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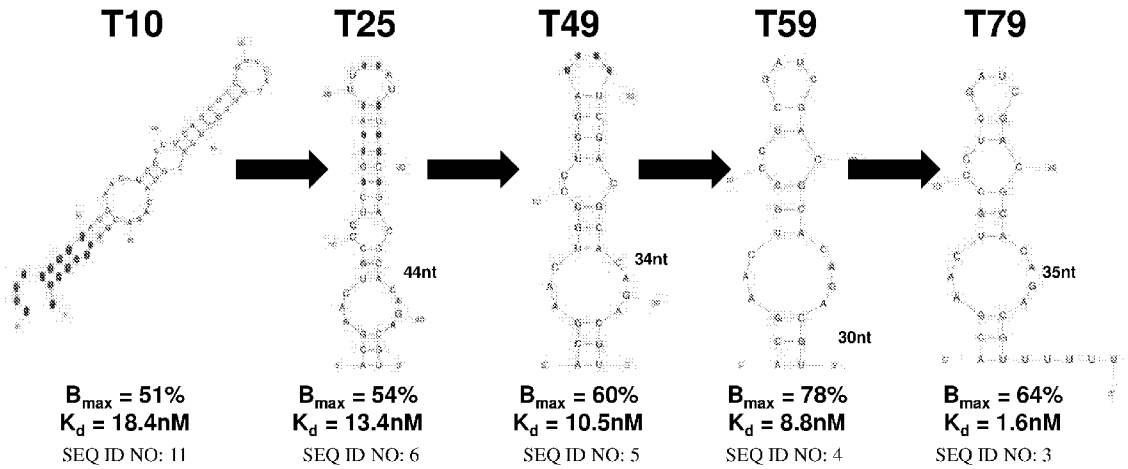
Figure 1



(57) Abstract: Provided herein are aptamers capable of inhibiting the activity of Von Willebrand Factor (VWF). Pharmaceutical compositions comprising these aptamers are also provided. Methods of preventing blood clot formation in a subject by administering the aptamers are provided and methods of treating a blood clot by administering a VWF-targeting agent are also provided.

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[Continued on next page]

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VON WILLEBRAND FACTOR (VWF)-TARGETING AGENTS AND METHODS OF USING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application claims the benefit of priority of United States Provisional Patent Application No. 62/395,642, filed September 16, 2016, which is incorporated herein by reference in its entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This invention was made with government support by the National Institutes of Health under Award Numbers 1U54HL112307 and 5K12NS080223-3,220901. The government has certain rights in the invention.

SEQUENCE LISTING

This application is being filed electronically via EFS-Web and includes an electronically submitted Sequence Listing in .txt format. The .txt file contains a sequence listing entitled "2017-09-18 5667-00413_ST25_Seq_Listing.txt" created on September 18, 2017 and is 35,071 bytes in size. The Sequence Listing contained in this .txt file is part of the specification and is hereby incorporated by reference herein in its entirety.

FIELD OF INVENTION

The invention generally relates to compositions and methods for preventing and treating thrombosis. More specifically, the invention relates to Von Willebrand Factor (VWF)-targeting agents and their use in preventing blood clotting (anti-thrombotic activity) and treating and/or reducing formed blood clots (thrombolytic activity).

INTRODUCTION

Thrombosis is a major underlying problem in many cardiovascular and cerebrovascular diseases and is also a major post-surgical complication. Antithromotic drugs have been developed over the past 25 years with the goal of reducing the complications associated with cerebrovascular and cardiovascular disease. However, while reducing thrombotic events in patients, these drugs create a challenge with regard to hemorrhagic risk due to the lack of rapid and predictable reversibility.

Aptamers are single-stranded nucleic acids that adopt specific secondary and tertiary structures based on their sequence which enables specific binding to their target. Aptamers can

bind to and inhibit protein targets. They are commonly generated by an *in vitro* selection process called SELEX (Systematic Evolution of Ligands by EXponential enrichment). *See, e.g.*, Ellington AD, Szostak JW. 1990. *In vitro* selection of RNA molecules that bind specific ligands, Nature 346:818-22; Tuerk C, Gold L. 1990. Systematic evolution of ligands by exponential enrichment: RNA ligands to bacteriophage T4 DNA polymerase, *Science* 249:505-10. Aptamers can be systematically isolated to virtually any protein and may undergo extensive molecular modifications to optimize their pharmacokinetics for an intended use. Pegaptanib sodium, developed to treat macular degeneration, was the first aptamer approved for use and other compounds are in development. *See, e.g.*, Wang P, Yang Y, Hong H, Zhang Y, Cai W, Fang D. 2011. Aptamers as therapeutics in cardiovascular diseases. *Curr Med Chem* 18:4169-74. Aptamers offer a promising safer class of anti-thrombotics given that aptamer activity may be rapidly reversed using universal or rationally designed antidotes. *See, e.g.*, Rusconi CP, Scardino E, Layzer J, Pitoc GA, Ortel TL, et al. 2002, RNA aptamers as reversible antagonists of coagulation factor IXa, *Nature* 419:90-4; WO/2008/066621 A3; and WO/2008/121354.

Von Willebrand Factor (VWF) is a promising target for aptamer-based anti-thrombotics. VWF is a multimeric plasma glycoprotein that binds to glycoprotein IbIX, resulting in platelet adhesion—the first non-redundant step in platelet aggregation, resulting in a thrombus. The basic subunit is 260 kDa and is produced in endothelium and platelets. VWF is required for normal hemostatic plug formation and is a carrier protein for factor VIII. Aptamers targeting VWF have been shown to inhibit the formation of blood clots. *See, e.g.*, WO/2008/066621 A3.

There is a need in the art, however, for new VWF-targeting aptamers having increased stability against nuclease degradation, smaller sizes to facilitate chemical synthesis, and increased circulation times *in vivo*.

SUMMARY

Provided herein are VWF-targeting aptamer compositions and antidote compositions targeting such aptamer compositions as well as methods for preventing and treating blood clots using VWF-targeting agents.

In one aspect, aptamers are provided. The aptamer may include a polynucleotide having at least 50%, 60%, 70%, 80%, 85%, 90%, 95%, 98%, 99%, or 100% sequence identity to SEQ ID NO: 1 and SEQ ID NO: 2, or any one of SEQ ID NOs: 3-102. See Tables 1 and 2 below.

Alternatively, the aptamer may include a polynucleotide having at least 50%, 60%, 70%, 80%, 85%, 90%, 95%, 98%, 99%, or 100% sequence identity to a polynucleotide comprising from 5' to 3' a first stem forming region comprising or consisting of 2, 3, 4, or 5 nucleotides, a first loop region comprising or consisting of the nucleotide sequence AAC, a second stem forming region comprising or consisting of 3, 4, or 5 nucleotides, a second loop region comprising or consisting of the nucleotide sequence CC, a third stem forming region consisting of 2-8 nucleotides, a third loop region consisting of 1-12 nucleotides and/or a spacer sequence, a fourth stem forming region consisting of 2-8 nucleotides and capable of forming a stem with the third stem forming region, a fourth loop region comprising or consisting of the nucleotide C, a fifth stem forming region comprising or consisting of 3, 4, or 5 nucleotides and capable of forming a stem with the second stem forming region, a fifth loop region comprising or consisting the nucleotide sequence CAGA, and a sixth stem forming region comprising or consisting of 2, 3, 4, or 5 nucleotides and capable of forming a stem with the first stem forming region.

In some embodiments, the aptamers described herein may be no more than 58, 57, 56, 55, 54, 53, 52, 51, 50, 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, or 16 nucleotides in length. In some embodiments the polynucleotide comprises unmodified nucleotides. In other embodiments, the polynucleotide comprises a modified form having at least one nucleotide base modification. The nucleotide base modifications include a 2' O-methyl or 2' fluoro modification of the nucleotide.

In some embodiments, the dissociation binding constant of the aptamer for vWF (Kd) is less than 500nM, less than 100nM, less than 50nM, less than 10nM, less than 5nM, less than 3nM, or less than 2nM.

In another aspect, dimers, trimers, and tetramers including the aptamers described herein are also disclosed.

In another aspect, antidotes to the aptamers described herein are provided. The antidotes may include a polynucleotide having at least 50%, 60%, 70%, 80%, 85%, 90%, 95%, 98%, 99%, or 100% sequence identity to any one of SEQ ID NOs: 103-180 (the nucleotide sequences in Table 3). Alternatively, the antidote may include a polynucleotide having sequence reverse complementary to and capable of hybridizing to at least 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24 or more nucleotides of any one of the aptamers described herein.

In a further aspect, pharmaceutical compositions including any of the aptamers or antidotes described herein are provided. The pharmaceutical compositions may include a pharmaceutical carrier, excipient, or diluent (i.e., agents), which are nontoxic to the cell or mammal being exposed thereto at the dosages and concentrations employed.

In another aspect, methods for preventing blood clot formation in a subject are provided. The methods may include administering to the subject any one of the aptamer compositions described herein in a therapeutically effective amount to prevent blood clot formation in the subject.

In a further aspect, methods for treating a blood clot in a subject are also provided. The methods may include administering to the subject a VWF-targeting agent in a therapeutically effective amount to reduce the blood clot in the subject.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a summary of VWF9.14 truncations T10 (SEQ ID NO: 10), T25 (SEQ ID NO: 6), T49 (SEQ ID NO: 5), T59 (SEQ ID NO: 4), and T79 (SEQ ID NO: 3). In addition to the predicted secondary structures of these aptamers, the length (nt), Kd (nM), and Bmax (%) (as determined by *in vitro* nitrocellulose filter binding assays) of these aptamers are shown at the bottom of these secondary structures. It was found that the aptamer could be truncated from 60 to 30 nucleotides without a reduction in its ability to bind to VWF. NOTE: Nucleotides highlighted in RED signify major deletions created at each subsequent progressive step. Nucleotides highlighted in Yellow signify a base substitution. VWF aptamer 9.14T79 is T59 with five uracil nucleotides at the 3' end.

Figure 2 shows the predicted secondary structures of the VWF9.14T59 (SEQ ID NO: 4) and VWF9.14T79 (SEQ ID NO: 3) aptamers. The T79 aptamer includes the T59 aptamer in addition to a 3' uracil tail to facilitate antidote binding. The dots on the T59 and T79 structures show the location of binding by designed antidotes VWF9.14T59-AO11 (AO11; SEQ ID NO: 113) and VWF9.14T79-AO2 (AO55; SEQ ID NO: 157), respectively.

Figure 3 shows the predicted secondary structure of the optimized VWF aptamer, T79 VRT7 (SEQ ID NO: 7). 2'-O-methyl modified bases are highlighted in red and 2'-fluoro modified bases are highlighted in green; the length (nt), Kd (nM), and Bmax (%) (as determined by *in vitro* nitrocellulose filter binding assays) of these aptamers are shown at the bottom of these secondary structures.

Figure 4 shows a carotid artery blood flow tracing in a murine arterial thrombosis model experiment injecting a vehicle (no aptamer/negative control) prior to $FeCl_3$ injury. Based on measurements from the flow probe, the vessel was occluded in approximately 4 to 5 minutes following removal of the $FeCl_3$ patch.

Figure 5 shows a carotid artery blood flow tracing in two murine arterial thrombosis model experiments injecting the VWF9.14T79-VRT7 aptamer at a dosing of 0.375 mg/kg (top tracing) or 0.0375 mg/kg (bottom tracing) prior to $FeCl_3$ injury. Based on measurements from the flow probe, the vessel remained patent for > 60 minutes following removal of the $FeCl_3$ patch.

Figure 6 shows a carotid artery blood flow tracing in a murine arterial thrombosis model experiment injecting the PEG-VWF9.14T79-VRT7 aptamer at a dosing of 0.375 mg/kg prior to $FeCl_3$ injury. Based on measurements from the flow probe, the vessel remained patent for > 60 minutes following removal of two 7.5% $FeCl_3$ patches.

Figure 7 shows a summary of the percent carotid blood flow in a murine arterial thrombosis model experiment injecting the VWF9.14T79-VRT7 aptamer at various doses (0.009375 mg/kg to 0.375 mg/kg) prior to $FeCl_3$ injury. Negative control is shown for reference. Based on measurements from the flow probe, dosing as low as 0.0375 mg/kg was sufficient to maintain >75% blood flow (compared to blood flow prior to patch placement) for 60 minutes following removal of the $FeCl_3$ patch.

Figure 8 shows a scatter plot of the number of clot disruptions before (PRE) and after (POST) injection of a 10 fold molar ratio of VWF9.14T79-AO2 (AO55; SEQ ID NO: 157) antidote or no antidote (Neg) following injection of either saline or the PEG-VWF9.14T79-VRT7 (SEQ ID NO: 7) aptamer (dose 0.375 mg/kg) in the murine saphenous vein bleeding model.

Figure 9A shows a scatter plot of the clot disruptions before and after injection of a 10 fold molar ratio of VWF9.14T79-AO2 (DTRI-025; SEQ ID NO: 157) antidote or no antidote (Saline) following injection of either saline (Control) or the VWF9.14T79-VRT7 aptamer (dose 0.375 mg/kg; SEQ ID NO: 7) in the murine saphenous vein bleeding model.

Figure 9B shows a bar graph of the clot disruptions before and after injection of a 10 fold molar ratio of VWF9.14T79-AO2 (DTRI-025; SEQ ID NO: 157) antidote or no antidote (Saline)

following injection of either saline (Control) or the VWF9.14T79-VRT7 aptamer (dose 0.375 mg/kg; SEQ ID NO: 7) in the murine saphenous vein bleeding model.

Figure 10 shows an example of a carotid artery blood flow tracing and timeline from a single study of the combined arterial thrombosis and saphenous vein bleeding model. The left side of the figure captures the first half of the study evaluating carotid artery vessel patency after thrombosis challenge. The right side captures vessel transection, bleeding, and clot formation before and after antidote administration.

Figure 11 shows the number of disruptions before (PRE) and after (POST) injection of the VWF9.14T9-AO2 (AO55; SEQ ID NO: 157) antidote post-thrombosis saphenous vein bleeding following injection of the PEG-VWF9.14T79-VRT7 aptamer (SEQ ID NO: 7), the Cholesterol-VWF9.14T79-VRT7 aptamer, or the Elastin-like polypeptide (ELP)-VWF9.14T79-VRT7 aptamer in the combined murine arterial thrombosis and saphenous vein bleeding model.

Figure 12 shows platelet function assay (PFA) results for VWF9.14T59 (SEQ ID NO: 4) with and without antidotes VWF9.14T59-AO3,-AO10, and –AO11 (AO3 (SEQ ID NO: 105), AO10 (SEQ ID NO: 112), and AO11 (SEQ ID NO: 113, respectively). Also shown are PFA results for aptamer VWF9.14T79 (SEQ ID NO: 3) with and without antidotes VWF9.14T79-AO1 (AO43; SEQ ID NO: 145) and VWF9.14T79–AO2 (AO55; SEQ ID NO: 157). Results are shown for aptamer VWF9.14T82 (SEQ ID NO: 78) with and without antidotes VWF9.14T82-AO1 (AO46; SEQ ID NO: 148) and VWF9.14T82-AO2 (AO58; SEQ ID NO: 160). Results are shown for aptamer VWF9.14T84 (SEQ ID NO: 80) with and without antidotes VWF9.14T84-AO1 (AO48; SEQ ID NO: 150) and VWF9.14T84-AO2 (AO60; SEQ ID NO: 162)).

Figure 13 shows PFA results for VWF9.14T86 (SEQ ID NO: 82), VWF9.14T87 (SEQ ID NO: 83), VWF9.14T89 (SEQ ID NO: 85), VWF9.14T90 (SEQ ID NO: 86), VWF9.14T93(SEQ ID NO: 89), VWF9.14T94 (SEQ ID NO: 90), and VWF9.14T95 (SEQ ID NO: 91) with and without antidotes (AO61 (SEQ ID NO: 163), AO62 (SEQ ID NO: 164), AO63 (SEQ ID NO: 165), AO64 (SEQ ID NO: 166), AO65 (SEQ ID NO: 167), AO66 (SEQ ID NO: 168), and AO67 (SEQ ID NO: 169), respectively.

Figure 14 shows the predicted secondary structure and PFA data for VWF9.14T79vrt7 (DTRI-031; SEQID NO: 7) without or with varying molar ratios of the antidote DTRI-038 (SEQ ID NO: 180).

Figure 15 shows the predicted secondary structures of the T79 vrt7/DTRI-031 (SEQ ID NO: 7) and T59 vrt19 (SEQ ID NO: 4 and Table 2) aptamers and the sequences of the DTRI-006 – DTRI-013 aptamers (see Table 2 and SEQ ID NOs: 4, 98, 99, 100, and 101, respectively). DTRI-008 (SEQ ID NO: 4) showed no impact and was comparable to DTRI-006 (SEQ ID NO: 4). DTRI-009 (SEQ ID NO: 98) showed a K_D comparable to DTRI-006 but lower Bmax. DTRI-013 (SEQ ID NO: 101) showed a K_D comparable to DTRI-006 but lower Bmax.

Figure 16 shows predicted secondary structure and nitrocellulose filter binding assay data for the DTRI-019 (SEQ ID NO: 8) aptamer.

Figure 17 shows nitrocellulose filter binding assay data for T79VRT7/DTRI-031 (SEQ ID NO: 7) aptamer.

Figure 18 shows a graph indicating the percentage of initial carotid flow at various time points after occlusion in mice treated with control, rTPA (recombinant tissue plasminogen activator), anti-VWF aptamer (both VWF9.14T79VRT7 and Cholesterol-VWF9.14T79-VRT7), or no perfusion. As indicated in the graph, the anti-VWF aptamer (VWF9.14T79VRT7; SEQ ID NO: 7) had superior thrombolytic activity compared to rTPA.

Figure 19 shows a graph indicating stroke volume following vascular injury in the murine intracranial hemorrhage model in mice treated with vehicle, rTPA, anti-VWF aptamer (VWF9.14T79-VRT7; SEQ ID NO: 7), or anti-VWF aptamer (VWF9.14T79-VRT7) and VWF antidote (VWF9.14T79-T79-AO2, also called AO55; SEQ ID NO: 157).

