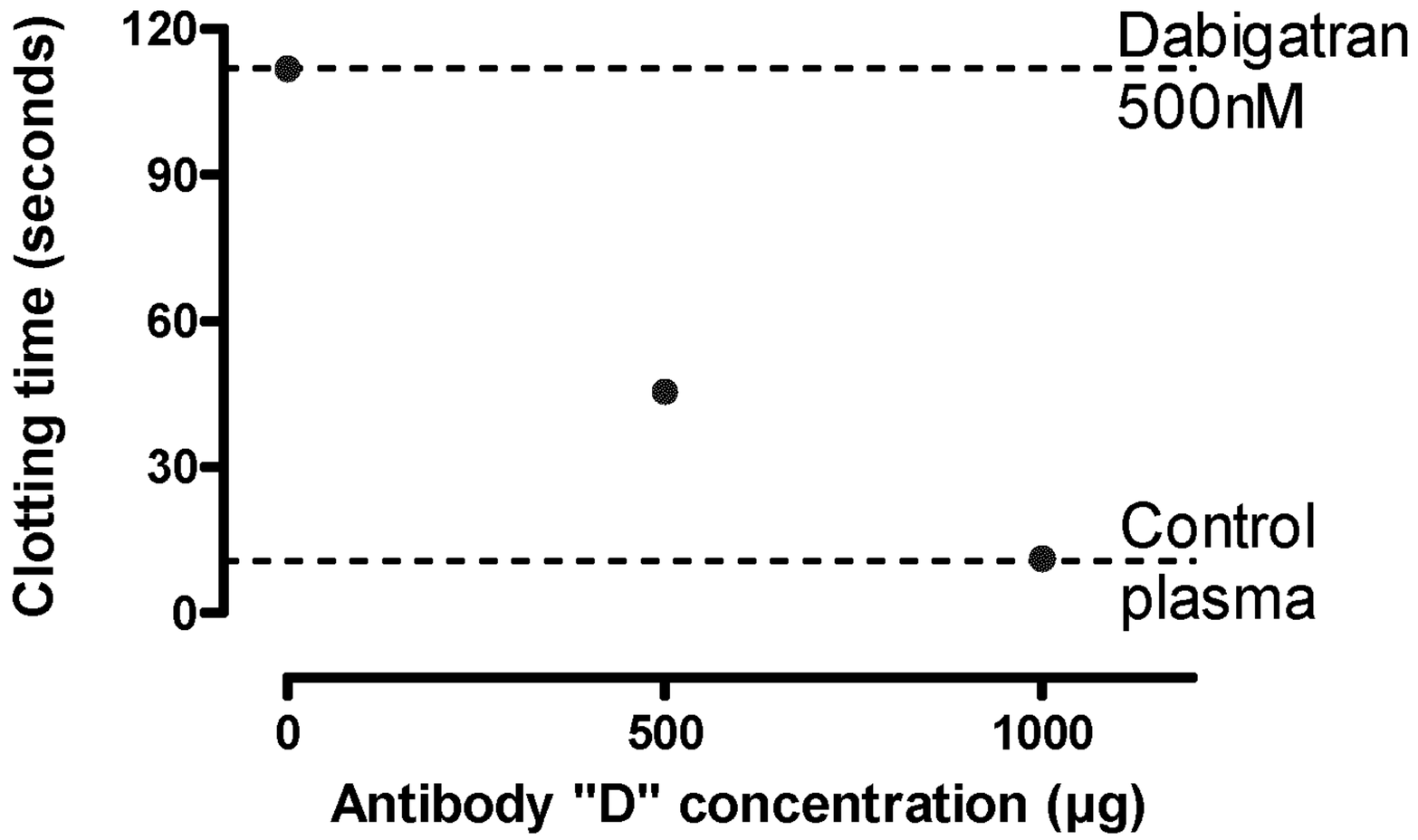

Clotting time (seconds)
120
90
60
30
0
Dabigatran
500nM
Control
plasma
0
500
1000
Antibody "D" concentration (µg)

FIGURE 4

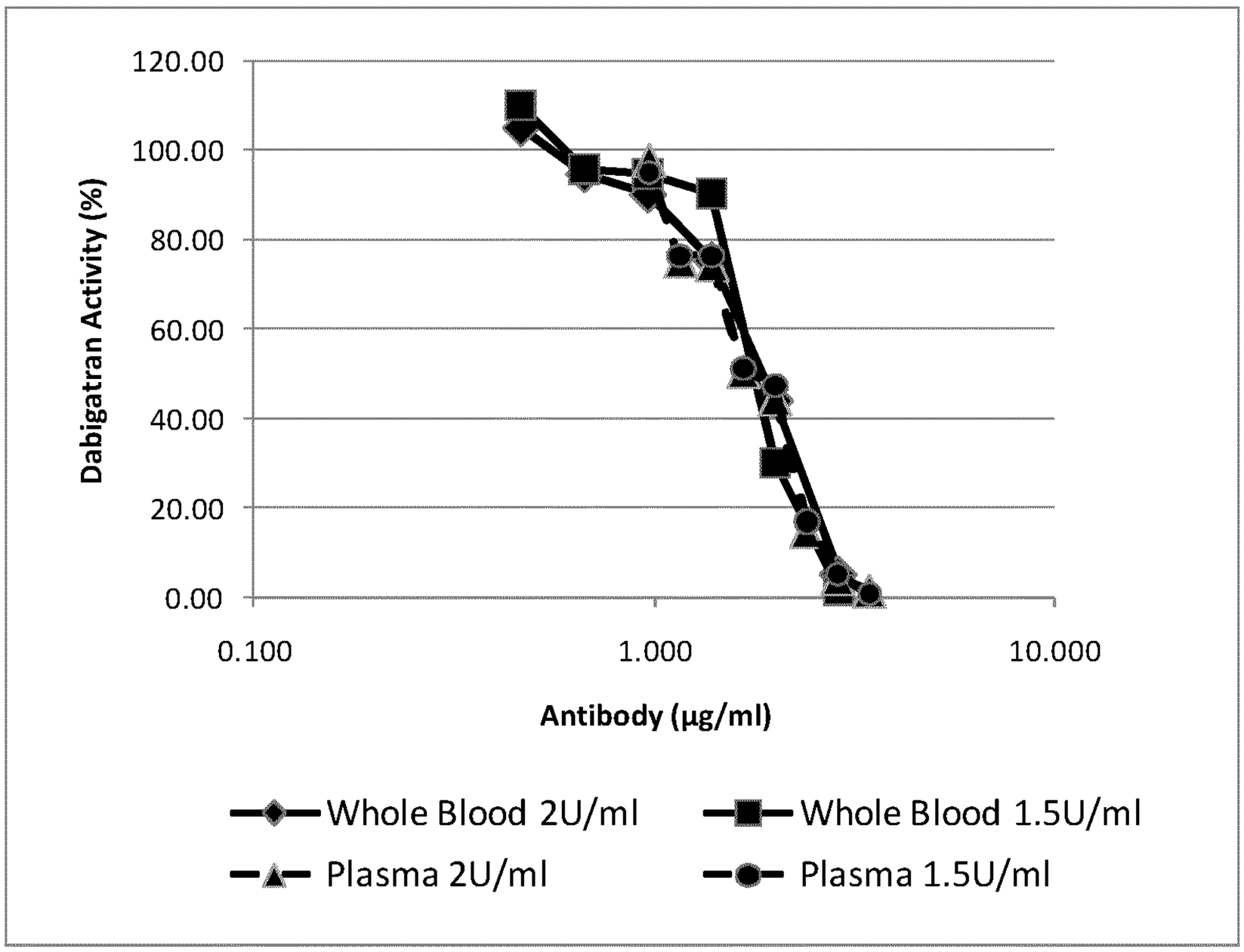

120.00
100.00
80.00
60.00
40.00
20.00
0.00
Dabigatran Activity (%)
0.100
1.000
10.000
Antibody (µg/ml)
Whole Blood 2U/ml
Whole Blood 1.5U/ml
Plasma 2U/ml
Plasma 1.5U/ml

