

ANTIDOTES FOR FACTOR XA INHIBITORS AND METHODS OF USING THE SAME IN COMBINATION WITH BLOOD COAGULATING AGENTS

CROSS REFERENCE TO RELATED APPLICATIONS

5 [0001] This application claims the benefit of United States Provisional Patent Application Serial Number 61/114,948, filed on November 14, 2008, which is hereby incorporated by reference in its entirety.

FIELD OF INVENTION

10 [0002] The present invention relates to the methods of using a factor Xa (fXa) derivative in combination with a blood coagulating agent to prevent or reduce bleeding in a subject undergoing anticoagulant therapy with a factor Xa inhibitor. The invention also relates to compositions comprising the fXa derivative and the blood coagulating agent. The fXa derivative has reduced or no intrinsic procoagulant activity, is capable of binding and/or neutralizing fXa inhibitors, and does not assemble into a
15 prothrombinase complex. The blood coagulating agent has procoagulant, anti-thrombolytic, and/or anti-fibrinolytic activity.

BACKGROUND OF THE INVENTION

 [0003] Anticoagulants serve a need in the marketplace in treatment or prevention of undesired thrombosis in patients with a tendency to form blood clots, such
20 as, for example, those patients having clotting disorders, confined to periods of immobility or undergoing medical surgeries. One of the major limitations of anticoagulant therapy, however, is the bleeding risk associated with the treatments, and limitations on the ability to rapidly reverse the anticoagulant activity in case of overdosing or if an urgent surgical procedure is required. Thus, specific and effective
25 antidotes to all forms of anticoagulant therapy are highly desirable. For safety considerations, it is also advantageous to have an anticoagulant-antidote pair in the development of new anticoagulant drugs.

 [0004] Currently available anticoagulant-antidote pairs for over-anticoagulation are heparin - protamine and warfarin - vitamin K. Fresh frozen plasma
30 and recombinant factor VIIa (rfVIIa) 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
5 mteins (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).

[0005] One promising form of anticoagulant therapy targets factor Xa (fXa), and in fact, several direct fXa inhibitors are currently in different stages of clinical
10 development for use in anticoagulant therapy. One direct fXa inhibitor XareltoTM (rivaroxaban) has been approved for clinical use in the European Union and Canada for the prevention of venous thromboembolism in orthopedic surgery patients. Many of these are small molecules. While these new fXa inhibitors show promise for treatment, specific and effective antidotes are still needed. In cases of over-anticoagulation or requirement
15 for surgery in patients treated with these fXa inhibitors, an agent may be required to substantially neutralize the administered fXa inhibitor or inhibitors and restore normal hemostasis.

[0006] Currently available agents, such as recombinant factor VIIa (rfVIIa), are mechanistically limited and not specific for reversal of fXa inhibitors and
20 thus improved options for the clinician are highly desirable. In human studies, rfVIIa has been used to reverse the effect of indirect antithrombin III dependent fXa 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). The mechanism of action of factor VIIa (fVIIa) is to act with tissue factor to convert factor X
25 (fX) present in blood circulation to fXa to restore normal hemostasis in patients. This mode of action necessarily dictates that the highest potential concentration of fXa that could be attained to neutralize active site directed fXa inhibitors is limited by the circulating plasma concentration of fX. Thus the potential of using rfVIIa to reverse the effect of direct fXa inhibitors is mechanistically limited. Since the circulating plasma
30 concentration of fX is 150 nanomolar ("nM"), the maximal amount of fXa produced by this mode would be 150 nM. Reported therapeutic concentrations of small molecule fXa inhibitors such as rivaroxaban have been higher (approximately 600 nM, Kubitz D, et al,

Eur. J. Clin. Pharmacol., 2005, 61:873-880) than the potential amount of fXa generated by rfVIIa. Use of rfVIIa for reversal of therapeutic or supratherapeutic levels of anticoagulation by fXa inhibitor would therefore provide inadequate levels of efficacy. As shown in Figure 4, using rfVIIa has limited effect in neutralizing the anticoagulant activity of a factor Xa inhibitor betrixaban (described below). Recombinant fVIIa showed a dose responsive antidote activity from 50 nM to 100 nM, but the effect leveled off between 100 nM to 200 nM, indicating that its antidote effect is limited by factors other than its concentration. In all of the rfVIIa concentrations tested, betrixaban still showed a dose responsive inhibition of fXa, up to about 75 % inhibition at a concentration of 250 nM. This observation is consistent with fVIIa's proposed mechanism of action. This is also supported by studies showing that rfVIIa by itself did not completely reverse the inhibitory effect of fondaparinux on the parameters of thrombin generation and prothrombin activation (Gerotiafas, GT, et al, *Thrombosis & Haemostasis* 2204(91):531-537).

[0007] Exogenous active fXa cannot be administered directly to a subject in a way similar to rfVIIa. Unlike rfVIIa, which has very low procoagulant activity in the absence of its cofactor tissue factor, native fXa is a potent enzyme and has a potential risk of causing thrombosis. Thus, the use of either rfVIIa or active fXa as an antidote to a fXa anticoagulant therapy has disadvantages.

[0008] Thus, there is a need for improved antidote agents that do not cause undesired thrombosis and that are effective in substantially neutralizing the anticoagulant activity of a fXa inhibitor in the event of an overdose of the fXa inhibitor or in the event that normal hemostasis needs to be restored to prevent or stop bleeding.

[0009] United States Patent Application Publication 2009-0098119, which is incorporated by reference in its entirety, teaches fXa protein derivatives that have reduced or no intrinsic procoagulant activity, are capable of binding and/or neutralizing fXa inhibitors and do not assemble into a prothrombinase complex can be effective antidotes to prevent or reduce bleeding in a subject undergoing anticoagulant therapy with a factor Xa inhibitor.

[0010] Since the fXa protein derivatives have reduced or no intrinsic procoagulant activity, fXa protein derivatives alone may require a high dose to initiate or

enhance the coagulation process in a subject undergoing anticoagulation therapy, so as to efficiently prevent or stop bleeding. Thus, there is a need for improved antidote agents that are effective and efficient in substantially neutralizing the anticoagulant activity of a fXa inhibitor, as well as in initiating the coagulation process in the event of an overdose
5 of the fXa inhibitor.

[0011] Any and all publications, patents, patent applications mentioned herein are hereby incorporated by reference in their entirety.

SUMMARY OF THE INVENTION

[0012] It is contemplated that administering a specific antidote to a factor
10 Xa (fXa) inhibitor, together, with another blood coagulating agent would produce a synergistic or additive effect, such as to allow for one or both agents to be administered at subtherapeutic doses, or to reduce any potential side effects by either agent due to the reduced doses. It is further contemplated that the combined use of a specific antidote to the fXa inhibitor and a blood coagulating agent or another antidote, such as an antidote to
15 heparin, may result in 1) reduction in effective dose of the specific antidote; 2) reduction of amount of the blood coagulating agent compared to the amount needed to treat hemophiliacs or to alleviate bleeding with the blood coagulating agent alone; and/or 3) reduction of potential side effects of both the specific antidote and the coagulating agent.

[0013] It has now been discovered that administration of modified
20 derivatives of fXa proteins in combination with administration of blood coagulating agents or another antidote such as an antidote to heparin are useful to prevent or reduce bleeding in subjects undergoing fXa anticoagulation therapy.

[0014] In some embodiments, the modified derivatives of fXa proteins do not compete with fXa in assembling into the prothrombinase complex, but instead bind
25 and/or substantially neutralize the anticoagulants, such as fXa inhibitors. The derivatives useful as antidotes are modified factor Xa proteins to reduce or remove intrinsic procoagulant and anticoagulant activities, while retaining the ability to bind to the inhibitors. In some embodiments, the modified derivatives are isolated polypeptides comprising the amino acid sequence of SEQ ID NO. 12, 13 or 15 or polypeptides having
30 at least 80% homology to SEQ ID NO. 12, 13 or 15.

[0015] In one aspect, the blood coagulating agent has procoagulant, anti-thrombolytic, and/or anti-fibrinolytic activity. In another aspect, the blood coagulating agent may initiate or enhance blood coagulation. In another aspect, the blood coagulating agent may inhibit fibrinolysis or thrombolysis.

5 [0016] It is contemplated that the blood coagulating agent may be selected from the group consisting of a coagulation factor, a polypeptide related to the coagulation factor, a recombinant coagulation factor and combinations thereof. It is further contemplated that the coagulation factor may be selected from the group consisting of plasma derived factors VII/VIIa, IX/IXa, X/Xa, II/IIa, VIII/VIIIa, V/Va and
10 combinations thereof. It is further contemplated that the recombinant coagulation factor may be selected from the group consisting of recombinant factors VII/VIIa, IX/IXa, X/Xa, II/IIa, VIII/VIIIa, V/Va and combinations thereof.

[0017] In one aspect, the blood coagulating agent may be recombinant factor VIIa.

15 [0018] It is also contemplated that the blood coagulating agent may be a non-specific anti-bleeding agent. It is further contemplated that the blood coagulating agent may be selected from the group consisting of an adsorbent chemical, a hemostatic agent, thrombin, fibrin glue, desmopressin, cryoprecipitate and fresh frozen plasma, coagulation factor concentrate, activated or non-activated prothrombin complex
20 concentrate, Feiba Vh, platelet concentrates and combinations thereof. More examples of available blood coagulation factors are available in the citation Brooker M, Registry of Clotting Factor Concentrates, Eighth Edition, World Federation of Hemophilia, 2008, which is hereby incorporated by reference in its entirety.

[0019] It is also contemplated that the blood coagulating agent may be
25 selected from the group consisting of thrombin-activatable fibrinolysis inhibitor (TAFI), protein C inhibitor (PCI), protein S inhibitor (PSI), alpha-2-antiplasmin, tranexamic acid, aminocaproic acid, aprotinin and combinations thereof.

[0020] It is further contemplated that the other antidote administered in conjunction with the fXa derivative could be an antidote for heparin or heparin-like drugs.
30 In one embodiment, the other antidote could be for example, but not limited to, protamine

or novel slicylamide derivatives such as PMX60102, PMX60126, PMX60138 and PMX60100.

[0021] In one aspect, the fXa inhibitor may be selected from the group consisting of fondaparinux, idraparinux, biotinylated idraparinux, enoxaparin, fragmin, NAP-5, rNAPc2, tissue factor pathway inhibitor, heparin, low molecular weight heparin, DX-9065a, YM-60828, YM-150, apixaban, rivaroxaban, betrixaban, PD-348292, otamixaban, DU-176b, LY517717, GSK913893 and combinations thereof.

[0022] One aspect of the present invention is the use of the factor Xa derivatives and the blood coagulating agent or other antidotes including antidotes to heparin and heparin-like drugs and compositions containing the same to treat patients who have received or are receiving over-anticoagulation therapy with a factor Xa inhibitor. The methods are also useful for patients who had previously been administered a factor Xa inhibitor and are then in need of hemostasis, such as required by elective or emergency surgery. In one aspect, the modified fXa proteins are distinguished from naturally occurring fXa in that they have reduced or lack intrinsic procoagulant activity and will not interfere with physiological fXa function in hemostasis, while still capable of binding and substantially neutralizing fXa inhibitors.

[0023] In one aspect, the fXa protein derivative is administered prior to the administration of the blood coagulating agent. In another aspect, the fXa protein derivative is administered after the administration of the blood coagulating agent. In yet another aspect, the fXa protein derivative is administered at the same time as, *i.e.* coadministered with, the blood coagulating agent.

[0024] In another aspect, the modified factor Xa protein is co-administered with an agent capable of extending the plasma half life (or circulating half life) of the factor Xa derivative. In yet another aspect, the antidote is conjugated with a moiety to extend its plasma half-life.

[0025] Also provided are pharmaceutical compositions that contain the factor Xa derivative and a blood coagulating agent or another antidote, such as heparin antidotes. In some embodiments, the derivative is an isolated polypeptide comprising the amino acid sequence of SEQ ID NO. 12, 13 or 15 or a polypeptide having at least 80%

homology to SEQ ID NO. 12, 13 or 15. The pharmaceutical composition optionally comprises a pharmaceutically acceptable carrier.

[0026] In one aspect, this invention provides a kit comprising a fXa derivative and a blood coagulating agent or another antidote. In another aspect, this invention provides a kit comprising a fXa inhibitor for anticoagulant use and a fXa inhibitor antidote/blood coagulating agent (or factor Xa derivative/blood coagulating agent) for use when substantial neutralization of the fXa inhibitor's anticoagulant activity is needed.

[0027] Further provided herein is that the compositions or methods may further comprise a peptide conjugate of the isolated polypeptide comprising a carrier covalently or non-covalently linked to a polypeptide just described. The carrier can be a liposome, a micelle, a pharmaceutically acceptable polymer, or a pharmaceutically acceptable carrier.

[0028] Additional embodiments of the invention may be found throughout the remainder of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Figure 1 shows schematically the domain structure of human factor X (SEQ ID NO. 1) shown in Table 1 as reported in Leytus et al, *Biochem.*, 1986, 25, 5098-5102. SEQ ID NO. 1 is the amino acid sequence of human fX coded by the nucleotide sequence of human fX (SEQ ID NO. 2) as shown in Table 2 known in the prior art. For example, the translated amino acid sequence is reported in Leytus et al, *Biochem.*, 1986, 25, 5098-5102 and can be found in GenBank, "NM_000504" at <<http://www.ncbi.nlm.nih.gov/entrez/viewer.fcgi?db=nucleotide&id=89142731>>. The amino acid numbering in this sequence is based on fX sequence. Human fX precursor (SEQ ID NO. 1) contains a prepro-leader sequence (amino acids 1 to 40 of SEQ ID NO. 1) followed by sequences corresponding to the fX light chain (LC) (amino acids 41 to 179 of SEQ ID NO. 1), the RKR triplet (amino acids 180 to 182 of SEQ ID NO. 1) which is removed during fX secretion, and the fX heavy chain (amino acids 183 to 488 of SEQ ID NO. 1) containing the activation peptide (AP) (amino acids 183 to 234 of SEQ ID NO. 1) and the catalytic domain (amino acids 235 to 488 of SEQ ID NO. 1).

[0030] Figure 2 (SEQ ID NO. 3) shows the amino acid sequence of mature human factor X. The amino acid numbering in this figure is based on mature fX sequence starting from the N-terminal of fX light chain. Factor X circulates in plasma as a two-chain molecule linked by a disulfide bond. The light chain (LC) has 139 amino acid (amino acids 41 through 179 of SEQ ID NO. 1) residues and contains the γ -carboxyglutamic acid (Gla)-rich domain (amino acids 1-45 of SEQ ID NO. 3), including a short aromatic stack (AS) (amino acids 40-45 of SEQ ID NO. 3), followed by two epidermal growth factor (EGF)-like domains (EGF1: amino acids 46-84, EGF2: amino acids 85-128 of SEQ ID NO. 3). The heavy chain (HC) has 306 amino acids and contains a 52 amino acids activation peptide (AP: amino acids 143-194 of SEQ ID NO. 3) followed by the catalytic domain (amino acids 195-448 of SEQ ID NO. 3). The catalytic triad equivalents to H57-D102-S195 in chymotrypsin numbering are located at His236, Asp282, and Ser379 in fX sequence and are underlined (amino acids 236, 282 and 379 of SEQ ID NO. 3).

[0031] Figure 3 shows schematically the domain structure of mature human factor X shown in Figure 2. The amino acid numbering in this figure is based on mature fX sequence. The cleavage sites for chymotrypsin digestion to remove the Gla-domain containing fragment (amino acid 1-44 of SEQ ID NO. 3) and fX activation to remove the activation peptide are highlighted. Chymotryptic digestion of fXa results in a Gla-domainless fXa lacking the 1-44 amino acid residues (SEQ ID NO. 4).

[0032] Figure 4 shows the effect of varying concentrations of rfVIIa in the presence of tissue factor on the anticoagulant activity of a fXa inhibitor betrixaban (described below) in a thrombin generation (expressed as relative fluorescence units (RFU) assay (as described in Example 2)). The data show that a combination of rfVIIa and tissue factor was unable to completely neutralize the anticoagulant activity of a fXa inhibitor, betrixaban, in concentrations up to 200 nM of rVIIa.

[0033] Figure 5 shows that anhydro-fXa with its Gla-domain intact reverses fXa inhibition by betrixaban in a purified system containing active fXa and betrixaban (open circle), while anhydro-fXa alone has negligible procoagulant activity (open triangle) compared with active fXa. FXa chromogenic activity was normalized to active fXa in the absence of any inhibitor (open square). This is more thoroughly

described in Example 4. The data show that anhydro-fXa is inactive toward fXa substrate yet retains the fXa inhibitor binding ability.

5 **[0034]** Figure 6 shows that the anhydro-fXa with intact Gla domain in Figure 5 is a potent inhibitor in plasma thrombin generation (expressed as relative fluorescence units (RFU)) assay (as described in Example 2). It almost completely inhibited thrombin generation at about 115 nM. The data show that anhydro-fXa without modification of the Gla-domain is not suitable for use as a fXa inhibitor antidote.

10 **[0035]** Figure 7 shows the comparison of the clotting activity of active fXa in a 96-well plate format before chymotrypsin digestion, and after 15 minutes and 30 minutes of chymotrypsin digestion. As shown in this figure, clotting time (change of OD405) was significantly delayed after the fXa had been digested by chymotrypsin for 15 minutes and no clotting was observed for up to 20 minutes when the fXa was digested for 30 minutes. This result was also used to establish conditions for chymotrypsin digestion of anhydro-fXa because it has no activity that can be monitored during digestion. This is
15 more thoroughly described in Example 3.

20 **[0036]** Figure 8 shows the binding affinity of des-Gla anhydro-fXa to a factor Xa inhibitor betrixaban as described in Example 4. The data show that des-Gla anhydro-fXa, prepared by chymolytic digestion of anhydro-fXa to remove the Gla-domain containing fragment (residues 1-44), is able to bind betrixaban with similar affinity as native fXa (fXa: $K_i=0.12$ nM, des-Gla anhydro-fXa: $K_d=0.32$ nM).

25 **[0037]** Figure 9 shows reversal of the anticoagulant activity of varying concentrations of betrixaban by addition of a concentrate of 680 nM of the antidote (des-Gla anhydro-fXa) in a thrombin generation assay of Example 2. At the concentration of 680 nM, des-Gla anhydro-fXa was able to produce substantially complete restoration of fXa activity.

[0038] Figure 10 shows reversal of the anticoagulant activity of 250 nM of betrixaban by varying concentrations of the antidote (des-Gla anhydro-fXa) in clotting prolongation assays using aPTT reagent in a 96-well plate format (as described in Example 3). The data show that clotting time was comparable to that of control platelet

poor plasma when about 608 nM of the antidote was used to neutralize 250 nM of the fXa inhibitor betrixaban.

5 **[0039]** Figure 11 shows the effect on the anticoagulant activity of enoxaparin (0.3125 – 1.25 U/mL) by 563 nM of the antidote (des-Gla anhydro-fXa) in clotting prolongation assays using aPTT reagent in a 96-well plate format, expressed as fold changes after normalization. The assay protocol is described in Example 3. The data show that addition of 563 nM of the antidote significantly neutralized the activity of a low molecular weight heparin enoxaparin.

10 **[0040]** Figure 12 shows the effect of the antidote, des-Gla anhydro-fXa, on the activity of thrombin (5 nM) and its inhibition by 50 nM of argatroban, a specific thrombin inhibitor, in a chromogenic assay. The antidote of fXa inhibitor does not detectably affect either thrombin activity or its inhibition by the specific inhibitor argatroban at concentrations up to 538 nM. This is more thoroughly described in Example 14.

15 **[0041]** Figure 13 shows the effect on the anticoagulant activity of 400 nM betrixaban by varying concentrations of the antidote, des-Gla anhydro-fXa, in an aPTT assay using a standard coagulation timer. The assay protocol is described in Example 3. The data shows that the antidote of fXa inhibitor substantially reverses the inhibition of fXa by 400 nM of betrixaban. The EC₅₀ of the antidote was estimated to be
20 about 656 nM with 400 nM betrixaban.

[0042] Figure 14 shows the map of the DNA construct for expression of the fXa triple mutant (SEQ ID NO. 12) in CHO cells. Plasmid DNA was linearized and transfected into CHO dhfr(-) cells. Cells were selected using tetrahydrofolate (HT) deficient media plus methotrexate (MTX). Stable clones were screened for high protein
25 expression by ELISA. The fXa triple mutant was produced in serum free medium and purified by combination of ion exchange and affinity columns. The numbering in the map was based on polynucleotide sequence encoding human fX SEQ ID NO.1. For example, an alanine mutation at the active site S419 (SEQ ID NO.1) is equivalent to the mutation at S379 (SEQ ID NO. 3) of mature human fX discussed throughout the
30 application and more particularly, Example 7. Primers used to construct the polynucleotide encoding the r-Antidote triple mutant are listed in Table 21.

[0043] Figure 15A shows a Western blot of purified r-Antidote by ion exchange and affinity purification. Upon reduction of the disulfide bond which connects the light and heavy chains, the r-Antidote heavy chain migrates at expected molecular weight similar to that of plasma derived fXa. Deletion of 6-39 aa in the Gla-domain of fXa mutant results in a lower molecular weight band of the r-Antidote light chain compared to normal FXa.

[0044] Figure 15B and 15C shows a SDS-PAGE and Western blot of purified r-Antidote by ion exchange and affinity purification followed by size exclusion chromatography.

[0045] Figure 16 shows betrixaban plasma level in mice (n=7-10 per group) after oral administration of betrixaban alone (15 mg/kg), or betrixaban (15mg/kg) followed by intravenous injection (300 µg, IV) of plasma derived antidote (pd-Antidote) prepared according to Example 1. pd-Antidote was administered 5 minutes prior to the 1.5 hr. time point, and mouse blood samples (0.5 mL) were taken at 1.5, 2.0, and 4.0 hrs following oral administration of betrixaban. Whole blood INR, betrixaban and antidote plasma levels were analyzed. Betrixaban level (Mean±SEM) in mouse plasma was plotted as a function of time for mice after 15 mg/kg (open square) and 15 mg/kg followed by antidote injection (open circle). The PK-PD correlation of antidote treated group at 1.5 hr time point (5 min after antidote injection) was summarized in Table 13. Single injection of the antidote resulted in >50% reduction of functional betrixaban based on INR measurements. This is more thoroughly described in Example 8.

[0046] Figures 17A and 17B shows the results of a mouse experiment with purified r-Antidote (n=4-10 per group). Betrixaban level in mouse plasma (Figure 17A) and whole blood INR (Figure 17B) were compared after oral administration of betrixaban alone (15 mg/kg) or betrixaban (15 mg/kg) followed by intravenous injection (300 µg) of r-antidote. Mean values for each treated group were indicated. As summarized in Table 14, single IV injection of the r-antidote resulted in >50% correction of *ex vivo* whole blood INR, justifying effective neutralization of fXa inhibitors by the antidote via a single or multiple injections or other regimes. These results demonstrate that the fXa variants of this invention have potential of acting as universal antidotes to

reverse the anticoagulant effect of fXa inhibitors in patients with bleeding or other medical emergencies. This is more thoroughly described in Example 8.

[0047] Figure 18 shows r-Antidote reversal of the inhibitory effect of enoxaparin in a 96-well turbidity change clotting assay. The results are essentially similar to pd-Antidote (Figure 11) indicating both fXa derivatives have comparable functional
5 antidote activity. 50 nM r-Antidote substantially corrected (>75%) the inhibitory effect of 1.25 U/mL enoxaparin. The assay protocol is presented in Example 11.

[0048] Figure 19 shows r-Antidote reversal of the inhibitory effect of low molecular weight heparin (LMWH) as tested in human plasma clotting assay. Both
10 Figures 18 and 19 are discussed in Example 11.

[0049] Figure 20 shows the r-Antidote reversal of the anticoagulation effect of rivaroxaban. This is more thoroughly discussed in Example 12.

[0050] Figure 21 shows the alignment of the polynucleotide sequence and translated polypeptide sequence of r-Antidote.

[0051] Figures 22A and 22B shows the results of a mouse experiment with a single IV injection (1 injection) or two injections (2 injections) of the r-antidote (n=5 per group, 312 ug/200 ul r-Antidote). Betrixaban level in plasma (Figure 22A) were compared after oral administration of betrixaban (15 mg/kg) followed by intravenous injection of vehicle or r-Antidote (see Example 8 for details). As shown in Figure 22A, a
15 single IV injection of r-Antidote increased betrixaban level in plasma by more than 8 fold compared to vehicle control (control_1), indicating the ability of the antidote to effectively bind betrixaban *in vivo*. A second injection of the antidote further increased betrixaban level by less than 2 fold compared to the single injection, indicating limiting amount of betrixaban in mouse blood and reversal of its anticoagulant effect by the
20 antidote. Figure 22B demonstrates that measured INR decreases as the ratio of antidote/betrixaban increases in mouse plasma following single and double injections of the antidote.

[0052] Figure 23 shows the combination effect of rVIIa with r-Antidote on the anticoagulant activity of 250 nM betrixaban, a fXa inhibitor, in thrombin

generation. The results were expressed as relative thrombin generation activity (% activity) after normalization of RFU in plasma without any added inhibitor, rVIIa or r-Antidote. The data show that r-Antidote independently reversed the anticoagulant effect of 250 nM betrixaban. Combination of 100 nM rVIIa with r-Antidote further increased thrombin generation activity at each r-Antidote concentration, while 100 nM rVIIa alone only slightly increased thrombin generation activity in the absence of r-Antidote. rVIIa also slightly increased thrombin generation activity in control plasma in the absence of betrixaban.

[0053] Figures 24A and 24B shows the combination effect of rVIIa and r-Antidote (also referred to as “r-antidote” or “antidote” in the figure) on the anticoagulant activity of 1 μ M rivaroxaban, a fXa inhibitor, measured by prothrombin time (PT) in human plasma. Figure 24A shows that in the absence of rivaroxaban, 380 nM r-Antidote slightly reduced the PT while 2.2 nM rVIIa had a more profound effect. In the presence of rivaroxaban, addition of r-Antidote (380 nM) produced a 14% correction (21.5 $\pm$ 0.2 sec), and 2.2 nM rVIIa produced a 46% correction. Single agent treatment (r-Antidote or rVIIa alone) did not produce complete reversal of anticoagulation. A combination of 380 nM r-antidote and 2.2 nM rVIIa produced a complete correction (resulting PT = 12 sec) of rivaroxaban induced anticoagulation. Figure 24B shows that in the presence of rivaroxaban, addition of r-Antidote (760 nM) produced a 28% correction. A combination of 760 nM r-antidote and 0.55 nM rVIIa produced a close to complete correction (resulting PT = 12 sec) of rivaroxaban induced anticoagulation.

[0054] Figure 25 shows the combination effect of human plasma derived fIX and r-Antidote (also referred to as “antidote” in the figure) on the anticoagulant activity of 400 nM betrixaban, a fXa inhibitor, measured by activated partial thromboplastin time (APTT) in human plasma. In the absence of betrixaban, fIX slightly reduced aPTT in human plasma. The baseline aPTT (25.5 $\pm$ 0.1 sec) was prolonged by approximately 2 fold (51.6 $\pm$ 0.4 sec) upon addition of 400 nM betrixaban. In the presence of betrixaban, addition of r-antidote (1.14 μ M) produced a 42% correction, whereas human plasma derived fIX (258 nM) only produced a 15% correction. Thus, fIX alone is not an effective reversal agent for betrixaban anticoagulation. A combination of r-Antidote (1.14 μ M) and fIX (258 nM) was sufficient to produce complete in-vitro reversal of the anticoagulant effect to baseline clotting parameter conditions.