Figure 20 shows aptamer 9.14T79vrt7 (SEQ ID NO: 7) inhibits platelet adhesion under high shear, inhibits platelet aggregation in whole blood and prevents thrombosis *in vivo*. The aptamer prevented human platelet adhesion in a dose-dependent manner. Figure 20A. Buffer control demonstrated 100% platelet adhesion. Aptamer activity was measured as a percentage of the control. Figure 20B. 56nmol/L demonstrated approximately 50% platelet adhesion in this assay while Figure 20C. 900 nmol/L demonstrated complete inhibition (n=3 per group). Figure 20D. Aptamer inhibited platelet adhesion in a dose-dependent manner with significant inhibition at doses between 56 – 900 nmol/L ($p<0.05$) (n=3 per group). Figure 20E. A linear regression analysis of the dose response curve determined the $\log IC_{50}$ of the aptamer was 1.86 (72.5 nmol/L).

Figure 21 is a graph showing PFA-100 results demonstrating that T79vrt7 (SEQ ID NO: 7) completely inhibits platelet aggregation. Doses between 100 – 400 nmol/L exceeded the

upper limit of the assay and 25 nM demonstrated significant platelet aggregation compared to control (n=4 per group) ($p<0.01$).

Figure 22 is a graph showing murine carotid artery thrombosis, dose range 0.009375 mg/kg – 3 mg/kg., 9.14T79vrt7 (SEQ ID NO: 7)-treated mice demonstrated that at dose as low as 0.0185 mg/kg, there was patency of the carotid artery compared to negative control (n=3 per group). Doses over 0.0375mg/kg not shown for clarity, but all demonstrate vessel patency.

Figure 23 shows aptamer 9.14T79vrt7/DTRI-031 (SEQ ID NO: 7) demonstrates superior thrombolysis in murine carotid artery occlusion compared to rTPA. Figure 23A. Aptamer-treated animals at a dose of 0.5 mg/kg (n=8) demonstrated superior thrombolysis compared to both rTPA-treated animals at a dose of 10 mg/kg (n=8) ($p<0.05$) and saline control (n=8) ($p<0.01$). Histopathology of mouse carotid arteries demonstrated that Figure 23B. aptamer-treated animals had patent vessels free of occlusive thrombus compared to Figure 23C rTPA animals and Figure 23D saline control (n=8 per group).

Figure 24 shows aptamer 9.14T79vrt7/DTRI-031 (SEQ ID NO: 7) prevents platelet adhesion and aggregation in Total Thrombus-formation Analysis System in canine whole blood, recanalizes carotid artery occlusion in canines and demonstrates no brain hemorrhage or embolization. Figure 24A. Canine whole blood incubated with 9.14T79vrt7 at doses of 12.5 nmol/L, 18.75 nmol/L, 25 nmol/L and 100 nmol/L compared to negative saline control (n=5 per group) ($p<0.05$). Figure 24B. Still images of whole blood flowing over collagen tubules from the first 10 seconds of each minute. The cloudy patches seen in the control group are aggregated platelets. 9.14T79vrt7 dose was 100nmol/L. (Figure 24C-G) After 45 minutes of occlusion, 9.14T79vrt7 administration resulted in recanalization in each of the 3 dogs tested (Figure 24C – E) compared to Figure 24F. rTPA or Figure 24G. Saline control (n=3 per group). Figure 24H. 9.14T79vrt7 did not cause intracranial hemorrhage nor cerebral thromboembolism compared to Figure 24I. rTPA or Figure 24J. control (n=3 per group). Carotid artery histology verified recanalization of the occluded segment in Figure 24K. 9.14T79vrt7-treated dog compared to Figure 24L. rTPA and Figure 24M. control (n=3 per group).

Figure 25 shows an antidote oligonucleotide reverses 9.14T79vrt7/DTRI-031 (SEQ ID NO: 7) *ex vivo* and in a murine femoral vein bleeding model. The graph is represented as a % of normal hemostasis in a mouse without any treatment. The untreated control group (not shown) was similar to the saline-treated group of (n=7 per group). 9.14T79 administered at 0.375 mg/kg

demonstrated no clot disruptions (n=11) compared to the control and control and saline-treated groups ($p<0.0001$). Adding antidote 5 minutes after aptamer administration and measuring clot disruption 2 minutes later revealed complete reversal of bleeding similar to animals that never received the aptamer (n=7). AO administered alone did not result in increased thrombosis compared to negative control (data not shown) (*=statistical significance).

DETAILED DESCRIPTION

The present disclosure is based, in part, on the inventors' discovery of new optimized reversible VWF-targeting aptamers useful for both preventing (anti-thrombotic activity) and treating (thrombolytic activity) blood clots. Compared to previous VWF-targeting aptamers, the presently disclosed VWF-targeting aptamers have increased stability against nuclease degradation, are smaller in size to facilitate chemical synthesis, and demonstrate increased circulation times *in vivo*.

Disclosed herein are compositions of aptamers and antidotes as well as methods for preventing and treating blood clots in a subject using VWF-targeting agents such as the newly discovered VWF-targeting aptamers. These compositions and methods may be useful in several applications including, without limitation, prevention or treatment of thrombi (*in vitro*, *in vivo*, or *ex vivo*), or the prevention or treatment of thrombi associated with stroke, cerebrovascular thrombi, deep vein thrombosis (DVT), pulmonary embolism (PE), atrial fibrillation, coronary artery thrombus, intra-cardiac thrombi, post-surgical thrombi, cancer-induced thrombosis, cancer-related thrombin expression, infection, and disseminated intravascular coagulation (DIC).

Aptamers are provided herein. As used herein, the term "aptamer" refers to single-stranded oligonucleotides that bind specifically to targets molecules with high affinity. Aptamers can be generated against target molecules, such as VWF, by screening combinatorial oligonucleotide libraries for high affinity binding to the target (*See, e.g.*, Ellington and Szostak, Nature 1990; 346: 8 18-22 (1990), Tuerk and Gold, Science 249:505-1 0 (1990)). The aptamers disclosed herein may be synthesized using methods well-known in the art. For example, the disclosed aptamers may be synthesized using standard oligonucleotide synthesis technology employed by various commercial vendors including Integrated DNA Technologies, Inc. (IDT), Sigma-Aldrich, Life Technologies, or Bio-Synthesis, Inc.

The aptamer may include a polynucleotide having at least 50%, 60%, 70%, 80%, 85%, 90%, 95%, 98%, 99%, or 100% sequence identity to SEQ ID NO: 1 and SEQ ID NO: 2, or any

one of SEQ ID NOS: 3-102. The aptamer may include a polynucleotide having at least 70%, 75%, 80%, 85%, 90%, 95%, 98%, 99%, or 100% sequence identity to any one of SEQ ID NOs: 3-6 (nucleotide sequences T25, T49, T59, or T79 in Table 1). In some embodiments, the aptamer includes SEQ ID NO: 7 (T79vrt7 in Table 2), SEQ ID NO: 8 (nucleotide sequence DTRI-019 in Table 2), or SEQ ID NO: 9 (nucleotide sequence DTRI-021 in Table 2).

The terms "polynucleotide," "nucleotide sequence," "polynucleotide sequence," "nucleic acid" and "nucleic acid sequence" refer to a nucleotide, oligonucleotide, polynucleotide (which terms may be used interchangeably), or any fragment thereof. These phrases may refer to DNA or RNA of genomic, natural, or synthetic origin.

Regarding nucleotide sequences, the terms "sequence identity," "percent identity," and "% identity" refer to the percentage of base matches between at least two nucleotide sequences aligned using a standardized algorithm. Such an algorithm may insert, in a standardized and reproducible way, gaps in the sequences being compared in order to optimize alignment between two sequences, and therefore achieve a more meaningful comparison of the two sequences. Sequence identity for a nucleotide sequence may be determined as understood in the art. (*See, e.g.*, U.S. Patent No. 7,396,664). A suite of commonly used and freely available sequence comparison algorithms is provided by the National Center for Biotechnology Information (NCBI) Basic Local Alignment Search Tool (BLAST), which is available from several sources, including the NCBI, Bethesda, Md., at its website. The BLAST software suite includes various sequence analysis programs including "blastn," that is used to align a known nucleotide sequence with other polynucleotide sequences from a variety of databases. Also available is a tool called "BLAST 2 Sequences" that is used for direct pairwise comparison of two nucleotide sequences. "BLAST 2 Sequences" can be accessed and used interactively at the NCBI website.

Regarding nucleotide sequences, sequence identity is measured over the length of an entire defined nucleotide sequence, for example, as defined by a particular sequence identified herein. Furthermore, sequence identity, as measured herein, is based on the identity of the nucleotide base in the nucleotide sequence, irrespective of any further modifications to the nucleotide sequence. For example, the nucleotide sequences in the tables described herein may include modifications to the nucleotide sequences such 2'flouro, 2'O-methyl, and inverted deoxythymidine (idT) modifications. These modifications are not considered in determining sequence identity. Thus if a base, for example, is a 2'fluoro adenine (or 2'O-methyl, etc.), it is

understood to be an adenine for purposes of determining sequence identity with another sequence. Likewise, the 3' idT modifications to the nucleotide sequences in the tables described herein also are not considered in determining sequence identity.

Alternatively, the aptamer may include a polynucleotide having at least 50%, 60%, 70%, 80%, 85%, 90%, 95%, 98%, 99%, or 100% sequence identity to a polynucleotide comprising from 5' to 3' a first stem forming region comprising or consisting of 2, 3, 4, or 5 nucleotides, a first loop region comprising or consisting of the nucleotide sequence AAC, a second stem forming region comprising or consisting of 3, 4, or 5 nucleotides, a second loop region comprising or consisting of the nucleotide sequence CC, a third stem forming region consisting of 2-8 nucleotides, a third loop region consisting of 1-12 nucleotides or a spacer sequence, a fourth stem forming region consisting of 2-8 nucleotides and capable of forming a stem with the third stem forming region, a fourth loop region comprising or consisting of the nucleotide C, a fifth stem forming region comprising or consisting of 3, 4, or 5 nucleotides and capable of forming a stem with the second stem forming region, a fifth loop region comprising or consisting the nucleotide sequence CAGA, and a sixth stem forming region comprising or consisting of 2, 3, 4, or 5 nucleotides and capable of forming a stem with the first stem forming region. Nonlimiting examples of such aptamers are shown as T25, T49, T59, T59 vrt19, T79, T79 vrt7, or DTRI-019 in Figures 1-3 and 15-16.

As used herein, a "spacer sequence" may be any chemical spacer that does not interfere with the binding activity of the aptamer. For example, the spacer sequence may include, without limitation, a hexaethylene glycol spacer (see, e.g., DTRI-009), a C3 spacer, spacer 9, or any other suitable stable linker known to those skilled in the art which would facilitate and maintain the proper folding and secondary structure of the aptamer.

Based on the general aptamer structure presented, for example, in Figures 1-3 and 15-16, a person of ordinary skill in the art would readily recognize that several modifications could be made to the sequence while preserving the overall structure and presumably the function of the aptamer. For example, a person of ordinary skill in the art could simply switch the first stem forming region ACG and the sixth stem forming region CGU to UGC and GCA or CCG and CGG (DTRI-013; SEQ ID NO: 101), respectively, and still retain the stem structure of the aptamer. Additionally, modifications to the stem regions could be made that change the bases within the stem region but conserve the overall pyrimidine and purine base composition so that

the stem region hybridizes at a similar melting temperature. A person of ordinary skill would also recognize that changes made to the aptamer that disturbed the general aptamer stem loop structure would likely result in an aptamer incapable of efficiently binding its target.

In some embodiments, the aptamer may include a polynucleotide having at least 50%, 60%, 70%, 80%, 85%, 90%, 95%, 99%, or 100% sequence identity to a polynucleotide comprising from 5' to 3' SEQ ID NO: 1 (CGAAC(U/T)GCCC(U/T)C), a variable nucleotide sequence consisting of 1-18 (or any range therein) nucleotides or a spacer sequence, and SEQ ID NO: 2 (GACGCACAGACG).

As used herein, a "variable nucleotide sequence" may be any of the possible nucleotide sequences for a given length. For example, a "variable nucleotide sequence" consisting of 5 nucleotides may include any of the 4^5 (or 1,025) possible nucleotide sequences having 5 nucleotides.

In some embodiments, the aptamer may be no more than 58, 57, 56, 55, 54, 53, 52, 51, 50, 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, or 16 nucleotides in length.

In some embodiments, the aptamer may have a dissociation constant (K_D) for the human VWF protein that is less than 150, 125, 100, 90, 80, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10, 5, 2.5, 2, 1, 0.5, or 0.1 nanomolar (nM). The K_D of an aptamer may be measured using the methodology used by the inventors in the Examples. For example, binding studies using the double-filter nitrocellulose-filter binding assay with the human VWF protein may be performed.

The aptamers may include a polynucleotide (RNA, DNA, or peptide nucleic acid (PNA)) that is in an unmodified form or may be in a modified form including at least one nucleotide base modification. Nucleotide base modifications of polynucleotides to, for example, protect the polynucleotide from nuclease degradation and/or increase the stability of the polynucleotide are well-known in the art. Common nucleotide base modifications that may be used in accordance with the present invention include, without limitation, deoxyribonucleotides, 2'-O-Methyl bases, 2'-Fluoro bases, 2' Amino bases, inverted deoxythymidine bases, 5' modifications, and 3' modifications.

In some embodiments, the aptamer may include a polynucleotide including a modified form including at least one nucleotide base modification selected from the group consisting of a 2'fluoro modification, a 2'O-methyl modification, a 5' modification, and a 3'modification.

Typical 5' modifications may include, without limitation, inverted deoxythymidine bases, addition of a linker sequence such as C6, addition of a cholesterol, addition of a reactive linker sequence which could be conjugated to another moiety such as a PEG. Typical 3' modifications may include, without limitation, inverted deoxythymidine bases, and inverted abasic residues.

In some embodiments, the aptamer may further include a tail nucleotide sequence at the 5' end or the 3' end of the polynucleotide which is not capable of base pairing with 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 or more consecutive nucleotides in the polynucleotide. The tail nucleotide sequence may consist of 2-20 nucleotides or any range therein. As an exemplary tail nucleotide sequence, the present inventors added a 5-nucleotide Uracil (oligo-U tail) to the 3'-end of an aptamer as a potential artificial nucleation site for antidote binding. Thus, in some embodiments, the tail nucleotide sequence may include the nucleotide sequence (U/T)(U/T)(U/T)(U/T)(U/T). However, it is also contemplated that other nucleotide sequences could serve as tail nucleotide sequences so as that they were not capable of base pairing with 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 or more consecutive nucleotides in the polynucleotide of the aptamer. Additionally, tail nucleotide sequences were also added successfully to the 5' end of the aptamer without significantly affecting the activity of the aptamer.

As additional 5' and/or 3' modifications, the aptamer may include a polynucleotide including a 5' linker and/or a 3' linker. Common 5' and/or 3' linkers for polynucleotides are known in the art and may include peptides, amino acids, nucleic acids, as well as homofunctional linkers or heterofunctional linkers. Particularly useful conjugation reagents that can facilitate formation of a covalent bond with an aptamer may comprise a N-hydroxysuccinimide (NHS) ester and/or a maleimide or using click chemistry. Typical 5' and/or 3' linkers for polynucleotides may include without limitation, amino C3, C4, C5, C6, or C12-linkers.

The aptamer may further include a stability agent. As used herein, a "stability agent" refers to any substance(s) that may increase the stability and/or increase the circulation time of a polynucleotide *in vivo*. Typical stability agents are known in the art and may include, without limitation, polyethylene glycol (PEG), cholesterol, albumin, or Elastin-like polypeptide.

The aptamer and stability agent may be "linked" either covalently or non-covalently. Additionally, the aptamer and stability agent may be linked using the 5' and/or 3' linkers described herein. The aptamer and stability agent may be linked at the 5' end and/or the 3' end of the aptamer. To link the aptamer and stability agent non-covalently, the aptamer and the

stability agent may be linked by a tag system. A "tag system" may include any group of agents capable of binding one another with a high affinity. Several tag systems are well-known in the art and include, without limitation, biotin/avidin, biotin/streptavidin, biotin/NeutrAvidin, or digoxigenin (DIG) systems. In some embodiments, the tag system comprises biotin/avidin or biotin/streptavidin. In such embodiments, the aptamer may be modified at either the 5' or 3' end to include biotin while the stability agent may be modified to include streptavidin or avidin. Alternatively, the aptamer may be modified at either the 5' or 3' end to include streptavidin or avidin while the stability agent may be modified to include biotin.

Dimers, trimers, and tetramers including any one of the aptamers described herein are also provided. A "dimer" refers to the linking together of two aptamer molecules in order to, for example, to increase the stability and/or increase the circulation time of a polynucleotide *in vivo*. A "trimer" refers to the linking together of three aptamer molecules in order to, for example, to increase the stability and/or increase the circulation time of a polynucleotide *in vivo*. A "tetramer" refers to the linking together of four aptamer molecules in order to, for example, to increase the stability and/or increase the circulation time of a polynucleotide *in vivo*. The aptamer molecules may be linked together covalently, noncovalently, or a combination of both. The aptamer molecules may be linked at their 5' or 3' ends. To link the aptamers noncovalently, the aptamers may be linked by a tag system or through a scaffold system.

Antidotes are also provided herein and include a polynucleotide having at least 50%, 60%, 70%, 80%, 85%, 90%, 95%, 98%, 99%, or 100% sequence identity to any one of SEQ ID NOS: 103-180 (the nucleotide sequences in Table 3). Alternatively, the antidote may include a polynucleotide having sequence reverse complementary to and capable of hybridizing to at least 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24 or more nucleotides of any one of the aptamers described herein.

Pharmaceutical compositions including any of the aptamers or antidotes described herein are provided. The pharmaceutical compositions may include a pharmaceutical carrier, excipient, or diluent (i.e., agents), which are nontoxic to the cell or mammal being exposed thereto at the dosages and concentrations employed. Often a pharmaceutical agent is in an aqueous pH buffered solution. Examples of pharmaceutical carriers include buffers such as phosphate, citrate, and other organic acids; antioxidants including ascorbic acid; low molecular weight (less than about 10 residues) polypeptides; proteins, such as serum albumin, gelatin, or

immunoglobulins; hydrophilic polymers such as polyvinylpyrrolidone; amino acids such as glycine, glutamine, asparagine, arginine or lysine; monosaccharides, disaccharides, and other carbohydrates including glucose, mannose, or dextrins; chelating agents such as EDTA; sugar alcohols such as mannitol or sorbitol; salt-forming counterions such as sodium; and/or nonionic surfactants such as TWEEN™ brand surfactant, polyethylene glycol (PEG), and PLURONICS™ surfactant. In some embodiments, the pharmaceutical carrier may include a buffer including about 20 mM Hepes, pH 7.4; 150 mM NaCl; 1 mM $CaCl_2$; 1mM $MgCl_2$; 5 mM KCl.