FIGURE 5

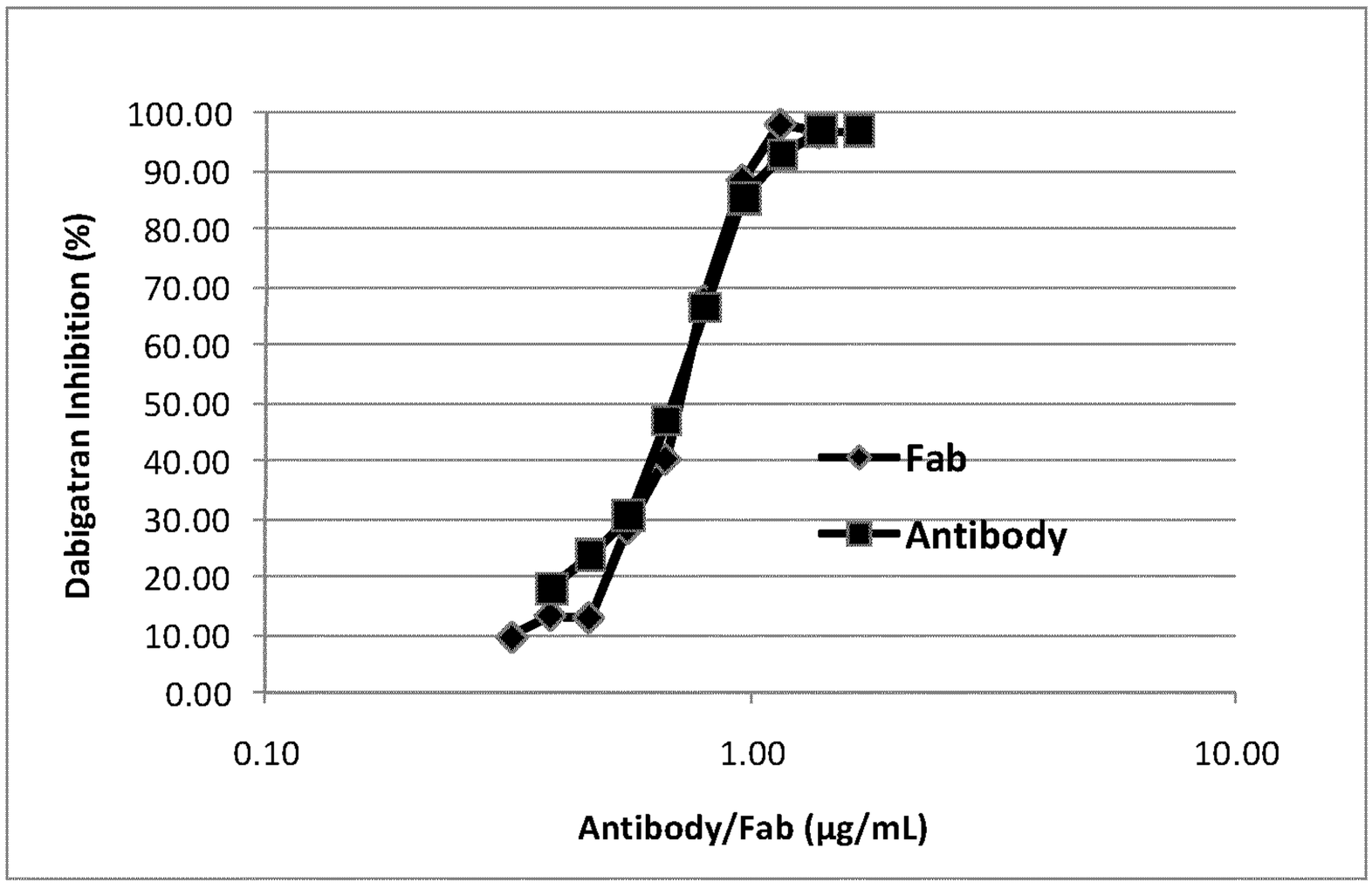

100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Dabigatran Inhibition (%)
0.10
1.00
10.00
Antibody/Fab (µg/mL)
Fab
Antibody