[0055] Figure 26 shows the combination effect of fX with recombinant antidote (r-Antidote) on the anticoagulant activity of 125 nM betrixaban. The results were expressed as fold changes after normalization of the clotting time in plasma without any added inhibitor, fX or r-Antidote (Control, No FX). The data show that 125 nM betrixaban doubled the clotting time (0 nM r-Antidote, No FX). Addition of 125 nM r-Antidote substantially reversed the anticoagulant effect of betrixaban. 170 nM fX independently reduced the clotting time by ~20% in plasma with or without 125 nM inhibitor. Combination of 170 nM fX with 125 nM r-Antidote further corrected the inhibitory effect of 125 nM betrixaban.

DETAILED DESCRIPTION OF THE INVENTION

I. Definitions

[0056] The practice of the present invention will employ, unless otherwise indicated, conventional techniques of tissue culture, immunology, molecular biology, microbiology, cell biology and recombinant DNA, which are within the skill of the art. *See, e.g.,* Sambrook and Russell eds. (2001) *Molecular Cloning: A Laboratory Manual*, 3rd edition; the series Ausubel et al. eds. (2007) *Current Protocols in Molecular Biology*; the series *Methods in Enzymology* (Academic Press, Inc., N.Y.); MacPherson et al. (1991) *PCR 1: A Practical Approach* (IRL Press at Oxford University Press); MacPherson et al. (1995) *PCR 2: A Practical Approach*; Harlow and Lane eds. (1999) *Antibodies, A Laboratory Manual*; Freshney (2005) *Culture of Animal Cells: A Manual of Basic Technique*, 5th edition; Gait ed. (1984) *Oligonucleotide Synthesis*; U.S. Patent No. 4,683,195; Hames and Higgins eds. (1984) *Nucleic Acid Hybridization*; Anderson (1999) *Nucleic Acid Hybridization*; Hames and Higgins eds. (1984) *Transcription and Translation; Immobilized Cells and Enzymes* (IRL Press (1986)); Perbal (1984) *A Practical Guide to Molecular Cloning*; Miller and Calos eds. (1987) *Gene Transfer Vectors for Mammalian Cells* (Cold Spring Harbor Laboratory); Makrides ed. (2003) *Gene Transfer and Expression in Mammalian Cells*; Mayer and Walker eds. (1987) *Immunochemical Methods in Cell and Molecular Biology* (Academic Press, London); Herzenberg et al. eds (1996) *Weir's Handbook of Experimental Immunology*; Manipulating the Mouse Embryo: A Laboratory Manual, 3rd edition (Cold Spring Harbor Laboratory Press (2002)).

[0057] All numerical designations, e.g., pH, temperature, time, concentration, and molecular weight, including ranges, are approximations which are varied (+) or (-) by increments of 0.1. It is to be understood, although not always explicitly stated that all numerical designations are preceded by the term “about”. It also
5 is to be understood, although not always explicitly stated, that the reagents described herein are merely exemplary and that equivalents of such are known in the art.

[0058] As used in the specification and claims, the singular form “a”, “an” and “the” include plural references unless the context clearly dictates otherwise. For example, the term “a pharmaceutically acceptable carrier” includes a plurality of
10 pharmaceutically acceptable carriers, including mixtures thereof.

[0059] As used herein, the term “comprising” is intended to mean that the compositions and methods include the recited elements, but do not exclude others. “Consisting essentially of” when used to define compositions and methods, shall mean excluding other elements of any essential significance to the combination for the intended
15 use. Thus, a composition consisting essentially of the elements as defined herein would not exclude trace contaminants from the isolation and purification method and pharmaceutically acceptable carriers, such as phosphate buffered saline, preservatives, and the like. “Consisting of” shall mean excluding more than trace elements of other ingredients and substantial method steps for administering the compositions of this
20 invention. Embodiments defined by each of these transition terms are within the scope of this invention.

[0060] A “subject” of diagnosis or treatment is a cell or a mammal, including a human. Non-human animals subject to diagnosis or treatment include, for example, murine, such as rats, mice, canine, such as dogs, leporids, such as rabbits,
25 livestock, sport animals, and pets.

[0061] The term “protein” and “polypeptide” are used interchangeably and in their broadest sense to refer to a compound of two or more subunit amino acids, amino acid analogs or peptidomimetics. The subunits may be linked by peptide bonds. In another embodiment, the subunit may be linked by other bonds, e.g., ester, ether, etc.
30 A protein or peptide must contain at least two amino acids and no limitation is placed on the maximum number of amino acids which may comprise a protein's or peptide's

sequence. As used herein the term “amino acid” refers to either natural and/or unnatural or synthetic amino acids, including glycine and both the D and L optical isomers, amino acid analogs and peptidomimetics. Single letter and three letter abbreviations of the naturally occurring amino acids are listed below. A peptide of three or more amino acids is commonly called an oligopeptide if the peptide chain is short. If the peptide chain is long, the peptide is commonly called a polypeptide or a protein.

1-Letter	3-Letter	Amino Acid
Y	Tyr	L-tyrosine
G	Gly	L-glycine
F	Phe	L-phenylalanine
M	Met	L-methionine
A	Ala	L-alanine
S	Ser	L-serine
I	Ile	L-isoleucine
L	Leu	L-leucine
T	Thr	L-threonine
V	Val	L-valine
P	Pro	L-proline
K	Lys	L-lysine
H	His	L-histidine
Q	Gln	L-glutamine
E	Glu	L-glutamic acid
W	Trp	L-tryptophan
R	Arg	L-arginine
D	Asp	L-aspartic acid
N	Asn	L-asparagine
C	Cys	L-cysteine

[0062] “Factor Xa” or “fXa” or “fXa protein” refers to a serine protease in the blood coagulation pathway, which is produced from the inactive factor X (fX).

Factor X is activated by either factor IXa with its cofactor, factor VIIIa, in a complex known as intrinsic Xase, or factor VIIa with its cofactor, tissue factor, in a complex known as extrinsic Xase. fXa forms a membrane-bound prothrombinase complex with factor Va and is the active component in the prothrombinase complex that catalyzes the conversion of prothrombin to thrombin. Thrombin is the enzyme that catalyzes the conversion of fibrinogen to fibrin, which ultimately leads to blood clot formation. Thus, the biological activity of fXa is sometimes referred to as “procoagulant activity” herein.

[0063] The nucleotide sequence coding human factor X ("fX") can be found in GenBank, "NM_000504" at <<http://www.ncbi.nlm.nih.gov/entrez/viewer.fcgi?db=nucleotide&id=89142731>>, and is listed in Figure 1b and SEQ ID No. 2. The corresponding amino acid sequence and domain structure of fX are described in Leytus et al, *Biochemistry*, 1986, 25:5098-5102. The domain structure of mature fX is also described in Venkateswarlu, D. et al, *Biophysical Journal*, 2002, 82:1190-1206. Upon catalytic cleavage of the first 52 residues (amino acids 143 to 194 of SEQ ID NO. 3) of the heavy chain, fX is activated to fXa (SEQ ID NO. 6). fXa contains a light chain (SEQ ID NO. 8) and a heavy chain (SEQ ID NO. 9). The first 45 amino acid residues (residues 1-45 of SEQ ID NO. 6) of the light chain is called the Gla domain because it contains 11 post-translationally modified γ -carboxyglutamic acid residues (Gla). It also contains a short (6 amino acid residues) aromatic stack sequence (residues 40-45 of SEQ ID NO. 6). Chymotrypsin digestion selectively removes the 1-44 residues resulting in Gla-domainless fXa (SEQ ID NO. 4). The serine protease catalytic domain of fXa locates at the C-terminal heavy chain. The heavy chain of fXa is highly homologous to other serine proteases such as thrombin, trypsin, and activated protein C.

[0064] The domain structure of mature factor X may be found in Venkateswarlu D. et al, *Biophysical J.*, 2002, 82, 1190-1206, which is hereby incorporated by reference in its entirety. The amino acid numbering in this figure is the same as in Figure 3. The tripeptide of Arg140-Lys141-Arg142 (the RKR triplet as shown in Figure 1) that connects the light chain to the activation peptide is not shown because the form that lacks the tripeptide is predominant in circulation blood plasma. Individual domains are shown in boxes. This includes amino acids 1-45 in Figure 2 (SEQ ID NO. 3). Functionally important catalytic residues are circled, and " γ " represents Gla (γ -carboxyglutamic acid) residue.

[0065] "Native fXa" or "wild-type fXa" refers to the fXa naturally present in plasma or being isolated in its original, unmodified form, which processes the biological activity of activating prothrombin therefore promoting formation of blood clot. The term includes naturally occurring polypeptides isolated from tissue samples as well as recombinantly produced fXa. "Active fXa" refers to fXa having the biological activity of

activating prothrombin. "Active fXa" may be a native fXa or modified fXa that retains procoagulant activity.

[0066] "fXa Derivatives" or "modified fXa" or "derivatives of a factor Xa protein" refers to fXa proteins that have been modified such that they bind, either
5 directly or indirectly, to a factor Xa inhibitor and do not assemble into the prothrombinase complex. Structurally, the derivatives are modified to provide either no procoagulant activity or reduced procoagulant activity. "Procoagulant activity" is referred to herein as an agent's ability to cause blood coagulation or clot formation. Reduced procoagulant activity means that the procoagulant activity has been reduced by at least about 50%, or
10 more than about 90%, or more than about 95% as compared to wild-type fXa during the same period. For example, recombinant fX-S395A essentially has no procoagulant activity as measured by *in vitro* assays, such as fXa activity assays.

[0067] The derivatives have either modified active sites or modified Gla domains or both. Additional modifications are also contemplated. It is contemplated that
15 such modifications may be made in one or more of the following ways: deletion of one or more of the amino acid from the sequence, substitution of one or more amino acid residues with one or more different amino acid residues, and/or manipulation of one or more amino acid side chains or its "C" or "N" terminals.

[0068] The term "active site" refers to the part of an enzyme or antibody
20 where a chemical reaction occurs. A "modified active site" is an active site that has been modified structurally to provide the active site with increased or decreased chemical reactivity or specificity. Examples of active sites include, but are not limited to, the catalytic domain of human factor X comprising the 235-488 amino acid residues (Figure 1), and the catalytic domain of human factor Xa comprising the 195-448 amino acid
25 residues (Figures 2 and 3). Examples of modified active site include, but are not limited to, the catalytic domain of human factor Xa comprising 195-448 amino acid residues in SEQ ID NOS. 10, 11, 12, 13, or 15 with at least one amino acid substitution at position Arg306, Glu310, Arg347, Lys351, Lys414, or Arg424.

[0069] As stated above, the derivatives of the invention may have
30 modified Gla domains or have the entire Gla domain removed. Examples of fXa derivatives suitable as antidotes in the methods of this invention are Gla-domainless fXa

(SEQ ID NOS. 4 or 5), Gla-deficient fXa (SEQ ID NO. 7 with modifications described herein), fXa with modifications at the catalytic site (SEQ ID NOS. 10 or 11), and fXa with modifications at the sites known to be important for fV/fVa interaction or fVIII/fVIIIa interaction (SEQ ID NOS. 4, 5, 7, 10, or 11 with at least one amino acid substitution at position Arg306, Glu310, Arg347, Lys351, Lys414 or Arg424), as described in detail herein. Further examples of the fXa derivatives contemplated by this invention are provided below.

[0070] “Gla-domainless fXa” or “des-Gla fXa” refers to fXa that does not have a Gla-domain and encompasses fXa derivatives bearing other modification(s) in addition to the removal of the Gla-domain. Examples of Gla-domainless fXa in this invention include, but are not limited to, fXa derivative lacking the 1-39 amino acid residues of SEQ ID NO. 3; fXa derivative lacking the 6-39 amino acid residues of SEQ ID NO. 3, corresponding to a fXa mutant expressed in CHO cells described in more details below (SEQ ID NO. 12, Table 12); fXa derivative lacking the 1-44 amino acid residues of SEQ ID NO. 3, corresponding to des-Gla fXa after chymotryptic digestion of human fXa (SEQ ID NO. 4, Figure 3); and fXa derivative lacking the entire 1-45 Gla-domain residues of SEQ ID NO. 3 as described in Padmanabhan et al, *Journal Mol. Biol.*, 1993, 232:947–966 (SEQ ID NO 5). Other examples include des-Gla anhydro fXa (SEQ ID NO. 10, Table 10) and des-Gla fXa-S379A (SEQ ID NO. 11, Table 11).

[0071] In some embodiments, the des-Gla fXa comprises at least amino acid residues 40 to 448 of SEQ ID NO. 3 or an equivalent thereof. In some embodiment, the des-Gla fXa comprises at least amino acid residues 45 to 488 (SEQ ID NO. 4) or 46 to 488 (SEQ ID NO. 5) of SEQ ID NO. 3 or equivalents thereof.

[0072] In some embodiment, the des-Gla fXa comprises at least amino acid residues 40 to 139 and 195 to 448 of SEQ ID NO. 3 or equivalents thereof. In some embodiment, the des-Gla fXa comprises at least amino acid residues 45 to 139 and 195 to 448 of SEQ ID NO. 3 or equivalents thereof. In another embodiment, the des-Gla fXa comprises at least amino acid residues 46 to 139 and 195 to 448 of SEQ ID NO. 3 or equivalents thereof.

[0073] “Gla-deficient fXa” refers to fXa with reduced number of free side chain γ -carboxyl groups in its Gla-domain. Like Gla-domainless fXa, Gla-deficient

fXa can also bear other modifications. Gla-deficient fXa includes uncarboxylated, undercarboxylated and decarboxylated fXa. "Uncarboxylated fXa" or "decarboxylated fXa" refers to fXa derivatives that do not have the γ -carboxy groups of the γ -carboxyglutamic acid residues of the Gla domain, such as fXa having all of its Gla domain γ -carboxyglutamic acid replaced by different amino acids, or fXa having all of its side chain γ -carboxyl removed or masked by means such as amination, esterification, etc. For recombinantly expressed protein, uncarboxylated fXa is, sometimes, also called non-carboxylated fXa. "Undercarboxylated fXa" refers to fXa derivatives having reduced number of γ -carboxy groups in the Gla domain as compared with wild-type fXa, such as fXa having one or more but not all of its Gla domain γ -carboxyglutamic acids replaced by one or more different amino acids, or fXa having at least one but not all of its side chain γ -carboxyl removed or masked by means such as amination and esterification, etc.

[0074] The domain structure of human Gla-domainless factor Xa may be found in Padmanabhan et al., *J. Mol. Biol.*, 1993, 232, 947-966, which is hereby incorporated by reference in its entirety. The numbering of the amino acid is based on topological equivalences with chymotrypsin, where, for example, Ser195 corresponds to Ser379 in Figure 2 when the human mature fX numbering is used. Insertions are indicated with letters, and deletions are indicated by 2 successive numberings. 300 are added to light chain numbering to differentiate from the heavy chain numbering. β 363 is β -hydroxy aspartate. Slashes indicate proteolytic cleavages observed in crystallized material. The sequence of Gla-domainless fXa lacking the 1-45 amino acid residues based mature fX (SEQ ID NO. 3) is listed in SEQ ID NO. 5.

[0075] In one embodiment, the fXa derivative may lack a light chain of fXa but still contains a serine protease catalytic domain present in the heavy chain. In addition chimeras with other serine protease catalytic domain may be used to make substitutions in the heavy chain.

[0076] "pd-Antidote" or "plasma-derived antidote" refers to the des-Gla anhydro fXa derivative and has the amino acid residues of SEQ ID NO. 10.

[0077] "r-Antidote" or "recombinant antidote" refers to a fXa derivative lacking the 6-39 amino acid residues of SEQ ID NO. 3, corresponding to a fXa mutant

expressed in CHO cells and after removal of the linker described in more detail below (SEQ ID NO. 13, Table 12a).

[0078] “Anticoagulant agents” or “anticoagulants” are agents that inhibit blood clot formation. Examples of anticoagulant agents include, but are not limited to, specific inhibitors of thrombin, factor IXa, factor Xa, factor XIa, factor XIIa or factor VIIa, heparin and derivatives, vitamin K antagonists, and anti-tissue factor antibodies. Examples of specific inhibitors of thrombin include hirudin, bivalirudin (Angiomax®), argatroban and lepirudin (Refludan®). Examples of heparin and derivatives include unfractionated heparin (UFH), low molecular weight heparin (LMWH), such as enoxaparin (Lovenox®), dalteparin (Fragmin®), and danaparoid (Orgaran®); and synthetic pentasaccharide, such as fondaparinux (Arixtra®). Examples of vitamin K antagonists include warfarin (Coumadin®), phenocoumarol, acenocoumarol (Sintrom®), clorindione, dicumarol, diphenadione, ethyl biscoumacetate, phenprocoumon, phenindione, and tiocloamarol. In one embodiment, the anticoagulant is an inhibitor of factor Xa. In one embodiment, the anticoagulant is betrixaban.

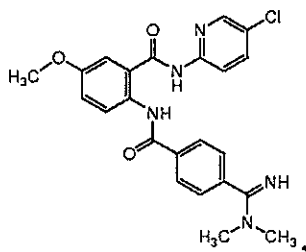
[0079] “Anticoagulant therapy” refers to a therapeutic regime that is administered to a patient to prevent undesired blood clots or thrombosis. An anticoagulant therapy comprises administering one or a combination of two or more anticoagulant agents or other agents at a dosage and schedule suitable for treating or preventing the undesired blood clots or thrombosis in the patient.

[0080] The term “factor Xa inhibitors” or “inhibitors of factor Xa” refer to compounds that can inhibit, either directly or indirectly, the coagulation factor Xa’s activity of catalyzing conversion of prothrombin to thrombin *in vitro* and/or *in vivo*. Examples of known fXa inhibitors include, without limitation, edoxaban, fondaparinux, idraparinux, biotinylated idraparinux, enoxaparin, fragmin, NAP-5, rNAPc2, tissue factor pathway inhibitor, DX-9065a (as described in, e.g., Herbert, J.M., et al, *J Pharmacol Exp Ther.* 1996 276(3):1030-8), YM-60828 (as described in, e.g., Taniuchi, Y., et al, *Thromb Haemost.* 1998 79(3):543-8), YM-150 (as described in, e.g., Eriksson, B.I. et. al, *Blood* 2005;106(11), Abstract 1865), apixaban, rivaroxaban, PD-348292 (as described in, e.g., Pipeline Insight: Antithrombotics - Reaching the Untreated Prophylaxis Market, 2007), otamixaban, razaxaban (DPC906), BAY 59-7939 as described in, e.g., Turpie, A.G., et

al, *J. Thromb. Haemost.* 2005, 3(11):2479-86), edoxaban (as described in, e.g., Hylek EM, *Curr Opin Invest Drugs* 2007 8(9):778-783), LY517717 (as described in, e.g., Agnelli, G., et al, *J. Thromb. Haemost.* 2007 5(4):746-53), GSK913893, betrixaban (as described below) and derivatives thereof. Low molecular weight heparin ("LMWH") is also considered a factor Xa inhibitor.

[0081] In one embodiment, the factor Xa inhibitor is selected from betrixaban, rivaroxaban, apixaban, edoxaban, LMWH, and combinations thereof.

[0082] The term "betrixaban" refers to the compound "[2-({4-
[(dimethylamino)iminomethyl]phenyl}carbonylamino)-5-methoxyphenyl]-N-(5-chloro(2-
pyridyl))carboxamide" or pharmaceutically acceptable salts thereof. "[2-({4-
[(dimethylamino)iminomethyl]phenyl}carbonylamino)-5-methoxyphenyl]-N-(5-chloro(2-
pyridyl))carboxamide" refers to the compound having the following structure:



or a tautomer or pharmaceutically acceptable salt thereof.

[0083] Betrixaban is described in U.S. Patent Nos. 6,376,515 and 6,835,739 and U.S. Patent Application Publication No. 2007/0112039, filed on November 7, 2006, the contents of which are incorporated herein by reference. Betrixaban is known to be a specific inhibitor of factor Xa.

[0084] As used herein, the term "antidote" or "antidote to a factor Xa inhibitor" refers to molecules, such as derivatives of fXa, which can substantially neutralize or reverse the coagulation inhibitory activity of a fXa inhibitor by competing with active fXa to bind with available fXa inhibitors. Examples of the antidotes of this invention are fXa derivatives with reduced phospholipid membrane binding, such as des-Gla fXa or Gla-deficient fXa, and fXa derivatives with reduced catalytic activity, such as the active site modified fXa derivatives, and derivatives with reduced interaction with fV/Va, or fVIII/fVIIIa. Examples of antidotes of the invention with reduced membrane

binding and reduced catalytic activity include, but are not limited to, des-Gla anhydro-fXa by chymotryptic digestion of anhydro-fXa (as described in Example 1); des-Gla fXa-S379A (S195A in chymotrypsin numbering) by mutagenesis (as described in Example 6).

[0085] Other examples of antidotes of the invention include proteins or
5 polypeptides containing serine protease catalytic domains which possess sufficient structural similarity to fXa catalytic domain and are therefore capable of binding small molecule fXa inhibitors. Examples include, but are not limited to, thrombin which binds to the fXa inhibitor GSK913893 (Young R., et al., *Bioorg. Med. Chem. Lett.* 2007, 17(10): 2927-2930); plasma kallikrein which binds to the fXa inhibitor apixaban
10 (Luettgen J., et al., *Blood*, 2006, 108(11) abstract 4130); and trypsin (or its bacterial homolog subtilisin) which binds the fXa inhibitor C921-78 with subnanomolar affinity (K_d=500pM) (Betz A, et al, *Biochem.*, 1999, 38(44):14582-14591).

[0086] In one embodiment, the derivative of the invention binds, either directly or indirectly to a factor Xa inhibitor. The terms "binding," "binds,"
15 "recognition," or "recognize" as used herein are meant to include interactions between molecules that may be detected using, for example, a hybridization assay. The terms are also meant to include "binding" interactions between molecules. Interactions may be, for example, protein-protein, protein-nucleic acid, protein-small molecule or small molecule-nucleic acid in nature. Binding may be "direct" or "indirect". "Direct" binding comprises
20 direct physical contact between molecules. "Indirect" binding between molecules comprises the molecules having direct physical contact with one or more intermediate molecules simultaneously. For example, it is contemplated that derivatives of the invention indirectly bind and substantially neutralize low molecular weight heparin and other indirect inhibitors of factor Xa. This binding can result in the formation of a
25 "complex" comprising the interacting molecules. A "complex" refers to the binding of two or more molecules held together by covalent or non-covalent bonds, interactions or forces.

[0087] "Neutralize," "reverse," "correct," or "counteract" the activity of an inhibitor of fXa or similar phrases refer to inhibit or block the factor Xa inhibitory or
30 anticoagulant function of a fXa inhibitor. Such phrases refer to partial inhibition or blocking of the function, as well as to inhibiting or blocking most or all of fXa inhibitor

activity, *in vitro* and/or *in vivo*. These terms also refer to corrections of at least about 20% of fXa inhibitor dependent pharmacodynamic or surrogate markers. Examples of markers include, but are not limited to , INR, PT, aPTT, ACT, anti fXa units, thrombin generation (Technothrombin TGA, thromboelastography, CAT (calibrated automater thrombogram) and the like.

[0088] In certain embodiments, the factor Xa inhibitor is neutralized substantially (or corrected as just described) meaning that its ability to inhibit factor Xa, either directly or indirectly, is reduced by at least about 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, or 100%.

10 [0089] The term “phospholipid membrane binding” refers to an active fXa’s ability to bind to the negatively charged phospholipid membrane or other cellular membrane, such as platelets, in the presence of Ca^{2+} ions. This binding is mediated by the Y-carboxyglutamic acid residues in the Gla domain of fXa.

[0090] The term “reduced interaction” refers to fXa derivative’s diminished ability to bind or form a complex with ions or other co-factors which normally binds or complexes with wild fXa. Examples of such interaction include but are not limited to fXa’s binding with Ca^{2+} ions and phospholipid membrane, interaction with fV/fVa, or fVIII/f/VIIIa, etc. It is preferred that the interaction of a fXa derivative with the ions or other co-factors is reduced to 50% of that of a wild fXa. More preferably, the interaction is reduced to 10 %, 1 %, and 0.1 % of that of a wild-type fXa. This refers to the derivatives’ ability to “assemble into the prothrombinase complex.”

[0091] “fXa inhibitor binding activity” refers to a molecule’s ability to bind an inhibitor of fXa. An antidote of the present invention possesses fXa inhibitor binding activity, whether it is directly or indirectly.

25 [0092] The term “circulating half life” or “plasma half life” refers to the time required for the plasma concentration of an antidote that circulates in the plasma to reduce to half of its initial concentration after a single administration or following cessation of infusion.

[0093] The term “conjugated moiety” refers to a moiety that can be added to a fXa derivative by forming a covalent bond with a residue of the fXa derivative. The moiety may bond directly to a residue of the fXa derivative or may form a covalent bond with a linker which in turn forms a covalent bond with a residue of the fXa derivative.

[0094] As used herein, an “antibody” includes whole antibodies and any antigen binding fragment or a single chain thereof. Thus the term “antibody” includes any protein or peptide containing molecule that comprises at least a portion of an immunoglobulin molecule. Examples of such include, but are not limited to a complementarity determining region (CDR) of a heavy or light chain or a ligand binding portion thereof, a heavy chain or light chain variable region, a heavy chain or light chain constant region, a framework (FR) region, or any portion thereof, or at least one portion of a binding protein.

[0095] The antibodies can be polyclonal or monoclonal and can be isolated from any suitable biological source, e.g., murine, rat, sheep and canine.

[0096] The term “blood coagulating agents” as used herein refer to agents that are capable of initiating or enhancing blood coagulation or inhibiting fibrinolysis or thrombosis. All agents known to possess this activity are contemplated by this invention. In some embodiments, a blood coagulating agent has procoagulant, anti-thrombolytic, and/or anti-fibrinolytic activity. In some embodiments, a blood coagulating agent may be a coagulation factor, a polypeptide related to the coagulation factor, a recombinant coagulation factor or combinations thereof. In some other embodiments, the blood coagulating agent may be a non-specific anti-bleeding agent. Examples of blood coagulating agents include but not limited to plasma derived factors VII/VIIa, IX/IXa, X/Xa, II/IIa, VIII/VIIIa, V/Va, recombinant factors VII/VIIa (Recombinant human factor VIIa (NovoSeven, eptacog alfa (activated), ATC code B02BD08)), IX/IXa, X/Xa, II/IIa, VIII/VIIIa, V/Va and combinations thereof. Examples of blood coagulating agent also include but are not limited to an adsorbent chemical, a hemostatic agent, thrombin, fibrin glue, desmopressin (trade names: DDAVP, Stimate, Minirin), cryoprecipitate and fresh frozen plasma, coagulation factor concentrate, activated or non-activated prothrombin complex concentrate, Feiba Vh, platelet concentrates and combinations thereof.

Additional examples of blood coagulating agents include but are not limited to thrombin-activatable fibrinolysis inhibitor (TAFI), protein C inhibitor (PCI), protein S inhibitor (PSI), alpha-2-antiplasmin, tranexamic acid (commonly marketed as Cyklokapron® in the U.S. and as Transamin® in Asia), aminocaproic acid, aprotinin and combinations thereof.

- 5 More examples of available blood coagulation factors are available in the citation Brooker M, Registry of Clotting Factor Concentrates, Eighth Edition, World Federation of Hemophilia, 2008.

[0097] In certain aspects of the invention, the fXa derivative is administered in conjunction with another antidote. Additional antidotes contemplated by this invention are antidotes known in the art, such as for example, antidotes to heparin or heparin-like drugs. One additional agent contemplated to be useful in the methods of the invention is protamine, e.g. protamine sulfate and other novel salicylamide derivatives, e.g. PMX60102, PMX60126, PMX60138 and PMX60100 (available from PolyMedix Copr., Radnor, PA). It is contemplated that when these agents are used in combination with the fXa derivative antidotes described herein, a synergistic or additive effect will be observed, namely that the fXa inhibitor will be substantially more neutralized than if either antidote were to be used alone. Collectively, the other antidotes just described will be referred to as "heparin antidotes."

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[0098] A "composition" is intended to mean a combination of active agent and another compound or composition, inert (for example, a detectable agent or label) or active, such as an adjuvant.