Methods for preventing blood clot formation in a subject are provided. The methods may include administering to the subject any one of the aptamer compositions described herein in a therapeutically effective amount to prevent blood clot formation in the subject. "Preventing blood clot formation" may include reducing the likelihood of blood clots, reducing the size of blood clots or slowing further progression of blood clotting.

As used herein, the term "subject" refers to both human and non-human animals. The term "non-human animals" of the disclosure includes all vertebrates, *e.g.*, mammals and non-mammals, such as non-human primates, sheep, dog, cat, horse, cow, mice, chickens, amphibians, reptiles, and the like. In some embodiments, the subject is a human patient.

The subject in need of blood clot prevention may need prevention of blood clots associated with, for example without limitation, stroke, cerebrovascular thrombi, deep vein thrombosis (DVT), pulmonary embolism (PE), atrial fibrillation, coronary artery thrombus, intra-cardiac thrombi, post-surgical thrombi, cancer-induced thrombosis, cancer-related thrombin expression, infection, disseminated intravascular coagulation (DIC), and arterial thrombosis including cerebral arteries, coronary arteries and peripheral arteries in the head and neck, visceral arteries, arms and legs arteries. In some embodiments, the subject in need of blood clot prevention may suffer from atrial fibrillation, or be at risk of having a Deep Vein Thrombosis, a stroke, a heart attack, or a pulmonary embolism.

A therapeutically effective amount or an effective amount as used herein means the amount of a composition that, when administered to a subject for preventing or treating a blood clot is sufficient to effect a treatment (as defined above). The therapeutically effective amount will vary depending on the formulation or composition, the disease and its severity and the age, weight, physical condition and responsiveness of the subject to be treated.

In addition to disclosing methods of preventing blood clots in a subject, the inventors demonstrate that VWF-targeting agents may be used thrombolytically to reduce or "bust" blood clots that have already formed. In the Examples, the inventors demonstrate that one of the disclosed VWF-targeting aptamers, T79vrt7/DTRI-031, was superior to recombinant tissue plasminogen activator (rTPA) in a murine carotid artery occlusion model. These results surprisingly demonstrate that VWF-targeting agents may also be used to treat formed blood clots (thrombolytic activity) as well as being used to prevent blood clot formation (anti-thrombotic activity).

Based on this new use of VWF-targeting agents, methods for treating a blood clot in a subject are also provided. The methods may include administering to the subject a VWF-targeting agent in a therapeutically effective amount to reduce the blood clot in the subject. "Treating a blood clot" or "reducing a blood clot" refers to reducing the size and/or shape of the blood clot so as to allow blood flow to increase at the clot site.

The subject in need of blood clot treatment may need treatment of blood clots associated with, for example without limitation, stroke, cerebrovascular thrombi, deep vein thrombosis (DVT), pulmonary embolism (PE), atrial fibrillation, coronary artery thrombus, intra-cardiac thrombi, post-surgical thrombi, cancer-induced thrombosis, cancer-related thrombin expression, infection, disseminated intravascular coagulation (DIC), and arterial thrombosis including cerebral arteries, coronary arteries and peripheral arteries in the head and neck, visceral arteries, arms and legs arteries.. In some embodiments, the subject in need of blood clot treatment suffers from a Deep Vein Thrombosis, a stroke, a heart attack, or a pulmonary embolism.

As used herein, a "VWF-targeting agent" is any agent capable of partially or fully blocking, inhibiting, or neutralizing one or more of the biological activities of a von Willebrand Factor (VWF) protein including, without limitation, a polypeptide, a polynucleotide, or a small molecule. In some embodiments, a VWF-targeting agent may include an agent capable of binding to the A1 domain of a VWF protein and blocking the VWF protein's binding with a gp1b alpha protein. A VWF-targeting agent may function in a direct or indirect manner. For example, the VWF-targeting agent may directly bind to a VWF protein, thus partially or fully blocking, inhibiting or neutralizing one or more biological activities of the VWF protein, *in vitro* or *in vivo*. The VWF-targeting agent may also function indirectly by (1) interacting with (e.g., activating, inducing, blocking or inhibiting) another molecule that can bind to VWF or (2)

modulating or affecting the expression (i.e, transcription or translation) of a VWF protein in a cell.

VWF proteins may be any of the VWF proteins found in any mammal including, without limitation, humans or domesticated animals such as dogs, cats, horses, cows, pigs, mice, or rats.

The VWF-targeting agent may be a polypeptide including, without limitation, a peptide or an antibody. As used herein, the term "antibody" is used in the broadest sense used in the art to refer to polypeptide affinity agents based on antibodies. For example, the antibody may include a polyclonal antibody, a monoclonal antibody, a single chain antibody, or antibody fragments such as Fab, Fab', $F(ab')_2$, Fv fragments, diabodies, linear antibodies, nanobodies, or multispecific antibodies formed from antibody fragments. The antibody may be chimeric, humanized, or fully human. The antibody may be any one of the five known major classes of immunoglobulins including IgA, IgD, IgE, IgG, and IgM. In some embodiments, the VWF-targeting agent may be an anti-VWF antibody that is capable of binding a VWF protein and thereby partially or fully blocking, inhibiting, or neutralizing one or more of the biological activities of the VWF protein. Suitable anti-VWF antibodies include, without limitation, caplacizumab, ALX-0681, or ALX-0081.

Peptides useful as VWF-targeting agents may be identified using techniques well-known in the art such as phage display.

In some embodiments, the VWF-targeting agent may be an aptamer that is capable of binding a VWF protein and thereby partially or fully blocking, inhibiting, or neutralizing one or more of the biological activities of the VWF protein. Suitable VWF aptamers include, without limitation those described in WO/2008/066621 A3 to Sullenger et al. and the aptamers described herein.

The VWF-targeting agent may also be a small molecule. The small molecule may be chemical molecule having a molecular weight below about 2500 Daltons, 2000 Daltons, 1000 Daltons, or 500 Daltons.

The methods of preventing or treating blood clots described herein may further include administering to the subject an antidote in a therapeutically effective amount to neutralize the aptamer or the VWF-targeting agent. "Neutralizing" the aptamer or VWF-targeting agent refers to decreasing either the anti-thrombotic or thrombolytic activity of the aptamer or VWF-targeting agent.

Antidotes that may be used in accordance with the present methods may include sequence-specific antidotes such as the antidotes described herein and those described in WO/2008/066621 A3. The antidotes may also include sequence non-specific antidotes (i.e., cationic polymers) described in, for example, WO/2008/121354.

The compositions (i.e. aptamers, antidotes, and pharmaceutical compositions) described herein may be administered by any means known to those skilled in the art, including, but not limited to, oral, topical, intranasal, intraperitoneal, parenteral, intravenous, intramuscular, subcutaneous, intrathecal, transcutaneous, nasopharyngeal, intra-lesional, intra-tumoral, intradermal, or transmucosal absorption. Thus the compositions may be formulated as an ingestable, injectable, topical or suppository formulation. Administration of the compositions to a subject may exhibit beneficial effects in a dose-dependent manner. Thus, within broad limits, administration of larger quantities of the compositions is expected to achieve increased beneficial biological effects than administration of smaller amount. Moreover, efficacy is also contemplated at dosages below the level at which toxicity is seen.

It will be appreciated that the specific dosage administered in any given case will be adjusted in accordance with the composition(s) being administered, the disease to be treated or inhibited, the condition of the subject, and other relevant medical factors that may modify the activity of the compositions or the response of the subject, as is well known by those skilled in the art. For example, the specific dose for a particular subject depends on age, body weight, general state of health, diet, the timing and mode of administration, the rate of excretion, medicaments used in combination and the severity of the particular disorder to which the therapy is applied. Dosages for a given patient can be determined using conventional considerations, e.g., by customary comparison of the differential activities of the compositions described herein and of a known agent, such as by means of an appropriate conventional pharmacological protocol.

The maximal dosage for a subject is the highest dosage that does not cause undesirable or intolerable side effects. The number of variables in regard to an individual treatment regimen is large, and a considerable range of doses is expected. The route of administration will also impact the dosage requirements. It is anticipated that dosages of the compositions will prevent or treat blot clots by at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100% or more as compared to no treatment.

The compositions described herein may be administered one time or more than one time to the subject to effectively prevent or treat blood clots. Suitable dosage ranges are of the order of several hundred micrograms effective ingredient with a range from about 0.01 to 10 mg/kg/day, preferably in the range from about 0.1 to 1 mg/kg/day. Precise amounts of effective ingredient required to be administered depend on the judgment of the practitioner and may be peculiar to each subject. It will be apparent to those of skill in the art that the therapeutically effective amount of the compositions described herein will depend, inter alia, upon the administration schedule, the unit dose of drug administered, whether the composition is administered in combination with other therapeutic agents, the status and health of the recipient, and the therapeutic activity of the particular composition.

The present disclosure is not limited to the specific details of construction, arrangement of components, or method steps set forth herein. The compositions and methods disclosed herein are capable of being made, practiced, used, carried out and/or formed in various ways that will be apparent to one of skill in the art in light of the disclosure that follows. The phraseology and terminology used herein is for the purpose of description only and should not be regarded as limiting to the scope of the claims. Ordinal indicators, such as first, second, and third, as used in the description and the claims to refer to various structures or method steps, are not meant to be construed to indicate any specific structures or steps, or any particular order or configuration to such structures or steps. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to facilitate the disclosure and does not imply any limitation on the scope of the disclosure unless otherwise claimed. No language in the specification, and no structures shown in the drawings, should be construed as indicating that any non-claimed element is essential to the practice of the disclosed subject matter. The use herein of the terms "including," "comprising," or "having," and variations thereof, is meant to encompass the elements listed thereafter and equivalents thereof, as well as additional elements. Embodiments recited as "including," "comprising," or "having" certain elements are also contemplated as "consisting essentially of" and "consisting of" those certain elements.

Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise

indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. For example, if a concentration range is stated as 1% to 50%, it is intended that values such as 2% to 40%, 10% to 30%, or 1% to 3%, etc., are expressly enumerated in this specification. These are only examples of what is specifically intended, and all possible combinations of numerical values between and including the lowest value and the highest value enumerated are to be considered to be expressly stated in this disclosure. Use of the word "about" to describe a particular recited amount or range of amounts is meant to indicate that values very near to the recited amount are included in that amount, such as values that could or naturally would be accounted for due to manufacturing tolerances, instrument and human error in forming measurements, and the like. All percentages referring to amounts are by weight unless indicated otherwise.

No admission is made that any reference, including any non-patent or patent document cited in this specification, constitutes prior art. In particular, it will be understood that, unless otherwise stated, reference to any document herein does not constitute an admission that any of these documents forms part of the common general knowledge in the art in the United States or in any other country. Any discussion of the references states what their authors assert, and the applicant reserves the right to challenge the accuracy and pertinence of any of the documents cited herein. All references cited herein are fully incorporated by reference in their entirety, unless explicitly indicated otherwise. The present disclosure shall control in the event there are any disparities between any definitions and/or description found in the cited references.

Unless otherwise specified or indicated by context, the terms "a", "an", and "the" mean "one or more." For example, "a protein" or "an RNA" should be interpreted to mean "one or more proteins" or "one or more RNAs," respectively.

The following examples are meant only to be illustrative and are not meant as limitations on the scope of the invention or of the appended claims.

EXAMPLES

Example 1 – VWF Aptamer Optimization

Materials and Methods

RNA APTAMER PREPARATION AND FOLDING

RNA aptamers were synthesized using conventional oligonucleotide synthetic methods in house. Prior to platelet function analysis (PFA) and *in vivo* models, RNA-based aptamers may

be "folded" in an appropriate physiological buffer, e.g. Platelet Binding Buffer (20 mM Hepes, pH 7.4; 150 mM NaCl; 1 mM $CaCl_2$; 1mM $MgCl_2$; 5 mM KCl). Aptamer solution is heated to 95°C for 3 minutes, immediately placed on ice for 3 minutes, and then allowed to come to room temperature over approximately 5 to 10 minutes.

APTAMER BINDING ASSAYS

Affinity constants (K_d values) were determined using double-filter nitrocellulose filter binding assays (Rusconi et al, Thromb. Haemost. 84:841-848 (2000)). All binding studies were performed in binding buffer F (20 mM HEPES, pH 7.4, 150 mM NaCl, 2 mM $CaCl_2$, and 0.01% BSA) at 37°C. Human purified VWF (factor VIII free) was purchased from Haematologic Technologies Inc. (Essex Junction, VT) and used in the double-filter nitrocellulose filter binding assay to determine the K_d of the aptamers. Briefly, RNA were end- labeled at the 5' end with T4 polynucleotide kinase (New England Biolabs, Beverly, MA) and [γ^{32}P] ATP (Amersham Pharmacia Biotech, Piscataway, NJ) (Fitzwater and Polisky, Methods Enzymol. 267:275-301 (1996)). End-labeled RNA was diluted in binding buffer F, heat denatured at 65°C for 5 minutes, and subsequently equilibrated at 37°C. Direct binding was performed by incubating trace ^{32}P-RNA with varying concentrations of VWF protein in binding buffer F at 37°C for 5 min. The fraction of the nucleic acid-protein complex which bound to the nitrocellulose membrane was quantified with a phosphorimager (Molecular Dynamics, Sunnyvale, CA). Non-specific binding of the radiolabeled nucleic acid was subtracted out of the binding such that only specific binding remained (Wong and Lohman, Proc. Natl. Acad. Sci. USA 90:5428-5432 (1993)).

$FeCl_3$-INDUCED ARTERIAL THROMBOSIS

A $FeCl_3$ chemical injury model for inducing arterial thrombosis in the mouse is described. The anesthesia was induced with 4 to 5% isoflurane inhaled in a sealed chamber for 5-7 minutes prior to intubation. After gas induction, a single injection of Avertin/tribromoethanol (1.25%, 12.5mg/ml) was given IP with 27g ½" needle at a dose between 100-250 mg/kg depending on effect. The total volume ranged from 0.15 to 0.50 cc depending on weight (typically 20-25g mouse). The animal was returned to the induction chamber for 1-2 more minutes prior to attempting intubation. The mouse was moved to a purpose built intubation stand and intubated with a needleless 20 to 22-gauge catheter. Once intubation was confirmed, the ventral neck was shaved and the mouse transferred to a heated surgery table. While in dorsal recumbency the mouse was immediately connected to a Harvard Apparatus rodent ventilator and

maintained with a 70% nitrogen:30% oxygen mix at approximately 90-110 breaths per minute and a tidal volume of ~0.2ml. Isoflurane was maintained at ~1-3%. Body temperature was maintained at approximately 37°C with a Physitemp TCAT-2DF.

After ensuring a surgical plane of anesthesia, a midline cervical incision of the skin was made and the fascia was bluntly dissected to expose the right common carotid artery. After exposure and isolation of the right common carotid artery, the left jugular vein was exposed by blunt dissection and three 7-0 silk ligatures placed. A small incision was made with microsurgical scissors, hemostasis maintained with a single 7-0 silk ligature, and a PE-10 polyethylene catheter, or equivalent, was placed in the vein and secured with the two remaining 7-0 silk ligatures. Once catheter patency was confirmed with 0.9% saline, a continuous rate infusion of 0.9% saline was started with a Harvard Apparatus PHD2000 (or equivalent) infusion pump at a rate between 0.5-3 µL/min and maintained until the end of study. A 0.5-PSB transit-time flow probe (Transonic Systems Inc.) was placed around the carotid artery to measure blood flow. Blood flow and temperature measurements were captured with LabChart Software (ADInstruments) throughout the study. Once a normal blood flow (1.0 to 3.0 mL/min) was maintained for at least 5 minutes, antithrombotic test drug, or control, was administered via the jugular catheter in a volume of 100 to 200µl with a saline based vehicle and given over one minute of time. Aptamer drug doses ranged from 0.005 to 1.0 mg/kg.

Approximately 5 minutes after drug or antidote administration, one or two small pieces of filter paper (1 mm x 2 mm) was saturated with 2.5% to 10% $FeCl_3$. These "patches" were then placed on the ventral +/- dorsal aspect of the exposed carotid artery proximal to the flow probe. They were left in place for 3 minutes. After removal of the patches, the respective region of the artery was lightly rinsed with 0.9% saline. Carotid artery blood transit time was then continually measured until the endpoint of the study. The endpoint of the procedure was defined as no more than 60 minutes beyond the formation of a stable thrombus (ie. ~0.0 ml/min carotid artery transit time) or no more than 60 minutes beyond the application of the $FeCl_3$ patches. Once the endpoint was reached, isoflurane was increased to 2-4%. Two encircling ligatures of 7-0 silk were then placed on the artery proximal to the site of thrombus formation. The flow probe was removed and the artery was transected between the silk ligatures and at a point approximately 5 to 8 mm distal. The artery section was removed for histopathology. The animals were then euthanized by an overdose of anesthetic gas followed by a secondary physical method.

SAPHENOUS VEIN BLEEDING MODEL

A saphenous vein bleeding model for evaluating hemostasis in the mouse is described. Anesthesia was induced with 4 to 5% isoflurane inhaled in a sealed chamber for 2-3 minutes. A single injection of Avertin/tribromoethanol (1.25%, 12.5 mg/mL) was given IP with 27g ½" needle at a dose between 100-250 mg/kg depending on effect. The total volume ranged from 0.15 to 0.50 cc depending on weight (typically 20-25g mouse). The animal was then returned to the induction chamber for 1-2 more minutes prior to intubation. The mouse was then moved to a purpose built intubation stand and intubated with a needleless 20 to 22-gauge catheter. Once intubation was confirmed, the ventral neck and the medial aspect of both pelvic limbs was shaved and the mouse transferred to a heated surgery table. While in dorsal recumbency the mouse was immediately connected to a Harvard Apparatus rodent ventilator and maintained with a 70% nitrogen:30% oxygen mix at approximately 90-110 breaths per minute and a tidal volume of ~0.2 mL. Isoflurane was maintained at ~1-3%. Body temperature was maintained at approximately 37°C with a Physitemp TCAT-2DF and rectal probe.

After ensuring a surgical plane of anesthesia, a midline cervical incision of the skin was made. Surgical exposure of the left jugular vein was accomplished by blunt dissection. Once the jugular vein was isolated, a PE-10 polyethylene catheter, or equivalent, was placed in the vein and secured with two encircling 7-0 silk ligatures. Once catheter patency was confirmed with 0.9% saline, a continuous rate infusion of 0.9% saline was started with a Harvard Apparatus PHD2000 (or equivalent) infusion pump at a rate between 0.5-3 µL/min and maintained until the end of study. After catheter placement was complete, the skin on the medial aspect of the left or right pelvic limb was incised to expose a length of the saphenous vascular bundle (saphenous vein and artery, medial saphenous vein). The bundle was maintained under 1-2 drops of 0.9% saline to prevent drying.