FIGURE 6

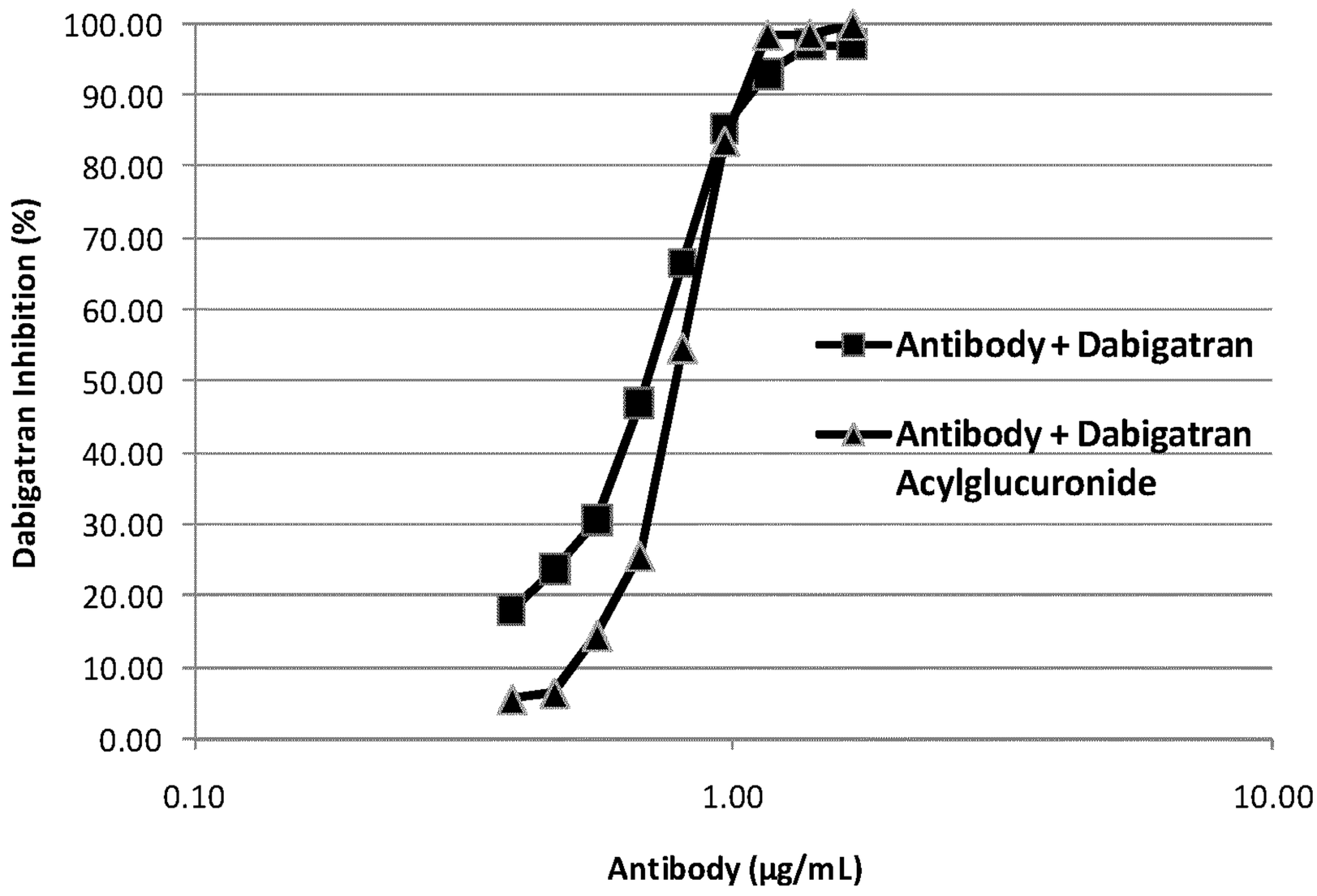

100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Dabigatran Inhibition (%)
0.10
1.00
10.00
Antibody (µg/mL)
Antibody + Dabigatran
Antibody + Dabigatran Acylglucuronide

FIGURE 7

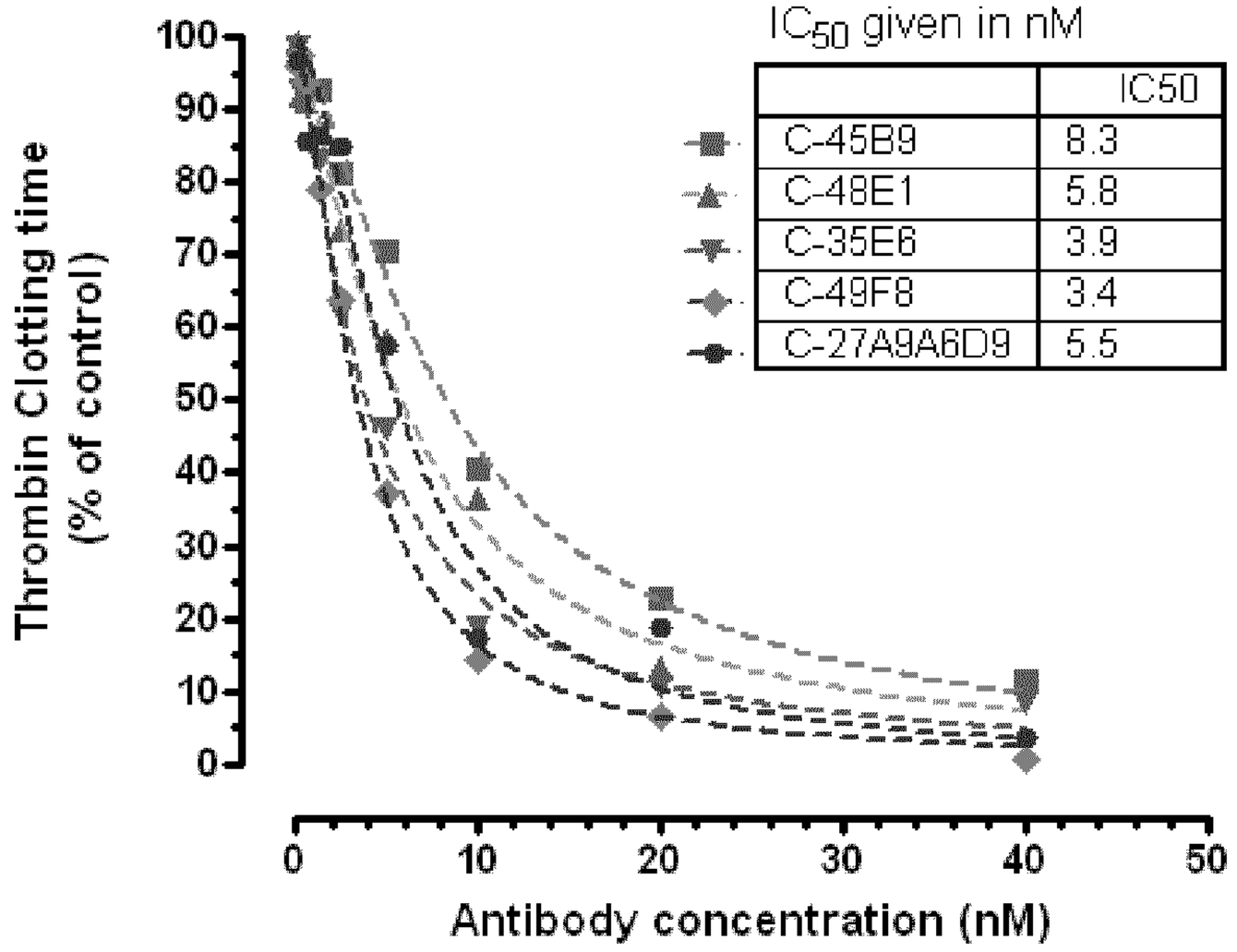

IC50 given in nM
IC50
C-45B9 8.3
C-48E1 5.8
C-35E6 3.9
C-49F8 3.4
C-27A9A6D9 5.5
Thrombin Clotting time (% of control)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
Antibody concentration (nM)