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[0099] A "pharmaceutical composition" is intended to include the combination of an active agent with a carrier, inert or active, making the composition suitable for diagnostic or therapeutic use *in vitro*, *in vivo* or *ex vivo*.

[0100] "An effective amount" or "a therapeutically effective amount" refers to the amount of a fXa derivative, when administered alone or together with a blood coagulating agent, sufficient to induce a desired biological and/or therapeutic result. It may also refer to the amount of a blood coagulating agent, when administered alone or together with a fXa derivative, sufficient to induce a desired biological and/or therapeutic result. It may also refer to the amount of a composition comprising a fXa derivative and a blood coagulating agent sufficient to induce a desired biological and/or therapeutic result.

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That result can be alleviation of the signs, symptoms, or causes of a disease, or any other desired alteration of a biological system. In the present invention, the result will typically involve one or more of the following: neutralization of a fXa inhibitor that has been administered to a patient, reversal of the anticoagulant activity of the fXa inhibitor, removal of the fXa inhibitor from the plasma, restoration of hemostasis, and reduction or cessation of bleeding. The effective amount will vary depending upon the specific fXa derivative or blood coagulating agent used, the specific fXa inhibitor the subject has been administered, the dosing regimen of the fXa inhibitor, timing of administration of the antidote, the subject and disease condition being treated, the weight and age of the subject, the severity of the disease condition, the manner of administration and the like, all of which can be determined readily by one of ordinary skill in the art. "An sub-effective amount" or "a sub-therapeutically effective amount" refers to the amount of a fXa derivative, or a blood coagulating agent, when administered alone or in combination, sufficient to induce a biological and/or therapeutic result, which may not reach a desired level when one agent (either the blood coagulating agent or the fXa protein derivative) is administered alone.

[0101] Effective unit doses of the antidotes described herein are described in United States Provisional Application Serial No. 61/225,887, filed on July 15, 2009 and entitled "Unit Dose Formulation of Antidotes for Factor Xa Inhibitors and Methods of Using the Same," which is hereby incorporated by reference in its entirety. Specifically, it is contemplated that the unit dose formulation comprising a pharmaceutically acceptable carrier and a two chain polypeptide comprising the amino acid sequence of SEQ ID NO. 13 or a polypeptide having at least 80% homology to SEQ ID NO. 13 is an amount from about 10 milligrams to about 2 grams or from about 100 milligrams to about 1.5 grams or from about 200 milligrams to about 1 gram or from about 400 milligrams to about 900 milligrams. It is contemplated that by administering in conjunction with a blood coagulating agent, the dose of the antidote would be less. Alternatively, the amount of blood coagulating agent may be reduced and the amount of antidote would be administered according to the amounts just described. The standard dose for the blood coagulating amount is well within the skill in the art.

[0102] One method of determining if the biological or therapeutic result is achieved is measuring fXa inhibitor dependent pharmacodynamic or surrogate markers

in a patient. The marker may be , but is not limited to , INR, PT, aPTT, ACT, anti fXa units, and thrombin generation (Technothrombin TGA, thromboelastography, CAT (calibrated automated thrombogram)).

5 [0103] As used herein, the terms "treating," "treatment" and the like are used herein to mean obtaining a desired pharmacologic and/or physiologic effect. The effect may be prophylactic in terms of completely or partially preventing a disorder or sign or symptom thereof, and/or may be therapeutic in terms of a partial or complete cure for a disorder and/or adverse effect attributable to the disorder.

10 [0104] "Treating" also covers any treatment of a disorder in a mammal, and includes: (a) preventing a disorder from occurring in a subject that may be predisposed to a disorder, but may have not yet been diagnosed as having it, e.g., prevent bleeding in a patient with anticoagulant overdose; (b) inhibiting a disorder, i.e., arresting its development, e.g., inhibiting bleeding; or (c) relieving or ameliorating the disorder, e.g., reducing bleeding.

15 [0105] As used herein, to "treat" further includes systemic amelioration of the symptoms associated with the pathology and/or a delay in onset of symptoms. Clinical and sub-clinical evidence of "treatment" will vary with the pathology, the individual and the treatment.

[0106] Further, the term "prevent" also refers to "inhibiting."

20 [0107] "Administration" can be effected in one dose, continuously or intermittently throughout the course of treatment. Methods of determining the most effective means and dosage of administration are known to those of skill in the art and will vary with the composition used for therapy, the purpose of the therapy, the target cell being treated, and the subject being treated. Single or multiple administrations can be
25 carried out with the dose level and pattern being selected by the treating physician. Suitable dosage formulations and methods of administering the agents are known in the art.

[0108] The agents and compositions of the present invention can be used in the manufacture of medicaments and for the treatment of humans and other animals by

administration in accordance with conventional procedures, such as an active ingredient in pharmaceutical compositions.

[0109] An agent of the present invention can be administered for therapy by any suitable route, specifically by parental (including subcutaneous, intramuscular, intravenous and intradermal) administration. It will also be appreciated that the preferred route will vary with the condition and age of the recipient, and the disease being treated.

[0110] One can determine if the method, *i.e.*, inhibition or reversal of a factor Xa inhibitor is achieved, by a number of *in vitro* assays, such as thrombin generation assay and anti fXa units, and clinical clotting assays such as aPTT, PT and ACT.

[0111] The term "isolated" as used herein with respect to nucleic acids, such as DNA or RNA, refers to molecules separated from other DNAs or RNAs, respectively that are present in the natural source of the macromolecule. The term "isolated nucleic acid" is meant to include nucleic acid fragments which are not naturally occurring as fragments and would not be found in the natural state. The term "isolated" is also used herein to refer to polypeptides and proteins that are isolated from other cellular proteins and is meant to encompass both purified and recombinant polypeptides. In other embodiments, the term "isolated" means separated from constituents, cellular and otherwise, in which the cell, tissue, polynucleotide, peptide, polypeptide, protein, antibody or fragment(s) thereof, which are normally associated in nature. For example, an isolated cell is a cell that is separated from tissue or cells of dissimilar phenotype or genotype. As is apparent to those of skill in the art, a non-naturally occurring polynucleotide, peptide, polypeptide, protein, antibody or fragment(s) thereof, does not require "isolation" to distinguish it from its naturally occurring counterpart.

[0112] As used herein, the term "equivalent thereof" when referring to a reference protein, polypeptide or nucleic acid, intends those having minimal homology while still maintaining desired functionality. It is contemplated that any modified protein mentioned herein also includes equivalents thereof. For example, the homology can be, at least 75 % homology and alternatively, at least 80 %, or alternatively at least 85 %, or alternatively at least 90 %, or alternatively at least 95 %, or alternatively 98 % percent homology and exhibit substantially equivalent biological activity to the reference

polypeptide or protein. A polynucleotide or polynucleotide region (or a polypeptide or polypeptide region) has a certain percentage (for example, 80%, 85%, 90%, or 95%) of “sequence identity” to another sequence means that, when aligned, that percentage of bases (or amino acids) are the same in comparing the two sequences. It should be noted that when only the heavy chain of fXa (or a related serine protease) is used, the overall homology might be lower than 75%, such as, for example, 65% or 50% however, the desired functionality remains. This alignment and the percent homology or sequence identity can be determined using software programs known in the art, for example those described in CURRENT PROTOCOLS IN MOLECULAR BIOLOGY (F.M. Ausubel *et al.*, eds., 1987) Supplement 30, section 7.7.18, Table 7.7.1. Preferably, default parameters are used for alignment. A preferred alignment program is BLAST, using default parameters. In particular, preferred programs are BLASTN and BLASTP, using the following default parameters: Genetic code = standard; filter = none; strand = both; cutoff = 60; expect = 10; Matrix = BLOSUM62; Descriptions = 50 sequences; sort by = HIGH SCORE; Databases = non-redundant, GenBank + EMBL + DDBJ + PDB + GenBank CDS translations + SwissProtein + SPupdate + PIR. Details of these programs can be found at the following Internet address: <http://www.ncbi.nlm.nih.gov/cgi-bin/BLAST>.

[0113] The terms “polynucleotide” and “oligonucleotide” are used interchangeably and refer to a polymeric form of nucleotides of any length, either deoxyribonucleotides or ribonucleotides or analogs thereof. Polynucleotides can have any three-dimensional structure and may perform any function, known or unknown. The following are non-limiting examples of polynucleotides: a gene or gene fragment (for example, a probe, primer, EST or SAGE tag), exons, introns, messenger RNA (mRNA), transfer RNA, ribosomal RNA, ribozymes, cDNA, recombinant polynucleotides, branched polynucleotides, plasmids, vectors, isolated DNA of any sequence, isolated RNA of any sequence, nucleic acid probes and primers. A polynucleotide can comprise modified nucleotides, such as methylated nucleotides and nucleotide analogs. If present, modifications to the nucleotide structure can be imparted before or after assembly of the polynucleotide. The sequence of nucleotides can be interrupted by non-nucleotide components. A polynucleotide can be further modified after polymerization, such as by conjugation with a labeling component. The term also refers to both double- and single-stranded molecules. Unless otherwise specified or required, any embodiment of

this invention that is a polynucleotide encompasses both the double-stranded form and each of two complementary single-stranded forms known or predicted to make up the double-stranded form.

5 [0114] A polynucleotide is composed of a specific sequence of four nucleotide bases: adenine (A); cytosine (C); guanine (G); thymine (T); and uracil (U) for thymine when the polynucleotide is RNA. Thus, the term “polynucleotide sequence” is the alphabetical representation of a polynucleotide molecule. This alphabetical representation can be input into databases in a computer having a central processing unit and used for bioinformatics applications such as functional genomics and homology
10 searching.

 [0115] “Homology” or “identity” or “similarity” refers to sequence similarity between two peptides or between two nucleic acid molecules. Homology can be determined by comparing a position in each sequence which may be aligned for purposes of comparison. When a position in the compared sequence is occupied by the
15 same base or amino acid, then the molecules are homologous at that position. A degree of homology between sequences is a function of the number of matching or homologous positions shared by the sequences. An “unrelated” or “non-homologous” sequence shares less than 40% identity, or alternatively less than 25% identity, with one of the sequences of the present invention.

20 [0116] A polynucleotide or polynucleotide region (or a polypeptide or polypeptide region) has a certain percentage (for example, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 98% or 99%) of “sequence identity” to another sequence means that, when aligned, that percentage of bases (or amino acids) are the same in comparing the two sequences. This alignment and the percent homology or sequence identity can be
25 determined using software programs known in the art, for example those described in Ausubel et al. eds. (2007) Current Protocols in Molecular Biology. Preferably, default parameters are used for alignment. One alignment program is BLAST, using default parameters. In particular, programs are BLASTN and BLASTP, using the following default parameters: Genetic code = standard; filter = none; strand = both; cutoff = 60;
30 expect = 10; Matrix = BLOSUM62; Descriptions = 50 sequences; sort by = HIGH SCORE; Databases = non-redundant, GenBank + EMBL + DDBJ + PDB + GenBank

CDS translations + SwissProtein + SPupdate + PIR. Details of these programs can be found at the following Internet address: <http://www.ncbi.nlm.nih.gov/blast/Blast.cgi>, last accessed on November 26, 2007. Biologically equivalent polynucleotides are those having the specified percent homology and encoding a polypeptide having the same or similar biological activity.

[0117] The term “a homolog of a nucleic acid” refers to a nucleic acid having a nucleotide sequence having a certain degree of homology with the nucleotide sequence of the nucleic acid or complement thereof. A homolog of a double stranded nucleic acid is intended to include nucleic acids having a nucleotide sequence which has a certain degree of homology with or with the complement thereof. In one aspect, homologs of nucleic acids are capable of hybridizing to the nucleic acid or complement thereof.

[0118] A “gene” refers to a polynucleotide containing at least one open reading frame (ORF) that is capable of encoding a particular polypeptide or protein after being transcribed and translated. Any of the polynucleotide or polypeptide sequences described herein may be used to identify larger fragments or full-length coding sequences of the gene with which they are associated. Methods of isolating larger fragment sequences are known to those of skill in the art.

[0119] The term “express” refers to the production of a gene product.

[0120] As used herein, “expression” refers to the process by which polynucleotides are transcribed into mRNA and/or the process by which the transcribed mRNA is subsequently being translated into peptides, polypeptides, or proteins. If the polynucleotide is derived from genomic DNA, expression may include splicing of the mRNA in an eukaryotic cell.

[0121] The term “encode” as it is applied to polynucleotides refers to a polynucleotide which is said to “encode” a polypeptide if, in its native state or when manipulated by methods well known to those skilled in the art, it can be transcribed and/or translated to produce the mRNA for the polypeptide and/or a fragment thereof. The antisense strand is the complement of such a nucleic acid, and the encoding sequence can be deduced therefrom.

[0122] A “peptide conjugate” refers to the association by covalent or non-covalent bonding of one or more polypeptides and another chemical or biological compound. In a non-limiting example, the “conjugation” of a polypeptide with a chemical compound results in improved stability or efficacy of the polypeptide for its intended purpose. In one embodiment, a peptide is conjugated to a carrier, wherein the carrier is a liposome, a micelle, or a pharmaceutically acceptable polymer.

[0123] “Liposomes” are microscopic vesicles consisting of concentric lipid bilayers. Structurally, liposomes range in size and shape from long tubes to spheres, with dimensions from a few hundred Angstroms to fractions of a millimeter. Vesicle-forming lipids are selected to achieve a specified degree of fluidity or rigidity of the final complex providing the lipid composition of the outer layer. These are neutral (cholesterol) or bipolar and include phospholipids, such as phosphatidylcholine (PC), phosphatidylethanolamine (PE), phosphatidylinositol (PI), and sphingomyelin (SM) and other types of bipolar lipids including but not limited to dioleoylphosphatidylethanolamine (DOPE), with a hydrocarbon chain length in the range of 14-22, and saturated or with one or more double C=C bonds. Examples of lipids capable of producing a stable liposome, alone, or in combination with other lipid components are phospholipids, such as hydrogenated soy phosphatidylcholine (HSPC), lecithin, phosphatidylethanolamine, lysolecithin, lysophosphatidylethanol-amine, phosphatidylserine, phosphatidylinositol, sphingomyelin, cephalin, cardiolipin, phosphatidic acid, cerebroside, distearoylphosphatidylethanolamine (DSPE), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), palmitoyl-oleoylphosphatidylcholine (POPC), palmitoyl-oleoylphosphatidylethanolamine (POPE) and dioleoylphosphatidylethanolamine 4-(N-maleimido-methyl)cyclohexane-1-carboxylate (DOPE-mal). Additional non-phosphorous containing lipids that can become incorporated into liposomes include stearylamine, dodecylamine, hexadecylamine, isopropyl myristate, triethanolamine-lauryl sulfate, alkyl-aryl sulfate, acetyl palmitate, glycerol ricinoleate, hexadecyl stearate, amphoteric acrylic polymers, polyethoxylated fatty acid amides, and the cationic lipids mentioned above (DDAB, DODAC, DMRIE, DMTAP, DOGS, DOTAP (DOTMA), DOSPA, DPTAP, DSTAP, DC-Chol). Negatively charged lipids include phosphatidic acid (PA), dipalmitoylphosphatidylglycerol (DPPG), dioleoylphosphatidylglycerol and (DOPG),

dicetylphosphate that are able to form vesicles. Typically, liposomes can be divided into three categories based on their overall size and the nature of the lamellar structure. The three classifications, as developed by the New York Academy Sciences Meeting, "Liposomes and Their Use in Biology and Medicine," December 1977, are multi-lamellar vesicles (MLVs), small uni-lamellar vesicles (SUVs) and large uni-lamellar vesicles (LUVs).

[0124] A "micelle" is an aggregate of surfactant molecules dispersed in a liquid colloid. A typical micelle in aqueous solution forms an aggregate with the hydrophilic "head" regions in contact with surrounding solvent, sequestering the hydrophobic tail regions in the micelle center. This type of micelle is known as a normal phase micelle (oil-in-water micelle). Inverse micelles have the head groups at the center with the tails extending out (water-in-oil micelle). Micelles can be used to attach a polynucleotide, polypeptide, antibody or composition described herein to facilitate efficient delivery to the target cell or tissue.

[0125] The phrase "pharmaceutically acceptable polymer" refers to the group of compounds which can be conjugated to one or more polypeptides described here. It is contemplated that the conjugation of a polymer to the polypeptide is capable of extending the half-life of the polypeptide *in vivo* and *in vitro*. Non-limiting examples include polyethylene glycols, polyvinylpyrrolidones, polyvinylalcohols, cellulose derivatives, polyacrylates, polymethacrylates, sugars, polyols and mixtures thereof.

[0126] A "gene delivery vehicle" is defined as any molecule that can carry inserted polynucleotides into a host cell. Examples of gene delivery vehicles are liposomes, micelles biocompatible polymers, including natural polymers and synthetic polymers; lipoproteins; polypeptides; polysaccharides; lipopolysaccharides; artificial viral envelopes; metal particles; and bacteria, or viruses, such as baculovirus, adenovirus and retrovirus, bacteriophage, cosmid, plasmid, fungal vectors and other recombination vehicles typically used in the art which have been described for expression in a variety of eukaryotic and prokaryotic hosts, and may be used for gene therapy as well as for simple protein expression.

[0127] A polynucleotide of this invention can be delivered to a cell or tissue using a gene delivery vehicle. "Gene delivery," "gene transfer," "transducing," and

the like as used herein, are terms referring to the introduction of an exogenous polynucleotide (sometimes referred to as a “transgene”) into a host cell, irrespective of the method used for the introduction. Such methods include a variety of well-known techniques such as vector-mediated gene transfer (by, e.g., viral infection/transfection, or various other protein-based or lipid-based gene delivery complexes) as well as techniques facilitating the delivery of “naked” polynucleotides (such as electroporation, “gene gun” delivery and various other techniques used for the introduction of polynucleotides). The introduced polynucleotide may be stably or transiently maintained in the host cell. Stable maintenance typically requires that the introduced polynucleotide either contains an origin of replication compatible with the host cell or integrates into a replicon of the host cell such as an extrachromosomal replicon (e.g., a plasmid) or a nuclear or mitochondrial chromosome. A number of vectors are known to be capable of mediating transfer of genes to mammalian cells, as is known in the art and described herein.

[0128] A “viral vector” is defined as a recombinantly produced virus or viral particle that comprises a polynucleotide to be delivered into a host cell, either *in vivo*, *ex vivo* or *in vitro*. Examples of viral vectors include retroviral vectors, adenovirus vectors, adeno-associated virus vectors, alphavirus vectors and the like. Alphavirus vectors, such as Semliki Forest virus-based vectors and Sindbis virus-based vectors, have also been developed for use in gene therapy and immunotherapy. *See*, Schlesinger and Dubensky (1999) *Curr. Opin. Biotechnol.* 5:434-439 and Ying, et al. (1999) *Nat. Med.* 5(7):823-827. In aspects where gene transfer is mediated by a retroviral vector, a vector construct refers to the polynucleotide comprising the retroviral genome or part thereof, and a therapeutic gene. As used herein, “retroviral mediated gene transfer” or “retroviral transduction” carries the same meaning and refers to the process by which a gene or nucleic acid sequences are stably transferred into the host cell by virtue of the virus entering the cell and integrating its genome into the host cell genome. The virus can enter the host cell via its normal mechanism of infection or be modified such that it binds to a different host cell surface receptor or ligand to enter the cell. As used herein, retroviral vector refers to a viral particle capable of introducing exogenous nucleic acid into a cell through a viral or viral-like entry mechanism.

[0129] Retroviruses carry their genetic information in the form of RNA; however, once the virus infects a cell, the RNA is reverse-transcribed into the DNA form

which integrates into the genomic DNA of the infected cell. The integrated DNA form is called a provirus.

[0130] In aspects where gene transfer is mediated by a DNA viral vector, such as an adenovirus (Ad) or adeno-associated virus (AAV), a vector construct refers to the polynucleotide comprising the viral genome or part thereof, and a transgene. Adenoviruses (Ads) are a relatively well characterized, homogenous group of viruses, including over 50 serotypes. *See, e.g.,* International PCT Application No. WO 95/27071. Ads do not require integration into the host cell genome. Recombinant Ad derived vectors, particularly those that reduce the potential for recombination and generation of wild-type virus, have also been constructed. *See, International PCT Application Nos. WO 95/00655 and WO 95/11984.* Wild-type AAV has high infectivity and specificity integrating into the host cell's genome. *See, Hermonat and Muzyczka (1984) Proc. Natl. Acad. Sci. USA 81:6466-6470 and Lebkowski et al. (1988) Mol. Cell. Biol. 8:3988-3996.*

[0131] Vectors that contain both a promoter and a cloning site into which a polynucleotide can be operatively linked are well known in the art. Such vectors are capable of transcribing RNA *in vitro* or *in vivo*, and are commercially available from sources such as Stratagene (La Jolla, CA) and Promega Biotech (Madison, WI). In order to optimize expression and/or *in vitro* transcription, it may be necessary to remove, add or alter 5' and/or 3' untranslated portions of the clones to eliminate extra, potential inappropriate alternative translation initiation codons or other sequences that may interfere with or reduce expression, either at the level of transcription or translation. Alternatively, consensus ribosome binding sites can be inserted immediately 5' of the start codon to enhance expression.

[0132] Gene delivery vehicles also include DNA/liposome complexes, micelles and targeted viral protein-DNA complexes. Liposomes that also comprise a targeting antibody or fragment thereof can be used in the methods of this invention. To enhance delivery to a cell, the nucleic acid or proteins of this invention can be conjugated to antibodies or binding fragments thereof which bind cell surface antigens, e.g., a cell surface marker found on stem cells or cardiomyocytes. In addition to the delivery of polynucleotides to a cell or cell population, direct introduction of the proteins described herein to the cell or cell population can be done by the non-limiting technique of protein

transfection, alternatively culturing conditions that can enhance the expression and/or promote the activity of the proteins of this invention are other non-limiting techniques.

[0133] The phrase “solid support” refers to non-aqueous surfaces such as “culture plates” “gene chips” or “microarrays.” Such gene chips or microarrays can be used for diagnostic and therapeutic purposes by a number of techniques known to one of skill in the art. In one technique, oligonucleotides are arrayed on a gene chip for determining the DNA sequence by the hybridization approach, such as that outlined in U.S. Patent Nos. 6,025,136 and 6,018,041. The polynucleotides of this invention can be modified to probes, which in turn can be used for detection of a genetic sequence. Such techniques have been described, for example, in U.S. Patent Nos. 5,968,740 and 5,858,659. A probe also can be affixed to an electrode surface for the electrochemical detection of nucleic acid sequences such as described by Kayem et al. U.S. Patent No. 5,952,172 and by Kelley et al. (1999) *Nucleic Acids Res.* **27**:4830-4837.

[0134] Various “gene chips” or “microarrays” and similar technologies are known in the art. Examples of such include, but are not limited to, LabCard (ACLARA Bio Sciences Inc.); GeneChip (Affymetrix, Inc.); LabChip (Caliper Technologies Corp); a low-density array with electrochemical sensing (Clinical Micro Sensors); LabCD System (Gamera Bioscience Corp.); Omni Grid (Gene Machines); Q Array (Genetix Ltd.); a high-throughput, automated mass spectrometry systems with liquid-phase expression technology (Gene Trace Systems, Inc.); a thermal jet spotting system (Hewlett Packard Company); Hyseq HyChip (Hyseq, Inc.); BeadArray (Illumina, Inc.); GEM (Incyte Microarray Systems); a high-throughput microarraying system that can dispense from 12 to 64 spots onto multiple glass slides (Intelligent Bio-Instruments); Molecular Biology Workstation and NanoChip (Nanogen, Inc.); a microfluidic glass chip (Orchid biosciences, Inc.); BioChip Arrayer with four PiezoTip piezoelectric drop-on-demand tips (Packard Instruments, Inc.); FlexJet (Rosetta Inpharmatic, Inc.); MALDI-TOF mass spectrometer (Sequenome); ChipMaker 2 and ChipMaker 3 (TeleChem International, Inc.); and GenoSensor (Vysis, Inc.) as identified and described in Heller (2002) *Annu. Rev. Biomed. Eng.* **4**:129-153. Examples of “gene chips” or a “microarrays” are also described in U.S. Patent Publ. Nos.: 2007-0111322, 2007-0099198, 2007-0084997, 2007-0059769 and 2007-0059765 and U.S. Patent Nos.: 7,138,506, 7,070,740, and 6,989,267.

[0135] In one aspect, “gene chips” or “microarrays” containing probes or primers homologous to a polynucleotide, polypeptide or antibody described herein are prepared. A suitable sample is obtained from the patient, extraction of genomic DNA, RNA, protein or any combination thereof is conducted and amplified if necessary. The sample is contacted to the gene chip or microarray panel under conditions suitable for hybridization of the gene(s) or gene product(s) of interest to the probe(s) or primer(s) contained on the gene chip or microarray. The probes or primers may be detectably labeled thereby identifying the gene(s) of interest. Alternatively, a chemical or biological reaction may be used to identify the probes or primers which hybridized with the DNA or RNA of the gene(s) of interest. The genotypes or phenotype of the patient is then determined with the aid of the aforementioned apparatus and methods.

[0136] Other non-limiting examples of a solid phase support include glass, polystyrene, polypropylene, polyethylene, dextran, nylon, amylases, natural and modified celluloses, polyacrylamides, gabbros, and magnetite. The nature of the carrier can be either soluble to some extent or insoluble. The support material may have virtually any possible structural configuration so long as the coupled molecule is capable of binding to a polynucleotide, polypeptide or antibody. Thus, the support configuration may be spherical, as in a bead, or cylindrical, as in the inside surface of a test tube, or the external surface of a rod. Alternatively, the surface may be flat such as a sheet, test strip, etc. or alternatively polystyrene beads. Those skilled in the art will know many other suitable carriers for binding antibody or antigen, or will be able to ascertain the same by use of routine experimentation..

[0137] “Eukaryotic cells” comprise all of the life kingdoms except monera. They can be easily distinguished through a membrane-bound nucleus. Animals, plants, fungi, and protists are eukaryotes or organisms whose cells are organized into complex structures by internal membranes and a cytoskeleton. The most characteristic membrane-bound structure is the nucleus. A eukaryotic host, including, for example, yeast, higher plant, insect and mammalian cells, or alternatively from a prokaryotic cells as described above. Non-limiting examples include simian, bovine, porcine, murine, rats, avian, reptilian and human.

[0138] "Prokaryotic cells" that usually lack a nucleus or any other membrane-bound organelles and are divided into two domains, bacteria and archaea. Additionally, instead of having chromosomal DNA, these cells' genetic information is in a circular loop called a plasmid. Bacterial cells are very small, roughly the size of an animal mitochondrion (about 1-2 μ m in diameter and 10 μ m long). Prokaryotic cells feature three major shapes: rod shaped, spherical, and spiral. Instead of going through elaborate replication processes like eukaryotes, bacterial cells divide by binary fission. Examples include but are not limited to *bacillus* bacteria, *E. coli* bacterium, and *Salmonella* bacterium.

10 [0139] The term "human antibody" as used herein, is intended to include antibodies having variable and constant regions derived from human germline immunoglobulin sequences. The human antibodies of the invention may include amino acid residues not encoded by human germline immunoglobulin sequences (e.g., mutations introduced by random or site-specific mutagenesis *in vitro* or by somatic mutation *in vivo*). However, the term "human antibody" as used herein, is not intended to include antibodies in which CDR sequences derived from the germline of another mammalian species, such as a mouse, have been grafted onto human framework sequences. Thus, as used herein, the term "human antibody" refers to an antibody in which substantially every part of the protein (e.g., CDR, framework, C_L, C_H domains (e.g., C_{H1}, C_{H2}, C_{H3}), hinge, (VL, VH)) is substantially non-immunogenic in humans, with only minor sequence changes or variations. Similarly, antibodies designated primate (monkey, baboon, chimpanzee, etc.), rodent (mouse, rat, rabbit, guinea pig, hamster, and the like) and other mammals designate such species, sub-genus, genus, sub-family, family specific antibodies. Further, chimeric antibodies include any combination of the above. Such changes or variations optionally and preferably retain or reduce the immunogenicity in humans or other species relative to non-modified antibodies. Thus, a human antibody is distinct from a chimeric or humanized antibody. It is pointed out that a human antibody can be produced by a non-human animal or prokaryotic or eukaryotic cell that is capable of expressing functionally rearranged human immunoglobulin (e.g., heavy chain and/or light chain) genes. Further, when a human antibody is a single chain antibody, it can comprise a linker peptide that is not found in native human antibodies. For example, an Fv can comprise a linker peptide, such as two to about eight glycine or other amino acid

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residues, which connects the variable region of the heavy chain and the variable region of the light chain. Such linker peptides are considered to be of human origin.