Test drug or control was administered IV via the jugular catheter in a volume of 100 to 200 µL with a saline vehicle and given over one minute of time. Aptamer drug doses ranged from 0.005 to 1.0 mg/kg. Approximately 5 to 120 minutes after the test drug was given, the exposed saphenous vein was transected with a 23-26g needle followed by a ~1 to 2 mm longitudinal incision made in the distal portion of the vessel with micro-dissecting scissors. Extravasated blood was gently wicked away with a tapered mini cotton-tipped applicator until hemostasis occurs. The clot on the distal portion of the vessel was then removed with a 23-26g

needle to restart bleeding. Blood was again wicked away until hemostasis re-occurs. Clot disruption was repeated after every incidence of hemostasis for a total time of 15 to 30 minutes after the initial injury. Injury, clot disruption, hemostasis, and temperature measurements were captured with LabChart Software (ADInstruments) throughout the study. Corresponding antidote molecules were then administered IV via the jugular catheter in a volume of 100 to 200 μL after the test drug. RNA-based oligonucleotide antidotes ranged from 0.005 to 100 mg/kg. Approximately 5 minutes after the administration of the antidote, the clot on the distal portion of the vessel was again removed with a 23-26g needle to restart bleeding. Blood was wicked away until hemostasis re-occurs. Clot disruption was repeated after every incidence of hemostasis for a total time of 15 to 30 minutes. Once the endpoint was reached, ~0.5mL of blood was collected via cardiac puncture or withdrawn from the caudal vena cava. The animal was then euthanized by an overdose of anesthetic gas followed by a secondary physical method.

PFA100 Protocol

Platelet Function Analyzer, PFA-100 (Dade Behring, Deerfield, IL) provides a quantitative measure of platelet function in anti-coagulated whole blood (Ortel et al, Thromb. Haemost. 84:93-97 (2000)). Briefly, aptamers were diluted in an appropriate buffer (i.e. 150 mM NaCl; 20 mM HEPES pH: 7.4; 5 mM KCl; 1 mM $MgCl_2$ and 1 mM $CaCl_2$, or 150 mM NaCl; 20 mM HEPES pH: 7.4; 2mM $CaCl_2$; or PBS) and heat denatured. Aptamers were added to fresh whole blood at the final concentration indicated; incubated at RT for 3-5 minutes and then run utilizing a collagen /ADP test cartridge in a PFA-100. The maximum closing time of the PFA-100 is 300 seconds. Antidote activity of aptamer was measured by mixing whole blood with aptamer in buffer followed by administration of antidote and measuring in PFA.

Results

VWF9.14 variants

To optimize the VWF9.14 aptamer, we generated several VWF9.14 aptamer truncation variants and several VWF9.14 aptamer modification variants. *See, e.g.*, Figures 1-3. The VWF9.14 aptamer truncation variants are listed in Table 1 below.

TABLE 1: Truncated Aptamers

A = 2'OH adenine; C = 2'fluorocytosine; G = 2'OH guanine; U = 2'flourouracil

idT = inverted deoxythymidine on 3' end (Sequence lengths and SEQ ID NOs: below do not include the idT)
NB = No Binding; ND = Not Determined

ID	Length	Sequence	Bmax (%)	Kd (nM)	SEQ ID NO:
Apt. 9-14	80nt	GGGAGGACGAUGCGGUGGACGAACUGCCCU CAGCUACUUUCAUGUUGCUGACGCACAGAC GACUCGCUGAGGAUCCGAGA	70	12.0	10
T10	60nt	GGGAGGUGGACGAACUGCCCUCAGCUACUU UCAUGUUGCUGACGCACAGACGACUCGCUG -idT	51	18.4	11
T11	57nt	GGGAGGACGAACUGCCCUCAGCUACUUUCA UGUUGCUGACGCACAGACGACUCGCUG	54	16.5	12
T12	54nt	GGGAGGAACUGCCCUCAGCUACUUUCAUGU UGCUGACGCACAGACGACUCGCUG	NB	NB	13
T13	51nt	GGGAGGUGCCCUCAGCUACUUUCAUGUUGC UGACGCACAGACGACUCGCUG	NB	NB	14
T14	28nt	GGGAGGUCAGCUACUUUCAUGUUGCUGA	NB	NB	15
T15	57nt	GGGAGGUGGACGAACUGCCCUCAGCUACCA UGUUGCUGACGCACAGACGACUCGCUG	13	83.0	16
T16	54nt	GGGAGGUGGACGAACUGCCCUCAGCUACGU UGCUGACGCACAGACGACUCGCUG	13	126. 0	17
T17	40nt	GGGAGGUGGACGAACUGCCCUACGCACAGA CGACUCGCUG	NB	NB	18
T18	57nt	GGGAGGUGGACGAACUGCCCUCUACUUUCA UGUUGCUGACGCACAGACGACUCGCUG	NB	NB	19
T19	54nt	GGGAGGUGGACGAACUGCCCUCUUUCAUGU UGCUGACGCACAGACGACUCGCUG	NB	NB	20
T20	54nt	GGGAGGUGGACGAACUGCCCUCUACUUUCA UGUUGACGCACAGACGACUCGCUG	NB	NB	21
T21	46nt	GGGAGGUCAGCUACUUUCAUGUUGCUGACG CACAGACGACUCGCUG	10	26.0	22
T22	53nt	GGACGAACUGCCCUCAGCUACUUUCAUGUU GCUGACGCACAGACGACUCGCUG	43	28.0	23
T23	51nt	ACGAACUGCCCUCAGCUACUUUCAUGUUGC UGACGCACAGACGACUCGCUG-idT	ND	ND	24
T24	48nt	GGACGAACUGCCCUCAGCUACUUUCAUGUU GCUGACGCACAGACGUCC-idT	ND	ND	25

T25	44nt	ACGAACUGCCCUCAGCUACUUUCAUGUUGC UGACGCACAGACGU-idT	54	13.4	6
T26	44nt	CCGAACUGCCCUCAGCUACUUUCAUGUUGC UGACGCACAGACGG-idT	ND	ND	26
T27	55nt	GGGAGGACGAACUGCCCUCAGCUACUUAUG UUGCUGACGCACAGACGACUCGCUG-idT	ND	ND	27
T28	56nt	GGGAGGACGAACUGCCCUCAGCUACUUCAU GUUGCUGACGCACAGACGACUCGCUG-idT	ND	ND	28
T29	53nt	GGGAGGACGAACUGCCCUCAGCUAUUAUUA GCUGACGCACAGACGACUCGCUG-idT	ND	ND	29
T30	40nt	CCGAACUGCCCUCAGCUAUUAUUAGCUGAC GCACAGACGG-idT	21	39.3	30
T31	44nt	GGGAACUGCCCUCAGCUACUUUCAUGUUGC UGACGCACAGACCC-idT	ND	ND	31
T32	48nt	GGACGAACUGCCCUCAGCUACUUUCAUGUU GCUGACGCACAGACGACU-idT	ND	ND	32
T33	42nt	ACGAACUGCCCUCAGCACUUUCAUGUGCUG ACGCACAGACGU-idT	66	15.0	33
T34	42nt	ACGAACUGCCCUCGCUACUUUCAUGUUGCG ACGCACAGACGU-idT	61	10.0	34
T35	42nt	ACGAACUGCCCUCAGUACUUUCAUGUUCUG ACGCACAGACGU-idT	66	12.0	35
T36	42nt	ACGAACUGCCCUCAGCUAUUUCAUUUGCUG ACGCACAGACGU-idT	58	11.0	36
T37	42nt	ACGAACUGCCCUCAGCUACUUAUGUUGCUG ACGCACAGACGU-idT	68	10.0	37
T38	40nt	ACGAACUGCCCUCGCACUUUCAUGUGCGAC GCACAGACGU-idT	55	9.6	38
T39	40nt	ACGAACUGCCCUCAGACUUUCAUGUCUGAC GCACAGACGU-idT	50	11.0	39
T40	40nt	ACGAACUGCCCUCAGCAUUUCAUUGCUGAC GCACAGACGU-idT	54	11.0	40
T41	40nt	ACGAACUGCCCUCAGCACUUAUGUGCUGAC GCACAGACGU-idT	49	8.6	41
T42	40nt	ACGAACUGCCCUCGUACUUUCAUGUUCGAC GCACAGACGU-idT	ND	ND	42
T43	40nt	ACGAACUGCCCUCGCUAUUUCAUUUGCGAC GCACAGACGU-idT	ND	ND	43
T44	40nt	ACGAACUGCCCUCGCUACUUAUGUUGCGAC GCACAGACGU-idT	ND	ND	44

T45	40nt	ACGAACUGCCCUCAGUAUUUCAUUUCUGAC GCACAGACGU-idT	ND	ND	45
T46	40nt	ACGAACUGCCCUCAGUACUUAUGUUCUGAC GCACAGACGU-idT	ND	ND	46
T47	40nt	ACGAACUGCCCUCAGCUAUUAUUUGCUGAC GCACAGACGU-idT	ND	ND	47
T48	36nt	ACGAACUGCCCUCGACUUAUGUCGACGCAC AGACGU-idT	52	12.0	48
T49	34nt	ACGAACUGCCCUCGAUUAUUCGACGCACAG ACGU-idT	60	10.5	5
T50	38nt	ACGAACUGCCCUCGCACUUAUGUGCGACGC ACAGACGU-idT	61	9.6	49
T51	38nt	ACGAACUGCCCUCAGACUUAUGUCUGACGC ACAGACGU-idT	56	17.0	50
T52	38nt	ACGAACUGCCCUCAGCAUUAUUGCUGACGC ACAGACGU-idT	58	16.0	51
T53	43nt	ACGAACUGCCCUCAGCUACUUUCAUGUUGC UGACGCACAACGU-idT	NB	NB	52
T54	43nt	ACGAACUGCCCUCAGCUACUUUCAUGUUGC UGACGCACGACGU-idT	NB	NB	53
T55	41nt	ACGACUGCCCUCAGCUACUUUCAUGUUGCU GACGCACACGU-idT	NB	NB	54
T56	24nt	ACGAACUGCCCUACGCACAGACGU-idT	NB	NB	55
T57	26nt	ACGAACUGCCCUCGACGCACAGACGU-idT	NB	NB	56
T58	28nt	ACGAACUGCCCUCGCGACGCACAGACGU-idT	NB	NB	57
T59	30nt	ACGAACUGCCCUCGAUCGACGCACAGACGU-idT	78	8.8	4
T60	32nt	ACGAACUGCCCUCGAUUUCGACGCACAGAC GU-idT	71	12.5	58
T61	22nt	ACGAACUGCCCCGCACAGACGU-idT	NB	NB	59
T62	32nt	ACGAACUCCCUCGAUUAUUCGACGACAGAC GU-idT	NB	NB	60
T63	32nt	ACGAACGCCCUCGAUUAUUCGACGCACGAC GU-idT	10	83.0	61
T64	30nt	ACGAACUGCCCUAUUAUUACGCACAGACGU-idT	13	54.0	62
T65	28nt	ACGAACUGCCCUUUAUACGCACAGACGU-idT	NB	NB	63

T66	31nt	ACGAACUGCUCGAUUAUUCGAGCACAGACG U-idT	NB	NB	64
T67	33nt	ACGAACUGCCCUCGAUUAUUCGACCACAGA CGU-idT	NB	NB	65
T68	30nt	ACGAACUGCCCUCUUAUGACGCACAGACGU -idT	82	16.0	66
T69	32nt	ACGAACUGCCCUGAUUAUUCACGCACAGAC GU-idT	52	26.0	67
T70	32nt	ACGAACUGCCCUCAUUAUUGACGCACAGAC GU-idT	81	13.0	68
T71	32nt	ACGAACUGCCCUCGUUAUCGACGCACAGAC GU-idT	77	10.0	69
T73	35nt	GCAUAACGAACUGCCCUCGAUCGACGCACA GACGU-idT	ND	ND	70
T74	33nt	CCCACGAACUGCCCUCGAUCGACGCACAGA CGU-idT	37	23.0	71
T75	35nt	CCCCCACGAACUGCCCUCGAUCGACGCACA GACGU-idT	ND	ND	72
T76	35nt	CACACACGAACUGCCCUCGAUCGACGCACA GACGU-idT	ND	ND	73
T77	34nt	AAAAACGAACUGCCCUCGAUCGACGCACAG ACGU-idT	59	8.8	74
T78	36nt	CCCAAAACGAACUGCCCUCGAUCGACGCAC AGACGU-idT	55	6.6	75
T79	35nt	ACGAACUGCCCUCGAUCGACGCACAGACGU UUUUU-idT	64	1.6	3
T80	33nt	ACGAACUGCCCUCGAUCGACGCACAGACGU AAA-idT	77	6.3	76
T81	35nt	ACGAACUGCCCUCGAUCGACGCACAGACGU ACACA-idT	63	4.2	77
T82	35nt	ACGAACUGCCCUCGAUCGACGCACAGACGU ACCCG-idT	76	5.3	78
T83	35nt	ACGAACUGCCCUCGAUCGACGCACAGACGU AAAAA-idT	61	3.5	79
T84	35nt	ACGAACUGCCCUCGAUCGACGCACAGACGU ACACG-idT	76	3.7	80
T85	36nt	ACGAACUGCCCUCGAUUUCAUUCGACGCAC AGACGU-idT	ND	ND	81
T86	34nt	ACGAACUGCCCUCGUUUCAUCGACGCACAG ACGU-idT	88	16.0	82

T87	32nt	ACGAACUGCCCUCUUUCAUGACGCACAGAC GU-idT	86	11.0	83
T88	38nt	ACGAACUGCCCUCGAUAUUAUUUUCGACGC ACAGACGU-idT	ND	ND	84
T89	36nt	ACGAACUGCCCUCGUAUUAUUUCGACGCAC AGACGU-idT	79	12.0	85
T90	34nt	ACGAACUGCCCUCUAUUAUUUGACGCACAG ACGU-idT	77	3.8	86
T91	40nt	ACGAACUGCCCUCGAUAUUUCAUUUUCGAC GCACAGACGU-idT	ND	ND	87
T92	38nt	ACGAACUGCCCUCGUAUUUCAUUUCGACGC ACAGACGU-idT	ND	ND	88
T93	36nt	ACGAACUGCCCUCUAUUUCAUUUGACGCAC AGACGU-idT	76	6.4	89
T94	32nt	ACGAACUGCCCUCUUUUUUGACGCACAGAC GU-idT	87	5.0	90
T95	34nt	ACGAACUGCCCUCUUUUUUUUGACGCACAG ACGU-idT	81	12.0	91
T96	34nt	ACGAACUGCCCUCUUUUUUUUGACGCACCC CCGU-idT	NB	NB	92
T97	34nt	ACGAACUGCCCUCGUUUCAUCGACGCACCC CCGU-idT	NB	NB	93
T98	32nt	ACGAACUGCCCUCUUUCAUGACGCACCCCC GU-idT	NB	NB	94
T99	34nt	ACGAACUGCCCUCUAUUAUUUGACGCACCC CCGU-idT	NB	NB	95
T100	36nt	ACGAACUGCCCUCUAUUUCAUUUGACGCAC CCCCGU-idT	ND	ND	96
T101	32nt	ACGAACUGCCCUCUUUUUUGACGCACCCCC GU-idT	NB	NB	97

The VWF9.14 aptamer modification variants created are listed in Table 2 below.

Table 2 – Modified Versions of VWF9.14 Aptamer Truncates

Table Legend: All sequences are in 5' to 3' orientation

Lengths are not inclusive of inverted deoxythymidine

fU = 2'fluorouracil fA = 2'fluoroadenine fC = 2'fluorocytosine
mA = 2'O-methyladenine mC = 2'O-methylcytosine mG = 2'O-methylguanine

mU = 2'O-methyluracil fG = 2'fluoroguanine rG = 2' riboguanine
rA = 2' riboadenine idT = inverted deoxythymidine on 3' end
(C6L)=hexylamino linker; (6GLY)=hexaethylene glycol linker (incorporated using 9-O-Dimethoxytrityl-triethylene glycol,1-[(2-cyanoethyl)-(N,N-diisopropyl)]-phosphoramidite);
cholesterol=cholesterol triethyleneglycol amidite incorporated on 5' end
NB = No Binding; ND= Not Determined

ID	Length	Modified Sequence	Bmax (%)	Kd (nM)	SEQ ID NO:
T25 vrt1	44nt	mAfCmGmAmAfCfUmGfCfCfCfUfCmAmGfCfUmAfCfUfUfUfCmAfUmGfUfUmGfCfUmGmAfCmGfCmAfCmAmGmAfCmGfU-idT	NB	NB	6
T25 vrt2	44nt	mAmCmGmAmAmCmUmGmCmCmCmUmCmAmGmCmUmAmCmUmUmUmCmAmUmGmUmUmGmGmCmUmGmAmCmGmCmAmCmAmGmAmCmGmU-idT	NB	NB	6
T25 vrt3	44nt	mAfCmGrArAfCfUrGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGfCrAfCrArGrAfCmGfU-idT	38	9.2	6
T25 vrt4	44nt	mAmCmGrArAfCfUrGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGfCrAfCrArGrAmCmGmU-idT	33	5.9	6
T25 vrt5	44nt	rAfCrGmAmAfCfUrGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGfCrAfCmAmGmAfCrGfU-idT	58	7.1	6
T25 vrt6	44nt	rAfCrGmAmAmCfUrGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGfCrAmCmAmGmAfCrGfU-idT	67	3.1	6
T25 vrt7	44nt	rAfCrGrArAfCfUmGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGmAfCmGfCmAfCrArGrAfCrGfU-idT	NB	NB	6
T25 vrt8	44nt	rAfCrGrArAfCmUmGmCmCmCmUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGmAmCmGmCmAfCrArGrAfCrGfU-idT	NB	NB	6
T25 vrt9	44nt	rAfCrGrArAfCfUrGfCfCfCfUfCmAmGfCfUmAfCfUfUfUfCrAfUrGfUfUmGfCfUmGrAfCrGfCrAfCrArGrAfCrGfU-idT	57	9.8	6
T25 vrt10	44nt	rAfCrGrArAfCfUrGfCfCfCfUmCmAmGmCmUmAfCfUfUfUfCrAfUrGmUmUmGmCmUmGrAfCrGfCrAfCrArGrAfCrGfU-idT	62	5.7	6
T25 vrt11	44nt	rAfCrGrArAfCfUrGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCmAfUmGfUfUrGfCfUrGrAfCrGfCrAfCrArGrAfCrGfU-idT	57	7.2	6