Figure 8

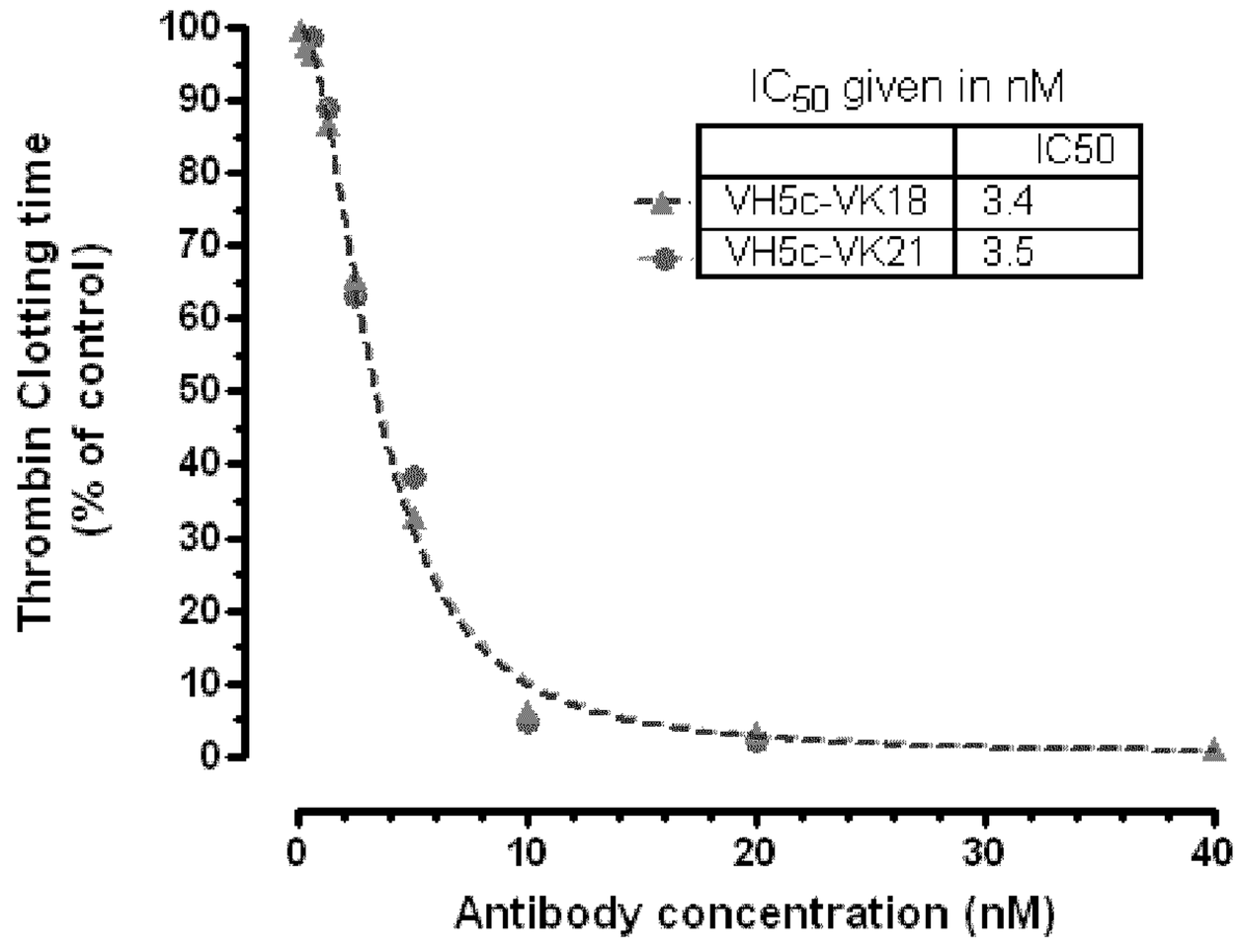

Thrombin Clotting time
(% of control)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
Antibody concentration (nM)
IC50 given in nM
IC50
VH5c-VK18 3.4
VH5c-VK21 3.5

Figure 9

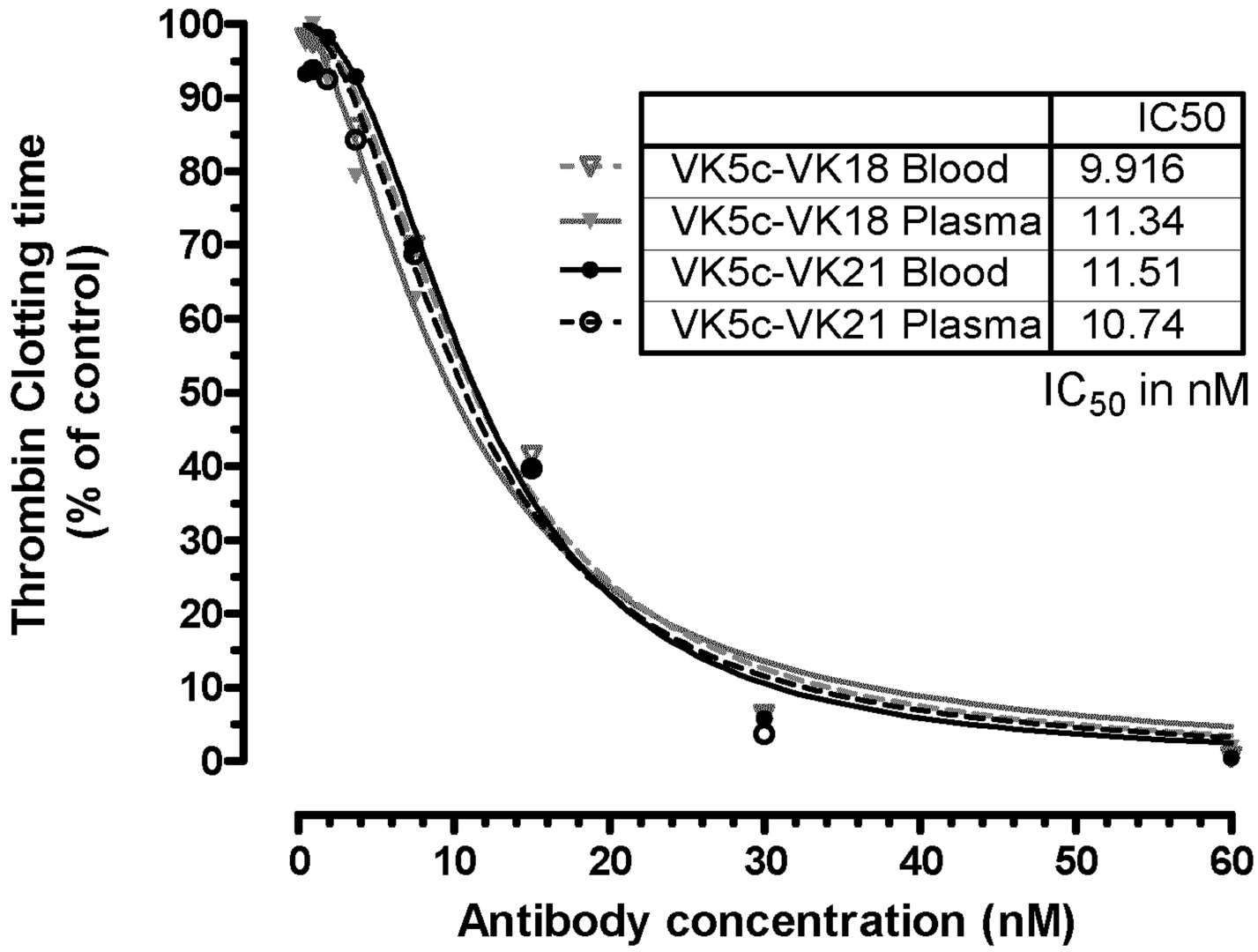
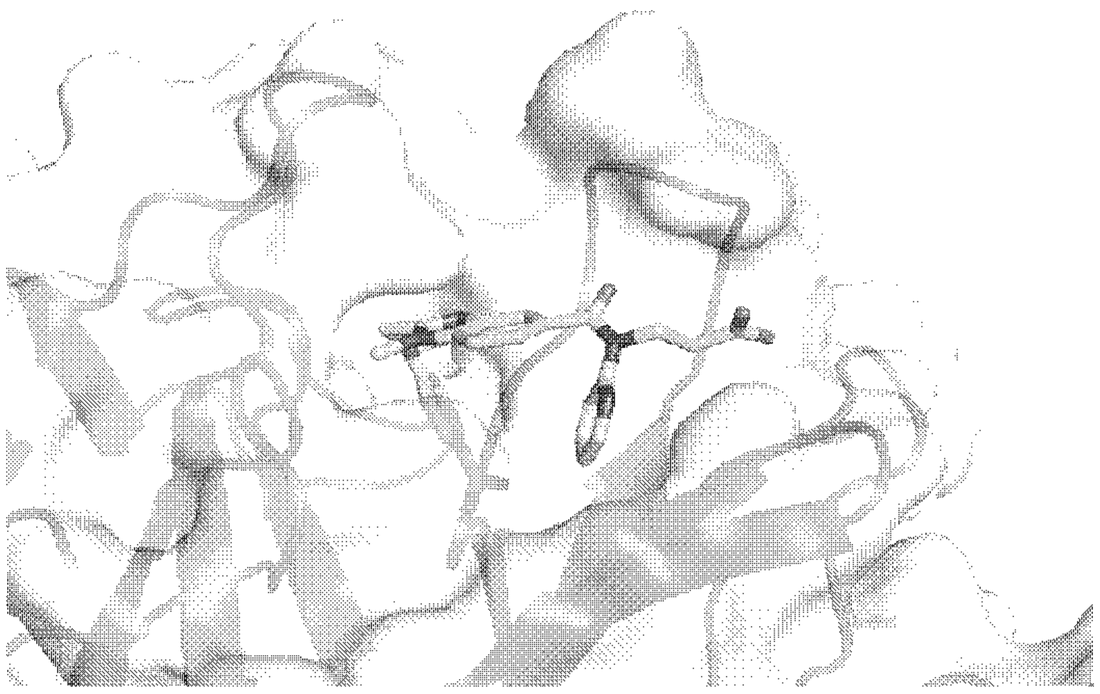
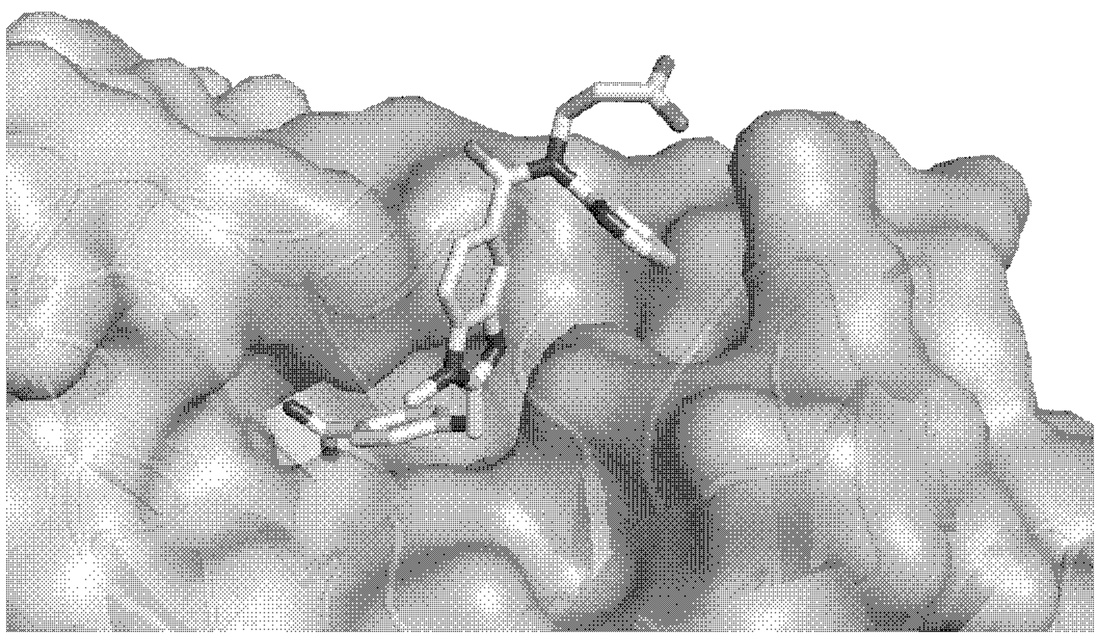