[0140] As used herein, a human antibody is “derived from” a particular germline sequence if the antibody is obtained from a system using human immunoglobulin sequences, e.g., by immunizing a transgenic mouse carrying human immunoglobulin genes or by screening a human immunoglobulin gene library. A human antibody that is “derived from” a human germline immunoglobulin sequence can be identified as such by comparing the amino acid sequence of the human antibody to the amino acid sequence of human germline immunoglobulins. A selected human antibody typically is at least 90% identical in amino acids sequence to an amino acid sequence encoded by a human germline immunoglobulin gene and contains amino acid residues that identify the human antibody as being human when compared to the germline immunoglobulin amino acid sequences of other species (e.g., murine germline sequences). In certain cases, a human antibody may be at least 95%, or even at least 96%, 97%, 98%, or 99% identical in amino acid sequence to the amino acid sequence encoded by the germline immunoglobulin gene. Typically, a human antibody derived from a particular human germline sequence will display no more than 10 amino acid differences from the amino acid sequence encoded by the human germline immunoglobulin gene. In certain cases, the human antibody may display no more than 5, or even no more than 4, 3, 2, or 1 amino acid difference from the amino acid sequence encoded by the germline immunoglobulin gene.

[0141] A “human monoclonal antibody” refers to antibodies displaying a single binding specificity which have variable and constant regions derived from human germline immunoglobulin sequences. The term also intends recombinant human antibodies. Methods to making these antibodies are described herein.

[0142] The term “recombinant human antibody”, as used herein, includes all human antibodies that are prepared, expressed, created or isolated by recombinant means, such as antibodies isolated from an animal (e.g., a mouse) that is transgenic or transchromosomal for human immunoglobulin genes or a hybridoma prepared therefrom, antibodies isolated from a host cell transformed to express the antibody, e.g., from a transfectoma, antibodies isolated from a recombinant, combinatorial human antibody

library, and antibodies prepared, expressed, created or isolated by any other means that involve splicing of human immunoglobulin gene sequences to other DNA sequences. Such recombinant human antibodies have variable and constant regions derived from human germline immunoglobulin sequences. In certain embodiments, however, such
5 recombinant human antibodies can be subjected to *in vitro* mutagenesis (or, when an animal transgenic for human Ig sequences is used, *in vivo* somatic mutagenesis) and thus the amino acid sequences of the VH and VL regions of the recombinant antibodies are sequences that, while derived from and related to human germline VH and VL sequences, may not naturally exist within the human antibody germline repertoire *in vivo*. Methods
10 to making these antibodies are described herein.

[0143] As used herein, "isotype" refers to the antibody class (e.g., IgM or IgG1) that is encoded by heavy chain constant region genes.

[0144] The terms "polyclonal antibody" or "polyclonal antibody composition" as used herein refer to a preparation of antibodies that are derived from
15 different B-cell lines. They are a mixture of immunoglobulin molecules secreted against a specific antigen, each recognizing a different epitope.

[0145] The terms "monoclonal antibody" or "monoclonal antibody composition" as used herein refer to a preparation of antibody molecules of single molecular composition. A monoclonal antibody composition displays a single binding
20 specificity and affinity for a particular epitope.

[0146] As used herein, the term "label" intends a directly or indirectly detectable compound or composition that is conjugated directly or indirectly to the composition to be detected, e.g., polynucleotide or protein such as an antibody so as to generate a "labeled" composition. The term also includes sequences conjugated to the
25 polynucleotide that will provide a signal upon expression of the inserted sequences, such as green fluorescent protein (GFP) and the like. The label may be detectable by itself (e.g. radioisotope labels or fluorescent labels) or, in the case of an enzymatic label, may catalyze chemical alteration of a substrate compound or composition which is detectable. The labels can be suitable for small scale detection or more suitable for high-throughput
30 screening. As such, suitable labels include, but are not limited to radioisotopes, fluorochromes, chemiluminescent compounds, dyes, and proteins, including enzymes.

The label may be simply detected or it may be quantified. A response that is simply detected generally comprises a response whose existence merely is confirmed, whereas a response that is quantified generally comprises a response having a quantifiable (e.g., numerically reportable) value such as an intensity, polarization, and/or other property. In
5 luminescence or fluorescence assays, the detectable response may be generated directly using a luminophore or fluorophore associated with an assay component actually involved in binding, or indirectly using a luminophore or fluorophore associated with another (e.g., reporter or indicator) component.

[0147] Examples of luminescent labels that produce signals include, but
10 are not limited to bioluminescence and chemiluminescence. Detectable luminescence response generally comprises a change in, or an occurrence of, a luminescence signal. Suitable methods and luminophores for luminescently labeling assay components are known in the art and described for example in Haugland, Richard P. (1996) Handbook of Fluorescent Probes and Research Chemicals (6th ed.). Examples of luminescent probes
15 include, but are not limited to, aequorin and luciferases.

[0148] Examples of suitable fluorescent labels include, but are not limited to, fluorescein, rhodamine, tetramethylrhodamine, eosin, erythrosin, coumarin, methyl-coumarins, pyrene, Malacite green, stilbene, Lucifer Yellow, Cascade BlueTM, and Texas Red. Other suitable optical dyes are described in the Haugland, Richard P. (1996)
20 Handbook of Fluorescent Probes and Research Chemicals (6th ed.).

[0149] In another aspect, the fluorescent label is functionalized to facilitate covalent attachment to a cellular component present in or on the surface of the cell or tissue such as a cell surface marker. Suitable functional groups, including, but not are limited to, isothiocyanate groups, amino groups, haloacetyl groups, maleimides,
25 succinimidyl esters, and sulfonyl halides, all of which may be used to attach the fluorescent label to a second molecule. The choice of the functional group of the fluorescent label will depend on the site of attachment to either a linker, the agent, the marker, or the second labeling agent.

II. Methods of the Invention

[0150] One aspect of the present invention relates to a method of preventing or reducing bleeding in a subject undergoing anticoagulant therapy by administering to the subject an effective amount of a factor Xa protein derivative and an effective amount of a blood coagulating agent or a heparin antidote. The blood coagulating agent initiates or enhances blood clot formation. In one embodiment, the coagulant agent has procoagulant, anti-thrombolytic, and/or anti-fibrinolytic activity. In one embodiment, the derivative has a modified active site and/or a modified Gla-domain thereby having either reduced or no procoagulant activity. The derivative acts as an antidote and substantially neutralizes the anticoagulant activity of the inhibitor. In one embodiment, the derivative is either Gla-deficient or Gla-domainless. In one embodiment, the blood coagulating agent is selected from the group consisting of a coagulation factor, a polypeptide related to the coagulation factor, a recombinant coagulation factor and combinations thereof. In another embodiment, the blood coagulating agent may be a non-specific anti-bleeding agent. In another embodiment, the blood coagulating agent may be selected from the group consisting of an adsorbent chemical, a hemostatic agent, thrombin, fibrin glue, desmopressin, cryoprecipitate and fresh frozen plasma, coagulation factor concentrate, activated or non-activated prothrombin complex concentrate, Feiba Vh, platelet concentrates and combinations thereof. More examples of available blood coagulation factors are available in the citation Brooker M, Registry of Clotting Factor Concentrates, Eighth Edition, World Federation of Hemophilia, 2008. The subject may be a mammal or more particularly, a human.

[0151] Patients suitable for this therapy have undergone prior anticoagulant therapy, for example, they have been administered one or more of an anticoagulant, such as an inhibitor of factor Xa. Examples of anticoagulants that are factor Xa inhibitors, include but are not limited to, fondaparinux, idraparinux, biotinylated idraparinux, enoxaparin, fragmin, NAP-5, rNAPc2, tissue factor pathway inhibitor, DX-9065a, YM-60828, YM-150, apixaban, rivaroxaban, PD-348292, otamixaban, DU-176b, LY517717, GSK913893, low molecular weight heparin, and betrixaban, or any combination thereof. The source of various anticoagulants is found throughout the description.

[0152] In one aspect, the derivative has a modified active site and/or a modified or removed Gla domain. In one aspect, the factor Xa derivative has or exhibits no procoagulant activity. In this aspect, the derivative comprises at least amino acid residues 40 to 448, 45 to 448, or 46 to 448 of SEQ ID NO. 3 or equivalents thereof. In
5 another aspect, the derivative comprises at least amino acid residues 45 to 139 and 195 to 448 or 46 to 139 and 195-448 of SEQ ID NO. 3 or equivalents thereof.

[0153] In another aspect of the invention, the fXa derivative retains the three dimensional structure of the active site of the fXa protein. Information regarding the three-dimensional structure of the des-Gla fXa may be found in Brandstetter, H et al.
10 *J. Bio. Chem.*, 1996, 271:29988-29992.

[0154] In another aspect of the invention, the fXa derivatives may lack the Gla domain as well as either one of the two EGF domains. In another aspect of the invention, the fXa derivatives are completely lacking the light chain. Other modifications of the heavy chain may comprise the catalytic domain of related serine proteases which
15 are capable of binding inhibitors. The related serine proteases have catalytic domains which possess sufficient structural similarity to fXa catalytic domain and are therefore capable of binding small molecule fXa inhibitors. Examples of related serine proteases include, but are not limited to, mammalian proteases such as plasma kallikrein, thrombin and trypsin or the bacterial protease subtilisin. These derivatives further include
20 modifications at the amino acids residues equivalent to the active site serine (SER379) or aspartic acid (ASP282) residues described herein.

[0155] In some embodiments, the factor Xa protein with reduced procoagulant activity comprises a modified light chain, wherein the modification is substitution, addition or deletion of the Gla-domain to reduce the phospholipid membrane
25 binding of fXa. In some embodiments, the prime amino acid sequence of fXa is not changed, but the side chain of certain amino acids has been changed. Examples of the modified Gla-domain that reduces the phospholipid membrane binding of fXa comprises polypeptides or proteins having the primary amino acid sequence of SEQ ID NO. 3 or an equivalent thereof, with at least one amino acid substitution, addition, or deletion as
30 compared to the Gla-domain of a wild type human factor Xa protein. In some embodiments, at least one amino acid being substituted or deleted is a γ -carboxyglutamic

acid (Gla). Gla residues are shown in SEQ ID NO. 3 at amino acid positions 6, 7, 14, 16, 19, 20, 25, 26, 29, 32, and 39. In some embodiments, the antidote's primary amino acid sequence is identical to SEQ ID NO. 3 or equivalent thereof, but is an uncarboxylated, undercarboxylated or decarboxylated factor Xa protein. In some embodiments, the
5 antidote is a des-Gla anhydro-fXa or des-Gla fX-S379A. In some embodiments, the factor Xa protein with reduced phospholipid membrane binding further comprises modification or deletion of the EGF1 and/or EGF2 (shown in Figure 3 as amino acids 46 to 84 and 85 to 128, respectively) or a part, i.e. fragment of the EGF1 and/or EGF2 domains. In some embodiments, the entire light chain or substantially the entire light
10 chain is modified or removed. For example, the modified fXa protein with reduced phospholipid membrane binding may contain only the heavy chain or the modified fXa may contain the heavy chain and a fragment of the light chain that contains Cys132, the amino acid residue that forms the single disulfide bond with Cys302 of the heavy chain in SEQ ID NO. 3. In some embodiments, the derivative comprises the amino acid sequence
15 of SEQ ID NO. 12. In some embodiments, the derivative is the two chain polypeptide comprising SEQ ID NO. 13. In other embodiments, the derivative is the polypeptide of SEQ ID NO. 15.

[0156] In some embodiments, the factor Xa protein derivative comprises a modified heavy chain that contains the catalytic domain of said factor Xa protein. In
20 some embodiments, at least one amino acid substitution is present at one or more amino acid position of fXa selected from the group consisting of Glu216, Glu218, Arg332, Arg347, Lys351, and Ser379 in SEQ ID NOS. 3 and 7 (Glu37, Glu39, Arg150, Arg165, Lys169, and Ser195 in chymotrypsin numbering, respectively). In some embodiments, the antidote is a factor Xa protein with active site serine (Ser379 in SEQ ID NOS. 3 and 7,
25 Ser195 in chymotrypsin numbering) residue modified to dehydro-alanine or alanine. Such modifications may be made to wild type fXa protein or to any of the modified fXa proteins or fragments described above. For example, the des-Gla anhydro-fXa with active site serine residues replaced by dehydro-alanine described in Example 1 has shown antidote activity.

30 [0157] In other embodiments, the derivative has reduced interaction with ATIII, cofactors fV/fVa and fVIII/fVIIIa as compared to wild-type or naturally occurring factor Xa. In some embodiments, at least one amino acid substitution is present at amino

acid position Arg306, Glu310, Arg347, Lys351, Lys414 or Arg424 in SEQ ID NOS. 3 and 7 (Arg125, Glu129, Arg165, Lys169, Lys230 or Arg240 in chymotrypsin numbering, respectively). Such modifications may be made to wild type fXa protein or to any of the modified fXa proteins or fragments described above.

5 [0158] In other embodiments, the fXa derivative is a protein comprising the amino acid sequence of a serine protease catalytic domain which can mimic the inhibitor binding capability of the fXa heavy chain. Such proteins may include mammalian proteases such as plasma kallikrein, thrombin, trypsin (or its bacterial homolog subtilisin) which have been recombinantly modified to lack serine protease
10 activity capable of cleaving protein substrates but still possess the structural characteristics of the active site cleft.

 [0159] Also provided by this invention are pharmaceutical compositions containing one or more of the modified factor Xa derivatives, one or more of the blood coagulating agent or heparin antidotes and a pharmaceutically acceptable carrier. The
15 compositions are administered to a subject in need thereof in an amount that will provide the desired benefit, a reduction or stopping of bleeding. The compositions can be co-administered with any suitable agent or therapy that complements or enhances the activity of the factor Xa derivative. An example of such is a stabilizing agent capable of extending the plasma half-life of the fXa derivative. Examples of suitable stabilizing
20 agents include but are not limited to an anti-fXa antibody recognizing the exosite of fXa heavy chain or an alpha-2-macroglobulin bound fXa derivative. Formation of the complex between fXa derivative and a stabilizing agent (exosite antibody or alpha-2-macroglobulin) would block macromolecular interactions but retains the ability of active site dependent inhibitor bindings. Examples of anti-fXa antibodies suitable for co-
25 administration include but are not limited to those described in Yang Y.H., et al, *J. Immunol.* 2006, 1;177(11):8219-25, Wilkens, M and Krishnaswamy, S., *J. Bio. Chem.*, 2002, 277 (11), 9366-9374, and Church WR, et al, *Blood*, 1988, 72(6), 1911-1921.

 [0160] In some embodiments, a factor Xa protein is modified by chemical, enzymatic or recombinant means. For example, the active site Ser379 may be
30 chemically modified to dehydroalanine, and the Gla domain may be enzymatically removed by chymotrypsin digestion as described in Example 1. A modified fXa

described herein may also be produced by recombinant means by modifying the sequence of the cDNA encoding wild-type fX (SEQ ID NO. 2) described in more details in Example 7 for direct expression of recombinant antidote (r-Antidote) or alternatively, a fX protein with the desired modification may be produced by recombinant means followed by activation to the modified fXa by an activator, such as a snake venom, e.g. Russell's viper venom, and complexes of fVIIa/tissue factor or fIXa/fVIIIa.

[0161] In some embodiments, the blood coagulating agent may be selected from the group consisting of a coagulation factor, a polypeptide related to the coagulation factor, a recombinant coagulation factor and combinations thereof. In some embodiments, the coagulation factor may be selected from the group consisting of plasma derived factors VII/VIIa, IX/IXa, X/Xa, II/IIa, VIII/VIIIa, V/Va and combinations thereof. In some embodiments, the recombinant coagulation factor may be selected from the group consisting of recombinant factors VII/VIIa, IX/IXa, X/Xa, II/IIa, VIII/VIIIa, V/Va and combinations thereof.

[0162] In one aspect, the blood coagulating agent may be recombinant factor VIIa.

[0163] In some embodiments, the blood coagulating agent may be a non-specific anti-bleeding agent. In some embodiments, the blood coagulating agent may be selected from the group consisting of an adsorbent chemical, a hemostatic agent, thrombin, fibrin glue, desmopressin, cryoprecipitate and fresh frozen plasma, coagulation factor concentrate, activated or non-activated prothrombin complex concentrate, Feiba Vh, platelet concentrates and combinations thereof. More examples of available blood coagulation factors are available in the citation Brooker M, Registry of Clotting Factor Concentrates, Eighth Edition, World Federation of Hemophilia, 2008.

[0164] In some embodiments, the blood coagulating agent may be selected from the group consisting of thrombin-activatable fibrinolysis inhibitor (TAFI), protein C inhibitor (PCI), protein S inhibitor (PSI), alpha-2-antiplasmin, tranexamic acid, aminocaproic acid, aprotinin and combinations thereof.

[0165] In some embodiments, the blood coagulating agent may be one agent that has procoagulant, anti-thrombolytic, and/or anti-fibrinolytic activity, or may

comprise one or more different agents that have procoagulant, anti-thrombolytic, and/or anti-fibrinolytic activity, as disclosed in this application, or disclosed in cited patents, patent applications or other references, or known in the art.

[0166] Subjects that will benefit from the administration of the compositions described herein and the accompanying methods include those that are experiencing, or predisposed to a clinical major bleeding event or a clinically significant non-major bleeding event. Examples of clinical major bleeding events are selected from the group consisting of hemorrhage, bleeding into vital organs, bleeding requiring re-operation or a new therapeutic procedure, and a bleeding index of ≥ 2.0 with an associated overt bleed. (Turpie AGG, et al, *NEJM*, 2001, 344: 619-625.) Additionally, the subject may be experiencing or predisposed to a non-major bleeding event selected from the group consisting of epistaxis that is persistent or recurrent and in substantial amount or will not stop without intervention, rectal or urinary tract bleeding that does not rise to a level requiring a therapeutic procedure, substantial hematomas at injection sites or elsewhere that are spontaneous or occur with trivial trauma, substantial blood loss more than usually associated with a surgical procedure that does not require drainage, and bleeding requiring unplanned transfusion.

[0167] In some embodiments, the antidote is administered after the administration of an overdose of a fXa inhibitor or prior to a surgery, which may expose subjects to the risk of hemorrhage.

[0168] In any of the methods described herein, it should be understood, even if not always explicitly stated, that an effective amount of the derivative and/or the blood coagulating agent is administered to the subject. The amount can be empirically determined by the treating physician and will vary with the age, gender, weight and health of the subject. Additional factors to be considered by the treating physician include but are not limited to the identity and/or amount of factor Xa inhibitor, which may have been administered, the method or mode that the antidote will be administered to the subject, the formulation of the antidote, and the therapeutic end point for the patient. With these variables in mind, one of skill will administer a therapeutically effective amount to the subject to be treated. It is contemplated that a therapeutically effective amount of the antidotes described herein sufficient to counteract, or substantially neutralize, an

anticoagulant in a subject may contain from about 0.01 milligram of fXa derivative per kilogram of a subject's body weight to 1 gram of antidote per kilogram of a subject's body weight of antidote. It is further contemplated that the fXa derivative may be provided to the subject in a concentration a range of from about 10 nanomolar to about 5 100 micromolar, or about 10 nanomolar to about 5 micromolar, or about 100 nanomolar to about 2.5 micromolar. Blood coagulating agents may be administered in an amount readily ascertained by a skilled clinician. The amount can range from 0.01µg per kilogram to 1g per kilogram of body weight. For example, administration of the factors or recombinant factors such as rVIIa may range from about 1 µg to 200 µg per kilogram 10 of body weight. Desmopressin may be administered about 1µg to 500 µg per subject. It is contemplated that the effective amount of Feiba Vh may be from about 1 µg to 200 µg per kilogram of body weight. Tranexamic acid may be administered between about 1 mg and 100 mg per kilogram of body weight to a subject.

[0169] In one aspect, the fXa protein derivative is administered prior to 15 the administration of the blood coagulating agent. In another aspect, the fXa protein derivative is administered after the administration of the blood coagulating agent. Yet in another aspect, the fXa protein derivative is administered at the same time as the blood coagulating agent. Yet in another aspect, the fXa protein derivative is administered together with the blood coagulating agent.

[0170] In still another aspect, the inventions is directed to a kit 20 comprising a) a fXa protein derivative that binds to the fXa inhibitor and does not assemble into a prothrombinase complex; and b) a blood coagulating agent having procoagulant, anti-thrombolytic, or anti-fibrinolytic activity. In another aspect, the invention is directed to a kit comprising a) an isolated polypeptide and b) a blood 25 coagulating agent having procoagulant, anti-thrombolytic, or anti-fibrinolytic activity. In one aspect, the isolated polypeptide comprises the amino acid sequence of SEQ ID NO. 12 or a polypeptide having at least 80% homology to SEQ ID NO. 12. In another aspect, the isolated polypeptide is an isolated two chain polypeptide comprising the amino acid sequence of SEQ ID NO. 13 or a polypeptide having at least 80% homology to SEQ ID 30 NO. 13. Yet in another aspect the isolated polypeptide is an isolated polypeptide

comprising the amino acid sequence of SEQ ID NO. 15 or a polypeptide having at least 80% homology to SEQ ID NO. 15.

[0171] In still another aspect, the invention relates to a pharmaceutical composition for reversing or neutralizing the anticoagulant activity of a factor Xa inhibitor administered to a subject, comprising administering an effective amount of a fXa derivative, an effective amount of a blood coagulating agent and a pharmaceutically acceptable carrier, with the proviso that the fXa derivative is not plasma derived factor VIIa, recombinant factor VIIa, fresh frozen plasma, activated or non-activated prothrombin complex concentrates and whole blood.

[0172] In some embodiments, the antidote is any one of the antidotes as described above. In some embodiments, the antidote is conjugated with a moiety capable of extending the circulating half-life of the antidote. In some embodiments, the moiety is selected from the group consisting of polyethylene glycol, an acyl group, a liposome, a carrier protein, an artificial phospholipid membrane, and a nanoparticle. For example, a non-active site lysine or cysteine residue of a fXa derivative described herein may be chemically modified to attach to a polyethylene glycol molecule. Other methods provided in Werle, M. & Bernkop-Schnürch, A. Strategies to Improve Plasma Half Life Time of Peptide and Protein Drugs, *Amino Acids* 2006, 30(4):351-367 may be used to extend the plasma half life of the antidotes of this invention.

[0173] In other embodiments of the invention, the half-life of the fXa derivative is improved by coupling the antidote to Fc carrier domains. In one embodiment, the antidote is coupled to an Fc fragment, such as an immunoglobulin peptide portion or an IgG1 fragment. In one embodiment, a chimeric protein is contemplated which comprises the fXa derivative and the immunoglobulin peptide portion. In yet another embodiment, the fXa derivative and the immunoglobulin peptide is coupled by a chemical reaction, such as a disulfide bond with the human IgG heavy chain and kappa light chain constant regions.

[0174] In some embodiments, the pharmaceutical composition further comprises an agent capable of extending the plasma half-life of the antidote. In another aspect, the pharmaceutical composition has been co-formulated with an agent capable of extending the plasma half-life of the antidote. In some embodiments, the co-administered

or co-formulated agent is an anti-fXa antibody recognizing the exosite of fXa or an alpha-2-macroglobulin bound fXa derivative.

III. Antidotes and Blood Coagulating Agents

Factor Xa Derivatives

5 [0175] In one aspect of the present invention, the fXa derivatives may be Gla-domain deficient fXa or des-Gla fXa.

 [0176] It is contemplated that a fXa derivative has reduced or no procoagulant activity but is capable of binding with a fXa inhibitor. It is contemplated that such limited activity permits dosing of the antidote at a level greater than the
10 circulating wild-type fXa. Certain fXa derivatives, such as des-Gla fXa and Gla-deficient fXa, are suitable antidotes of this invention. Besides having reduced or diminished procoagulant activity, antidotes of the present invention should also be substantially non-immunogenic to the subject. A fXa derivative may contain a combination of two or more the above mutations and/or modifications. In addition, any of the above fXa derivatives
15 may be administered alone or in combination with one another.

 [0177] Factor Xa is a serine protease in the blood coagulation pathway responsible for converting prothrombin to thrombin. It is produced from the inactive factor X upon activation by either the intrinsic Xase (complex formed by factor IXa with its cofactor, factor VIIIa) or the extrinsic Xase (complex formed by factor VIIa with its
20 cofactor, tissue factor). Activated fX (fXa) may undergo further autocatalytic cleavage at the C-terminal of its heavy chain, converting fXa α to the subform fXa β (Jesty, J et al. *J. Biol. Chem.* 1975, 250(12):4497-4504). Both fXa α and fXa β are suitable materials for the present invention. fXa itself converts prothrombin at slow rate that is not sufficient for supporting coagulation. Only when it forms a prothrombinase complex with cofactors
25 Ca²⁺, phospholipid, and factor Va, fXa can activate prothrombin at a rate rapid enough to support coagulation (Skogen, W.F., et al., *J. Biol. Chem.* 1984, 259(4):2306-10). The complex requires binding between the negatively charged phospholipid and γ -carboxyglutamic acid residues in the Gla domain of fXa via Ca²⁺ bridging.

 [0178] Therefore, although the Gla domain does not contain the active
30 site of fXa, it enables fXa to form the prothrombinase complex through the γ -

carboxyglutamic acid residues. This is demonstrated by selective removal of fXa Gla-domain by chymotrypsin digestion (see Figure 7 and Example 1). Clotting assays were performed on fXa during the time course of cleavage of the Gla domain by chymotrypsin digestion. It has been reported (Skogen et al *J. Biol. Chem.* 1984, 259(4):2306-10) that a reconstituted prothrombinase complex comprising of Gla- domainless fXa, fVa, phospholipids and calcium ions produces thrombin at a significantly reduced rate (0.5% product generated compared to control complex containing native fXa). As shown in Figure 7, fXa's activity in clot formation was partially reduced after the fXa was digested by chymotrypsin for 15 minutes and the activity was completely lost after 30 minute of digestion. Undercarboxylated or decarboxylated fXa, which lack the appropriate gamma-carboxyglutamic acid residues required for calcium ion dependent membrane binding, have thus been found to be incapable of membrane dependent coagulation complex assembly and not support blood clotting (Mann, KG et al, *Blood*, 1990, 76: 1-16).

[0179] It has also been established that Gla-domain deficient fXa is capable of binding active site-directed inhibitors of fXa. (Brandstetter, H et al, *J. Bio. Chem.*, 1996, 271:29988-29992). There have been reports of crystallography of small molecule fXa inhibitor bound to des-Gla human fXa, which have provided structural description of the active site cleft (Brandstetter, *J. Bio. Chem.*, 1996, 271:29988-29992 and Roehrig, *J. Med. Chem.* 2005, 48(19):5900-8). Figure 8 shows that a des-Gla anhydro-fXa exhibited a binding affinity of 0.319 nM with a fXa inhibitor betrixaban, comparable to that of a native fXa.

[0180] It has now been discovered that des-Gla fXa, and other fXa derivatives that have reduced procoagulant activity but are capable of fXa inhibitor binding, can be used as an antidote to a fXa inhibitor. As shown in Figure 9, the des-Gla anhydro-fXa exhibited complete reversion of betrixaban's anticoagulant activity at a concentration of 680 nM. As detailed in Example 2, the thrombin generation was initiated by adding TF-containing reagent (Innovin) and, thus, indicative of coagulation factors function in the extrinsic coagulation pathway. It has also been demonstrated in Examples 9-13, that the recombinant antidote is useful to reverse a wide variety of anticoagulants.