T25 vrt12	44nt	rAfCrGrArAfCfUrGfCfCfCfUfCrArGfCfUrAmCmUmUmUmCmAmUmGfUfUrGfCfUrGrAfCrGfCrAfCrArGrAfCrGfU-idT	59	7.1	6
T25 vrt13	44nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmAmGmCmUmAmCmUmUmUmCmAmUmGmUmUmGmCmUmGrAfCrGfCrAmCmAmGmAfCrGfU-idT	79	1.9	6
T25 vrt14	44nt	mAfCrGrArAfCfUrGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGfCrAfCrArGrAfCrGmU-idT	54	9.2	6
T25 vrt15	44nt	rAmCrGrArAfCfUrGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGfCrAfCrArGrAfCmGfU-idT	73	7.3	6
T25 vrt16	44nt	rAfCmGrArAfCfUrGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGfCrAfCrArGrAmCrGfU-idT	78	4.3	6
T25 vrt17	44nt	rAfCrGrArAfCmUrGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGfCmAfCrArGrAfCrGfU-idT	56	23.0	6
T25 vrt18	44nt	rAfCrGrArAfCfUmGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGmCrAfCrArGrAfCrGfU-idT	NB	NB	6
T25 vrt19	44nt	rAfCrGrArAfCfUrGmCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCmGfCrAfCrArGrAfCrGfU-idT	NB	NB	6
T25 vrt20	44nt	rAfCrGrArAfCfUrGfCmCmCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAmCrGfCrAfCrArGrAfCrGfU-idT	NB	NB	6
T25 vrt21	44nt	rAfCrGrArAfCfUrGfCfCfCmUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGmAfCrGfCrAfCrArGrAfCrGfU-idT	62	17.0	6
T25 vrt22	44nt	rAfCrGrArAfCfUrGfCmCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGfCrAfCrArGrAfCrGfU-idT	NB	NB	6
T25 vrt23	44nt	rAfCrGrArAfCfUrGfCfCmCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAfCrGfCrAfCrArGrAfCrGfU-idT	NB	NB	6
T25 vrt24	44nt	rAfCrGrArAfCfUrGfCfCfCfUfCrArGfCfUrAfCfUfUfUfCrAfUrGfUfUrGfCfUrGrAmCrGfCrAfCrArGrAfCrGfU-idT	25	55.0	6
T59 vrt1	30nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmGmAmUmCmGrAfCrGfCrAmCmAmGmAfCrGfU-idT	76	1.5	4
T59 vrt2	30nt	rAfCrGmAmAmCfUrGfCfCfCmUmCmGmAmUmCmGmAfCrGfCrAmCmAmGmAfCrGfU-idT	87	5.5	4

T59 vrt3	30nt	rAfCrGmAmAmCfUmGfCfCfCfUmCmGmAmUmCmGrAfCmGfCmAmCmAmGmAfCrGfU-idT	49	288.0	4
T59 vrt4	30nt	mAfCmGmAmAmCfUmGfCfCfCfUmCmGmAmUmCmGmAfCmGfCmAmCmAmGmAfCmGfU-idT	53	364.0	4
T59 vrt5	30nt	mAmCmGmAmAmCfUmGfCfCfCmUmCmGmAmUmCmGmAfCmGfCmAmCmAmGmAmCmGfU-idT	61	260.0	4
T59 vrt6	30nt	mAmCmGmAmAmCfUrGfCfCfCfUmCmGmAmUmCmGrAfCrGfCrAmCmAmGmAmCmGfU-idT	82	0.5	4
T59 vrt7	30nt	mAfCmGmAmAmCfUrGfCfCfCfUmCmGmAmUmCmGrAfCrGfCrAmCmAmGmAfCmGfU-idT	84	0.8	4
T59 vrt8	30nt	mAfCrGmAmAmCfUrGfCfCfCfUmCmGmAmUmCmGrAfCrGfCrAmCmAmGmAfCrGfU-idT	86	1.8	4
T59 vrt9	30nt	rAmCrGmAmAmCfUrGfCfCfCfUmCmGmAmUmCmGrAfCrGfCrAmCmAmGmAfCmGfU-idT	86	1.0	4
T59 vrt10	30nt	rAfCmGmAmAmCfUrGfCfCfCfUmCmGmAmUmCmGrAfCrGfCrAmCmAmGmAmCrGfU-idT	81	0.4	4
T59 vrt11	30nt	rAfCrGmAmAmCfUmGfCfCfCfUmCmGmAmUmCmGrAfCrGfCrAmCmAmGmAfCrGfU-idT	88	1.3	4
T59 vrt12	30nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmGmAmUmCmGrAfCrGfCmAmCmAmGmAfCrGfU-idT	85	6.9	4
T59 vrt13	30nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmGmAmUmCmGrAfCmGfCrAmCmAmGmAfCrGfU-idT	76	29.0	4
T59 vrt14	30nt	mAmCmGmAmAmCfUrGfCfCfCmUmCmGmAmUmCmGmAfCrGfCrAmCmAmGmAmCmGfU-idT	81	1.7	4
T59 vrt15	30nt	mAmCmGmAmAmCfUmGfCfCfCmUmCmGmAmUmCmGmAfCmGfCrAmCmAmGmAmCmGfU-idT	65	32.5	4
T59 vrt16	30nt	mAmCmGmAmAmCfUrGfCfCfCmUmCmGmAmUmCmGmAfCmGfCmAmCmAmGmAmCmGfU-idT	57	132.5	4
T59 vrt17	30nt	mAmCmGmAmAmCfUmGfCfCfCmUmCmGmAmUmCmGmAfCrGfCmAmCmAmGmAmCmGfU-idT	70	13.0	4
T59 vrt18	30nt	mAmCmGmAmAmCmUrGfCfCfCmUmCmGmAmUmCmGmAfCrGfCmAmCmAmGmAmCmGfU-idT	83	5.7	4

T59 vrt19	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCrGfCmAmCmAmGmAmC mGfU-idT	82	5.5	4
T59 vrt20	30nt	mAmCmGmAmAmCmUrGfCfCfCmUmCmGm AmUmCmGmAfCmGfCmAmCmAmGmAmC mGfU-idT	NB	NB	4
T59 vrt21	30nt	mAmCmGmAmAmCfUmGfCfCfCfUmCmGm AmUmCmGmAfCmGfCrAmCmAmGmAmCm GfU-idT	85	27.0	4
T59 vrt22	30nt	mAmCmGmAmAmCfUrGfCfCfCfUmCmGmA mUmCmGmAfCmGfCmAmCmAmGmAmCm GfU-idT	NB	NB	4
T59 vrt23	30nt	mAmCmGmAmAmCfUmGfCfCfCfUmCmGm AmUmCmGmAfCrGfCmAmCmAmGmAmCm GfU-idT	77	1.7	4
T59 vrt24	30nt	mAmCmGmAmAmCfUmGfCfCfCfUmCmGm AmUmCmGrAfCrGfCmAmCmAmGmAmCmG fU-idT	83	2.4	4
T59 vrt25	30nt	mAmCmGmAmAmCfUrGfCfCfCfUmCmGmA mUmCmGrAfCmGfCmAmCmAmGmAmCmGf U-idT	86	76.0	4
T59 vrt26	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCrGfCmAmCmAmGmAmC mGmU-idT	89	18.0	4
T59 vrt27	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCrGmCmAmCmAmGmAm CmGfU-idT	NB	NB	4
T59 vrt28	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCmGfCmAmCmAmGmAm CmGfU-idT	NB	NB	4
T59 vrt29	30nt	mAmCmGmAmAmCmUmGmCfCfCmUmCm GmAmUmCmGmAfCrGfCmAmCmAmGmAm CmGfU-idT	76	19.0	4
T59 vrt30	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCmGfCmAmCmAmGmAm CmGmU-idT	ND	ND	4
T59 vrt31	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCmGmCmAmCmAmGmAm CmGfU-idT	ND	ND	4
T59 vrt32	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCfGfCmAmCmAmGmAmC mGmU-idT	ND	ND	4
T79 vrt1	35nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmGmAmU mCmGrAfCrGfCrAmCmAmGmAfCrGfUmUm UmUmUmU-idT	78	1.9	3

T79 vrt2	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCrGfCmAmCmAmGmAmC mGfUmUmUmUmUmU-idT	81	24.0	3
T79 vrt3	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCmGfCmAmCmAmGmAm CmGfUmUmUmUmUmU-idT	20	66.0	3
T79 vrt4	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCrGfCmAmCmAmGmAmC mGmUmUmUmUmUmU-idT	75	13.0	3
T79 vrt6	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCfGfCmAmCmAmGmAmC mGfUmUmUmUmUmU-idT	61	60.5	3
T79 vrt7; DTRI-031	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCfGfCmAmCmAmGmAmC mGmUmUmUmUmUmU-idT	56	11.2	3; modified: 7
T79 vrt8	35nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmGmA mUmCmGfAfCfGfCfAmCmAmGmAmCmGfU mUmUmUmUmU-idT	NB	NB	3
T79 vrt9	35nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmGmA mUmCmGfAfCfGfCfAmCmAmGmAmCmGm UmUmUmUmUmU-idT	ND	ND	3
T82 vrt1	35nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmGmAmU mCmGrAfCrGfCrAmCmAmGmAfCrGfUmAm CmCmCmG-idT	76	3.8	78
T82 vrt4	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCrGfCmAmCmAmGmAmC mGmUmAmCmCmCmG-idT	87	38.5	78
T82 vrt6	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCfGfCmAmCmAmGmAmC mGfUmAmCmCmCmG-idT	67	223.0	78
T82 vrt7	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCfGfCmAmCmAmGmAmC mGmUmAmCmCmCmG-idT	78	268.5	78
T82 vrt8	35nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmGmA mUmCmGfAfCfGfCfAmCmAmGmAmCmGfU mAmCmCmCmG-idT	NB	NB	78
T83 vrt1	35nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmGmAmU mCmGrAfCrGfCrAmCmAmGmAfCrGfUmAm AmAmAmA-idT	73	2.1	79
T83 vrt4	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCrGfCmAmCmAmGmAmC mGmUmAmAmAmAmA-idT	77	20.0	79
T83 vrt6	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCfGfCmAmCmAmGmAmC	67	209.0	79

		mGfUmAmAmAmAmA-idT			
T83 vrt7	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCfGfCmAmCmAmGmAmC mGmUmAmAmAmAmA-idT	83	265.0	79
T83 vrt8	35nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmGmA mUmCmGfAfCfGfCfAmCmAmGmAmCmGfU mAmAmAmAmA-idT	NB	NB	79
T84 vrt1	35nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmGmAmU mCmGrAfCrGfCrAmCmAmGmAfCrGfUmAm CmAmCmG-idT	72	1.7	80
T84 vrt4	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCrGfCmAmCmAmGmAmC mGmUmAmCmAmCmG-idT	77	22.0	80
T84 vrt6	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCfGfCmAmCmAmGmAmC mGfUmAmCmAmCmG-idT	71	149.0	80
T84 vrt7	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCfGfCmAmCmAmGmAmC mGmUmAmCmAmCmG-idT	74	182.0	80
T84 vrt8	35nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmGmA mUmCmGfAfCfGfCfAmCmAmGmAmCmGfU mAmCmAmCmG-idT	NB	NB	80
T86 vrt1	34nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmGmUmU mUmCmAmUmCmGrAfCrGfCrAmCmAmGm AfCrGfU-idT	80	0.9	82
T86 vrt4	34nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mUmUmUmCmAmUmCmGmAfCrGfCmAmC mAmGmAmCmGmU-idT	88	12.0	82
T86 vrt6	34nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mUmUmUmCmAmUmCmGmAfCfGfCmAmC mAmGmAmCmGfU-idT	85	52.0	82
T86 vrt7	34nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mUmUmUmCmAmUmCmGmAfCfGfCmAmC mAmGmAmCmGmU-idT	88	50.0	82
T86 vrt8	34nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmGmU mUmUmCmAmUmCmGfAfCfGfCfAmCmAm GmAmCmGfU-idT	NB	NB	82
T87 vrt1	32nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmUmUmU mCmAmUmGrAfCrGfCrAmCmAmGmAfCrGf U-idT	85	1.5	83
T89 vrt1	36nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmGmUmA mUmUmAmUmUmUmCmGrAfCrGfCrAmCm AmGmAfCrGfU-idT	84	1.2	85

T89 vrt2	36nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mUmAmUmUmAmUmUmUmCmGmAfCrGfC mAmCmAmGmAmCmGfU-idT	80	12.0	85
T89 vrt3	36nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mUmAmUmUmAmUmUmUmCmGmAfCmGf CmAmCmAmGmAmCmGfU-idT	49	63.0	85
T89 vrt4	36nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mUmAmUmUmAmUmUmUmCmGmAfCrGfC mAmCmAmGmAmCmGmU-idT	85	8.4	85
T89 vrt6	36nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mUmAmUmUmAmUmUmUmCmGmAfCfGfC mAmCmAmGmAmCmGfU-idT	73	34.5	85
T89 vrt7	36nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mUmAmUmUmAmUmUmUmCmGmAfCfGfC mAmCmAmGmAmCmGmU-idT	75	38.5	85
T89 vrt8	36nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmGmU mAmUmUmAmUmUmUmCmGfAfCfGfCfAm CmAmGmAmCmGfU-idT	NB	NB	85
T89 vrt9	36nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmGmU mAmUmUmAmUmUmUmCmGfAfCfGfCfAm CmAmGmAmCmGmU-idT	ND	ND	85
T89 vrt10	36nt	mAmCmGmAmAmCmUfGfCfCfCmUmCmGm UmAmUmUmAmUmUmUmCmGfAfCfGfCfA mCmAmGmAmCmGmU-idT	86	548.0	85
T90 vrt1	34nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmUmAmU mUmAmUmUmUmGrAfCrGfCrAmCmAmGm AfCrGfU-idT	87	0.9	86
T90 vrt4	34nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmU mAmUmUmAmUmUmUmGmAfCrGfCmAmC mAmGmAmCmGmU-idT	85	10.2	86
T90 vrt6	34nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmU mAmUmUmAmUmUmUmGmAfCfGfCmAmC mAmGmAmCmGfU-idT	80	46.0	86
T90 vrt7	34nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmU mAmUmUmAmUmUmUmGmAfCfGfCmAmC mAmGmAmCmGmU-idT	80	42.0	86
T90 vrt8	34nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmUmA mUmUmAmUmUmUmGfAfCfGfCfAmCmAm GmAmCmGfU-idT	ND	ND	86
T93 vrt1	36nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmUmAmU mUmUmCmAmUmUmUmGrAfCrGfCrAmCm AmGmAfCrGfU-idT	89	0.8	89
T93 vrt4	36nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmU mAmUmUmUmCmAmUmUmUmGmAfCrGfC mAmCmAmGmAmCmGmU-idT	82	5.7	89

T93 vrt6	36nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmU mAmUmUmUmCmAmUmUmUmGmAfCfGfC mAmCmAmGmAmCmGfU-idT	82	33.0	89
T93 vrt7	36nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmU mAmUmUmUmCmAmUmUmUmGmAfCfGfC mAmCmAmGmAmCmGmU-idT	76	20.0	89
T93 vrt8	36nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmUmA mUmUmUmCmAmUmUmUmGfAfCfGfCfAm CmAmGmAmCmGfU-idT	ND	ND	89
T94 vrt1	32nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmUmUmU mUmUmUmGrAfCrGfCrAmCmAmGmAfCrGf U-idT	90	0.9	90
T94 vrt6	32nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmU mUmUmUmUmUmGmAfCfGfCmAmCmAmG mAmCmGfU-idT	78	42.0	90
T94 vrt7	32nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmU mUmUmUmUmUmGmAfCfGfCmAmCmAmG mAmCmGmU-idT	71	29.0	90
T94 vrt8	32nt	mAmCmGmAmAmCfUfGfCfCfCfUmCmUmU mUmUmUmUmGfAfCfGfCfAmCmAmGmAm CmGfU-idT	ND	ND	90
T95 vrt1	34nt	rAfCrGmAmAmCfUrGfCfCfCfUmCmUmUmU mUmUmUmUmGrAfCrGfCrAmCmAmGm AfCrGfU-idT	90	0.9	91
DTRI-006	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCrGfCmAmCmAmGmAmC mGfUidT	80	7.0	4
DTRI-007	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCfGfCmAmCmAmGmAmC mGfUidT	44	16.0	4
DTRI-008	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCrGfCmAmCmAmGmAmC mGmUidT	67	7.0	4
DTRI-009	26nt	mAmCmGmAmAmCmUmGfCfCfCmUmC(6G LY)mGmAfCrGfCmAmCmAmGmAmCmGfUi dT	60	11.0	98
DTRI-010	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mAmUmCmGmAfCdGfCmAmCmAmGmAmC mGfUidT			4
DTRI-011	30nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mUmAmAmGmAfCrGfCmAmCmAmGmAmC mGfUidT	72	3.8	99
DTRI-012	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmG mUmAmAmGmAfCrGfCmAmCmAmGmAmC mGfUmUmUmUmUmUidT	73	5.5	100

DTRI-013	30nt	mCmCmGmAmAmCmUmGfCfCfCmUmCmGmAmUmCmGmAfCrGfCmAmCmAmGmAmCmGmGidT	58	5.4	101
DTRI-019	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmGmUmAmAmGmAfCrGfCmAmCmAmGmAmCmGmUmUmUmUmUmUidT	64.8	4.3	100 unmod; mod: 8;
DTRI-020	35nt	(C6L)mAmCmGmAmAmCmUmGfCfCfCmUmCmGmUmAmAmGmAfCrGfCmAmCmAmGmAmCmGmUmUmUmUmUmUidT	ND	ND	100 unmod
DTRI-021	35nt	Cholesterol-mAmCmGmAmAmCmUmGfCfCfCmUmCmGmUmAmAmGmAfCrGfCmAmCmAmGmAmCmGmUmUmUmUmUmUidT	ND	ND	unmod: 100; mod: 9;
DTRI-022	35nt	mAmCmGmAmAmAmUmGmGmAmAmUmCmGmUmAmAmGmAmAmCmCmAmCmAmGmAmCmGmUmUmUmUmUmUidT	NB	NB	102
DTRI-023	35nt	Cholesterol-mAmCmGmAmAmAmUmGmGmAmAmUmCmGmUmAmAmGmAmAmCmCmAmCmAmGmAmCmGmUmUmUmUmUmUidT	ND	ND	102
DTRI-034	35nt	mAmCmGmAmAmCmUmGfCfCfCmUmCmGmUmAmAmGmAfCfGfCmAmCmAmGmAmCmGmUmUmUmUmUmUidT	60	2.8	100

In addition to creating the VWF9.14 aptamer truncation variants and the VWF9.14 aptamer modification variants, we created several antidote sequences targeting these variants, which are listed in Table 3 below.