Thrombin Clotting time
(% of control)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
Antibody concentration (nM)
IC50
VK5c-VK18 Blood 9.916
VK5c-VK18 Plasma 11.34
VK5c-VK21 Blood 11.51
VK5c-VK21 Plasma 10.74
IC50 in nM

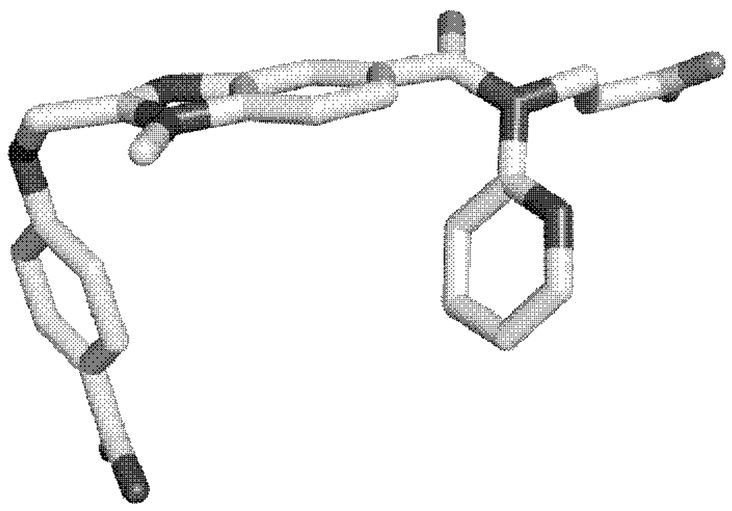