[0181] Clotting prolongation assays with the activated partial thromboplastin time (aPTT) reagent (Actin FS) that determine the function of the coagulation factor in the intrinsic coagulation pathway also indicate that the des-Gla anhydro-fXa possess antidote activity. Figure 10 shows the dose responsive antidote effect of des-Gla anhydro-fXa against 250 nM of betrixaban, with complete reversion at 600 nM. Figure 11 shows that des-Gla anhydro-fXa was also capable of reversing the anticoagulant activity of another fXa inhibitor, enoxaparin. Figure 12 shows that des-Gla anhydro-fXa did not exhibit significant antidote activity against a direct thrombin inhibitor argatroban. Thus, the des-Gla anhydro-fXa is a selective antidote for fXa inhibitors and is capable of restoring fXa procoagulant activity initiated either by the extrinsic or the intrinsic pathway.

[0182] Further, the antidote activity of des-Gla anhydro-fXa was demonstrated by the aPTT prolongation assays measured with a traditional coagulation timer. As shown in Figure 13, des-Gla anhydro-fXa itself has no effect on aPTT of control plasma at the highest concentrations tested (2576 nM). 400 nM of betrixaban extended aPTT more than two folds. This anti-coagulant effect of betrixaban is reversed by des-Gla anhydro-fXa in a dose-responsive manner, with return of aPTT to near normal level of control plasma at antidote concentrations higher than 1610 nM.

[0183] It is contemplated that further truncations at the fXa light chain, for example, additional deletion of the EGF1 domain, EGF1 plus EGF2 domains, or fragments thereof, and inactive fXa with only the heavy chain may be useful antidotes of this invention.

[0184] Gla-domain deficient fXa does not support normal coagulation under physiologically relevant concentration. However, the protein has the ability of cleaving many substrates and causing clotting at higher concentrations. For example, Skogen et al (Skogen, W.F., et al., *J. Biol. Chem.* 1984, 259(4):2306-10) showed that bovine des-Gla fXa has about 0.5-1.0 % prothrombinase complex activity relative to the wild type fXa. Thus, modifications that further reduce or completely eliminate a fXa derivative's procoagulant activity is contemplated by methods of the invention. Such modification may be, for example, in a fXa's catalytic domain.

[0185] Several ways of modifying the catalytic domain in the fXa heavy chain to reduce its procoagulant activity are contemplated. The active site residue S379 of fXa (as shown in SEQ ID No. 7), for example, can be selectively replaced by dehydroalanine (see Example 1) or alanine (see Example 6) to reduce or eliminate the procoagulant activity. It is also known that complex formation between fXa and a reagent targeting fXa's exosite may block the macromolecular binding ability of fXa, thus reducing its procoagulant activity while retaining small molecule binding ability in the active site. This exosite targeting reagent includes, without limitation, monoclonal antibodies targeting a region removed from the active site (Wilkens, M and Krishnaswamy, S, *J. Bio. Chem.*, 2002, 277 (11), 9366-9374), or α -2-macroglobulin. It has been known that the α -2-macroglobulin-serine protease complex, such as with trypsin, thrombin or fXa, is capable of binding small molecule substrates (Kurolwa, K. et al, *Clin. Chem.* 1989, 35(11), 2169-2172).

[0186] It is also known that an inactive fXa with modifications solely in the heavy chain while keeping its light chain unchanged would act as an inhibitor of prothrombinase (Hollenbach, S. et al., *Thromb. Haemost.*, 1994, 71(3), 357-62) because it interferes with procoagulant activity of normal fXa as shown in Figure 6. Therefore, in one embodiment, the fXa derivative has modifications both in the light chain and heavy chain. It has been discovered that these modifications reduce or eliminate both procoagulant and anticoagulant activities while retaining the inhibitors binding ability of the fXa derivative.

[0187] Several methods can be used to produce Gla-domain deficient fXa derivatives or other fXa derivatives described herein. For example, the Gla-domain may be completely removed via chymotryptic cleavage, producing Gla-domainless fXa. Alternatively, a Gla-domainless fX may be produced by chymotryptic cleavage of native fX. The Gla-domainless fX may then be converted to Gla-domainless fXa by a fX activator. fX may be isolated from plasma of the same or a different species as the subject to be treated. Bovine fX, for example, has been shown to be functional in human plasma assays. Examples of a fX activator include, without limitation, a snake venom, such as Russell's viper venom, and complexes of fVIIa/tissue factor or fIXa/fVIIIa. Such means is known to a person of skill in the art. For example, Rudolph A.E. et al has reported a recombinant fXa produced from a recombinant factor X (fX) with a single

substitution of Arg347 by Glutamine (fXR347N) (*Biochem.* 2000, 39 (11): 2861 -2867). In one embodiment, the fXa derivatives produced from non-human sources are non-immunogenic or substantially non-immunogenic. Example 7 also provides a method of producing a recombinant antidote having the amino acid sequence of SEQ ID NO. 12 and
5 SEQ ID NO. 13.

[0188] The fXa derivatives may also be purified from human plasma, or may be produced by recombinant DNA method where an appropriate gene for the fXa derivative is expressed in a suitable host organism. Expression and purification of recombinant fXa has been reported by several groups, see, e.g., Larson, P.J., et al,
10 *Biochem.*, 1998, 37:5029-5038, and Camire, R.M., et al, *Biochem.*, 2000, 39, 14322-14329 for producing recombinant fX; Wolf, D.L. et al, *J. Bio. Chem.*, 1991, 266(21):13726-13730 for producing recombinant fXa. Modified fXa may be prepared according to these procedures using a genetically modified cDNA having a nucleotide sequence encoding the desired fXa mutant. Example 6 gives more details for direct
15 expression of a Gla-domainless fXa-S379 mutant with functional activity as an antidote.

[0189] It is contemplated that active-site mutated or modified fXa with deficient Gla-domain, such as under-carboxylated fXa, may also be useful as fXa inhibitor antidote. Under-carboxylated fXa may be prepared by recombinant means by withholding vitamin K derivatives during protein expression (vitamin K derivatives are
20 needed for post translational modification to form the Gla residues) or by adding vitamin K antagonists such as warfarin during tissue culture. Decarboxylated fXa can be prepared by heating (Bajaj P., *J. Biol. Chem.*, 1982, 257(7):3726-3731) or by proteolytic digestion by chymotrypsin (Morita T., et al., *J. Biol. Chem.*, 1986, 261(9):4015-4023). The antidote may also be generated in prokaryotic systems followed by *in vitro* refolding or
25 constitution of the fXa inhibitor binding site.

[0190] The Gla residues can also be chemically modified to remove the carboxyl group responsible for calcium ion dependent membrane binding. For example, the carboxyl groups on the Gla residues may be selectively removed under decarboxylation conditions or may be capped, for example, by esterification or amination.
30 It is desirable that such esterification or amination be resistant to *in vivo* hydrolysis so that the modified fXa is not readily converted to active fXa, which may cause thrombosis.

[0191] Other mutants or derivatives of fXa may also be useful antidotes of this invention. In one embodiment, this invention encompasses use of mutants described in Peter J. Larson et al, *Biochem.*, 1998, 37:5029-5038 as fXa inhibitor antidotes.

5 [0192] In another embodiment, this invention encompasses use of catalytically inactive fXa mutants to prepare fXa inhibitor antidotes. For example, mutants described in Sinha, U., et al, *Protein Expression and Purif.*, 1992, 3:518-524, rXai, mutants with chemical modifications, such as dehydro-alanine (anhydro fXa), as described in Nogami, et al, *J. Biol. Chem.* 1999, 274(43):31000-7. FXa with active site
10 serine (Ser379 in fX numbering as shown in SEQ ID NO. 7, and Ser195 in chymotrypsin numbering) replaced with alanine (fXa-S379A in fX numbering, or fXa-S195A in chymotrypsin numbering), where the procoagulant activity was eliminated, may also be used as fXa inhibitor antidotes. The invention also envisions fXa derivatives with the active site serine residue irreversibly acylated which is still capable of binding small
15 molecule inhibitors. FXa with the active site serine reversibly acylated has been reported by Wolf, et al., *Blood*, 1995, 86(11):4153-7. Such reversible acylation, however, is capable of time dependent production of active fXa and may lead to an excess of active fXa over a time period. The deacylation rate may be reduced by strategies similar to those described in Lin P.H. et al, *Thrombosis Res.*, 1997, 88(4), 365-372. For example,
20 fXa molecules with Ser379 (Ser195 in chymotrypsin numbering) acylated by 4-methoxybenzyl and 3-bromo-4-methoxybenzyl groups recover less than 50 % of their original activity when incubated in a buffer having pH 7.5 at 37 °C for 4 hours.

[0193] One embodiment is directed to the use of fXa derivatives with mutations at fXa residues known to be important for fXa interaction with cofactor fV/fVa.
25 Such residues include, without limitation, Arg306, Glu310, Arg347, Lys351, or Lys414 (SEQ ID NOS. 3 and 7, these amino acids correspond to Arg125, Glu129, Arg165, Lys169, Lys230 in the chymotrypsin numbering). Examples of such mutants are reported in Rudolph, A.E. et al, *J. Bio. Chem.*, 2001, 276:5123-5128. In addition, mutations at fXa residues known to be important for fVIII/fVIIIa interaction, such as Arg424 in SEQ
30 ID NOS. 3 and 7 (Arg240 in chymotrypsin numbering), may also be used as fXa inhibitor antidotes. Examples of such mutants are described in Nogami, K. et al, *J. Biol. Chem.*, 2004, 279(32):33104-33113.

[0194] Other modification of active site residues of fXa or residues known to be important for serine protease interactions may also lead to useful antidotes of this invention, for example, replacement of Glu216, Glu218, and Arg332 in SEQ ID NOS. 3 and 7 (Glu37, Glu39, and Arg150 in chymotrypsin numbering, respectively) with other amino acid residues.

[0195] In one embodiment, the residual procoagulant activity of an antidote, as assessed by amidolytic substrate cleavage assay, be < 1 % , preferably < 0.1 % , more preferably < 0.05 % of human plasma derived native fXa. For example, there is no measurable procoagulant activity for recombinant fXa-S379A when the active site Ser379 (S195 in chymotrypsin numbering) is replaced by an alanine residue as measured by clotting assays.

[0196] The invention further relates to nucleic acid sequences, in particular DNA sequences, which code for the fXa derivatives described above. These can easily be determined by translating the polypeptide sequence back into the corresponding DNA sequence in accordance with the genetic code. Codons preferably used are those which lead to good expression in the required host organism. The nucleic acid sequences can be prepared either by site-specific mutagenesis starting from the natural fXa gene sequence or else by complete DNA synthesis.

Polypeptides of the Invention

[0197] In certain aspects, the invention is related to an isolated polypeptide comprising the amino acid sequence of SEQ ID NO. 12, 13 or 15. Also encompassed by this invention are polypeptides having at least 80% homology to SEQ ID NO. 12, 13 or 15.

[0198] Polypeptides comprising the amino acid sequences of the invention can be prepared by expressing polynucleotides encoding the polypeptide sequences of this invention in an appropriate host cell. This can be accomplished by methods of recombinant DNA technology known to those skilled in the art. Accordingly, this invention also provides methods for recombinantly producing the polypeptides of this invention in a eukaryotic or prokaryotic host cells. The proteins and polypeptides of this invention also can be obtained by chemical synthesis using a commercially available

automated peptide synthesizer such as those manufactured by Perkin Elmer/Applied Biosystems, Inc., Model 430A or 431A, Foster City, CA, USA. The synthesized protein or polypeptide can be precipitated and further purified, for example by high performance liquid chromatography (HPLC). Accordingly, this invention also provides a process for
5 chemically synthesizing the proteins of this invention by providing the sequence of the protein and reagents, such as amino acids and enzymes and linking together the amino acids in the proper orientation and linear sequence.

[0199] It is known to those skilled in the art that modifications can be made to any peptide to provide it with altered properties. Polypeptides of the invention
10 can be modified to include unnatural amino acids. Thus, the peptides may comprise D-amino acids, a combination of D- and L-amino acids, and various "designer" amino acids (*e.g.*, β -methyl amino acids, C- α -methyl amino acids, and N- α -methyl amino acids, etc.) to convey special properties to peptides. Additionally, by assigning specific amino acids at specific coupling steps, peptides with α -helices, β turns, β sheets, α -turns, and cyclic
15 peptides can be generated. Generally, it is believed that α -helical secondary structure or random secondary structure is preferred.

[0200] In a further embodiment, subunits of polypeptides that confer useful chemical and structural properties will be chosen. For example, peptides comprising D-amino acids may be resistant to L-amino acid-specific proteases *in vivo*.
20 Modified compounds with D-amino acids may be synthesized with the amino acids aligned in reverse order to produce the peptides of the invention as retro-inverso peptides. In addition, the present invention envisions preparing peptides that have better defined structural properties, and the use of peptidomimetics, and peptidomimetic bonds, such as ester bonds, to prepare peptides with novel properties. In another embodiment, a peptide
25 may be generated that incorporates a reduced peptide bond, *i.e.*, $R_1\text{-CH}_2\text{NH-R}_2$, where R_1 , and R_2 are amino acid residues or sequences. A reduced peptide bond may be introduced as a dipeptide subunit. Such a molecule would be resistant to peptide bond hydrolysis, *e.g.*, protease activity. Such molecules would provide ligands with unique function and activity, such as extended half-lives *in vivo* due to resistance to metabolic breakdown, or
30 protease activity. Furthermore, it is well known that in certain systems constrained peptides show enhanced functional activity (Hruby (1982) Life Sciences 31:189-199 and

Hruby et al. (1990) *Biochem J.* **268**:249-262); the present invention provides a method to produce a constrained peptide that incorporates random sequences at all other positions.

[0201] The following non-classical amino acids may be incorporated in the peptides of the invention in order to introduce particular conformational motifs:

- 5 1,2,3,4-tetrahydroisoquinoline-3-carboxylate (Kazmierski et al. (1991) *J. Am. Chem. Soc.* **113**:2275-2283); (2S,3S)-methyl-phenylalanine, (2S,3R)- methyl-phenylalanine, (2R,3S)-methyl-phenylalanine and (2R,3R)-methyl-phenylalanine (Kazmierski and Hruby (1991) *Tetrahedron Lett.* **32**(41):5769-5772); 2-aminotetrahydronaphthalene-2- carboxylic acid (Landis (1989) Ph.D. Thesis, University of Arizona); hydroxy-1,2,3,4-
- 10 tetrahydroisoquinoline-3-carboxylate (Miyake et al. (1989) *J. Takeda Res. Labs.* **43**:53-76) histidine isoquinoline carboxylic acid (Zechel et al. (1991) *Int. J. Pep. Protein Res.* **38**(2):131-138); and HIC (histidine cyclic urea), (Dharanipragada et al. (1993) *Int. J. Pep. Protein Res.* **42**(1):68-77) and (Dharanipragada et al. (1992) *Acta. Crystallogr. C.* **48**:1239-1241).

- 15 [0202] The following amino acid analogs and peptidomimetics may be incorporated into a peptide to induce or favor specific secondary structures: LL-Acp (LL-3-amino-2-propenidone-6-carboxylic acid), a β -turn inducing dipeptide analog (Kemp et al. (1985) *J. Org. Chem.* **50**:5834-5838); β -sheet inducing analogs (Kemp et al. (1988) *Tetrahedron Lett.* **29**:5081-5082); β -turn inducing analogs (Kemp et al. (1988) *Tetrahedron Lett.* **29**:5057-5060); α -helix inducing analogs (Kemp et al. (1988) *Tetrahedron Lett.* **29**:4935-4938); α -turn inducing analogs (Kemp et al. (1989) *J. Org. Chem.* **54**:109:115); analogs provided by the following references: Nagai and Sato (1985) *Tetrahedron Lett.* **26**:647-650; and DiMaio et al. (1989) *J. Chem. Soc. Perkin Trans. p.* 1687; a Gly-Ala turn analog (Kahn et al. (1989) *Tetrahedron Lett.* **30**:2317); amide bond
- 25 isostere (Clones et al. (1988) *Tetrahedron Lett.* **29**:3853-3856); tetrazole (Zabrocki et al. (1988) *J. Am. Chem. Soc.* **110**:5875-5880); DTC (Samanen et al. (1990) *Int. J. Protein Pep. Res.* **35**:501:509); and analogs taught in Olson et al. (1990) *J. Am. Chem. Sci.* **112**:323-333 and Garvey et al. (1990) *J. Org. Chem.* **56**:436. Conformationally restricted mimetics of beta turns and beta bulges, and peptides containing them, are described in
- 30 U.S. Patent No. 5,440,013, issued August 8, 1995 to Kahn.

[0203] It is known to those skilled in the art that modifications can be made to any peptide by substituting one or more amino acids with one or more functionally equivalent amino acids that does not alter the biological function of the peptide. In one aspect, the amino acid that is substituted by an amino acid that possesses similar intrinsic properties including, but not limited to, hydrophobicity, size, or charge. Methods used to determine the appropriate amino acid to be substituted and for which amino acid are known to one of skill in the art. Non-limiting examples include empirical substitution models as described by Dayhoff et al. (1978) In Atlas of Protein Sequence and Structure Vol. 5 suppl. 2 (ed. M.O. Dayhoff), pp. 345-352. National Biomedical Research Foundation, Washington DC; PAM matrices including Dayhoff matrices (Dahoff et al. (1978), *supra*, or JTT matrices as described by Jones et al. (1992) Comput. Appl. Biosci. **8**:275-282 and Gonnet et al. (1992) Science **256**:1443-1145; the empirical model described by Adach and Hasegawa (1996) J. Mol. Evol. **42**:459-468; the block substitution matrices (BLOSUM) as described by Henikoff and Henikoff (1992) Proc. Natl. Acad. Sci. USA **89**:10915-10919; Poisson models as described by Nei (1987) Molecular Evolutionary Genetics. Columbia University Press, New York.; and the Maximum Likelihood (ML) Method as described by Müller et al. (2002) Mol. Biol. Evol. **19**:8-13.

Blood Coagulating Agents

[0204] In some embodiments, the blood coagulating agent may initiate or enhance blood coagulation or inhibit fibrinolysis or thrombosis. In some embodiments, the blood coagulating agent has procoagulant, anti-thrombolytic, and/or anti-fibrinolytic activity.

[0205] The blood coagulating agent may be selected from the group consisting of a coagulation factor, a polypeptide related to the coagulation factor, a recombinant coagulation factor and combinations thereof. It is further contemplated that the coagulation factor may be selected from the group consisting of factors or recombinant factors VII/VIIa (as described in e.g. Bijsterveld, NR et al, Circulation, 2002(106): 2550-2554; Bijsterveld, NR et al, British Journal of Haematology, 2004(124): 653-658), IX/IXa (see e.g. U.S. Patent Application Publication No. US 2008/0075711), X/Xa (see e.g. U.S. Patent No. 7,220,569), II/IIa (as described in, e.g. Gallistl S. et al

Blood Coagul Fibrinolysis. 2002 13(7):653-5), VIII/VIIIa (see e.g. U.S. Patent Application Publication No.: US 2008/0076702), V/Va (see e.g. U.S. Patent No. 7,125,846) and combinations thereof.

[0206] It is also contemplated that the blood coagulating agent may be a non-specific anti-bleeding agent. It is further contemplated that the blood coagulating agent may be selected from the group consisting of an adsorbent chemical, a hemostatic agent, thrombin, fibrin glue, desmopressin, cryoprecipitate and fresh frozen plasma, coagulation factor concentrate, activated or non-activated prothrombin complex concentrate, Feiba Vh, platelet concentrates and combinations thereof. More examples of available blood coagulation factors are available in the citation Brooker M, Registry of Clotting Factor Concentrates, Eighth Edition, World Federation of Hemophilia, 2008.

[0207] It is also contemplated that the blood coagulating agent may be selected from the group consisting of thrombin-activatable fibrinolysis inhibitor (TAFI) (see e.g. U.S. Patent No. US 7,291,587), protein C inhibitor (PCI) (see e.g. U.S. Patent Application Publication No. US 2008/0102064), protein S inhibitor (PSI) (see e.g. U.S. Patent Application Publication No. US 2008/0057059), alpha-2-antiplasmin (see, e.g. U.S. Patent No. US 7,078,479), tranexamic acid (as described in e.g. <http://www.patient.co.uk/showdoc/30002117/>), aminocaproic acid (as described in e.g. Eaton, M.P. Anesth Analg. 2008 106(4):1087-100), aprotinin (as described in e.g. Liu C.M. et al World J Gastroenterol. 2008 14(9):1425-9) and combinations thereof.

[0208] In one aspect, the fXa protein derivative is administered prior to the administration of the blood coagulating agent. In another aspect, the fXa protein derivative is administered after the administration of the blood coagulating agent. Yet in another aspect, the fXa protein derivative is administered at the same time as the blood coagulating agent. Yet in another aspect, the fXa protein derivative is administered together with the blood coagulating agent.

IV. Polypeptide Conjugates

[0209] The polypeptides and polypeptide complexes of the invention can be used in a variety of formulations, which may vary depending on the intended use. For example, one or more can be covalently or non-covalently linked (complexed) to various

other molecules, the nature of which may vary depending on the particular purpose. For example, a peptide of the invention can be covalently or non-covalently complexed to a macromolecular carrier, including, but not limited to, natural and synthetic polymers, proteins, polysaccharides, polypeptides (amino acids), polyvinyl alcohol, polyvinyl pyrrolidone, and lipids. A peptide can be conjugated to a fatty acid, for introduction into a liposome, *see* U.S. Patent No. 5,837,249. A peptide of the invention can be complexed covalently or non-covalently with a solid support, a variety of which are known in the art and described herein. An antigenic peptide epitope of the invention can be associated with an antigen-presenting matrix such as an MHC complex with or without co-stimulatory molecules.

[0210] Examples of protein carriers include, but are not limited to, superantigens, serum albumin, tetanus toxoid, ovalbumin, thyroglobulin, myoglobulin, and immunoglobulin.

[0211] Peptide-protein carrier polymers may be formed using conventional cross-linking agents such as carbodimides. Examples of carbodimides are 1-cyclohexyl-3-(2-morpholinyl-(4-ethyl) carbodiimide (CMC), 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide (EDC) and 1-ethyl-3-(4-azonia-44-dimethylpentyl) carbodiimide.

[0212] Examples of other suitable cross-linking agents are cyanogen bromide, glutaraldehyde and succinic anhydride. In general, any of a number of homo-bifunctional agents including a homo-bifunctional aldehyde, a homo-bifunctional epoxide, a homo-bifunctional imido-ester, a homo-bifunctional N-hydroxysuccinimide ester, a homo-bifunctional maleimide, a homo-bifunctional alkyl halide, a homo-bifunctional pyridyl disulfide, a homo-bifunctional aryl halide, a homo-bifunctional hydrazide, a homo-bifunctional diazonium derivative and a homo-bifunctional photoreactive compound may be used. Also included are hetero-bifunctional compounds, for example, compounds having an amine-reactive and a sulfhydryl-reactive group, compounds with an amine-reactive and a photoreactive group and compounds with a carbonyl-reactive and a sulfhydryl-reactive group.

[0213] Specific examples of such homo-bifunctional cross-linking agents include the bifunctional N-hydroxysuccinimide esters dithiobis(succinimidylpropionate),

disuccinimidyl suberate, and disuccinimidyl tartrate; the bifunctional imido-esters dimethyl adipimidate, dimethyl pimelimidate, and dimethyl suberimidate; the bifunctional
 5 sulfhydryl-reactive crosslinkers 1,4-di-[3'-(2'-pyridyldithio) propionamido]butane, bismaleimidohexane, and bis-N-maleimido-1, 8-octane; the bifunctional aryl halides 1,5-
 10 difluoro-2,4-dinitrobenzene and 4,4'-difluoro-3,3'-dinitrophenylsulfone; bifunctional photoreactive agents such as bis-[b-(4-azidosalicylamido)ethyl]disulfide; the bifunctional aldehydes formaldehyde, malondialdehyde, succinaldehyde, glutaraldehyde, and
 adipaldehyde; a bifunctional epoxide such as 1,4-butanediol diglycidyl ether; the bifunctional hydrazides adipic acid dihydrazide, carbohydrazide, and succinic acid
 15 dihydrazide; the bifunctional diazoniums o-tolidine, diazotized and bis-diazotized benzidine; the bifunctional alkylhalides N1N'-ethylene-bis(iodoacetamide), N1N'-
 hexamethylene-bis(iodoacetamide), N1N'-undecamethylene-bis(iodoacetamide), as well as benzylhalides and halomustards, such as 1,4-diiodo-p-xylene sulfonic acid and tri(2-
 chloroethyl)amine, respectively.

15 **[0214]** Examples of common hetero-bifunctional cross-linking agents that may be used to effect the conjugation of proteins to peptides include, but are not limited to, SMCC (succinimidyl-4-(N-maleimidomethyl)cyclohexane-1-carboxylate), MBS (m-maleimidobenzoyl-N-hydroxysuccinimide ester), SIAB (N-succinimidyl(4-iodoacetyl)aminobenzoate), SMPB (succinimidyl-4-(p-maleimidophenyl)butyrate),
 20 GMBS (N-(γ-maleimidobutyryloxy)succinimide ester), MPBH (4-(4-N-maleimidophenyl) butyric acid hydrazide), M2C2H (4-(N-maleimidomethyl) cyclohexane-1-carboxyl-hydrazide), SMPT (succinimidylloxycarbonyl-α-methyl-α-(2-pyridyldithio)toluene), and SPDP (N-succinimidyl 3-(2-pyridyldithio)propionate).

25 **[0215]** Cross-linking may be accomplished by coupling a carbonyl group to an amine group or to a hydrazide group by reductive amination.

[0216] Peptides of the invention also may be formulated as non-covalent attachment of monomers through ionic, adsorptive, or biospecific interactions. Complexes of peptides with highly positively or negatively charged molecules may be done through salt bridge formation under low ionic strength environments, such as in
 30 deionized water. Large complexes can be created using charged polymers such as poly-(L-glutamic acid) or poly-(L-lysine) which contain numerous negative and positive

charges, respectively. Adsorption of peptides may be done to surfaces such as microparticle latex beads or to other hydrophobic polymers, forming non-covalently associated peptide-superantigen complexes effectively mimicking cross-linked or chemically polymerized protein. Finally, peptides may be non-covalently linked through the use of biospecific interactions between other molecules. For instance, utilization of the strong affinity of biotin for proteins such as avidin or streptavidin or their derivatives could be used to form peptide complexes. These biotin-binding proteins contain four binding sites that can interact with biotin in solution or be covalently attached to another molecule. (See Wilchek (1988) Anal. Biochem. **171**:1-32). Peptides can be modified to possess biotin groups using common biotinylation reagents such as the N-hydroxysuccinimidyl ester of D-biotin (NHS-biotin) which reacts with available amine groups on the protein. Biotinylated peptides then can be incubated with avidin or streptavidin to create large complexes. The molecular mass of such polymers can be regulated through careful control of the molar ratio of biotinylated peptide to avidin or streptavidin.

[0217] Also provided by this application are the peptides and polypeptides described herein conjugated to a label, e.g., a fluorescent or bioluminescent label, for use in the diagnostic methods. For example, detectably labeled peptides and polypeptides can be bound to a column and used for the detection and purification of antibodies. Suitable fluorescent labels include, but are not limited to, fluorescein, rhodamine, tetramethylrhodamine, eosin, erythrosin, coumarin, methyl-coumarins, pyrene, Malacite green, stilbene, Lucifer Yellow, Cascade BlueTM, and Texas Red. Other suitable optical dyes are described in Haugland, Richard P. (1996) Molecular Probes Handbook.