Table 3: Antidote Sequences

All sequences are represented in a 5' to 3' orientation

Lengths are not inclusive of inverted deoxythymidine

mG=2'O-Methyl G; mA=2'O-Methyl A; mC=2'O-Methyl C; mU=2'O-Methyl U;

idT-inverted deoxythymidine

ID	Alt ID	Length	Modified Sequence	SEQ ID NO:
AO1	T59-AO1	15nt	mUmCmGmAmGmGmGmCmAmGmUmUmCmGmU-idT	103
AO2	T59-AO2	17nt	mGmAmUmCmGmAmGmGmGmCmAmGmUmUmCmGmU-idT	104
AO3	T59-AO3	14nt	mGmAmUmCmGmAmGmGmGmCmAmGmUmU-idT	105

AO4	T59-AO4	16nt	mUmCmGmAmUmCmGmAmGmGmGmCmAmGmUmU-idT	106
AO5	T59-AO5	17nt	mGmUmCmGmAmUmCmGmAmGmGmGmCmAmGmUmU-idT	107
AO6	T59-AO6	14nt	mGmUmCmGmAmUmCmGmAmGmGmGmCmA-idT	108
AO7	T59-AO7	17nt	mUmGmCmGmUmCmGmAmUmCmGmAmGmGmGmCmA-idT	109
AO8	T59-AO8	17nt	mUmGmUmGmCmGmUmCmGmAmUmCmGmAmGmGmG-idT	110
AO9	T59-AO9	19nt	mUmCmUmGmUmGmCmGmUmCmGmAmUmCmGmAmGmGmG-idT	111
AO10	T59-AO10	16nt	mUmCmUmGmUmGmCmGmUmCmGmAmUmCmGmA-idT	112
AO11	T59-AO11	14nt	mUmCmUmGmUmGmCmGmUmCmGmAmUmC-idT	113
AO12	T59-AO12	17nt	mAmCmGmUmCmUmGmUmGmCmGmUmCmGmAmUmC-idT	114
AO13	T70-AO1	16nt	mAmAmUmGmAmGmGmGmCmAmGmUmUmCmGmU-idT	115
AO14	T70-AO2	18nt	mAmUmAmAmUmGmAmGmGmGmCmAmGmUmUmCmGmU-idT	116
AO15	T70-AO3	13nt	mAmAmUmGmAmGmGmGmCmAmGmUmU-idT	117
AO16	T70-AO4	15nt	mAmUmAmAmUmGmAmGmGmGmCmAmGmUmU-idT	118
AO17	T70-AO5	18nt	mUmCmAmAmUmAmAmUmGmAmGmGmGmCmAmGmUmU-idT	119
AO18	T70-AO6	19nt	mGmUmCmAmAmUmAmAmUmGmAmGmGmGmCmAmGmUmU-idT	120
AO19	T70-AO7	16nt	mGmUmCmAmAmUmAmAmUmGmAmGmGmGmCmA-idT	121
AO20	T70-AO8	19nt	mUmGmCmGmUmCmAmAmUmAmAmUmGmAmGmGmGmCmA-idT	122
AO21	T70-AO9	13nt	mGmUmCmAmAmUmAmAmUmGmAmGmG-idT	123
AO22	T70-AO10	16nt	mUmGmCmGmUmCmAmAmUmAmAmUmGmAmGmG-idT	124
AO23	T70-AO11	15nt	mUmCmUmGmUmGmCmGmUmCmAmAmUmAmA-idT	125
AO24	T70-AO12	18nt	mAmCmGmUmCmUmGmUmGmCmGmUmCmAmAmUmAmA-idT	126
AO25	T49-AO1	17nt	mAmAmUmCmGmAmGmGmGmCmAmGmUmUmCmGmU-idT	127
AO26	T49-AO2	19nt	mAmUmAmAmUmCmGmAmGmGmGmCmAmGmUmUmCmGmU-idT	128

AO27	T49-AO3	14nt	mAmAmUmCmGmAmGmGmGmCmAmGmUmU-idT	129
AO28	T49-AO4	16nt	mAmUmAmAmUmCmGmAmGmGmGmCmAmGmUmU-idT	130
AO29	T49-AO5	20nt	mUmCmGmAmAmUmAmAmUmCmGmAmGmGmGmCmAmGmUmU-idT	131
AO30	T49-AO6	21nt	mGmUmCmGmAmAmUmAmAmUmCmGmAmGmGmGmCmAmGmUmU-idT	132
AO31	T49-AO7	18nt	mGmUmCmGmAmAmUmAmAmUmCmGmAmGmGmGmCmA-idT	133
AO32	T49-AO8	21nt	mUmGmCmGmUmCmGmAmAmUmAmAmUmCmGmAmGmGmGmCmA-idT	134
AO33	T49-AO9	15nt	mGmUmCmGmAmAmUmAmAmUmCmGmAmGmG-idT	135
AO34	T49-AO10	18nt	mUmGmCmGmUmCmGmAmAmUmAmAmUmCmGmAmGmG-idT	136
AO35	T49-AO11	16nt	mUmCmUmGmUmGmCmGmUmCmGmAmAmUmAmA-idT	137
AO36	T49-AO12	19nt	mAmCmGmUmCmUmGmUmGmCmGmUmCmGmAmAmUmAmA-idT	138
AO37	T73-AO1	22nt	mGmAmUmCmGmAmGmGmGmCmAmGmUmUmCmGmUmUmAmUmGmC-idT	139
AO38	T74-AO1	20nt	mGmAmUmCmGmAmGmGmGmCmAmGmUmUmCmGmUmGmGmG-idT	140
AO39	T75-AO1	22nt	mGmAmUmCmGmAmGmGmGmCmAmGmUmUmCmGmUmGmGmGmG-idT	141
AO40	T76-AO1	22nt	mGmAmUmCmGmAmGmGmGmCmAmGmUmUmCmGmUmGmUmGmG-idT	142
AO41	T77-AO1	21nt	mGmAmUmCmGmAmGmGmGmCmAmGmUmUmCmGmUmUmUmUmU-idT	143
AO42	T78-AO1	23nt	mGmAmUmCmGmAmGmGmGmCmAmGmUmUmCmGmUmUmUmGmGmG-idT	144
AO43	T79-AO1	22nt	mAmAmAmAmAmCmGmUmCmUmGmUmGmCmGmUmCmGmAmUmC-idT	145
AO44	T80-AO1	20nt	mUmUmUmAmCmGmUmCmUmGmUmGmCmGmUmCmGmAmUmC-idT	146
AO45	T81-AO1	22nt	mUmGmUmGmUmAmCmGmUmCmUmGmUmGmCmGmUmCmGmAmUmC-idT	147
AO46	T82-AO1	22nt	mCmGmGmGmUmAmCmGmUmCmUmGmUmGmCmGmUmCmGmAmUmC-idT	148
AO47	T83-AO1	22nt	mUmUmUmUmUmAmCmGmUmCmUmGmUmGmCmGmUmCmGmAmUmC-idT	149

AO48	T84-AO1	22nt	mCmGmUmGmUmAmCmGmUmCmUmGmUmGmCmGmUmCmGmAmUmC-idT	150
AO49	T73-AO2	16nt	mGmGmGmCmAmGmUmUmCmGmUmUmAmUmGmC-idT	151
AO50	T74-AO2	14nt	mGmGmGmCmAmGmUmUmCmGmUmGmGmG-idT	152
AO51	T75-AO2	16nt	mGmGmGmCmAmGmUmUmCmGmUmGmGmGmGmG-idT	153
AO52	T76-AO2	16nt	mGmGmGmCmAmGmUmUmCmGmUmGmUmGmUmG-idT	154
AO53	T77-AO2	15nt	mGmGmGmCmAmGmUmUmCmGmUmUmUmUmU-idT	155
AO54	T78-AO2	17nt	mGmGmGmCmAmGmUmUmCmGmUmUmUmUmGmGmG-idT	156
AO55	T79-AO2/DTRI-025	16nt	mAmAmAmAmAmAmCmGmUmCmUmGmUmGmCmG-idT	157
AO56	T80-AO2	14nt	mUmUmUmAmCmGmUmCmUmGmUmGmCmG-idT	158
AO57	T81-AO2	16nt	mUmGmUmGmUmAmCmGmUmCmUmGmUmGmCmG-idT	159
AO58	T82-AO2	16nt	mCmGmGmGmUmAmCmGmUmCmUmGmUmGmCmG-idT	160
AO59	T83-AO2	16nt	mUmUmUmUmUmAmCmGmUmCmUmGmUmGmCmG-idT	161
AO60	T84-AO2	16nt	mCmGmUmGmUmAmCmGmUmCmUmGmUmGmCmG-idT	162
AO61	T86-AO1	17nt	mUmCmUmGmUmGmCmGmUmCmGmAmUmGmAmAmA-idT	163
AO62	T87-AO1	16nt	mUmCmUmGmUmGmCmGmUmCmAmUmGmAmAmA-idT	164
AO63	T89-AO1	19nt	mUmCmUmGmUmGmCmGmUmCmGmAmAmAmUmAmAmUmA-idT	165
AO64	T90-AO1	18nt	mUmCmUmGmUmGmCmGmUmCmAmAmAmUmAmAmUmA-idT	166
AO65	T93-AO1	20nt	mUmCmUmGmUmGmCmGmUmCmAmAmAmUmGmAmAmAmUmA-idT	167
AO66	T94-AO1	16nt	mUmCmUmGmUmGmCmGmUmCmAmAmAmAmAmA-idT	168
AO67	T95-AO1	18nt	mUmCmUmGmUmGmCmGmUmCmAmAmAmAmAmAmAmA-idT	169
AO68	T96-AO1	18nt	mGmGmGmGmUmGmCmGmUmCmAmAmAmAmAmAmAmA-idT	170

AO69	T97-AO1	17nt	mGmGmGmGmUmGmCmGmUmCmGmAmUmGmAmAmA-idT	171
AO70	T98-AO1	16nt	mGmGmGmGmUmGmCmGmUmCmAmUmGmAmAmA-idT	172
AO71	T99-AO1	18nt	mGmGmGmGmUmGmCmGmUmCmAmAmAmUmAmAmUmA-idT	173
AO72	T101-AO1	16nt	mGmGmGmGmUmGmCmGmUmCmAmAmAmAmAmA-idT	174
AO73	T79-AO3	17nt	mAmAmAmAmAmAmCmGmUmCmUmGmUmAmGmUmU-idT	175
AO74	T79-AO4	15nt	mAmAmAmAmAmAmCmGmUmCmUmGmGmUmU-idT	176
AO75	T79-AO5	20nt	mAmAmAmAmAmAmCmGmUmCmUmGmUmAmGmUmUmCmGmU-idT	177
AO76	T79-AO6	18nt	mAmAmAmAmAmAmCmGmUmCmUmGmGmUmUmCmGmU-idT	178
AO85	T59-AO13	12nt	mUmCmUmGmUmGmCmGmUmCmGmA-idT	179
AO86	T79-AO7/DTRI-038	16nt	mAmAmAmAmAmAmCmGmUmCmUmGmUmGmCmG	180

Binding Studies

To determine the binding affinity of the VWF9.14 aptamer variants for the VWF protein, we performed binding assays with several of the variants. The binding data is summarized above in Tables 1-2. See also Figures 1, and 16-17.

PFA Analysis of VWF9.14 aptamer variants

As shown in Figure 12 and 13, we performed platelet function assay (PFA) for VWF9.14T59 with and without antidotes VWF9.14T59-AO3,-AO10, and –AO11 (AO3, AO10, and AO11 respectively). Also shown are PFA results for aptamer VWF9.14T79 with and without antidotes VWF9.14T79-AO1 (AO43) and VWF9.14T79–AO2 (AO55). Results are shown for aptamer VWF9.14T82 with and without antidotes VWF9.14T82-AO1 (AO46) and VWF9.14T82-AO2 (AO58). Results are shown for aptamer VWF9.14T84 with and without antidotes VWF9.14T84-AO1 (AO48) and VWF9.14T84-AO2 (AO60). These results demonstrate that the anti-thrombotic activity of several of the VWF9.14 aptamers could be reversed using designed antidotes.

In vivo testing of VWF9.14 aptamer variants

Several of the VWF9.14 aptamer variants were tested in a murine arterial thrombosis model and a murine saphenous vein bleeding model. *See* Figures 4-11. In the murine arterial thrombosis model, the left jugular vein was cannulated and the right carotid artery was exposed and a flow probe was placed. After 5 minutes the vehicle indicated was injected i.v. into the mouse and a 10% $FeCl_3$ patch was placed on the carotid artery for 3 minutes. The blood flow in the carotid artery was then monitored for 1 hour and recorded using the probe In the murine arterial thrombosis model, injecting a vehicle (no aptamer/negative control) prior to $FeCl_3$ injury resulted in the vessel becoming occluded in approximately 2 minutes following removal of the $FeCl_3$ patches. See Figure 4. On the other hand, injecting either T79vrt7/DTRI-031 or PEG-VWF9.14T79-VRT7/DTRI-031 aptamer at a dosing of 0.375 mg/kg into this model prior to $FeCl_3$ injury resulted in the vessel remaining patent for 60 minutes following removal of the $FeCl_3$ patches. See Figures 5 and 7. These results demonstrate that the aptamers had potent anti-thrombotic activity.

The VWF9.14T79-VRT7 aptamer was also injected at a dosing of 0.0375 mg/kg into the model prior to $FeCl_3$ injury, which resulted in the vessel remained patent for > 60 minutes following removal of the $FeCl_3$ patches. See Figure 5. This result demonstrated that the dosing of the VWF9.14T79-VRT7 aptamer may be decreased and still exhibit potent anti-thrombotic activity. The dose range study is presented in Figure 7.

In the murine saphenous vein bleeding model, the left jugular vein of a mouse is cannulated and the right medial saphenous vein is exposed prior to injecting the aptamer at the indicated dose. Five minutes after injecting the aptamer the saphenous vein is transected and bleeding is followed for 15 minutes, the antidote is then injected to reverse the effects of the aptamer and bleeding is followed for an additional 20 minutes. The activity of the PEG-VWF9.14T79-VRT7 aptamer could be successfully reversed by injecting the VWF9.14T79-AO2 (AO55) antidote. See Figure 8. For example, as shown in Figure 8, the clot disruptions increased after injection of the VWF9.14T9-AO2 (AO55) antidote demonstrating that the activity of the aptamers could be reversed.

Furthermore, we tested the PEG-VWF9.14T79-VRT7 aptamer, the Cholesterol-VWF9.14T79-VRT7 aptamer, the Elastin-like polypeptide (ELP)-VWF9.14T79-VRT7 aptamer, and the VWF9.14T79-AO2 (AO55) antidote in a combined murine arterial thrombosis and saphenous vein bleeding model. In this model the left jugular vein was cannulated and the right

carotid artery was exposed and a transonic flow probe was placed in the animal. Five minutes after placement of the probe the aptamer was injected at the indicated dose. After an additional 5 minutes two 7.5% $FeCl_3$ patches were placed on the right carotid artery for 3 minutes prior to removal. Thirty minutes after removal the saphenous vein was exposed and transected and bleeding monitored for 15 minutes. The antidote was injected and clot formation was observed for an additional 15 minutes. See Figures 10-11. In this model, after first demonstrating the potent anti-thrombotic activity of each aptamer, the VWF9.14T79-AO2 (AO55) antidote could still successfully reverse the activities of the aptamers.

Example 2 – VWF Aptamer Thrombolytic Activity

The T79VRT7 aptamer and was also tested for thrombolytic activity in a murine carotid artery occlusion model and a murine intracranial hemorrhage model. See Figures 18-19.

Murine Carotid Artery Occlusion and Thrombolysis Model

We employed a murine carotid artery occlusion model where we intubated adult C57BL/6J mice (Jackson Laboratory, Bar Harbor, ME) (18–24 g) and exposed the left jugular vein. Next, we exposed the right common carotid artery and placed a transonic flow probe (Transonic Systems Incorporated, Ithaca, NY) around the artery. The blood flow was measured for 5 minutes to achieve a stable baseline. We then induced thrombosis by applying 10% ferric chloride-soaked Whatmann paper on the vessel. The time to occlusion was then recorded. Twenty minutes after occlusion, we intravenously inject either saline (negative control), anti-VWF aptamer (VWF9.14T79VRT7) at a dose of 0.5 mg/kg, or recombinant tissue plasminogen activator (rTPA) at a dose of 10 mg/kg. We monitored for reperfusion using the Doppler flow probe and determine the time to re-establish perfusion. We terminated the experiment if no recanalization occurred after 60 minutes. The animals were then sacrificed and the brain and common carotid arteries harvested for analysis.

As shown in Figure 18, in the murine carotid artery occlusion model, the percentage of initial carotid flow increased to a greater degree over time with the T79VRT7 aptamer verses rTPA, control, or no perfusion. Thus, the VWF T79VRT7 aptamer had superior thrombolytic activity compared to rTPA.

Murine Intracranial Hemorrhage Model

We anesthetized adult C57BL/6J mice (18–24 g) and exposed the left jugular vein and right common carotid artery. We then injected either saline (negative control), anti-VWF

aptamer (VWF9.14T79-VRT7) at a dose of 0.5 mg/kg, rTPA at dose of 10 mg/kg or anti-VWF aptamer (0.5 mg/kg) and matched antidote oligonucleotide (VWF9.14T79 -AO2, also called AO55) at a dose of 2.5 mg/kg 5 minutes after the aptamer. To induce intracranial hemorrhage, we inserted a silicone-coated 6-0 nylon filament into the carotid artery and advanced it until we punctured the internal carotid artery (ICA) terminus, resulting in subarachnoid hemorrhage (SAH). To evaluate the volume of infarct and hemorrhage, we performed magnetic resonance imaging (MRI) on a 9.4 Tesla MRI (Bruker Biospin, Billerica, MA) 90 minutes after induced intracranial hemorrhage.