Figure 10



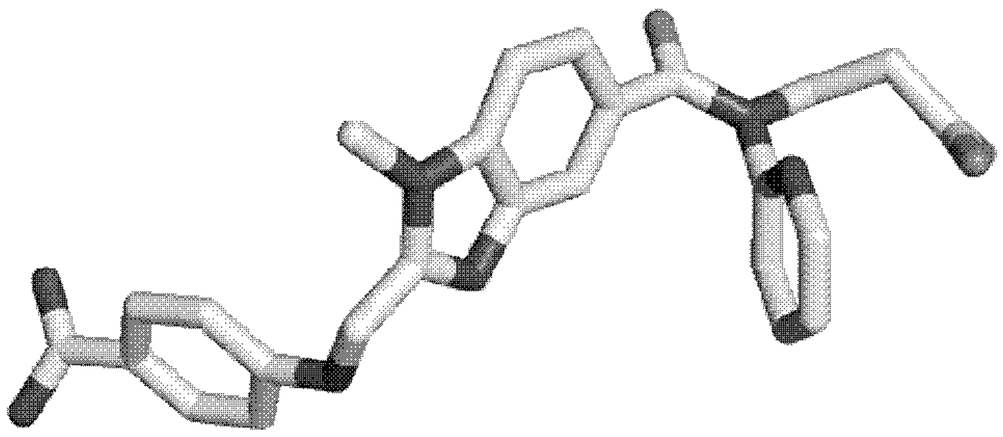
A



B



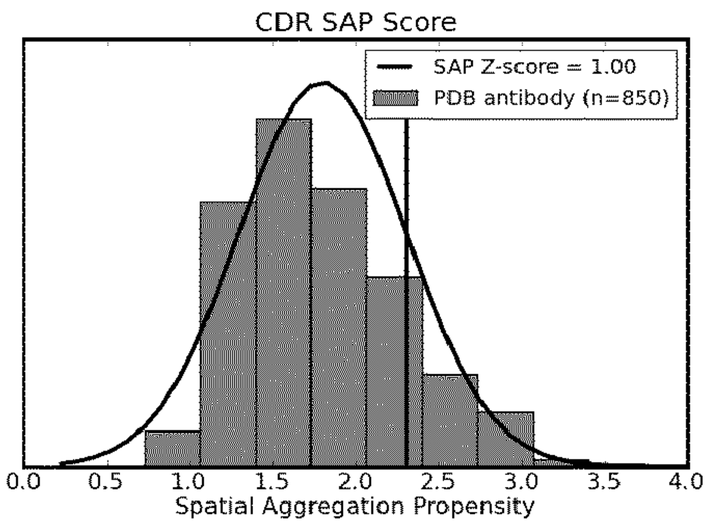
C

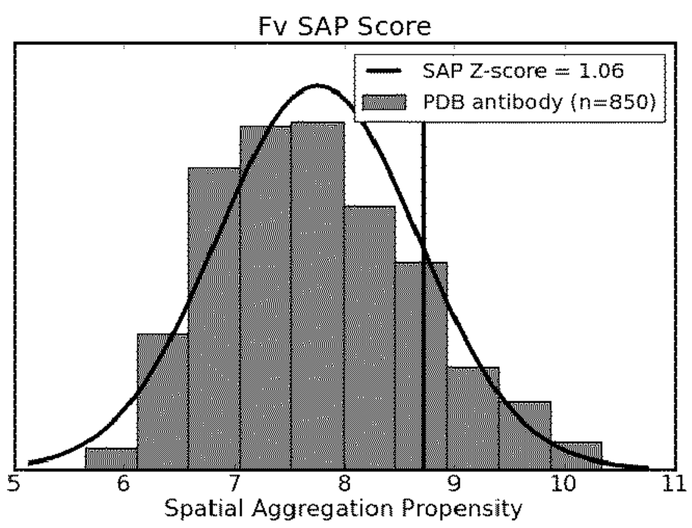


D

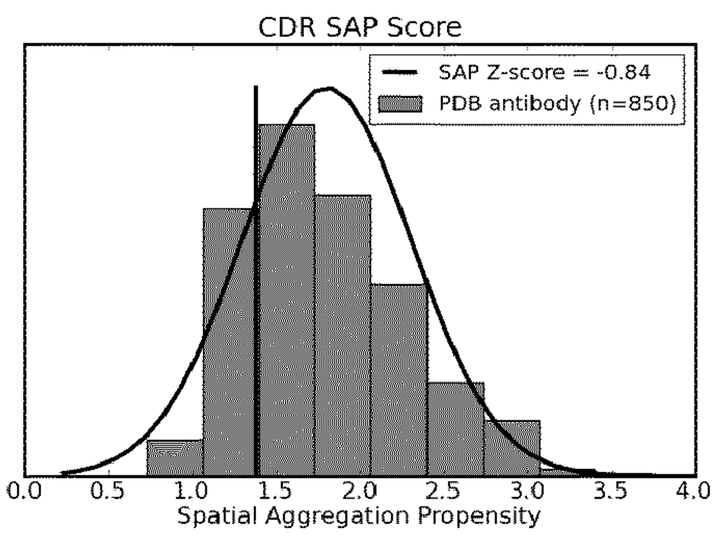
Figure 11

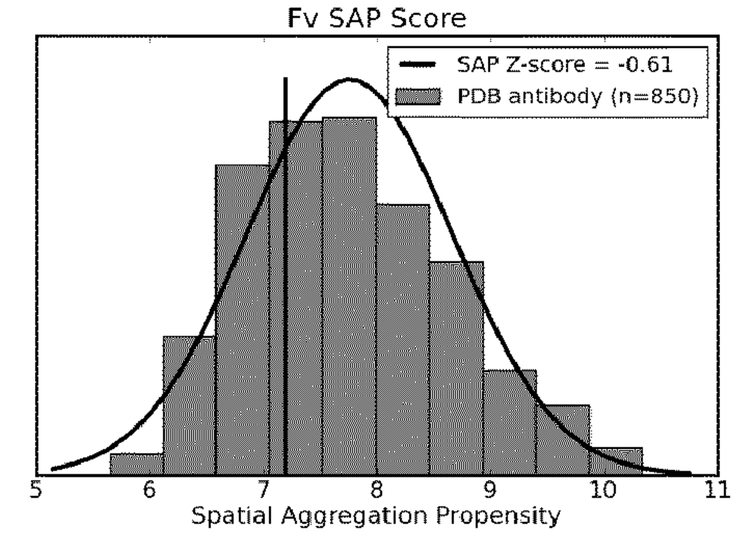
A) Fab 18/15