[0218] The polypeptides of this invention also can be combined with various liquid phase carriers, such as sterile or aqueous solutions, pharmaceutically acceptable carriers, suspensions and emulsions. Examples of non-aqueous solvents include propyl ethylene glycol, polyethylene glycol and vegetable oils. When used to prepare antibodies, the carriers also can include an adjuvant that is useful to non-specifically augment a specific immune response. A skilled artisan can easily determine whether an adjuvant is required and select one. However, for the purpose of illustration

only, suitable adjuvants include, but are not limited to, Freund's Complete Adjuvant, Freund's Incomplete Adjuvant and mineral salts.

V. Therapies

5 [0219] The present invention relates to a therapeutic method of preventing or reducing bleeding in a subject undergoing anticoagulant therapy. It is contemplated that the antidotes of the present invention may be short-duration drugs to be used in elective or emergency situations which can safely and specifically neutralize a fXa inhibitor's conventional anticoagulant properties without causing deleterious hemodynamic side-effects or exacerbation of the proliferative vascular response to injury.

10 [0220] In one embodiment, the therapeutically effective amount of an antidote exhibits a high therapeutic index. The therapeutic index is the dose ratio between toxic and therapeutic effects which can be expressed as the ratio between LD₅₀ and ED₅₀. The LD₅₀ is the dose lethal to 50 % of the population and the ED₅₀ is the dose therapeutically effective in 50 % of the population. The LD₅₀ and ED₅₀ are determined by
15 standard pharmaceutical procedures in animal cell cultures or experimental animals. The antidotes or derivatives of this invention may be administered once or several times when needed to neutralize the effect of a fXa inhibitor present in a subject's plasma. Preferably, the antidotes of this invention is sufficient when administered in a single dose.

20 [0221] It is contemplated that a typical dosage of the antidotes of the invention will depend on the actual clinical setting and inhibitor concentration in plasma. In *in vitro* assay, such as thrombin generation, clinical clotting assays such as aPTT, PT and ACT, a therapeutically effective amount of an antidote is expected to produce a correction of *ex vivo* clotting activity of 10 % or more. *In vitro* assays indicate that an antidote/inhibitor ratio > 0.5 should show reversal effect. The maximum plasma
25 concentration for antidote is expected to be in the micro molar range, probably at 10 micromolar or below.

 [0222] In a clinical setting, one of the criteria in determining the effectiveness of an antidote is that it produces any change of actual measures of bleeding. In clinical trials, categories of major bleeds include fatal hemorrhage, bleeds into vital
30 organs (intracranial, intraocular, retroperitoneal, spinal, pericardial), any bleed requiring

re-operation or a new therapeutic procedure (e.g., aspiration of an operated knee, thoracotomy tube insertion for hemothorax, endoscopic electrocoagulation, etc) or a bleeding index of ≥ 2.0 if it is associated with an overt bleed. The bleeding index is defined as the number of units of packed red cells or whole blood transfused plus the
5 hemoglobin values before the bleeding episode minus the hemoglobin values after the bleed has stabilized (in grams per deciliter).

[0223] Another criterion for antidote efficacy in clinical settings is that it reduces clinically significant non-major bleeding. This category of hemorrhages include bleeding that is not major but is more than usual and warrants clinical attention, including
10 epistaxis that is persistent or recurrent and in substantial amount or will not stop without intervention; rectal or urinary tract bleeding that does not rise to a level requiring a therapeutic procedure (e.g., new insertion of a Foley catheter or cystoscopic inspection), substantial hematomas at injection sites or elsewhere that are spontaneous or occur with trivial trauma; substantial blood loss; bleeding requiring unplanned transfusion. As used
15 herein, "substantial blood loss" refers to amount of blood loss that is more than that amount usually associated with surgical procedure. Substantial blood loss leads to swelling that is managed conservatively because it falls short of requiring drainage.

[0224] In one embodiment, the derivatives of this invention have sufficient plasma circulating half life for substantially neutralizing the fXa inhibitor
20 present in plasma. Activated fXa has essentially no circulating half life in humans, as it is effectively inhibited by ATIII, TFPI and other plasma inhibitors (Fuchs, H.E. and Pizzo, S.V., *J. Clin. Invest.*, 1983, 72:2041-2049). In a baboon model, the half-life of a fXa blocked in the active site by DEGR ([5-(dimethylamino)1-naphthalenesulfonyl]-glutamylglycylarginyl chloromethyl ketone) was approximately 10 hours or 2 hours, as
25 determined by isotopic or enzyme-linked immunosorbent assays, respectively (Taylor, F.B. et al, *Blood*, 1991, 78(2):364-368).

[0225] It may be desirable to extend the half life of an antidote fXa derivative to 24-48 hours. It is contemplated that conjugation or addition of one or more of the following moieties will increase the plasma half life of an antidote:

- 30 a) polyethylene glycol;
 b) an acyl group;

- c) liposomes and encapsulating agents;
- d) carrier proteins;
- e) artificial phospholipid membrane;
- f) immunoglobulin; and
- 5 g) nanoparticle.

[0226] The conjugation site may not be limited to special chain or residue so long as the conjugation does not mask the inhibitor binding site(s) of the antidote. The antidotes described herein may be administered in combination with any one or more than one of the compounds described above.

10 [0227] In general, administered antibodies have much longer half life than circulating blood coagulation proteins. It is possible to use a complex consisting of Gla-domain deficient fXa and an antibody bound to the exosite of fXa as an antidote with extended circulating half life. Formation of a complex between fXa and the antibody targeting the exosite may reduce interaction of an Gla-domain deficient fXa with
15 macromolecular substrates and inhibitors, such as prothrombin and antithrombin III, while leaving the active site cleft unperturbed so that the complex can act as an antidote to bind active site directed small molecule inhibitor. Formation of α -2-macroglobulin-fXa complex can also be of useful as an antidote for fXa small molecule inhibitors.

[0228] Efficacy of the antidotes in reversal of the anticoagulant activity
20 of fXa inhibitors as well as its procoagulant activity may be determined by *in vitro* assays and animal models by those of skill in the art. Examples of *in vitro* assays are thrombin generation, anti-factor Xa units, clinical clotting assays such as aPTT, PT and ACT. An antidote of this invention is contemplated to be capable of producing 10 % or more correction of *ex vivo* clotting activity. Several *in vivo* animal models of bleeding time
25 and/or blood loss in, for example, rodents, such as mice, dogs and primates, such as monkeys, may be used to measure efficacy.

VI. Pharmaceutical Compositions

[0229] The present invention further provides compositions comprising a
fXa derivative, a blood coagulating agent, and optionally a pharmaceutically acceptable
30 carrier. Also provided are compositions comprising an isolated polypeptide comprising the amino acid sequence of SEQ ID NO. 12, 13 or 15 or a peptide having at least 80%

homology to SEQ ID NO. 12, 13 or 15, a blood coagulating agent and optionally a pharmaceutically acceptable carrier.

[0230] “Pharmaceutically acceptable carriers” refers to any diluents, excipients, or carriers that may be used in the compositions of the invention.

5 Pharmaceutically acceptable carriers include ion exchangers, alumina, aluminum stearate, lecithin, serum proteins, such as human serum albumin, buffer substances, such as phosphates, glycine, sorbic acid, potassium sorbate, partial glyceride mixtures of saturated vegetable fatty acids, water, salts or electrolytes, such as protamine sulfate, disodium hydrogen phosphate, potassium hydrogen phosphate, sodium chloride, zinc salts, colloidal
10 silica, magnesium trisilicate, polyvinyl pyrrolidone, cellulose-based substances, polyethylene glycol, sodium carboxymethylcellulose, polyacrylates, waxes, polyethylene-polyoxypropylene-block polymers, polyethylene glycol and wool fat. Suitable pharmaceutical carriers are described in *Remington's Pharmaceutical Sciences*, Mack Publishing Company, a standard reference text in this field. They are preferably selected
15 with respect to the intended form of administration, that is, oral tablets, capsules, elixirs, syrups and the like, and consistent with conventional pharmaceutical practices.

[0231] The pharmaceutical compositions of the invention can be manufactured by methods well known in the art such as conventional granulating, mixing, dissolving, encapsulating, lyophilizing, or emulsifying processes, among others.

20 Compositions may be produced in various forms, including granules, precipitates, or particulates, powders, including freeze dried, rotary dried or spray dried powders, amorphous powders, injections, emulsions, elixirs, suspensions or solutions. Formulations may optionally contain stabilizers, pH modifiers, surfactants, bioavailability modifiers and combinations of these.

25 [0232] Pharmaceutical formulations may be prepared as liquid suspensions or solutions using a sterile liquid, such as oil, water, alcohol, and combinations thereof. Pharmaceutically suitable surfactants, suspending agents or emulsifying agents, may be added for oral or parenteral administration. Suspensions may include oils, such as peanut oil, sesame oil, cottonseed oil, corn oil and olive oil.
30 Suspension preparation may also contain esters of fatty acids, such as ethyl oleate, isopropyl myristate, fatty acid glycerides and acetylated fatty acid glycerides. Suspension

formulations may include alcohols, such as ethanol, isopropyl alcohol, hexadecyl alcohol, glycerol and propylene glycol. Ethers, such as poly(ethyleneglycol), petroleum hydrocarbons, such as mineral oil and petrolatum, and water may also be used in suspension formulations.

5 [0233] The compositions of this invention are formulated for pharmaceutical administration to a mammal, preferably a human being. Such pharmaceutical compositions of the invention may be administered in a variety of ways, preferably parenterally.

 [0234] It is contemplated that in order to quickly reverse the
10 anticoagulant activity of a fXa inhibitor present in a patient's plasma in a emergency situation, the antidote of this invention can or may be administered to the systemic circulation via parental administration. The fXa derivative and the blood coagulating agent may be administered separately or together. The term "parenteral" as used herein includes subcutaneous, intravenous, intramuscular, intra-articular, intra-synovial,
15 intrasternal, intrathecal, intrahepatic, intralesional and intracranial injection or infusion techniques. However, in cases where the fXa inhibitor being neutralized has a long plasma half life, a continuous infusion or a sustained release formulation may be required to bind to the fXa inhibitor and such free up the active fXa prior to the clearance of the fXa inhibitor from the body.

20 [0235] Sterile injectable forms of the compositions of this invention may be aqueous or oleaginous suspension. These suspensions may be formulated according to techniques known in the art using suitable dispersing or wetting agents and suspending agents. The sterile injectable preparation may also be a sterile injectable solution or suspension in a non-toxic parenterally acceptable diluent or solvent, for example as a
25 solution in 1,3-butanediol. Among the acceptable vehicles and solvents that may be employed are water, Ringer's solution and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose, any bland fixed oil may be employed including synthetic mono- or di-glycerides. Fatty acids, such as oleic acid and its glyceride derivatives are useful in the
30 preparation of injectables, as are natural pharmaceutically-acceptable oils, such as olive oil or castor oil, especially in their polyoxyethylated versions. These oil solutions or

suspensions may also contain a long-chain alcohol diluent or dispersant, such as carboxymethyl cellulose or similar dispersing agents which are commonly used in the formulation of pharmaceutically acceptable dosage forms including emulsions and suspensions. Other commonly used surfactants, such as Tweens, Spans and other emulsifying agents or bioavailability enhancers which are commonly used in the manufacture of pharmaceutically acceptable solid, liquid, or other dosage forms may also be used for the purposes of formulation. Compounds may be formulated for parenteral administration by injection such as by bolus injection or continuous infusion. A unit dosage form for injection may be in ampoules or in multi-dose containers.

10 [0236] In addition to dosage forms described above, pharmaceutically acceptable excipients and carriers and dosage forms are generally known to those skilled in the art and are included in the invention. It should be understood that a specific dosage and treatment regimen for any particular patient will depend upon a variety of factors, including the activity of the specific antidote employed, the age, body weight, general health, sex and diet, renal and hepatic function of the patient, and the time of administration, rate of excretion, drug combination, judgment of the treating physician or veterinarian and severity of the particular disease being treated.

VII. Kits

20 [0237] The invention further provides kits or packages. In some embodiments, the kit of the present invention comprises: (a) a first container containing a fXa derivative or an isolated polypeptide comprising the amino acid sequence of SEQ ID NO. 12, 13 or 15 or having at least 80% homology to SEQ ID NO. 12, 13 or 15, (b) a second container containing a blood coagulating agent. In other embodiments, the kit further comprises a fXa inhibitor for regular administration for the treatment of thrombosis. In other embodiments, the kit further comprises a label explaining when these agents should be used.

30 [0238] The first and second container can be a bottle, jar, vial, flask, syringe, tube, bag, or any other container used in the manufacture, storage, or distribution of a pharmaceutical product. The package insert can be a label, tag, marker, or the like, that recites information relating to the pharmaceutical composition of the kit. The information recited will usually be determined by the regulatory agency governing the

area in which the pharmaceutical composition is to be sold, such as the United States Food and Drug Administration. Preferably, the package insert specifically recites the indications for which the pharmaceutical composition has been approved. The package insert may be made of any material on which a person can read information contained therein or thereon. Preferably, the package insert is a printable material, such as paper, adhesive-backed paper cardboard, foil, or plastic, and the like, on which the desired information has been printed or applied.

EXAMPLES

[0239] The invention is further understood by reference to the following examples, which are intended to be purely exemplary of the invention. The present invention is not limited in scope by the exemplified embodiments, which are intended as illustrations of single aspects of the invention only. Any methods that are functionally equivalent are within the scope of the invention. Various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description and accompanying figures. Such modifications fall within the scope of the appended claims.

[0240] Unless otherwise stated all temperatures are in degrees Celsius. Also, in these examples and elsewhere, abbreviations have the following meanings:

aa	=	amino acid
ab	=	antibody
ACT	=	activated clotting time
aPTT	=	activated partial thromboplastin time
CHO cell	=	Chinese hamster ovary cell
CHO dhfr(-)cells	=	CHO cells lacking dhfr gene
hr	=	hour
INR	=	international normalized ratio
IV	=	intravenous
kg	=	kilogram
M	=	molar
mg	=	milligram
mg/kg	=	milligram/kilogram
mg/mL	=	milligram/milliliter
min	=	minute
mL	=	milliliter
mM	=	millimolar
nm	=	nanometer
nM	=	nanomolar

PO	=	oral
PRP	=	platelet rich plasma
PT	=	prothrombin time
RFU	=	relative fluorescence unit
s	=	second
TF	=	tissue factor
U/mL	=	units/milliliter
μ L or uL	=	microliter
μ M	=	micromolar
μ g	=	microgram
fXa	=	factor Xa
PCI	=	protein C inhibitor
PSI	=	protein S inhibitor
TAFI	=	thrombin-activatable fibrinolysis inhibitor
LMWH	=	Low molecular weight heparin

Example 1. Preparation of des-Gla anhydro-fXa by Chymotrypsin Digestion

[0241] Des-Gla anhydro-fXa was prepared according to the procedure of Morita, T. et al., *J. Bio. Chem.*, 1986, 261(9):4015-4023 by incubating anhydro-fXa, in which dehydroalanine replaces the active-site serine, with chymotrypsin in 0.05 M Tris-HCl, 0.1 M NaCl, at pH 7.5 and 22 °C for 60 minutes. In a typical experiment setting, 0.5 milligrams/milliliter (mg/mL) anhydro-fXa was incubated with 5 units/milliliter (U/mL) α -chymotrypsin-agarose beads with gentle agitation. At the end of the reaction, the α -chymotrypsin-agarose beads were removed by centrifugation or filtration. This was followed by incubation with excess amount of inhibitors 4-amidino-phenyl-methane-sulfonyl fluoride (APMSF), tosyl-L-lysine chloromethyl ketone (TLCK), and tosyl-L-phenylalanine chloromethyl ketone (TPCK) to quench the residual fXa activity or any activity of chymotrypsin possibly leached from the beads. Gla-domain fragment and inhibitors were removed from the final product, des-Gla anhydro-fXa, by an Amicon Ultra Centrifugal filter device (YM10 membrane) or by conventional dialysis. Concentrating or buffer exchange, if necessary, was also achieved at the same time.

[0242] The Gla-containing anhydro-fXa was prepared according to the procedure reported by Nogami et al., *J. Biol. Chem.*, 1999, 274(43):31000-7. As shown in Figure 5, the Gla-containing anhydro-fXa has diminished enzymatic activity but is capable of binding fXa inhibitors such as betrixaban. This is described in detail in Example 4.

[0243] α -Chymotrypsin-agarose bead was purchased from Sigma and the specific activity (U/mL) was based on manufacturer's data for the specific lot number used.

[0244] Chymotrypsin digestion of active fXa can be carried out according to above procedure without using APMSF. Clotting activity of active fXa was determined before the chymotrypsin digestion, and after 15, 30 and 60 minutes of chymotrypsin digestion according to the procedure described in Example 3 below. Figure 7 shows complete loss of clotting activity after 30 minutes of chymotrypsin digestion. The incubation time were extended to 60 minutes to ensure complete removal of the Gla domain.

Example 2. Thrombin Generation Assay in Platelet Poor Plasma (PPP) or Platelet Rich Plasma (PRP)

[0245] In this example, human platelet poor or platelet rich plasma samples were prepared from blood of healthy donors drawn into 0.32% citrate. PRP and PPP were prepared by spinning the anticoagulated blood at ~100 X gravity or 1000 X gravity for 20 minutes, respectively, at room temperature. 75-100 microliter (uL) plasma was mixed with CaCl_2 and Z-Gly-Gly-Arg-aminomethylcoumarin (Z-GGR-AMC, a thrombin fluorogenic substrate). Tissue factor (Innovin, Dade Behring) was added to initiate the generation of thrombin. For a typical experiment, the reaction mixture contained 15 millimolar (mM) Ca^{2+} , 100 micromolar (μM) Z-GGR-AMC, and 0.1 nanomolar (nM) tissue factor (TF) (Innovin). Thrombin formation was monitored continuously at 37 °C by a fluorometric plate reader (Molecular Devices) measuring the relative fluorescence units (RFU). Inhibitor and antidote, when present, were pre-incubated with plasma for 20 minutes at room temperature before initiation of thrombin generation.

[0246] The results of various experiments using this assay may be found in Figures 4, 6, and 9.

Example 3. Clotting Prolongation Assays

[0247] Two clotting assay formats were used to test the effects of factor Xa inhibitors and the antidote on clotting prolongation. In the first format, a 96-well plate

was used to measure multiple samples at the same time. In the second assay format, aPTT was measured with a conventional coagulation instrument (MLA Electra 800 automatic coagulation timer).

[0248] In the 96-well plate format method, human platelet poor plasma or platelet rich plasma was prepared similarly as procedures in Example 2. 75-100 μ L plasma was recalcified with CaCl_2 , incubated at 37 °C for 3 minutes and clot formation was initiated by adding tissue factor (Innovin, Dade Behring) or an aPTT reagent (Actin FS, Dade Behring). Change of OD405 was monitored continuously by a plate reader (Molecular Devices). Clotting time was defined as the time (second) when the half maximal value of absorbance (OD405nm) change was reached. Factor Xa inhibitor and antidote, when present, were pre-incubated with plasma at room temperature for 20 minutes before initiation of the reaction.

[0249] When an active fXa was tested for its clotting activity as shown in Figure 7, 75-100 μ L fX deficient plasma (George King Bio-Medical, Inc.) was recalcified with CaCl_2 , incubated at 37 °C for 3 minutes and fXa products following chymotrypsin digestion was added to the plasma to initiate clot formation. Change of OD405 was continuously monitored by a plate reader as described before.

[0250] In Figure 13, the effect of 400 nM betrixaban on aPTT prolongation of normal human plasma and the reversal of betrixaban inhibitory effect by antidote des-Gla anhydro-fXa was measured with a MLA Electra 800 Automatic coagulation timer. 100 μ L pooled human plasma was mixed with 400 nM betrixaban and different concentration of antidote. aPTT reagent (Actin FS, Dade Behring) and CaCl_2 were added per manufacturer's instructions for measurement of clotting times.

[0251] Results of additional experiments using this assay may be found in Figures 10 and 11.

Example 4. Reversal of Inhibition of fXa by Betrixaban by anhydro-fXa or des-Gla anhydro-fXa

[0252] To measure the inhibition of fXa activity by betrixaban and reversal of its inhibitory effect, purified active fXa, different concentrations of betrixaban and anhydro-fXa or des-Gla anhydro-fXa were added to 20 mM Tris, 150 mM NaCl, 5

mM Ca^{2+} , and 0.1% Bovine Serum Albumin (BSA). After incubation at room temperature for 20 minutes, 100 μM Spectrozyme-fXa (a factor Xa chromogenic substrate, American Diagnostica) was added to the mixture and the rate of substrate cleavage was monitored continuously for 5 minutes at 405 nanometer (nm) by a plate reader. In Figure 5, the chromogenic activity was normalized to active fXa in the absence of any inhibitor. Initial velocity of product formation as a function of inhibitor and antidote concentration was analyzed by nonlinear regression to estimate the affinity of betrixaban to the antidote (Figure 8).

[0253] The effect of the antidote des-Gla anhydro-fXa on thrombin activity toward a chromogenic substrate S2288 (200 μM) was measured similarly as before with or without Argatroban, a specific small molecule IIa inhibitor. As expected, the antidote (538 nM) does not affect the amidolytic activity of IIa (5 nM) or its inhibition by 50 nM Argatroban.

Example 5. Preparation of fXa with Decarboxylated γ -Carboxyglutamic Acid Residues

[0254] A fXa derivative with decarboxylated γ -carboxyglutamic acid residues can be prepared by treating fXa protein, for example, based on the procedure reported by Bajaj, et al. *J. Biol. Chem.*, 1982, 257(7):3726-3731. 2 to 5 mg of purified or recombinant fXa in 2 mL of 0.1 Molar ammonium bicarbonate at pH 8.0 is lyophilized. The resulting powder is sealed under a vacuum of less than 20 μm and heated at 110 $^{\circ}\text{C}$ for various periods of time to obtain decarboxylated fXa.

Example 6. Preparation of Recombinant des-Gla fXa-S379A

[0255] The fXa derivatives may be produced by recombinant DNA method with one of the following procedures based on fX cDNA (SEQ ID NO. 2) for expressing fX (SEQ ID NOS. 1, 3) or fXa derivatives (SEQ ID NOS. 4, 5, 9, and 11) in a suitable host organism according to general procedures of mutagenesis and molecular biology.

[0256] Recombinant fX and fX derivatives can be expressed in, for example, human embryonic kidney cells HEK293 based on procedures described in Larson, P.J., et al, *Biochem.*, 1998, 37:5029-5038, and Camire, R.M., et al, *Biochem.*,

2000, 39, 14322-14329. Recombinant fX can be activated to rfXa by factor X activator Russell's Viper Venom (RVV). rfXa can be further processed to des-Gla anhydro-fXa based on procedures described in Example 1.

5 [0257] Recombinant fX-S379A (S195A in chymotrypsin numbering) with the active site serine residue being replaced by alanine, and preferably the activated fXa mutant, rfXa-S379A, may be expressed, for example, in Chinese Hamster Ovary (CHO) cells based on procedures described by Sinha et al., *Protein Expression and Purif.* 1992, 3: 518-524; Wolf, D.L. et al, *J. Biol. Chem.*, 1991, 266(21):13726-13730.

10 [0258] Des-Gla fXa-S379A may be prepared by chymotrypsin digestion of fXa-S379A according to procedures described in Example 1.

15 [0259] More preferably, Des-Gla fXa-S379A may be expressed directly according to previous procedures with deletion of Gla-domain fragment by mutagenesis procedures. For example, recombinant protein expression can be used to express: des-Gla(1-39)-fXa-S379A, after removal of Gla-domain fragment 1-39 of SEQ ID NO. 3; des-Gla(1-44)-fXa-S379A, equivalent to SEQ ID NO. 10 with dehydro-alanine being replaced by alanine; and des-Gla(1-45)-fXa-S379A with entire Gla-domain being removed (SEQ ID NO. 11).

20 [0260] Further truncations at EGF1 or EGF1 *plus* EGF2 domain (Figure 2) can also be made to express des(1-84)-fXa-S379A or des(1-128)-fXa-S379A derivatives.

Example 7. Expression of Recombinant fXa Mutant in CHO Cell

25 [0261] This example describes the recombinant protein expression construct and the cell line for the direct expression of a Gla-domainless fXa-S379A (S195A in chymotrypsin numbering) variant. The recombinant antidote does not require activation or chemical modification steps necessary to produce the pd-Antidote and has comparable affinity to the plasma derived protein in the *in vitro* assays discussed herein.

 [0262] In this example, a fXa mutant (SEQ ID NO. 13, Table 12a) was directly expressed in CHO cell (see Figure 14 for expression vector) and functional

protein was purified from conditioned medium as described below. Recombinant antidote (r-Antidote) functional activity was tested *in vitro* and in animal model (Example 8).

[0263] PCR was used to mutate the cDNA sequence of fX (SEQ ID NO. 2) in three regions. The first mutation was the deletion of 6-39 aa in the Gla-domain of fX (SEQ ID NO. 3, Figure 3). The second mutation was replacing the activation peptide sequence 143-194 aa with -RKR-. This produced a -RKRRKR- linker connecting the light chain and the heavy chain. Upon secretion, this linker is removed in CHO resulting in a two-chain fXa molecule. The third mutation is mutation of active site residue S379 to an Ala residue.

10 [0264] The polypeptide produced by the cDNA (SEQ ID NO. 16) just described is described in Table 12 (SEQ ID NO. 12). The alignment of the cDNA to the polypeptide is shown in Figure 21. The two-chain fXa molecule produced after secretion (SEQ ID NO. 13) is a light chain fragment described in Table 12b (SEQ ID NO. 14) and a heavy chain fragment described in Table 12c (SEQ ID NO. 15).

15 [0265] The first 1-5 aa in fX sequence was reserved and used to connect the polypeptide of fXa mutant to the prepro peptide of fX (SEQ ID NO. 1, Figure 1), ensuring proper processing of the prepro peptide in fXa mutant.

[0266] DNA sequence encoding the polypeptide of fXa mutant described above was sequenced and inserted to the expression vector shown in Figure 14. The polynucleotide of the expression vector is shown in SEQ ID NO. 18. Plasmid DNA was linearized and transfected into CHO dhfr(-) cells. Cells were selected using tetrahydrofolate (HT) deficient media plus methotrexate (MTX). Stable clones were screened for high protein expression using a fX ELISA kit (Enzyme Research Laboratories, Catalogue Number FX-EIA). fXa mutant protein was expressed in serum free medium and conditioned medium was harvested and processed for purification.

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[0267] Target protein in the conditioned medium can be isolated by ion exchange chromatography and subsequently purified by single step affinity chromatography (such as an anti-fXa antibody coupled to a matrix) or by a combination of several chromatography steps such as hydrophobic and size exclusion matrices. The affinity purifications may include chromatographic material that selectively binds to fXa

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active site cleft, such as benzamidine-sepharose or soybean trypsin inhibitor-agarose (STI-Agarose).

[0268] Figure 15A shows the Western blots of affinity (STI-Agarose , Sigma Catalog # T0637) purified fXa mutant using monoclonal antibodies (Enzyme Research Laboratories , FX-EIA) recognizing fX heavy and light chain, respectively. Upon reduction of the disulfide bond which connects the light and heavy chain, r-Antidote shows the heavy chain band of expected mobility (similar to plasma derived fXa) in the Western blot. Deletion of amino acid residues (numbered 6 through 39) in the Gla-domain of fXa mutant results in a lower molecular weight band for the light chain of r-Antidote compared to plasma derived fXa. Position of molecular weight markers can also be seen on the blot.

[0269] Figure 15B and 15C shows a SDS-PAGE and Western blot of purified r-Antidote by ion exchange and affinity purification followed by size exclusion chromatography using a Superdex 75 10/300 GL column (GE Healthcare, Cat# 17-5174-01).