Figure 19 shows a graph indicating stroke volume following vascular injury in the murine intracranial hemorrhage model in mice treated with vehicle, rTPA, anti-VWF aptamer (VWF9.14T79-VRT7), or anti-VWF aptamer (VWF9.14T79-VRT7) and VWF antidote (VWF9.14T79-AO2, also called AO55).

Example 3 – Additional *In vivo* Studies with a VWF Aptamer

Ischemic stroke is a leading cause of death and disability in the western world.[1] Approved thrombolytic stroke therapy using recombinant tissue plasminogen activator (rTPA) is limited by several critical factors. First, the significant risk of hemorrhagic conversion resulting from in part, the inability to reverse rTPA activity. Second, the short therapeutic window for rTPA renders more than 90% of stroke patients ineligible for therapy. [2, 3] Finally, rTPA only achieves approximately 30% recanalization and re-occlusion commonly occurs after primary thrombolysis, resulting in loss of initial neurological improvement.

von Willebrand factor (VWF) is a glycoprotein involved in the seminal event of platelet plug formation. VWF interacts with glycoprotein Ib alpha-IX-V complex on the platelet surface to induce platelet adhesion to the vessel wall.[4] Following this glycoprotein IIb/IIIa (gpIIb/IIIa) becomes activated and binds to fibrinogen resulting in thrombus formation. von Willebrand disease (VWD) can be both a qualitative and quantitative reduction and von Willebrand factor. Type I VWD, the predominant form of VWF disease presents with mild bleeding after dental procedures or during menses and not spontaneous hemorrhage.[5] Moreover, VWD Type I patients are protected from cerebrovascular and cardiovascular events.[6] VWF therefore represents an attractive target in arterial thrombosis and may be superior to current therapies.

Aptamers are single-stranded oligonucleotides that have potential advantages over other classes of therapeutic agents. They bind to their target with high affinity and specificity.[7] They

can be chemically modified to customize their bioavailability, chemically synthesized in large scale and most pertinent to our application, can be rapidly reversed. [8-11]

In this Example, the inventors demonstrate that aptamer 9.14T79vrt7 inhibits platelet adhesion under high shear stress in a dose-dependent manner and prevents platelet aggregation. It prevents thrombus formation in a murine carotid injury model. It also demonstrates superior thrombolytic activity in both a murine and canine models of arterial occlusion compared to rTPA and did so without inducing intracranial hemorrhage or shedding of embolic clot to the brain. Finally, an antidote oligonucleotide designed against 9.14T79vrt7 reverses the antiplatelet activity of the aptamer within 2 minutes both in human blood and a murine model of bleeding.

The studies in this Example suggest that the 9.14T79vrt7 aptamer represents a novel and potentially safer approach to treat ischemic stroke and other acute thrombotic events.

Materials and Methods

Synthesis of aptamer truncates, modifications and antidote oligonucleotides (AOs)

Aptamer truncates were either transcribed or synthesized in-house. Briefly, T7 RNA polymerase was used to transcribe RNA aptamer truncates T10, T21, and T22. Aptamer truncates, modifications, and antidotes were synthesized using a MerMade 6/12 Oligonucleotide synthesizer (BioAutomation, Irving, TX). Software predicting RNA secondary structure (Mfold by M. Zuker) was used to predict secondary structure.

RNA aptamer preparation and folding

Prior to platelet function analysis (PFA) and *in vivo* models, RNA-based aptamers may be "folded" in an appropriate physiological buffer.[13] Aptamer solution is heated to 95°C for 3 minutes, immediately placed on ice for 3 minutes, and then allowed to come to room temperature over approximately 5 to 10 minutes.

Human whole blood studies

Human blood was collected from healthy volunteers by vena puncture after written informed consent. Blood draws were performed in accordance with protocols that have been approved by the Institutional Review Board from both the Durham Veterans Administration Medical Center and Duke University Medical Center.

Platelet adhesion analysis

The Venaflux™ microfluidics system (Cellix, Dublin, Ireland) measures platelet adhesion on a collagen surface. Human blood was collected into hirudin tubes from healthy volunteers by vena

puncture. An aliquot containing 300 µl of whole blood treated with aptamer or platelet-binding buffer alone was flowed through collagen-coated micro-channels at 60 dynes for 3 minutes. Channels were then rinsed with saline for 3 minutes to wash away RBC and unbound platelets. Venaflux imaging software and Image Pro Plus were used to image bound platelets and calculate covered surface area. Aptamer was incubated at 95°C for 3 minutes, placed on ice for 3 minutes, then incubated for 10 minutes at room temperature. After cooling, aptamer was kept on ice until use. Total surface area covered by bound platelets in treated blood was expressed as a percentage of total coverage in negative control blood. Statistical significance was determined by analysis of variance; IC_{50} of the aptamer was calculated using a fitted linear regression curve.

Total Thrombus-formation Analysis System (T-TAS)

The T-TAS (Zacrox, Fujimori Kogyo Co. Ltd., Tokyo, Japan) was used to assess thrombus formation in both human and canine whole blood.[15] Blood was collected in a tube with hirudin in a PL chip that contains 25 capillary channels coated with type 1 collagen. The blood flow across the chip was maintained at a rate of 14 µl/min. Platelet aggregation was measured as a function of the amount of pressure (kPa) needed to maintain the flow rate. A camera was also used to observe platelet activity across the collagen-coated capillary channels.

Murine *in vivo* studies

Investigators that performed surgery or analyzed carotid flow and imaging data were blinded to the treatment groups. All *in vivo* experiments were approved by the Duke University Institutional Animal Care and Use Committee and The Ohio State University Institutional Animal Care and Use Committee. Moreover, these committees adhere to the NIH Guide for the Care and Use of Laboratory Animals.

Carotid artery occlusion and thrombolysis

Murine carotid artery occlusion studies were performed on male and female 8-week old C57BL/6 mice were obtained from the Jackson Laboratory. Thrombosis/occlusion was achieved using Whatman filter paper soaked in $FeCl_3$. Following 20 minutes of carotid occlusion, treatment was initiated. Male and female 8-week old C57BL/6 mice were obtained from the Jackson Laboratory. Animals were anesthetized with ketamine (55 mg/kg) and xylazine (15 mg/kg). Through a midline ventral incision, the animal was intubated (Harvard Apparatus mouse ventilator, Holliston, MA) and the common carotid artery was isolated. Baseline carotid

flow was obtained with a Doppler flow probe (Transonic Systems Inc., Ithaca, NY). Whatman filter paper soaked in 10% ferric chloride was placed on the artery for 3 minutes. Following 20 minutes of carotid occlusion, treatment was initiated. Through an intravenous saphenous infusion (Harvard Apparatus PHD 2000 Infusion Pump, Holliston, MA), animals were treated with control (platelet-binding buffer), VWF aptamer, TPA, aptamer/antidote, TPA/VWF aptamer or no perfusion. Carotid flow was monitored for an additional 90 minutes to assess reperfusion. Heart rate, EKG (ADInstruments PowerLab 4/35 EKG monitoring system, Sydney, Australia) and blood pressure (Kent Scientific CODA Non-Invasive BP Measurement system, Torrington, CT) were monitored throughout the procedure. Histological analysis was performed on the carotid arteries.

Femoral vein bleeding

Murine femoral vein bleeding model was performed on male and female 8-week old C57BL/6 mice were obtained from the Jackson Laboratory to assess reversibility of antidote oligonucleotide.[16] Animals were anesthetized with isoflurane. The hair on the ventral side of both hind limbs was removed. They were then placed supine on a temperature and ECG monitoring board. Extremities were gently restrained. The skin on the left and right ventral hind limb was incised exposing a length of the saphenous neurovascular bundle; the bundle was covered with normal saline to prevent drying. The left saphenous vein was cannulated for drug administration. To assess hemostasis, the right saphenous vein was transected by piercing it with a 23-G needle followed by a longitudinal incision made in the distal portion of the vessel. Blood was gently wicked away until hemostasis occurred. The clot was then removed to restart bleeding and the blood was again wicked away until hemostasis occurs again. Clot disruption was repeated after every incidence of hemostasis for 30 minutes. Two parameters were measured: 1) the number of times that hemostasis occurs in a 30-minute period, and 2) the time required for each hemostasis.

Canine carotid artery occlusion and thrombolysis

Canine carotid artery occlusion studies were performed on male and female adult beagles (7 – 11 kg). Carotid occlusion was induced with $FeCl_3$ and stabilized for 45 minutes before treatment was initiated. Dogs were anesthetized and intubated. Right femoral arterial and venous catheter was obtained. The right carotid artery was exposed, and baseline carotid flow was obtained

using a Doppler flow probe. Thrombosis was induced with a 50% ferric chloride patch for 15 minutes, and the clot was stabilized for 45 minutes. Dogs were then intravenously infused with vehicle, 0.9 mg/kg TPA or 0.5 mg/kg VWF aptamer. The aptamer and vehicle were administered as a bolus while the rTPA was administered by standard clinical protocol of 10% bolus followed by the remaining drug infused over 45 minutes. Carotid flow was monitored for 120 minutes. A flow probe distal to the site of thrombosis monitored blood flow transit time throughout the experiment. Carotid angiography demonstrated baseline patency, thrombotic occlusion, and recanalization. Periodic blood draws assessed platelet inhibition (Platelet Function Analyzer-100). At the conclusion of the experiment, the brain and carotid arteries of each animal were collected and embedded for histological analysis.

Statistical analysis

Values are expressed as mean ± SD Statistical analysis was performed using multiple t-tests, chi-square analysis and two-way ANOVA where appropriate.

Results

Optimized VWF aptamer 9.14T79 binds and inhibits VWF activity *in vitro* and *ex vivo*

To create a VWF aptamer that would be amenable for future clinical, we designed and tested a series of VWF aptamer derivatives derived from the 2'Fluoro-pyrimidine modified RNA aptamer VWF9.14.[12, 13] *See* Example 1. This effort resulted in a lead VWF aptamer, T59, which is 30 nucleotides long that retained high affinity binding and inhibitory activity. Next, to improve nuclease resistance and optimize the composition, we systematically substituted 2' O-methyl and/or 2' Fluoro moieties into the T25 and T59 aptamer truncates. Almost 90 truncates were synthetized and tested *in vitro*. The fully optimized aptamer 9.14T79vrt7 is 35-nucleotides and binds to VWF with a dissociation constant (K_d)=11.2 nmol/L, B_{max}= 56% compared to the 60-mer K_d=18.4 nmol/L, B_{max}=51% (See Tables 1 and 2 above and Figures 1-3).

To evaluate the inhibitory effect of the aptamer on platelet adhesion, human whole blood samples were treated with aptamer starting at 900 nmol/L with 2-fold dilutions to 14 nmol/L and tested by measuring platelet adhesion under high-shear stress. The aptamer prevented platelet adhesion to the collagen surface in a dose-dependent manner (Figure 20-22). Near complete inhibition of platelet adhesion was achieved at doses from 225 to 900 nmol/L (Figure 20C and 20D) and intermediate inhibition at doses from 56 to 112 nmol/L (Figure 20B and 20D). Log-

dose versus response data fitting resulted in a $\log IC_{50}$ calculation of 1.9 (72.6 nmol/L) (Figure 20E).

The aptamer's effect on platelet aggregation was measured *ex vivo* in a PFA-100 human whole blood assay. The VWF aptamer completely inhibited platelet aggregation in this system at doses over 100nmol/L, where platelet plug formation and closing time exceeded 300 seconds, representing the upper limit of the assay (Figure 21). Thus VWF aptamer 9.14T79vrt7 prevents both platelet adhesion and aggregation *ex vivo*.

9.14T79 demonstrates increased thrombolysis in a murine model of carotid occlusion than recombinant tissue plasminogen activator (rTPA)

A murine model of carotid artery occlusion was next used to evaluate aptamer thrombolytic activity. After 20 minutes of stable carotid artery occlusion, animals received aptamer 9.14T79, saline control or rTPA. The dose of rTPA used in this experiment was 10 mg/kg, 11-fold higher than 0.9 mg/kg (the dose used to treat humans who present with ischemic strokes within 3 – 4.5 hours of last known well) because this was the dose reported to be effective for recanalization in murine models of arterial thrombosis.[17] The aptamer was dosed at 0.5 mg/kg and as shown in Figure 23A demonstrated significantly higher recanalization compared to rTPA ($p<0.05$) and buffer control (n=8 per group) ($p<0.01$). Histological analysis of the carotid arteries from each group grossly correlated with the degree of recanalization measured by the flow probe (Figure 23B, 23C, and 23D). Examination of the cross-sections of the affected carotid artery of the buffer-control group demonstrated complete occlusion of all animals tested (n=8) (Figure 23D). Vessel sections from the rTPA-treated mice, showed nearly complete thrombosis and occlusion of the carotid (n=8) (Figure 23C). Finally, the histology of the carotid artery section of the VWF aptamer-treated mice demonstrated complete patency in 6 of the samples and only evidence of small clot in a section of two of the previously occluded vessels (n=8) ($p=0.01$) (Figure 23B).

9.14T79vrt7 demonstrates dose-dependent platelet inhibition of canine whole blood

In order to evaluate platelet thrombus formation under high shear, and begin to assess the aptamer in a large animal model, we tested the VWF aptamer in a Total Thrombus-formation Analysis System (T-TAS) (Fujimori Kogyo Co., Yokohama, Japan)[18]. 9.14T79vrt7 inhibited canine platelet aggregation and maintained blood flow pressure at doses between 18.75 – 100 nmol/L (Figure 24A) (n=5 per group) ($p<0.05$ compared to buffer control). At a dose of 100

nmol/L, there was complete inhibition of platelet adhesion and aggregation (Figure 24B). Each picture represents the first 10 seconds of minutes 1 through 5. The areas of white haze seen from minutes 3 – 5 in the buffer control panel are platelets adhering to the horizontal capillary channel. The aptamer panel shows no such platelet accumulation indicating that 9.14T79vrt7 is potent inhibitor of canine platelet function under sheer stress *in vitro*.

9.14T79vrt7 demonstrates recanalization in a canine model of carotid occlusion

A canine model of cerebrovascular thrombotic disease was used to corroborate the murine results in a large, clinically relevant animal. Arterial occlusion established and persistent for 45 minutes before treatment. Animals received an intravenous injection of 0.5 mg/kg of 9.14T79vrt7 as a bolus or 0.9 mg/kg of rTPA by the standard clinical protocol of 10% injection followed by the remaining 90% infused over 45 minutes. The carotid arteries of all 3 dogs that received 9.14T79vrt7 recanalized between 5 and 15 minutes after administration (Figures 24F, 24G, respectively). By contrast animals treated with rTPA or saline control demonstrated no recanalization after treatment (n=3 per group).

To investigate the safety of 9.14T79vrt7, we evaluated bleeding and clotting in the brain of these dogs. 9.14T79vrt7 did not induce intracranial hemorrhage nor did carotid artery recanalization result in cerebral thromboemboli in any of the 3 animals (Figure 24H – J). Brain histology from both the 9.14T79vrt7 and rTPA group is identical to the control saline-treated group. The lack of cerebral thromboembolism in the aptamer group was reassuring as the carotid artery histology demonstrated essentially complete recanalization of the vessel (Figure 24K). The top carotid section is through the area of vessel damage where occlusion occurred while the bottom section is from the patent portion adjacent to the diagnostic catheter. By sharp contrast, both the rTPA and saline-treated control group of animals contained thrombi that continued to occlude the damaged carotids consistent with the inability of these approaches to restore blood flow (Figure 24L and 24M respectively).

An antidote oligonucleotide can rapidly reverse the antiplatelet activity of 9.14T79vrt7 *in vitro* and *in vivo*

We created an antidote oligonucleotide (AO, also called VWF9.14T79-AO2 or AO55) to reverse 9.14T79vrt7 activity if needed. None of the antidotes initially tested could reverse the 30-nucleotide aptamer T59 likely because they could not access a good nucleation site on the aptamer once it was tightly bound to VWF. Therefore, we added a 5-nucleotide Uracil (oligo-U

tail) to the 3'-end of the molecule as an artificial nucleation site and tested a 16-nucleotide antidote complementary to this tail and the 3' end of the aptamer. The antidote oligonucleotide (AO) reversed the aptamer's antiplatelet activity *in vitro* within 2 minutes at a ratio as low as of 2:1 over 9.14T79vrt7 (Figure 14) (n=2 per group).

The ability of the antidote to reverse the antiplatelet aptamer was evaluated in a murine femoral vein bleeding model.[16] The control untreated mice group demonstrated 12 ± 3 disruptions, (n=7) which were similar to the saline group of 17 ± 3 disruptions (n=7) ($p>0.05$). 9.14T79vrt7 administered at a dose of 0.375 mg/kg resulted in no clot disruptions, which was highly significant compared to untreated control and saline treated animals (n=11) ($p<0.0001$). 9.14T79vrt7 administration followed by antidote oligonucleotide addition demonstrated 16 ± 9 disruptions, which was similar to animals that never received the aptamer (n=7). This data was expressed as a % of normal thrombosis (Figure 25). Administration of antidote alone did not result in an increased or decreased clot disruption (data not shown). Thus, the antidote can rapidly reverse any bleeding associated with aptamer-mediated inhibition of VWF.

Discussion

Currently, there are no acute treatment options for the vast majority of ischemic stroke patients. rTPA treatment, results in hemorrhage, it time-limited and cannot be reversed. Our research demonstrates that an antidote-controlled VWF inhibitor may provide a robust yet safe treatment option for these patients. 9.14T79vrt7 demonstrated improved binding affinity compared to the full-length aptamer,[12] commensurate with the potency of a monoclonal antibody.[7, 19] Aptamer 9.14T79vrt7 prevented adhesion of human platelets to a collagen surface (Figure 20-22) as well as under high sheer stress (Figure 24).

In vivo, 9.14T79vrt7 maintained arterial patency and maintain a transit time greater than 75% at a dose as low as 0.0188mg/kg (Figure 22). In comparison to both negative control and intravenous rTPA, 9.14T79vrt7 demonstrated superior thrombolytic activity in a murine model of carotid occlusion (Figure 23). The dose of IV rTPA used is 10-fold higher than is used clinically largely because that is the dose required to achieve thrombolysis in mice.[17] Sixty minutes after drug administration, the rTPA group achieved 25% transit time of pre-injury flow compared to 75% for the aptamer-treated group. This effect persisted greater than 100 minutes after drug administration. The aptamer was infused over 5 minutes while the rTPA was infused over 45 minutes due to the risk of hemorrhage associated with rTPA.