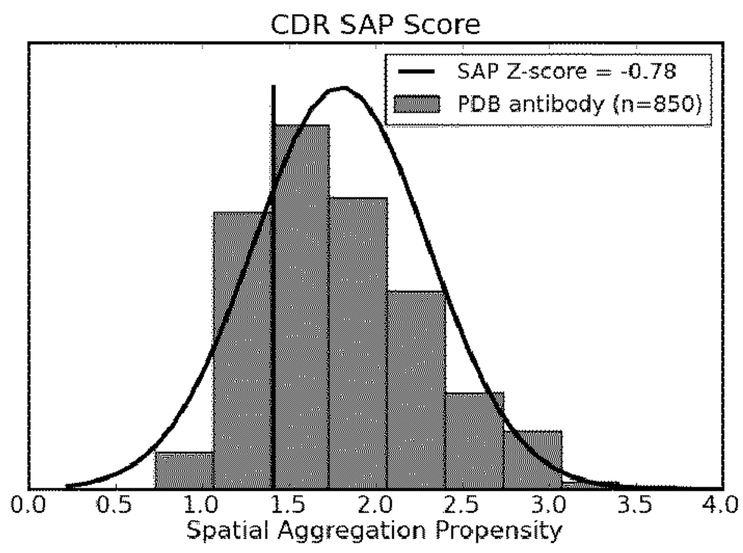


B) Fab VH5C/VK18





C) Fab VH5C/VK21



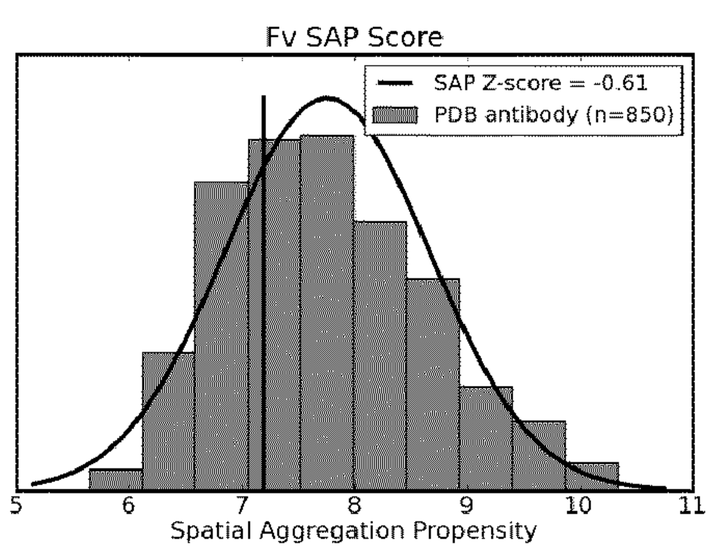


Figure 12

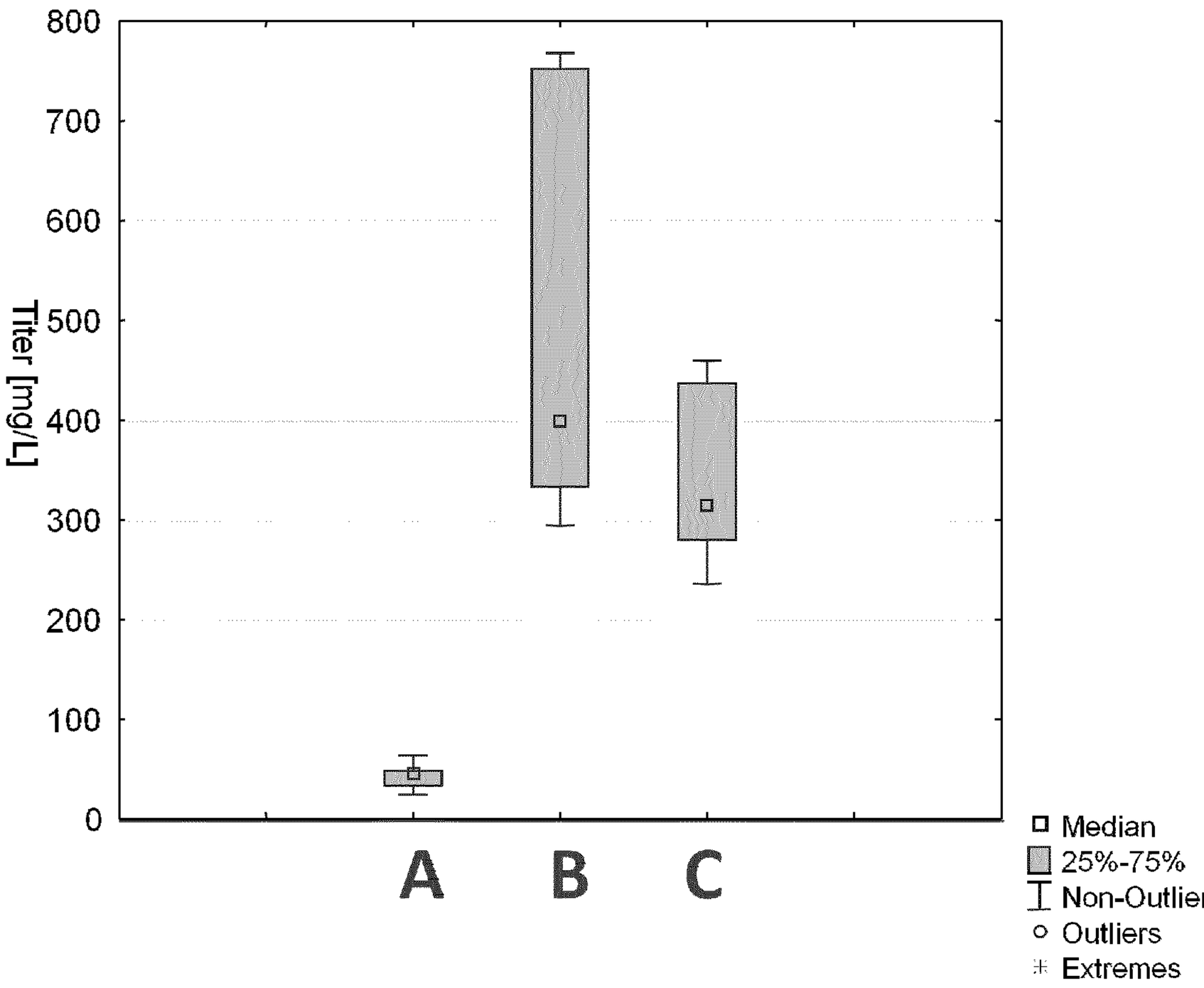
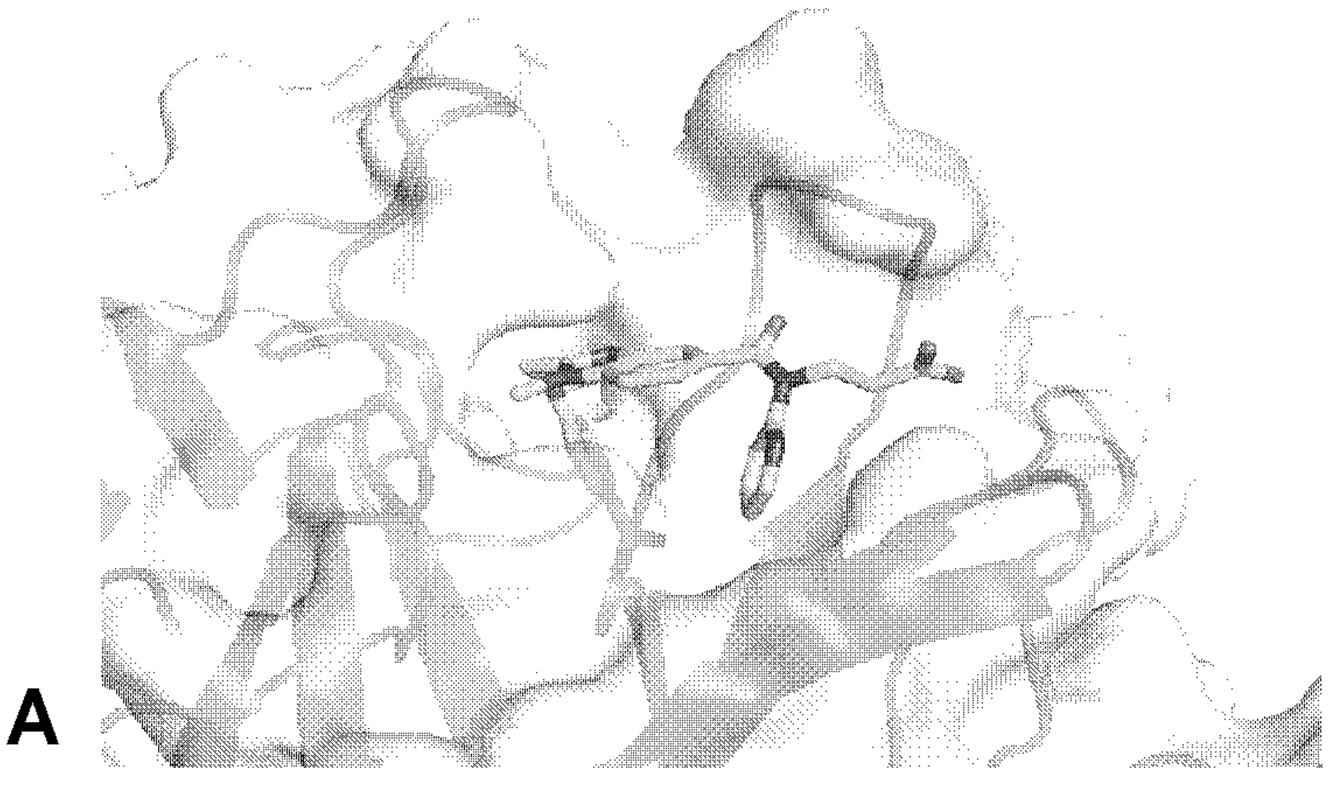
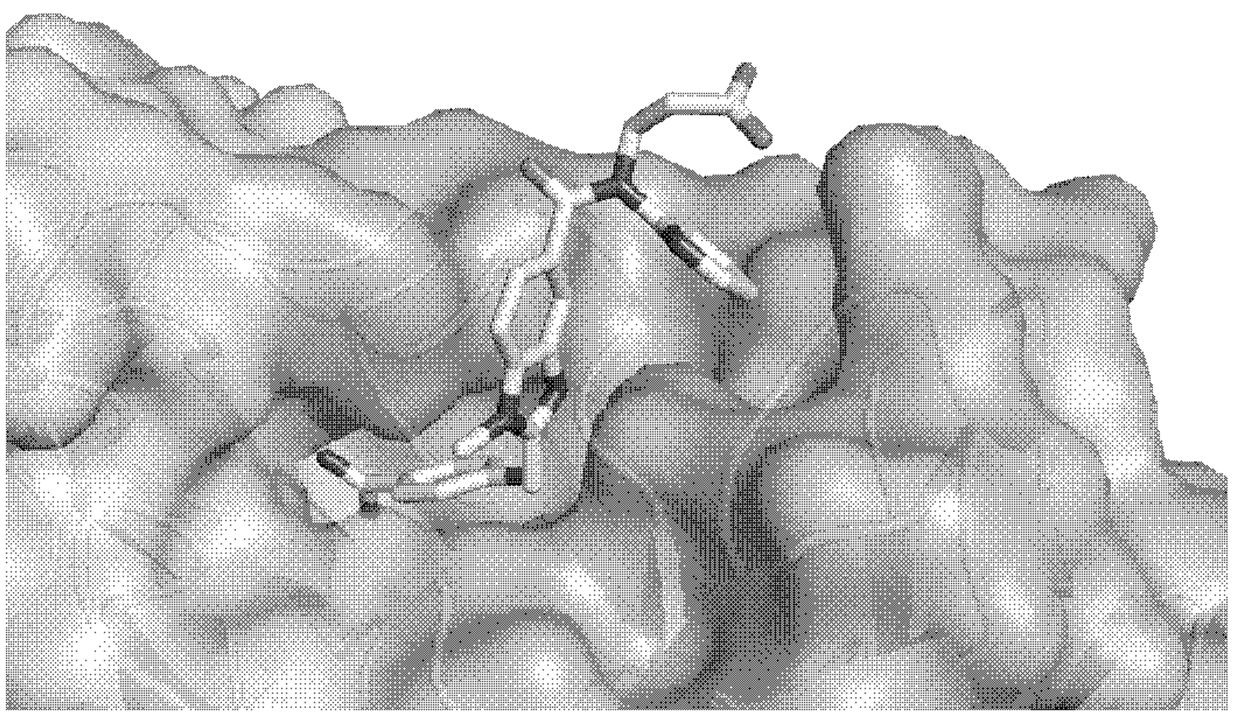