Example 8. *In vivo* Mouse Model

[0270] The pharmacokinetic and pharmacodynamic (PK-PD) profile of betrixaban in male C57Bl/6 mice with or without administering antidote were tested. Single oral administration of betrixaban was dosed at 0, 15, 25, and 75 mg/kg for controls groups. 15 mg/kg was used for antidote treated group. A single intravenous (IV) injection of antidote (300 ug/200 μ L) or vehicle (normal saline, 200 μ L) was administered 5 minutes prior to the 1.5 hr. time point.

[0271] At 1.5, 2.0, and 4.0 hrs following oral administration of betrixaban, mice were anesthetized with a ketamine cocktail (SC) and exsanguinated via cardiac puncture. Blood samples (0.5 mL) were obtained in 50 μ L trisodium citrate. Whole blood INR was measured using Hemochron Jr. cartridges (International Technidyne Corporation) per the manufacturer's instructions. Mouse platelet poor plasma was prepared by centrifugation for betrixaban and antidote (ELISA) plasma concentration determinations.

[0272] For recombinant antidote (r-Antidote) experiment, mice were orally dosed with betrixaban at 0, 15, 25, and 75 mg/kg for control groups. 15 mg/kg was used for antidote (300 µg/200 µL) treated group. Samples were taken at 1.5 hr after oral administration of betrixaban (5 min. following antidote injection).

5 [0273] As shown in Figures 16 and 17 and Tables 13 and 14, single injection (300 µg, IV) of plasma derived antidote (pd-Antidote) or recombinant fXa mutant (r-Antidote) to mice following administration of betrixaban (15mg/kg, PO) effectively captured the inhibitor *in vivo*. PK-PD correlation of whole blood INR and antidote plasma concentration (Tables 13-14) indicated >50% reduction of functional
10 betrixaban based on INR measurements, and justified effective neutralization of fXa inhibitors by the antidote via multiple injections or other regimes. It is contemplated that these results demonstrate that the fXa derivatives of this invention have potential of acting as universal antidotes to reverse the anticoagulant effect of fXa inhibitors in patients with bleeding or other medical emergencies.

15 [0274] Figure 22 shows mouse experiment with a single IV injection (1 injection) or two injections (2 injections) of the r-antidote (n=5 per group, 312 ug/200 ul r-Antidote) following oral administration of betrixaban (15 mg/kg). For the single injection group, mouse blood samples were taken at 1 hr. following oral administration of betrixaban. Vehicle (control_1) or r-Antidote (1 injection) was administered 5 min prior
20 to the 1 hr. time point. For the double injection group, vehicle or r-Antidote was injected at 55 min and repeated at 115 min following oral administration of betrixaban. Mouse blood samples were taken at 2 hr. for vehicle (control_2) and r-Antidote (2 injections) treated mice. Measured INR as a function of antidote/betrixaban ratio in mouse plasma following single or double injections of the antidote was shown in Figure 22 B.

25 **Example 9. *In vitro* Reversal of Rivaroxaban and Apixaban by Antidote**

[0275] As expected, the antidotes contemplated by this invention were also able to bind and neutralize other active site directed fXa inhibitors. Tables 15 and 16 show *in vitro* correction of inhibition by betrixaban, rivaroxaban and apixaban by pd-Antidote and r-Antidote. Purified fXa (3.0 nM), inhibitor (7.5 nM), and different
30 concentrations of antidote were incubated for 10 min at 22°C in a buffer with 20 mM Tris, 150 mM NaCl, 0.1% BSA, pH7.4. fXa activity was assayed similar to Example 4.

[0276] As shown in Table 15, 204 nM pd-Antidote produces at least 60% correction of the inhibitory effects of tested inhibitors, while in Table 16 >95% correction of inhibition was achieved by the r-Antidote (186 nM) for betrixaban and rivaroxaban, and >70% reversal of apixaban.

5 **Example 10. *In vitro* Reversal of Betrixaban by r-Antidote**

[0277] In Table 17, the effect of recombinant antidote protein on reversal of anticoagulation by betrixaban was tested in a human plasma clotting assay. The effect of 300nM and 400 nM betrixaban on aPTT prolongation of plasma and the reversal of inhibitory effect was measured by a MLA Electra 800 Automatic coagulation timer. 100
10 μL pooled citrate anticoagulated human plasma was mixed with 300 nM or 400 nM betrixaban and different concentrations of antidote. aPTT reagent (Actin FS, Dade Behring) and CaCl₂ were added per manufacturer's instructions.

Example 11. *In vitro* Reversal of Low Molecular Weight Heparin ("LMWH") by r-Antidote

15 [0278] In Figure 18, the effect of r-Antidote to reverse the inhibitory effect of LMWH enoxaparin (Sanofi-Aventis) was tested by turbidity changes in human plasma. Enoxaparin (0-1.25 U/mL) was incubated at 22°C for 20 min with or without 508 nM r-Antidote. Turbidity changes were measured according to procedures described in Example 3. 508 nM r-Antidote substantially corrected (>75%) the inhibitory effect of
20 0.3125-1.25 U/mL Enoxaparin.

[0279] In Figure 19, the effect of r-Antidote on reversal of anticoagulation by a low molecular weight heparin (LMWH enoxaparin, Sanofi-Aventis) was tested in a human plasma clotting assay. The effect of 1 antiXa Unit/mL LMWH on aPTT prolongation of plasma and the reversal of inhibitory effect was measured by a
25 MLA Electra 800 Automatic coagulation timer. 100 μL pooled citrate anticoagulated human plasma was mixed with enoxaparin and different concentrations of antidote. Prior to measurement of clotting time, aPTT reagent (Actin FS, Dade Behring) and CaCl₂ were added per manufacturer's instructions. Addition of 1.14 μM recombinant antidote produced a 52% correction of anticoagulation produced by 1 Unit/mL enoxaparin.

Example 12. *In vitro* Reversal of Rivaroxaban by r-Antidote

[0280] In Figure 20, the effect of recombinant antidote protein on reversal of anticoagulation by a small molecule factor Xa inhibitor (rivaroxaban, Bay 59-7939) was tested in a human plasma clotting assay. As reported by Perzborn et al, *J. Thromb. Haemost.* 3:514-521, 2005; prothrombin time measurements are an accurate method for evaluating the anticoagulant effect of rivaroxaban. The effect of 1 μ M rivaroxaban on prothrombin time (PT) prolongation of pooled human plasma and the reversal of inhibitory effect was measured by a MLA Electra 800 Automatic coagulation timer. 100 μ L pooled citrate anticoagulated human plasma was mixed with rivaroxaban and different concentrations of antidote. Prior to measurement of clotting time, rabbit brain Thromboplastin C Plus reagent (Dade Behring) was added to plasma samples per manufacturer's instructions. Addition of 1.9 μ M recombinant antidote produced a 100% correction of anticoagulation produced by 1 μ M rivaroxaban.

Example 13. *In vitro* Reversal of Apixaban by r-Antidote

[0281] In Table 18, the effect of recombinant antidote protein on reversal of anticoagulation by apixaban was tested in a human plasma clotting assay. As reported by Pinto et al., *J. Med. Chem.* 55(22):5339-5356, 2007; prothrombin time (PT) measurements are an accurate method of evaluating the *ex vivo* anticoagulant effects of apixaban. The effect of 1 μ M and 1.5 μ M apixaban on prothrombin time (PT) prolongation of pooled human plasma and the reversal of inhibitory effect was measured by a MLA Electra 800 Automatic coagulation timer. 100 μ L pooled citrate anticoagulated human plasma was mixed with apixaban and different concentrations of antidote. Prior to measurement of clotting time, rabbit brain Thromboplastin C Plus reagent (Dade Behring) was added to plasma samples per manufacturer's instructions. Addition of 1.9 μ M recombinant antidote produced a 97% correction of anticoagulation produced by 1.5 μ M apixaban.

Example 14. *In vitro* Inhibition of Argatroban by des-Gla anhydro-fXa

[0282] To measure the inhibition of thrombin activity by argatroban and reversal of its inhibitory effect, purified human thrombin (5 nM), argatroban (50 nM) and different concentrations of antidote des-Gla anhydro fXa were added to a buffer containing 20 mM Tris, 0.15 M NaCl, 5 mM Calcium chloride, 0.1% bovine serum

albumin, pH 7.4. After incubation at room temperature for 20 min, an amidolytic substrate S2288 (200 μ M) was added to the mixture and the rate of p-nitroanilide substrate cleavage was monitored by absorbance at 405 nm. The results are presented in Figure 12.

5 **Example 15. Thrombin generation assay in platelet poor plasma (PPP) or platelet rich plasma (PRP)**

[0283] In this example, human platelet poor or platelet rich plasma samples were prepared from blood of healthy donors drawn into 0.32% citrate. PRP and PPP were prepared by spinning the anticoagulated blood at ~100 X gravity or 1000 X gravity for 20 minutes, respectively, at room temperature. 75-100 Microliter (μ L) of plasma was mixed with Z-Gly-Gly-Arg-aminomethylcoumarin (Z-GGR-AMC, a thrombin fluorogenic substrate, Bachem Cat# I-1140). Tissue factor (Innovin, Dade Behring) and CaCl_2 were added to initiate the generation of thrombin. For a typical experiment, the reaction mixture contained 15 millimolar (mM) Ca^{2+} , 100 micromolar (μ M) Z-GGR-AMC, and 0.1 nanomolar (nM) tissue factor (TF) (Innovin). Thrombin formation was monitored continuously at 37 °C by a fluorometric plate reader (Molecular Devices) measuring the relative fluorescence units (RFU). When present, the inhibitor and the antidote were pre-incubated with plasma for 15 minutes at room temperature before initiation of thrombin generation. Recombinant VIIa (rVIIa, Novoseven), when present, was added before addition of TF to initiate the reaction.

[0284] Figure 23 shows the synergistic effect of rVIIa with recombinant fXa protein derivative antidote (r-Antidote) on the anticoagulant activity of 250 nM betrixaban, a fXa inhibitor, in thrombin generation. The results were expressed as relative thrombin generation activity (% activity) after normalization of RFU in plasma without any added inhibitor, rVIIa or r-Antidote. The data show that r-Antidote dose independently reversed the anticoagulant effect of 250 nM betrixaban. Combination of 100 nM rVIIa with r-Antidote further increased thrombin generation activity at each r-Antidote concentration, while 100 nM rVIIa alone only slightly increased thrombin generation activity in the absence of r-Antidote. rVIIa also slightly increased thrombin generation activity in control plasma in the absence of betrixaban.

Example 16. Reversal of Rivaroxaban anticoagulant activity by combination of r-Antidote and rVIIa

[0285] Rivaroxaban (XareltoTM, Bay 59-7939) is a small molecule factor Xa inhibitor indicated for prevention of venous thromboembolism in patients undergoing orthopedic surgery. As reported by Perzborn et al, *J. Thromb. Haemost.* **3**:514-521, 2005, prothrombin time (PT) measurements are an accurate method for evaluating the anticoagulant effect of rivaroxaban. Clinically effective doses of rivaroxaban produce peak plasma concentrations as high as 318 ng/ml (730 nM, Kubitza et al, *Eur. J. Clin. Pharmacol.* **61**:873-880, 2005). In order to mimic the anticoagulant effect of supratherapeutic concentrations, at levels likely to be implicated in clinically significant bleeding scenarios, the feasibility of reversing concentrations of rivaroxaban which were higher than 730 nM was examined.

[0286] The effect of 1 μ M rivaroxaban on prothrombin time (PT) prolongation of pooled human plasma (combination of citrate anticoagulated plasma from eight healthy volunteer donors) was measured in a MLA Electra 800 Automatic coagulation timer. In order to measure clotting time, rabbit brain Thromboplastin C Plus reagent (Dade Behring) was added to plasma samples (100 μ L) per manufacturer's instructions. The baseline PT (12.2 ± 0.1 sec) was prolonged by 2 folds (25 ± 0.4 sec) upon addition of rivaroxaban. *In vitro* reversal of anticoagulant effect was tested by addition of recombinant antidote protein (r-Antidote) or recombinant factor VIIa (rVIIa, NovoSevenTM, Novo Nordisk). Addition of r-Antidote alone produced partial correction of PT: addition of r-Antidote (380 nM) produced a 14% correction (21.5 ± 0.2 sec) and a higher concentration (760 nM) produced a 28% correction respectively. In comparator experiments, where rivaroxaban anticoagulated plasma was treated with rVIIa (2.2 nM), the resulting partial correction of PT was 46%. However, in human subjects rVIIa has a short half life of circulation ($T_{1/2} = 2.3$ hrs, prescribing information for NovoSeven) so the level of reversal observed in this *in vitro* experiment is unlikely to be sustained in a clinical setting. In order to attain higher levels of reversal of the rivaroxaban effect, varying combinations of r antidote and rVIIa were added to human plasma and the resulting PTs were measured (as summarized in Figure 24). A combination of 380 nM r-antidote and 2.2 nM rVIIa produced a complete correction (resulting PT = 12 sec) of

rivaroxaban induced anticoagulation. Similarly, a combination of 760 nM r-Antidote and 0.55 nM rVIIa exhibited great reversion of the anticoagulation effect of rivaroxaban.

Example 17. Reversal of Betrixaban anticoagulant activity by combination of r-Antidote and coagulation factor IX

5 [0287] Blood coagulation factor IX is indicated for the management of bleeding episodes in patients with Hemophilia B. Plasma derived protein (factor IX complex concentrates as listed in Brooker M, Registry of Clotting Factor Concentrates, World Federation of Hemophilia, Eighth Edition, 2008) and recombinant fIX (such as BeneFIX, Wyeth) are both used for the indication. In addition, use of factor IX has been
10 reported in clinical applications of reversal of anticoagulant associated intracerebral hemorrhage (Siddiq F et al, *Neurocrit Care*, 8(1):36-41, 2008).

 [0288] In order to mimic the effect of supratherapeutic anticoagulant concentrations, which are likely to be implicated in clinically significant bleeding scenarios, the feasibility of reversing high concentrations of betrixaban was tested. The
15 effect of 400 nM betrixaban (eight folds higher than therapeutic concentration for prophylaxis of deep vein thrombosis) on aPTT prolongation of normal human plasma and the reversal of betrixaban inhibitory effect by r-Antidote or human plasma derived fIX (Haematologic Technologies, Essex Junction, VT) was measured in a MLA Electra 800 Automatic coagulation timer. 100 μ L pooled human plasma was mixed with 400 nM
20 betrixaban and varying concentrations of r-Antidote, purified plasma fIX or combinations of r-Antidote and fIX. aPTT reagent (Actin FS, Dade Behring) and CaCl_2 were added per manufacturer's instructions for measurement of clotting times.

 [0289] The baseline aPTT (25.5 ± 0.1 sec) was prolonged by approximately 2 folds (51.6 ± 0.4 sec) upon addition of betrixaban. Addition of r-
25 Antidote alone produced partial correction of aPTT: addition of r-antidote (380 nM) produced a 25% correction (38.6 sec), and higher concentrations (760 nM and 1.14 μ M) produced 40% and 42% correction respectively. In comparator experiments, where betrixaban anticoagulated plasma was treated with human plasma derived fIX (258 nM or 387 nM), the resulting partial correction of aPTT was only 15% in both cases. Thus, fIX
30 alone is not an effective reversal agent for betrixaban anticoagulation. In order to attain higher levels of reversal for betrixaban mediated anticoagulation, varying concentrations

of r-Antidote and fIX were added to human plasma and the resulting aPTTs were measured (as summarized in Figure 25). A combination of r-Antidote (380 nM) and fIX (258 nM) produced an enhancement of correction (resulting aPTT = 33 sec) over those attained by single agent alone (38.6 sec and 43.8 sec respectively). Similarly, a combination of r-Antidote (760 nM) and fIX (258 nM) produced an enhancement of correction (resulting aPTT = 26.9 sec) over those attained by single agent alone (31.2 sec and 43.8 sec respectively). As shown in Figure 25, the combination of r-Antidote (1.14 μ M) and fIX (258 nM) was sufficient to produce complete in-vitro reversal of the anticoagulant effect to baseline clotting parameter conditions.

Example 18. Reversal of betrixaban anticoagulant activity by Combination of r-Antidote and coagulation factor X

[0290] In this example, the combination effect of human factor X (fX) and r-Antidote for reversing betrixaban inhibition was tested in a 96-well plate format clotting assay. Turbidity change of human platelet poor plasma (PPP) with an aPTT reagent (Actin FS) was monitored according to procedure described in Example 3. 125 nM betrixaban, 125 nM r-Antidote, or 170 nM FX (Hematologic Technologies), when present, was pre-incubated with plasma for 15 minutes at room temperature before adding Ca^{2+} to initiate the reaction.

[0291] Figure 26 shows the combination effect of fX with recombinant antidote (r-Antidote) on the anticoagulant activity of 125 nM betrixaban. The results were expressed as fold changes after normalization of the clotting time in plasma without any added inhibitor, fX or r-Antidote (Control, No FX). The data show that 125 nM betrixaban doubled the clotting time (0 nM r-Antidote, No FX). Addition of 125 nM r-Antidote substantially reversed the anticoagulant effect of betrixaban. 170 nM fX independently reduced the clotting time by ~20% in plasma with or without 125 nM inhibitor. Combination of 170 nM fX with 125 nM r-Antidote further corrected the inhibitory effect of 125 nM betrixaban.

[0292] It is to be understood that while the invention has been described in conjunction with the above embodiments, that the foregoing description and examples are intended to illustrate and not limit the scope of the invention. Other aspects,

advantages and modifications within the scope of the invention will be apparent to those skilled in the art to which the invention pertains.

Table 1 – Sequence ID NO. 1 – Polypeptide Sequence of Human Factor X

1	MGRPLHLVLL	SASLAGLLLL	GESLFIRREQ	ANNILARVTR	ANSFLEEMKK	GHLERECMEE
61	TCSYEEAREV	FEDSDKTNEF	WNKYKDGQDC	ETSPCQNQ GK	CKDGLGEYTC	TCLEGFEGKN
121	CELFTKRLCS	LDNGDCDQFC	HEEQNSVVC	CARGYTLADN	GKACIPTGPY	PCGKQTLERR
181	KRSVAQATSS	SGEAPDSITW	KPYDAADLDP	TENPFDLLDF	NQTQPERGDN	NLTRIVGGQE
241	CKDGECPWQA	LLINEENEGF	CGGTILSEFY	ILTAACHCLYQ	AKRFKVRVGD	RNTEQEEGGE
301	AVHEVEVVIK	HNRFKETYD	FDIAVLR LKT	PITFRMNVAP	ACLPERDWAE	STLMTQKTGI
361	VSGFGRTHEK	GRQSTR LKML	EVPIVDRNSC	KLSSSFIIITQ	NMFCAGYDTK	QEDACQGD SG
421	GPHVTRFKDT	YFVTGIVSWG	EGCARKGKYG	IYTKVTAFLK	WIDRSMKTRG	LPAKASHAPE
481	VITSSPLK					

Table 2 – Sequence ID NO. 2 – A polynucleotide Sequence Encoding Factor X

1	gactttgctc	cagcagcctg	tcccagtgag	gacagggaca	cagtaactcgg	ccacaccatg
61	gggcgcccac	tgcacctcgt	cctgctcagt	gcctccctgg	ctggcctcct	gctgctcggg
121	gaaagtctgt	tcatccgcag	ggagcaggcc	aacaacatcc	tggcgagggt	cacgagggcc
181	aattcccttc	ttgaagagat	gaagaaagga	cacctcgaaa	gagagtgcac	ggaagagacc
241	tgtcatatcg	aagaggcccg	cgaggtcttt	gaggacagcg	acaagacgaa	tgaattctgg
301	aataaataca	aagatggcga	ccagtgtgag	accagtcctt	gccagaacca	gggcaaattgt
361	aaagacggcc	tcggggaata	cacctgcacc	tgtttagaag	gattcgaagg	caaaaactgt
421	gaattattca	cacggaagct	ctgcagcctg	gacaacgggg	actgtgacca	gttctgccac
481	gaggaacaga	actctgtggt	gtgctcctgc	gcccgcgggt	acacctggc	tgacaacggc
541	aaggcctgca	ttcccacagg	gccctacccc	tgtgggaaac	agacctgga	acgcaggaag
601	aggtcagtg	cccaggccac	cagcagcagc	ggggaggccc	ctgacagcat	cacatggaag
661	ccatatgatg	cagccgacct	ggaccccacc	gagaacccct	tgcacctgct	tgacttcaac
721	cagacgcagc	ctgagagggg	cgacaacaac	ctcaccagga	tcgtgggagg	ccaggaatgc
781	aaggacgggg	agtgtccctg	gcaggccctg	ctcatcaatg	aggaaaacga	gggtttctgt
841	ggtggaacca	ttctgagcga	gttctacatc	ctaacggcag	cccactgtct	ctaccaagcc
901	aagagattca	aggtgagggt	aggggaccgg	aacacggagc	aggaggagg	cggtgaggcg
961	gtgcacgagg	tggaggtggt	catcaagcac	aaccggttca	caaaggagac	ctatgacttc
1021	gacatcgccg	tgtccggct	caagaccccc	atcaccttcc	gcataaacgt	gggcctgcc
1081	tgcctccccg	agcgtgactg	ggccgagtcc	acgctgatga	cgcagaagac	ggggattgtg
1141	agcggcttcg	ggcgcaccca	cgagaagggc	cggcagtcca	ccaggctcaa	gatgctggag
1201	gtgccctacg	tggaccgcaa	cagctgcaag	ctgtccagca	gcttcatcat	caccagaac
1261	atgtttctgtg	ccggctacga	caccaagcag	gaggatgcct	gccaggggga	cagcgggggc
1321	ccgcacgtca	cccgttcaa	ggacacctac	ttcgtgacag	gcacgtcag	ctggggagag
1381	ggctgtgccc	gtaaggggaa	gtacgggatc	tacaccaagg	tcaccgcctt	cctcaagtgg
1441	atcgacaggt	ccatgaaaac	caggggcttg	cccaaggcca	agagccatgc	cccggaggtc
1501	ataacgtcct	ctccattaaa	gtgagatccc	actcaaaaaa	aaaaaaaaaa	aaaaaaaaaa

5 Table 3 – Sequence ID NO. 3 – Polypeptide Sequence of Mature Human Factor X

1	ANSFLEEMKK	GHLERECMEE	TCSYEEAREV	FEDSDKTNEF	WNKYKDGQDC	ETSPCQNQ GK
61	CKDGLGEYTC	TCLEGFEGKN	CELFTKRLCS	LDNGDCDQFC	HEEQNSVVC	CARGYTLADN
121	GKACIPTGPY	PCGKQTLERR	KRSVAQATSS	SGEAPDSITW	KPYDAADLDP	TENPFDLLDF
181	NQTQPERGDN	NLTRIVGGQE	CKDGECPWQA	LLINEENEGF	CGGTILSEFY	ILTAACHCLYQ
241	AKRFKVRVGD	RNTEQEEGGE	AVHEVEVVIK	HNRFKETYD	FDIAVLR LKT	PITFRMNVAP
301	ACLPERDWAE	STLMTQKTGI	VSGFGRTHEK	GRQSTR LKML	EVPIVDRNSC	KLSSSFIIITQ
361	NMFCAGYDTK	QEDACQGD SG	GPHVTRFKDT	YFVTGIVSWG	EGCARKGKYG	IYTKVTAFLK
421	WIDRSMKTRG	LPAKASHAPE	VITSSPLK			

Table 4 – Sequence ID NO. 4 – Polypeptide Sequence of the Gla-domainless Factor Xa lacking 1 to 44 amino acid residues

Light Chain	
1	KDGDQC ETSPCQNQGK
61	CKDGLGEYTC TCLEGFEGKN CELFTRKLCS LDNGDCDQFC HEEQNSVVCS CARGYTLADN
121	GKACIPTGPY PCGKQTLER
Heavy Chain	
181	IVGGQE CKDGECPWQA LLINEENEGF CGGTILSEFY ILTAAHCLYQ
241	AKRFKVRVGD RNTEQEEGGE AVHEVEVVIK HNRFTKETD FDIIVLRRLKT PITFRMNVAP
301	ACLPERDWAE STLMTQKTGI VSGFGRTHEK GRQSTRKLML EVPYVDRNSC KLSSSFIIITQ
361	NMFCAGYDTK QEDACQGDSG GPHVTRFKDT YFVTGIVSWG EGCARKGKYG IYTKVTAFLK
421	WIDRSMKTRG LPAKASHAPE VITSSPLK

5 Table 5 – Sequence ID NO. 5 – Polypeptide Sequence of the Gla-domainless Factor Xa lacking 1 to 45 amino acid residues

Light Chain	
1	DGDQC ETSPCQNQGK
61	CKDGLGEYTC TCLEGFEGKN CELFTRKLCS LDNGDCDQFC HEEQNSVVCS CARGYTLADN
121	GKACIPTGPY PCGKQTLER
Heavy Chain	
181	IVGGQE CKDGECPWQA LLINEENEGF CGGTILSEFY ILTAAHCLYQ
241	AKRFKVRVGD RNTEQEEGGE AVHEVEVVIK HNRFTKETD FDIIVLRRLKT PITFRMNVAP
301	ACLPERDWAE STLMTQKTGI VSGFGRTHEK GRQSTRKLML EVPYVDRNSC KLSSSFIIITQ
361	NMFCAGYDTK QEDACQGDSG GPHVTRFKDT YFVTGIVSWG EGCARKGKYG IYTKVTAFLK
421	WIDRSMKTRG LPAKASHAPE VITSSPLK

10 Table 6 – Sequence ID NO. 6 – Polypeptide Sequence of Activated Human Factor Xa prior to Post-Translation of Glutamic Acid to γ -Carboxyglutamic acid

Light Chain	
1	ANSFLEEMKK GHLERECMEE TCSYEEAREV FEDSDKTNEF WNKYKDGDQC ETSPCQNQGK
61	CKDGLGEYTC TCLEGFEGKN CELFTRKLCS LDNGDCDQFC HEEQNSVVCS CARGYTLADN
121	GKACIPTGPY PCGKQTLER
Heavy Chain	
181	IVGGQE CKDGECPWQA LLINEENEGF CGGTILSEFY ILTAAHCLYQ
241	AKRFKVRVGD RNTEQEEGGE AVHEVEVVIK HNRFTKETD FDIIVLRRLKT PITFRMNVAP
301	ACLPERDWAE STLMTQKTGI VSGFGRTHEK GRQSTRKLML EVPYVDRNSC KLSSSFIIITQ
361	NMFCAGYDTK QEDACQGDSG GPHVTRFKDT YFVTGIVSWG EGCARKGKYG IYTKVTAFLK
421	WIDRSMKTRG LPAKASHAPE VITSSPLK

Table 7– Sequence ID NO. 7 – Polypeptide Sequence of Activated Human Factor Xa with Post-Translation of Glutamic Acid to γ -Carboxyglutamic acid (γ represents γ -Carboxyglutamic Acid Residue)

Light Chain	
1	ANSFLYYMKK GHLRYCMYY TCSYYARYV FYDSDKTNFY WNKYKDGQDC ETSPCQNQGK
61	CKDGLGEYTC TCLEGFEGKN CELFTRKLCs LDNGDCDQFC HEEQNSVVCs CARGYTLADN
121	GKACIPTGPY PCGKQTLER
Heavy Chain	
181	IVGGQE CKDGECPWQA LLINEENEGF CGGTILSEFY ILTAAHCLYQ
241	AKRFKVRVGD RNTEQEEGGE AVHEVEVVIK HNRFTKETVD FDI AVLRLKT PITFRMNVAP
301	ACLP ERDWA E STLMTQKTGI VSGFGRTHEK GRQSTR LKML E V P Y V D R N S C K L S S S F I I T Q
361	NMFCAGYDTK QEDACQGD SG GPHVTRFKDT YFVTGIVSWG EGCARKGKYG IYTKVT AFLK
421	WIDRSMKTRG LPAKSHAPE VITSSPLK

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Table 8 – Sequence ID NO. 8 – Polypeptide Sequence of Activated Human Factor Xa-Light Chain with Post-Translation of Glutamic Acid to γ -Carboxyglutamic acid