800
700
600
500
400
300
200
100
0
Titer [mg/L]
A
B
C
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

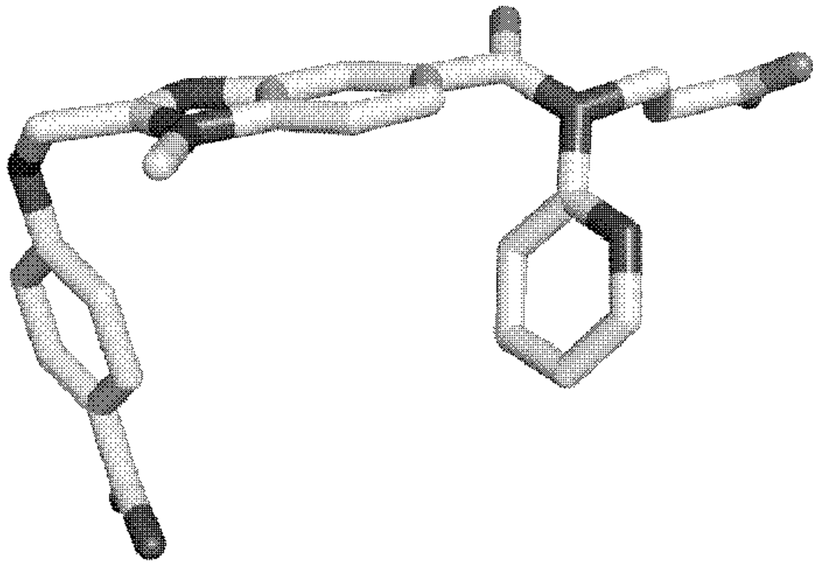
Figure 13



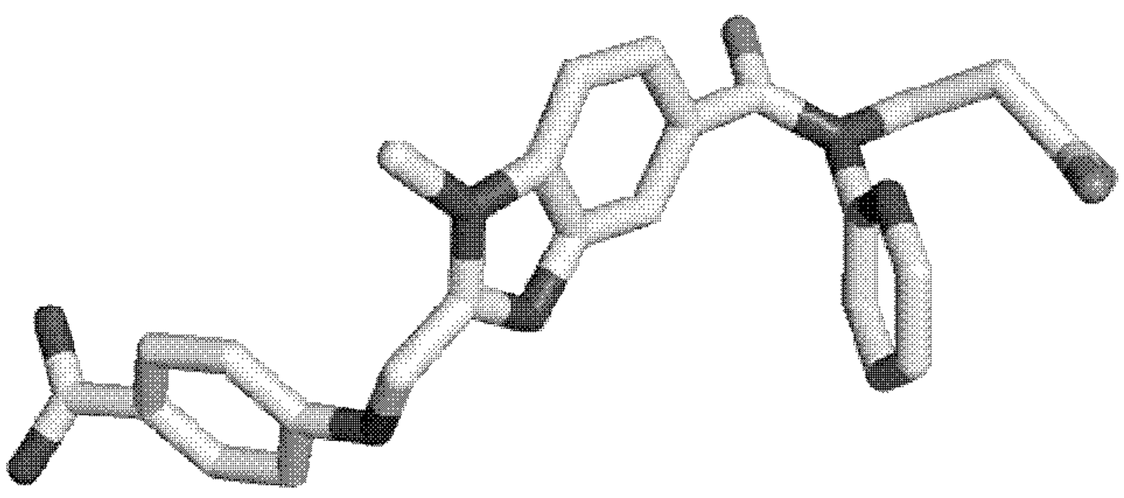
A



B



C



D

Figure 11