Light Chain	
1	ANSFLYYMKK GHLRYCMYY TCSYYARYV FYDSDKTNFY WNKYKDGQDC ETSPCQNQGK
61	CKDGLGEYTC TCLEGFEGKN CELFTRKLCs LDNGDCDQFC HEEQNSVVCs CARGYTLADN
121	GKACIPTGPY PCGKQTLER

10 Table 9 – Sequence ID NO. 9 – Polypeptide Sequence of Activated Human Factor Xa-Heavy Chain

181	IVGGQE CKDGECPWQA LLINEENEGF CGGTILSEFY ILTAAHCLYQ
241	AKRFKVRVGD RNTEQEEGGE AVHEVEVVIK HNRFTKETVD FDI AVLRLKT PITFRMNVAP
301	ACLP ERDWA E STLMTQKTGI VSGFGRTHEK GRQSTR LKML E V P Y V D R N S C K L S S S F I I T Q
361	NMFCAGYDTK QEDACQGD SG GPHVTRFKDT YFVTGIVSWG EGCARKGKYG IYTKVT AFLK
421	WIDRSMKTRG LPAKSHAPE VITSSPLK

Table 10 – Sequence ID NO. 10 – Polypeptide Sequence of the Des-Gla Anhydro Factor Xa (Å represents dehydroalanine)

Light Chain	
1	KDGDQC ETSPCQNQGK
61 CKDGLGEYTC TCLEGFEGKN CELFTRKLCS LDNGDCDQFC HEEQNSVVCS CARGYTLADN	
121 GKACIPTGPY PCGKQTLER	
Heavy Chain	
181	IVGGQE CKDGECPWQA LLINEENEGF CGGTILSEFY ILTAAHCLYQ
241 AKRFKVRVGD RNTEQEEGGE AVHEVEVVIK HNRFTKETD FDIIVLRRLKT PITFRMNVAP	
301 ACLPERDWAE STLMTQKTGI VSGFGRTHEK GRQSTRKLML EVPYVDRNSC KLSSSFIIITQ	
361 NMFCAGYDTK QEDACQGDÅG GPHVTRFKDT YFVTGIVSWG EGCARKGKYG IYTKVTAFLEK	
421 WIDRSMKTRG LPAKASHAPE VITSSPLK	

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Table 11 – Sequence ID NO. 11 – Polypeptide Sequence of the Des-Gla fXa-S379A

Light Chain	
1	DGDQC ETSPCQNQGK
61 CKDGLGEYTC TCLEGFEGKN CELFTRKLCS LDNGDCDQFC HEEQNSVVCS CARGYTLADN	
121 GKACIPTGPY PCGKQTLER	
Heavy Chain	
181	IVGGQE CKDGECPWQA LLINEENEGF CGGTILSEFY ILTAAHCLYQ
241 AKRFKVRVGD RNTEQEEGGE AVHEVEVVIK HNRFTKETD FDIIVLRRLKT PITFRMNVAP	
301 ACLPERDWAE STLMTQKTGI VSGFGRTHEK GRQSTRKLML EVPYVDRNSC KLSSSFIIITQ	
361 NMFCAGYDTK QEDACQGDÅG GPHVTRFKDT YFVTGIVSWG EGCARKGKYG	
IYTKVTAFLEK	
421 WIDRSMKTRG LPAKASHAPE VITSSPLK	

Table 12 – Sequence ID NO. 12 – Polypeptide Sequence of a Human Factor Xa triple mutant prior to removal of the –RKRRKR- linker

Light Chain	
1 ANSFL	F WNKYKDGDQC ETSPCQNQGK
61 CKDGLGEYTC TCLEGFEGKN CELFTRKLCS LDNGDCDQFC HEEQNSVVCS CARGYTLADN	
121 GKACIPTGPY PCGKQTLER	
Linker	
RKRRKR	
Heavy Chain	
181	IVGGQE CKDGECPWQA LLINEENEGF CGGTILSEFY ILTAAHCLYQ
241 AKRFKVRVGD RNTEQEEGGE AVHEVEVVIK HNRFTKETD FDIIVLRRLKT PITFRMNVAP	
301 ACLPERDWAE STLMTQKTGI VSGFGRTHEK GRQSTRKLML EVPYVDRNSC KLSSSFIIITQ	
361 NMFCAGYDTK QEDACQGDÅG GPHVTRFKDT YFVTGIVSWG EGCARKGKYG IYTKVTAFLEK	
421 WIDRSMKTRG LPAKASHAPE VITSSPLK	

Table 12a – Sequence ID NO. 13 – Polypeptide Sequence of a Human Factor Xa triple mutant after removal of the –RKRRKR- linker

Light Chain	
1	ANSFL F WNKYKDGQDC ETSPCQNQGK
61	CKDGLGEYTC TCLEGFEGKN CELFTRK LCS LDNGDCDQFC HEEQNSVVC S CARGYTLADN
121	GKACIPTGPY PCGKQTLER
Heavy Chain	
181	IVGGQE CKDGECPWQA LLINEENEGF CGGTILSEFY ILTAAHCLYQ
241	AKRFKVRVGD RNTEQEEGGE AVHEVEVVIK HNRFTKETD FDI AVLRLKT PITFRMNVAP
301	ACLP ERD WAE STLMTQKTGI VSGFGRTHEK GRQSTR LKML E V P Y V D R N S C K L S S S F I I T Q
361	NMFCAGYDTK QEDACQGD ^A G GPHVTRFKDT YFVTGIVSWG EGCARKGKYG IYTKVTAF LK
421	WIDRSMKTRG LPKAKSHAPE VITSSPLK

Table 12b – Sequence ID NO. 14 – Polypeptide Sequence of Light Chain Fragment of Human Factor Xa triple mutant after secretion

5

1	ANSFL F WNKYKDGQDC ETSPCQNQGK
61	CKDGLGEYTC TCLEGFEGKN CELFTRK LCS LDNGDCDQFC HEEQNSVVC S CARGYTLADN
121	GKACIPTGPY PCGKQTLER

Table 12c – Sequence ID NO. 15 – Polypeptide Sequence of Heavy Chain Fragment of Human Factor Xa triple mutant after secretion

Heavy Chain	
181	IVGGQE CKDGECPWQA LLINEENEGF CGGTILSEFY ILTAAHCLYQ
241	AKRFKVRVGD RNTEQEEGGE AVHEVEVVIK HNRFTKETD FDI AVLRLKT PITFRMNVAP
301	ACLP ERD WAE STLMTQKTGI VSGFGRTHEK GRQSTR LKML E V P Y V D R N S C K L S S S F I I T Q
361	NMFCAGYDTK QEDACQGD ^A G GPHVTRFKDT YFVTGIVSWG EGCARKGKYG IYTKVTAF LK
421	WIDRSMKTRG LPKAKSHAPE VITSSPLK

10

Table 13-PK-PD correlation in pd-Antidote treated mice at 1.5 hr after 15mg/kg Betrixaban oral administration (5 min after antidote injection)

pd-Antidote treated animal	1	2	3	4	5	6	7	Mean
Betrixaban (ng/mL)	673	793	1170	415	217	664	879	687
Expected INR	4.2	4.5	5.2	3.3	2.3	4.1	4.7	4.0
Measured INR	2.3	2.3	3.3	0.8	0.8	1.5	2.0	1.9
%Correction	63.9	66.6	52.3	100	100	83.1	74.4	77.2

Table 14- PK-PD correlation in r-Antidote treated mice at 1.5 hr after 15mg/kg Betrixaban oral administration (5 min after antidote injection)

r-Antidote treated animal	1	2	3	4	Mean
Betrixaban (ng/mL)	434	262	335	494	381
Expected INR	3.2	2.5	2.8	3.5	3.0
Measured INR	2.0	0.9	1.2	0.9	1.3
%Correction	50.0	94.1	80.0	93.6	77.3

Table 15- % Correction of inhibition by fXa inhibitors

pd-Antidote (nM)	Betrixaban	Rivaroxaban	Apixaban
0	0	0	0
10.2	13.1	10.6	6.5
20.4	34.8	37.4	11.4
40.7	47.1	46.8	15.0
61.1	68.4	55.7	40.3
101.8	67.5	69.4	52.3
162.9	80.5	74.0	56.0
203.7	82.6	72.6	60.2

Table 16- % Correction of inhibition by fXa inhibitors

r-Antidote (nM)	Betrixaban	Rivaroxaban	Apixaban
0	0	0	0
9.3	21.5	23.2	13.3
18.6	52.7	54.2	33.5
37.2	75.5	72.6	49.9
55.8	86.5	79.9	59.2
93.1	94.9	89.1	64.4
148.9	99.3	96.7	74.8
186.1	99.5	94.8	72.6

Table 17-r-Antidote reversal of anticoagulant activity of betrixaban

	aPTT (sec)	Fold Change	% Correction of anticoagulation
Control human plasma	35.2	1.00	-
300nM Betrixaban	61.8	1.76	-
300nM Betrixaban + 570nM r-Antidote	38.3	1.09	88
300nM Betrixaban + 760nM r-Antidote	38.2	1.09	88
300nM Betrixaban + 1140nM r-Antidote	38.1	1.08	90
400nM Betrixaban	66.3	1.88	-
400nM Betrixaban + 380nM rAntidote	47.1	1.34	61
400nM Betrixaban + 570nM rAntidote	39.9	1.13	85
400nM Betrixaban + 760nM rAntidote	39.9	1.13	85
400nM Betrixaban + 1140nM rAntidote	37.8	1.07	92
400nM Betrixaban + 1520nM rAntidote	39.4	1.12	86
1140nM rAntidote	38.9	1.11	-
1520nM rAntidote	38.8	1.10	-

5

Table 18-r-Antidote reversal of anticoagulant activity of Apixaban

	PT (sec)	Fold Change
Control human plasma	14.1	-
1 μ M apixaban	16.4	1.16
1 μ M apixaban + 380nM rAntidote	15.3	1.09
1 μ M apixaban + 760nM rAntidote	14.9	1.06
1 μ M apixaban + 1.14 μ M rAntidote	14.2	1.01
1 μ M apixaban + 1.52 μ M rAntidote	14.2	1.01
1.5 μ M apixaban	18.4	1.31
1.5 μ M apixaban + 1.52 μ M rAntidote	14.6	1.04
1.5 μ M apixaban + 1.90 μ M rAntidote	14.3	1.01
1.52 μ M rAntidote	14	-
1.90 μ M rAntidote	14.2	-

Table 19 - Sequence ID NO. 16 - A polynucleotide Sequence Encoding r-Antidote (a Factor X triple mutant)

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1  ATGGGGGCC CACTGCACCT CGTCCTGCTC AGTGCCTCCC TGGCTGGCCT CTGCTGCTC GGGGAAGATC TGTTCATCCG CAGGAGCAG GCCACACACA
101 TCCTGGCGAG GGTACAGAGG GCCAATTCCT TTCTTTTCTG GAATATAATAC AAAGATGGCG ACCAGTGTGA GACCAATCCT TGCCAGAACC AGGGCAAATG
201 TAAAGACGGC CTCGGGGAAT ACACCTGCAC CTGTTTAGAA GGATTCGAAG GCAAAACTG TGAATTATTC ACACGAAGC TCTGAGCCT GGACAAACGGG
301 GACTGTGACC AGTTCIGCCA CGAGGAACAG AACTCTGTGG TGTGCTCCTG CGCCCGCGGG TACACCCCTGG CAGGCCCTGC ATTCCCACAG
401 GGCCTACCC CTGTGGGAAA CAGACCTTGG AACGCAGGAA GAGGAGGAAG AGGATCGTGG GAGGCCAGGA ATGCAAGGAC GGGGAGTGTG CCTGGCAGGC
501 CCTGCTCATC AATGAGGAAA ACGAGGGTTT CTGTGGTGGT ACCATTCTGA GCGAGTTCTA CATCCTAAG CATCCTACCA AGCCAAAGAGA
601 TTCAAGGTGA GGTAGGGGA CCGGAACACG GAGCAGGAGG AGGGCGGTGA GCGGGTGCAC GAGGTGGAGG TGGTCAITCAA GCACAACCCG TTCACAAGG
701 AGACCTATGA CTTCGACATC GCCGTGCTCC GGCTCAAGAC CCCCATCAC TTCCGCATGA ACGTGGCGCC TGCCTGCCTC CCGAGCGTG ACTGGCCGA
801 GTCCACGCTG ATGACGCAGA AGACGGGGAT TGTGAGCGGC TTCGGGGCCA CCCACGAGAA GGGCCGGCAG TCCACAGGC TCAAGATGCT GGAGGTGCC
901 TACGTGGACC GCAACAGCTG CAAGCTGTCC AGCAGCTTCA TCAATCACCA GAACATGTTT TGTGCCGGCT ACCACACCAA GCAGGAGGAI GCCTGCCAGG
1001 GGGACGCAGG GGGCCCGCAC GTACCCCGCT TCAAGGACAC CTACTTCGTG ACAGGCATCG TCAGCTGGGG AGAGGCTGT GCCCGTAAG GGAAGTACGG
1101 GATCTACACC AAGGTCACCG CCTTCCTCAA GTGGATCGAC AGGTCCATGA AACCCAGGGG CTTGCCCAAG GCCAAGAGCC ATGCCCCCGGA GGTCAATAAG
1201 TCCTCTCCAI TAAAGTGA

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Table 20 - Sequence ID. NO. 18- Polynucleotide Sequence of the r-Antidote Expression Vector

1	1CTAGACACA	GTA	CTCGGCC	ACACCA	TGGG	GGGCCCA	CTG	CACCTCGTCC	TGCTCAGTGC	CTCCCTGGCT	GGCCTCTGCTGC	TGCTCGGGGA	AAGTCTGTTT
101	ATCCG	CAGG	AGCAGGCCAA	CAACAT	CTCTG	GGAGGG	CTCA	TTCCTTTCTT	TTCCTGGAATA	AATACAAAGA	TGCGACACCAG	TGTGAGACCA	
201	GTACCT	TGCCA	GAACCAAGGC	AAATGTAAAG	ACGGCTCTGG	GGATACAC	TGCACCTGTT	TAGAAGGATT	CGAAGCAAA	AACTGTGAAT	TATTCACACG		
301	GACCTCTGC	AGCCTGGACA	ACGGGACTG	TGACCGACTG	TGCCACAGG	AACAGAACTC	TGTGGTGGC	TCTGTGGCCC	GGGGTACAC	CCTGGCTGAC	CCTGGCTGAC		
401	AACGGCAAGG	CCTGCAATTCC	CACAGGGCCC	TACCCCTGTG	GGAAACAGC	CCTGGAACGC	AGGAAGAGGA	GGAAGAGGAT	CGTGGGAGGC	CAGGAATGCA			
501	AGACGGGGA	GTGTCCCTGG	CAGGCCCTGC	TCATCAATGA	GGAAACAGG	GGTTCTGTG	GTGGAACCAT	TCTGAGCAG	TCTACATCC	TACGGCAGC			
601	CCACTGTCTC	TACCAAGCA	AGAGATTCAA	GGTAGGGTGA	GGGACCGGA	ACACGGAGCA	GGAGGAGGC	GGTAGGCGG	TGCACGAGGT	GGAGGTGGTC			
701	ATCAAGCACA	ACCGGTTTCC	AAAGGAGACC	TATGACTTCG	ACATCGCGT	GCTCCGGCTC	AAGACCCCA	TCACCTTCG	CATGAACGTG	CGCCTGCCT			
801	GCTCCCGA	GCCTGACTGG	GCCGAGTCCA	CCCTGATGAC	GCAGAGACG	GGGATGTGA	CGGGCTTCGG	GCGGCTTCG	GCGACCCAC	GAGAAGGCC	GGCAGTCCAC		
901	CAGGCTCAAG	ATGCTGAGG	TGCCCTACGT	GGACCGCAAC	AGCTGGAAG	TGTCCAGCAG	CTTCATCATC	ACCGAACA	TGTTCTGTGC	GGCTACGAC			
1001	ACCAAGCAGG	AGGATGCGTG	CCAGGGGAC	CGAGGGGAC	CGCACGTCAC	CCGCTTCAAG	GACACCTACT	TCGTGACAGG	CATCGTACG	TGGGAGAGG			
1101	GCTGTGCCC	TAAGGGGAAG	TACGGGATCT	ACACCAAGGT	CACCGCTTC	CTCAAGTGA	TGCACAGGTC	CATGAAGACC	AGGGCTTGC	CCAGGGCCAA			
1201	GAGCCATGCC	CCGGAGGTCA	TAACGTCTCT	TCCATTAAAG	TGAGATCCCA	CTCGGATCCC	TATTTCTATAG	TGTCACCTAA	ATGCTAGAGC	TCGCTGATCA			
1301	GCTCGACTG	TGCTTCTAG	TTGCCAGCCA	TGTGTGTTT	GCCCTCCCTC	CGTGCCTTCC	TGACCCCTGG	AAGGTGCCAC	TCCACTGTC	CTTCTCTAAT			
1401	AAATGAGGA	AATTGCATCG	CATTGTCTGA	GTAGGTGTC	TTCTATTCTG	GGGGTGGGG	TGGGGCAGGA	CAGCAAGGGG	GAGGATTGGG	AAGACAATAG			
1501	CAGGATGCT	GGGATGCGG	TGGCTCTAT	GGCTTCTGAG	CCAGCTGGG	CTCGAGCGC	CGCCCTTCT	GAGCGGAAA	GAACCAAGT				
1601	TGGAATGCT	GTCAGTTAGG	GTGTGGAAG	TCCCAAGGAT	CCCCAGCAG	CAGAAGTATG	CAAGCATGTC	ATCTCAATTA	GTCCAGCAAC	AGGTGTGGA			
1701	AGTCCCCAGG	CTCCCCAGCA	GGCAGAAGTA	TGCAAAAGCAT	GCAATCAAT	TAGTCAGCA	CCATAGTCCC	CGCCCTAAT	CGCCCTAAT	CGCCCTAAT			
1801	TCCGCCCCAGT	TCCGCCCCAT	CTCCGCCCA	TGGCTGACTA	ATTTTTTTTA	TTTATGCGA	GGCCGAGGC	GCCTGGCCT	CTGAGCTATT	CCAGAAGTAG			
1901	TGAGGAGGCT	TTTTTGGAGG	CCTAGGCTTT	TGCAAAAAG	CTAGCTTCCC	GCTGCCATCA	TGGTTCGACC	ATTGAACTGC	ATCGTCGCG	TGTCCTCAAA			
2001	TATGGGAT	GGCAAGAACG	GAGACTACC	CTGGCTCCG	CTCAGGAAC	AGTTCAAGTA	TTTCCAAAG	ATGCCAATA	CCTTCTCAGT	GGAGGTAA			
2101	CAGAACTGG	TGATTATGG	TAGGAAACC	TGGTCTCCA	TTCTGAGAA	GAATCGACCT	TTAAAGGACA	GAATTAATAT	AGTCTCAGT	AGAGAATCA			
2201	AAGAACCACC	ACGAGGAGCT	CATTCTCTTG	CCAAAAGTTT	GGATGATGCC	TTAAGACATA	TGAAACAAC	GGAAATGGCA	AGTAAAGTAG	ACATGGTTG			
2301	GATAGTCGGA	GGCAGTTCTG	TTTACCAGGA	AGCCATGAAT	CAACCAAGGC	ACCTTAGACT	CTTTGTGACA	AGGATCATGC	AGGAATTTGA	AAGTGACACG			
2401	TTTTTCCAG	AAATTGATT	GGGAAATAT	AACTTCTCC	CAGAAATACC	AGGGTCTCTC	TCTGAGGTCC	AGGAGAAA	AGGCATCAAG	TATAAGTTG			
2501	AAGTCTACGA	GAAGAAGAC	TAACAGGAAG	ATGCTTTCAA	GTTCTCTGCT	CCCTCTCTAA	AGCTATGCTAT	TTTTATAAGA	CCATGGGACT	TTTGCTGGCT			
2601	TGATATCCG	CGGAGATCCA	GACATGATA	GATACATTGA	TGAGTTTGA	CAAAACCAAA	CTAGAATGCA	GTGAAAAA	TGCTTTATTT	TGAAATTTG			
2701	TGATGCTATT	GCTTTATTG	TAACCATTAT	AAGCTGCAAT	AAACAGTTA	ACACACAA	TTGCATTCAT	TTTATGTTT	AGGTTCAAGG	GGAGGTGTTG			
2801	GAGGTTTTTT	AAAGCAAGTA	AAACCTCTAC	AAATGTTGTA	TGGCTGATTA	TGAGCTCCAG	CTTTTGTTC	TTTTAGTGAG	GGTTAATTGC	GCGCTGGCG			
2901	TAATCATGGT	CATAGCTGTT	TCCGTGTGTA	AATTGTTCG	TGCGCTCCT	GGCTCGGAA	ACCTGCTGTC	CCAGTGCAT	TAATGAATCG	TGGGTGCTT			
3001	AAAGAGTGAG	CTAACTACA	TTAATGCGT	TGCGCTCCT	GGCTCGGAA	ACCTGCTGTC	CCAGTGCAT	TAATGAATCG	TGGGTGCTT	TGGGTGCTT			
3101	GGGAGAGGCG	GGTTTGCGTA	TTGGGCGCTC	TTCCGCTTCC	TGCGTCACTG	ACTCGCTGCG	CTCGGTCGTT	CGGCTGCGG	GAGCGGTATC	AGCTCACTCA			
3201	TGCTGGCGTAA	TACGGTTATC	CACAGAAATCA	GGGAGTAACG	CAGGATAACG	CATGTGAGCA	AAAGCCACG	AAAGCCACG	GAACCCCTAA	AAGCCCGCT			
3301	TGCTGGCGT	TTTTCCATAGG	CTCCGCCCCC	CTGACGAGT	CGAGCTCA	CGAGGAGTG	ACAGGACTAT	AAAGTACCA					
3401	GGGTTTTTCC	CTTGGAGCT	CCCTCGTGCG	CTCTCTCTGT	CCGACCTGCT	CGGTACCGG	ATACCTTCC	GCTTCTTCC	CTTCGGGAAG	CGTGGCGCTT			
3501	TCTCATAGCT	CACGCTGTAG	GTATCTCAGT	TGCGTGTAGG	TGCTTGCCTC	CAGCTGGGC	TGTTGTGACG	AACCCCTCGT	TCAGCCCGAC	CGTGGCGCTT			
3601	TATCCGGTAA	CTATCGTCTT	GAGTCCAAAC	CGGTAAAGACA	CGACTATATC	CCACTGGCAG	CAGCCACTGG	TAACAGGATT	ACGAGAGCGA	GGTATGTAGG			
3701	CGGTGCTACA	GAGTCTTGA	AGTGTGGCC	TAACCTACGGC	TACACTAGAA	GGACAGTATT	TGGTATCTGC	GCTCTGCTGA	AGCCAGTTAC	CTTCGGAAAA			
3801	AGAGTTGGTA	GCTCTTGATC	CGGCAAAACA	ACCACCGCTG	GTAGCGGTGG	TTTTTTTGT	TGCAAGCAGC	AGATTACGCG	CAGAAAAA	GGATCTCAAG			

Table 21. Oligonucleotide primers used to construct the polynucleotide encoding the r-Antidote triple mutant.

Name	Sequence	SEQ ID NO.
1. FXF1	AGTCTCTAGACACAGTACTCGGCCACACCATGGGG	19
2. FXR1	AGCTGGATCCGAGTGGGATCTCACTTTAATGGAGAGG	20
3. FXF2	GAGGCCAGGAATGCAAGGACGG	21
4. FXR2	CCGTCCTTGCATTCTTGGCCTC	22
5. FXR3	TCATCAGCGTGGACTCGGCCAGT	23
6. GLAF	CCAATTCCTTTCTTTTCTGGAATAAATACAAAGATGGCGA CC	24
7. GLAR	TTCCAGAAAAGAAAGGAATTGGCCCTCGTGACCC	25
8. FXAF	GGAAGAGGAGGAAGAGGATCGTGGGAGGCCAGGAA	26
9. FXAR	CACGATCCTCTTCCTCCTCTTCCTGCGTTCCAGGG	27
10. ALA419 F	AGGGGGACGCAGGGGGCCCGCACGTCACCC	28
11. ALA419 R	GGGTGACGTGCGGGCCCCTGCTTCCCCCT	29

The invention claimed is:

1. A pharmaceutical composition comprising (i) an isolated polypeptide comprising (a) the amino acid sequence of SEQ ID NO. 12, 13, or 15 or (b) an amino acid sequence having at least 95% sequence identity to SEQ ID NO. 12, 13, or 15, wherein the polypeptide has reduced procoagulant activity compared to wild-type factor Xa and does not assemble into a prothrombinase complex and (ii) a blood coagulating agent or a heparin antidote.
2. A pharmaceutical composition comprising (i) an isolated two-chain polypeptide comprising the amino acid sequence of SEQ ID NO. 13 or an amino acid sequence having at least 95% sequence identity to SEQ ID NO. 13, wherein the amino acid sequence having at least 95% sequence identity to SEQ ID NO. 13 has reduced procoagulant activity compared to wild-type factor Xa and does not assemble into a prothrombinase complex, and (ii) a blood coagulating agent that has procoagulant, anti-thrombolytic, or anti-fibrinolytic activity or a heparin antidote.
3. The composition of claim 1 or 2, wherein the blood coagulating agent is selected from the group consisting of a coagulation factor, a recombinant coagulation factor and combinations thereof.
4. The composition of claim 3, wherein the coagulation factor is selected from the group consisting of plasma derived factors VII/VIIa, IX/IXa, X/Xa, II/IIa, VIII/VIIIa, V/Va and combinations thereof.
5. The composition of claim 2, wherein the recombinant coagulation factor is selected from the group consisting of recombinant factors VII/VIIa, IX/IXa, X/Xa, II/IIa, VIII/VIIIa, V/Va and combinations thereof.
6. The composition of claim 1 or 2, wherein the blood coagulating agent is a non-specific anti-bleeding agent.
7. The composition of claim 6, wherein the non-specific anti-bleeding agent is selected from

the group consisting of an adsorbent chemical, a hemostatic agent, thrombin, fibrin glue, desmopressin, cryoprecipitate and fresh frozen plasma, coagulation factor concentrate, activated or non-activated prothrombin complex concentrate, Feiba Vh, platelet concentrates and combinations thereof.

8. The composition of claim 1 or 2, wherein the blood coagulating agent is selected from the group consisting of thrombin-activatable fibrinolysis inhibitor (TAFI), protein C inhibitor (PCI), protein S inhibitor (PSI), alpha-2-antiplasmin, tranexamic acid, aminocaproic acid, aprotinin and combinations thereof.

9. The composition of claim 1 or 2, wherein the heparin antidote is selected from the group consisting of protamine, PMX 60102, PMX 60126, PMX 60138, PMX 60100, PMX 60056, and combinations thereof.

10. The composition of claim 1 or 2 further comprising a pharmaceutically acceptable carrier.

11. A kit of parts comprising a) an isolated polypeptide comprising (i) the amino acid sequence of SEQ ID NO. 12, 13, or 15 or (ii) an amino acid sequence having at least 95% sequence identity to SEQ ID NO. 12, 13, or 15, wherein the polypeptide has reduced procoagulant activity compared to wild-type factor Xa and does not assemble into a prothrombinase complex; and b) a blood coagulating agent or a heparin antidote.

12. A kit of parts comprising a) an isolated two-chain polypeptide comprising the amino acid sequence of SEQ ID NO. 13 or an amino acid sequence having at least 95% sequence identity to SEQ ID NO. 13, wherein the amino acid sequence having at least 95% sequence identity to SEQ ID NO. 13 has reduced procoagulant activity compared to wild-type factor Xa and does not assemble into a prothrombinase complex, and b) a blood coagulating agent that has procoagulant, anti-thrombolytic, or anti-fibrinolytic activity or a heparin antidote.

13. The kit of any of claim 11 or 12, wherein the blood coagulating agent is selected from the group consisting of a coagulation factor, a recombinant coagulation factor and combinations thereof.