At first glance, the idea of a drug that targets an endothelial and platelet factor breaking up a formed arterial thrombus is not intuitive, however, a growing body of literature supports the "disaggregation" activity of VWF inhibitors. An *in vitro* study, high fluid shear stress and irregular vessel surface showed that VWF collates into thick bundles and meshes that span the vessel lumen, binding platelets together, resulting in arterial occlusion.[20] Anti-VWF therapy could therefore have an impact on arterial occlusion. This hypothesis is supported by our observation that even in major arteries in dogs, VWF aptamer 9.14T79vrt7 can engender recanalization of an occluded vessel (Figure 24).

The main class of parenteral anti-platelet agents used clinically is glycoprotein IIb/IIIa (gpIIb/IIIa) inhibitors (Abciximab, Eptifibatide and Tirofiban). These agents significantly improved outcomes in acute coronary syndromes (ACS) and percutaneous coronary interventions (PCI).[21] When tested in acute ischemic stroke however, they resulted in significant increase in intracranial hemorrhage without improvement in morbidity or mortality.[22] Therefore, we developed an antidote oligonucleotide that can readily reverse VWF aptamer activity in case of hemorrhage. The antidote completely reversed 9.14T7vrt79 activity at a molar ratio of aptamer to antidote as low as 1:2 (Figure 14). Durable reversal of aptamer was demonstrated *in vivo* in a venous model of bleeding (Figure 9A and 9B).[13, 16] At a dose of 0.375 mg/kg of aptamer, no clotting occurred; however administration of ten-fold molar excess of antidote oligonucleotide reversed the aptamer and restored normal hemostasis. The ability to completely and rapidly reverse such a potent antiplatelet agent by a matched antidote agent represents a significant step forward in developing safer potent parenteral anti-platelet drugs to treat thrombosis and particularly acute ischemic stroke.

References

1. Adams HP, Jr. Stroke: a vascular pathology with inadequate management. *J Hypertens Suppl*. 2003;21:S3-7.

2. Tissue Plasminogen Activator for Acute Ischemic Stroke. *New England Journal of Medicine*. 1995;333:1581-1588.

3. Lansberg MG, Bluhmki E and Thijs VN. Efficacy and safety of tissue plasminogen activator 3 to 4.5 hours after acute ischemic stroke: a metaanalysis. *Stroke*. 2009;40:2438-41.

4. Hoffman M and Monroe DM, 3rd. A cell-based model of hemostasis. *Thrombosis and haemostasis*. 2001;85:958-65.

5. Leebeek FW and Eikenboom JC. Von Willebrand's Disease. *The New England journal of medicine*. 2016;375:2067-2080.

6. Sanders YV, Eikenboom J, de Wee EM, van der Bom JG, Cnossen MH, Degenaar-Dujardin ME, Fijnvandraat K, Kamphuisen PW, Laros-van Gorkom BA, Meijer K, Mauser-Bunschoten EP, Leebeek FW and Wi NSG. Reduced prevalence of arterial thrombosis in von Willebrand disease. *Journal of thrombosis and haemostasis : JTH*. 2013;11:845-54.

7. Nimjee SM, Rusconi CP and Sullenger BA. Aptamers: an emerging class of therapeutics. *Annual review of medicine*. 2005;56:555-83.

8. Nimjee SM, Rusconi CP, Harrington RA and Sullenger BA. The potential of aptamers as anticoagulants. *Trends in cardiovascular medicine*. 2005;15:41-5.

9. Nimjee SM, Oney S, Volovyk Z, Bompiani KM, Long SB, Hoffman M and Sullenger BA. Synergistic effect of aptamers that inhibit exosites 1 and 2 on thrombin. *Rna*. 2009;15:2105-11.

10. Rusconi CP, Roberts JD, Pitoc GA, Nimjee SM, White RR, Quick G, Jr., Scardino E, Fay WP and Sullenger BA. Antidote-mediated control of an anticoagulant aptamer in vivo. *Nature biotechnology*. 2004;22:1423-8.

11. Rusconi CP, Scardino E, Layzer J, Pitoc GA, Ortel TL, Monroe D and Sullenger BA. RNA aptamers as reversible antagonists of coagulation factor IXa. *Nature*. 2002;419:90-4.

12. Oney S, Nimjee SM, Layzer J, Que-Gewirth N, Ginsburg D, Becker RC, Arepally G and Sullenger BA. Antidote-controlled platelet inhibition targeting von Willebrand factor with aptamers. *Oligonucleotides*. 2007;17:265-74.

13. Nimjee SM, Lohrmann JD, Wang H, Snyder DJ, Cummings TJ, Becker RC, Oney S and Sullenger BA. Rapidly regulating platelet activity in vivo with an antidote controlled platelet inhibitor. *Molecular therapy : the journal of the American Society of Gene Therapy*. 2012;20:391-7.

14. Ortel TL, James AH, Thames EH, Moore KD and Greenberg CS. Assessment of primary hemostasis by PFA-100 analysis in a tertiary care center. *Thrombosis and haemostasis*. 2000;84:93-7.

15. Daidone V, Barbon G, Cattini MG, Pontara E, Romualdi C, Di Pasquale I, Hosokawa K and Casonato A. Usefulness of the Total Thrombus-Formation Analysis System (T-TAS) in the diagnosis and characterization of von Willebrand disease. *Haemophilia : the official journal of the World Federation of Hemophilia*. 2016;22:949-956.

16. Monroe DM and Hoffman M. A mouse bleeding model to study oral anticoagulants. *Thrombosis research*. 2014;133 Suppl 1:S6-8.

17. Orset C, Macrez R, Young AR, Panthou D, Angles-Cano E, Maubert E, Agin V and Vivien D. Mouse model of in situ thromboembolic stroke and reperfusion. *Stroke*. 2007;38:2771-8.

18. Yamaguchi Y, Moriki T, Igari A, Matsubara Y, Ohnishi T, Hosokawa K and Murata M. Studies of a microchip flow-chamber system to characterize whole blood thrombogenicity in healthy individuals. *Thrombosis research*. 2013;132:263-70.

19. Nimjee SM, White RR, Becker RC and Sullenger BA. Aptamers as Therapeutics. *Annual review of pharmacology and toxicology*. 2017;57:61-79.

20. Zheng Y, Chen J and Lopez JA. Flow-driven assembly of VWF fibres and webs in in vitro microvessels. *Nature communications*. 2015;6:7858.

21. Topol EJ. Novel antithrombotic approaches to coronary artery disease. *The American journal of cardiology*. 1995;75:27B-33B.

22. Ciccone A, Motto C, Abraha I, Cozzolino F and Santilli I. Glycoprotein IIb-IIIa inhibitors for acute ischaemic stroke. *The Cochrane database of systematic reviews*. 2014;3:CD005208.

23. Markus HS, McCollum C, Imray C, Goulder MA, Gilbert J and King A. The von Willebrand inhibitor ARC1779 reduces cerebral embolization after carotid endarterectomy: a randomized trial. *Stroke*. 2011;42:2149-53.

24. Diaz JA, Wrobleski SK, Alvarado CM, Hawley AE, Doornbos NK, Lester PA, Lowe SE, Gabriel JE, Roelofs KJ, Henke PK, Schaub RG, Wakefield TW and Myers DD, Jr. P-selectin inhibition therapeutically promotes thrombus resolution and prevents vein wall fibrosis better than enoxaparin and an inhibitor to von Willebrand factor. *Arteriosclerosis, thrombosis, and vascular biology*. 2015;35:829-37.

CLAIMS

We claim:

1. An aptamer comprising

a polynucleotide having at least 70% sequence identity to SEQ ID NO: 1 and SEQ ID NO: 2, or any one of SEQ ID NOS: 3-102, or

a polynucleotide having at least 70% sequence identity to a polynucleotide comprising from 5' to 3' a first stem forming region comprising 3 nucleotides, a first loop region comprising the nucleotide sequence AAC, a second stem forming region comprising 3 nucleotides, a second loop region comprising the nucleotide sequence CC, a third stem forming region consisting of 2-8 nucleotides, a third loop region consisting of 1-12 nucleotides or a spacer sequence, a fourth stem forming region consisting of 2-8 nucleotides and capable of forming a stem with the third stem forming region, a fourth loop region comprising the nucleotide C, a fifth stem forming region comprising 3 nucleotides and capable of forming a stem with the second stem forming region, a fifth loop region comprising the nucleotide sequence CAGA, and a sixth stem forming region comprising 3 nucleotides and capable of forming a stem with the first stem forming region,

wherein the polynucleotide comprises an unmodified form or comprises a modified form comprising at least one nucleotide base modification, and

wherein the aptamer is no more than 53 nucleotides in length.

2. The aptamer of any one of the preceding claims, wherein the aptamer comprises a polynucleotide having at least 70% sequence identity to a polynucleotide comprising from 5' to 3' SEQ ID NO: 1, a variable nucleotide sequence consisting of 1-18 nucleotides or a spacer sequence, and SEQ ID NO: 2.

3. The aptamer of any one of the preceding claims, wherein the aptamer comprises a polynucleotide having at least 90% sequence identity to any one of SEQ ID NOS: 3-6.

4. The aptamer of any one of the preceding claims, wherein the dissociation constant (K_D) of the aptamer for the human VWF protein is less than 100 nanomolar (nM).

5. The aptamer of any one of the preceding claims, further comprising a tail nucleotide sequence at the 5' end or the 3' end of the polynucleotide which is not capable of base

pairing with 3 or more consecutive nucleotides in the polynucleotide, wherein the tail nucleotide sequence consists of 2-12 nucleotides.

6. The aptamer of claim 5, wherein the tail nucleotide sequence is at the 3' end of the polynucleotide and consists of the nucleotide sequence (U/T)(U/T)(U/T)(U/T)(U/T).

7. The aptamer of any one of the preceding claims, wherein the aptamer is no more than 39 nucleotides in length.

8. The aptamer of any one of the preceding claims, wherein the polynucleotide comprises an RNA polynucleotide.

9. The aptamer of any one of the preceding claims, wherein the polynucleotide comprises a modified form comprising at least one nucleotide base modification selected from the group consisting of a 2'fluoro modification, a 2'O-methyl modification, a 5' modification, and a 3'modification.

10. The aptamer of any one of the preceding claims, wherein the aptamer comprises SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9.

11. The aptamer of any one of the preceding claims, wherein the polynucleotide comprises a 5' linker and/or a 3' linker.

12. The aptamer of any one of the preceding claims, wherein the polynucleotide further comprises a stability agent.

13. The aptamer of claim 12, wherein the stability agent is selected from the group consisting of polyethylene glycol (PEG), cholesterol, albumin, and Elastin-like polypeptide.

14. The aptamer of any one of claims 12-13, wherein the stability agent is linked to the 5' end of the polynucleotide.

15. The aptamer of any one of claims 12-14, wherein the polynucleotide and the stability agent are linked by a covalent bond.

16. The aptamer of any one of claims 12-15, wherein the polynucleotide and the stability agent are linked by a tag system.

17. The aptamer of any one of claims 12-16, wherein the tag system is selected from the group consisting of biotin/avidin, biotin/streptavidin, and biotin/NeutrAvidin.

18. A dimer, trimer, or tetramer comprising any one of the aptamers of claims 1-17.

19. An antidote comprising a polynucleotide having at least 70% sequence identity to any one of SEQ ID NOS: 103-180.

20. An antidote comprising a polynucleotide having sequence reverse complementary to and capable of hybridizing to at least 8 nucleotides of any one of the aptamers of claims 1-18.

21. A pharmaceutical composition comprising a pharmaceutical carrier and any one of the compositions of claims 1-18 or the antidotes of claims 19-20.

22. The pharmaceutical composition of claim 21, wherein the pharmaceutical carrier comprises 20 mM Hepes, pH 7.4; 150 mM NaCl; 1 mM CaCl2; 1mM MgCl2; 5 mM KCl or buffered saline.

23. A method for preventing blood clot formation in a subject comprising administering to the subject any one of the compositions of claims 1-18, 21, or 22 in a therapeutically effective amount to prevent blood clot formation in the subject.

24. The method of claim 23, wherein the subject suffers from atrial fibrillation or is at risk of having a Deep Vein Thrombosis, a stroke, a heart attack, or a pulmonary embolism.

25. A method for treating a blood clot in a subject comprising administering to the subject a VWF-targeting agent in a therapeutically effective amount to reduce the blood clot in the subject.

26. The method of claim 25, wherein the VWF-targeting agent comprises an aptamer.

27. The method of claim 26, wherein the VWF-targeting agent comprises any one of the compositions of claims 1-18, 20, or 21.

28. The method of any one of claims 25-27, wherein the subject suffers a Deep Vein Thrombosis, a stroke, a heart attack, or a pulmonary embolism.

29. The method of any one of claims 23-28, further comprising administering to the subject an antidote in a therapeutically effective amount to neutralize the aptamer or the VWF-targeting agent.

30. The method of claim 29, wherein the antidote comprises any one of the antidotes of claims 19-20.

31. Use of the composition of any one of claims 1-22 in the manufacture of a medicament for preventing blood clot formation in a subject.

32. Use of a VWF-targeting agent in the manufacture of a medicament for treating a blood clot in a subject.

33. The method or use of any one of claims 23-32, wherein the subject is a mammal.

34. The method or use of claim 33, wherein the mammal is a human.

Figure 1

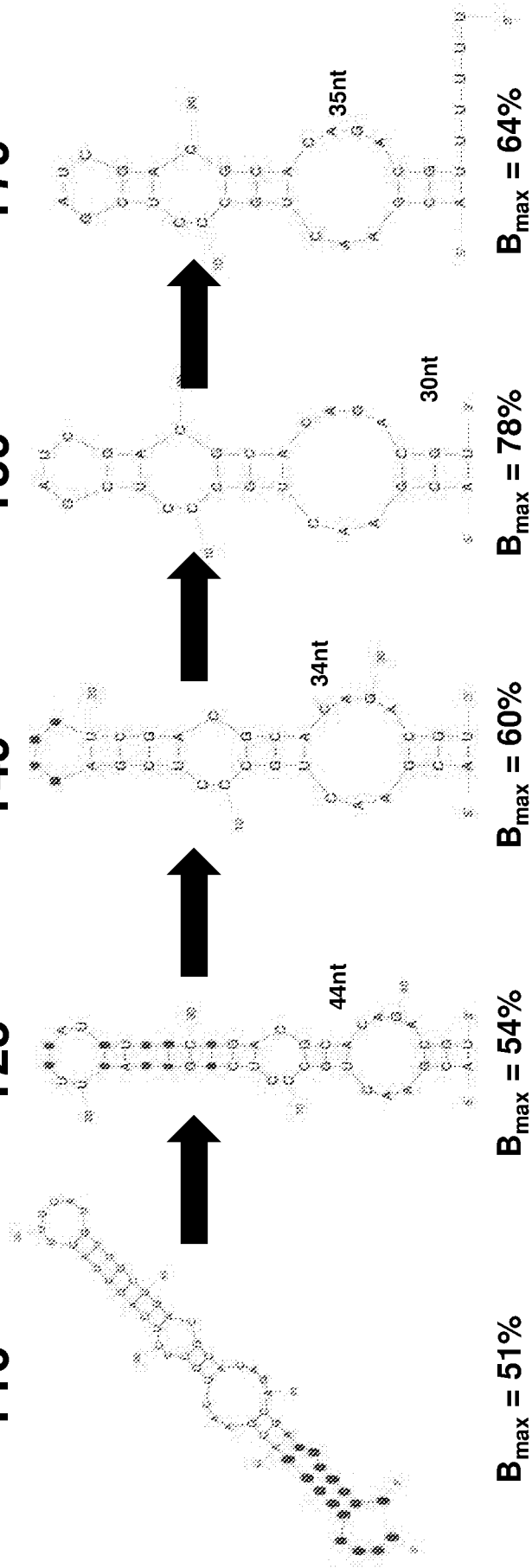
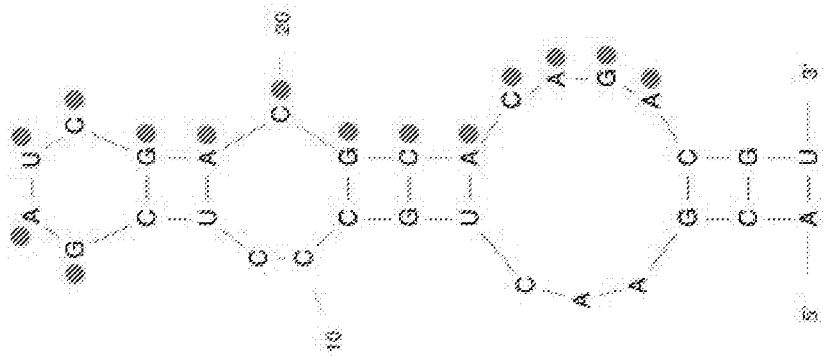

T10
T25
T49
T59
T79
44nt
34nt
30nt
35nt
B_{max} = 51%
K_d = 18.4nM
SEQ ID NO: 11
B_{max} = 54%
K_d = 13.4nM
SEQ ID NO: 6
B_{max} = 60%
K_d = 10.5nM
SEQ ID NO: 5
B_{max} = 78%
K_d = 8.8nM
SEQ ID NO: 4
B_{max} = 64%
K_d = 1.6nM
SEQ ID NO: 3

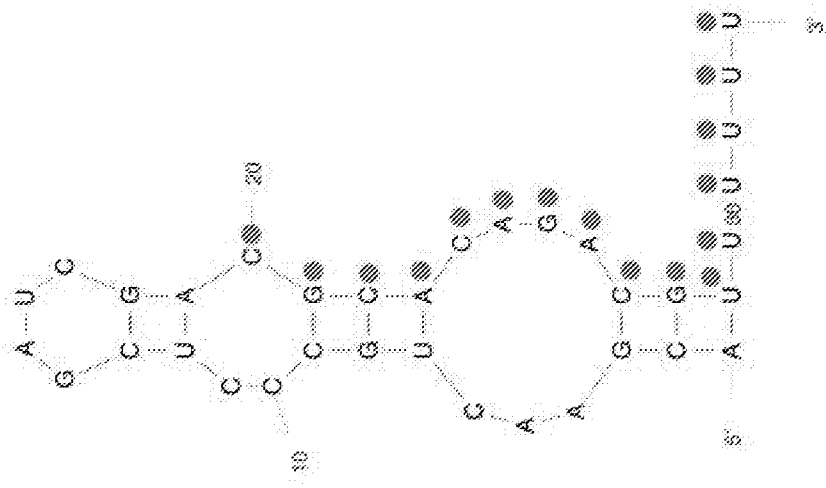
Figure 2

T59; SEQ ID NO: 4



Dots: Antidote: AO11; SEQ ID NO: 113

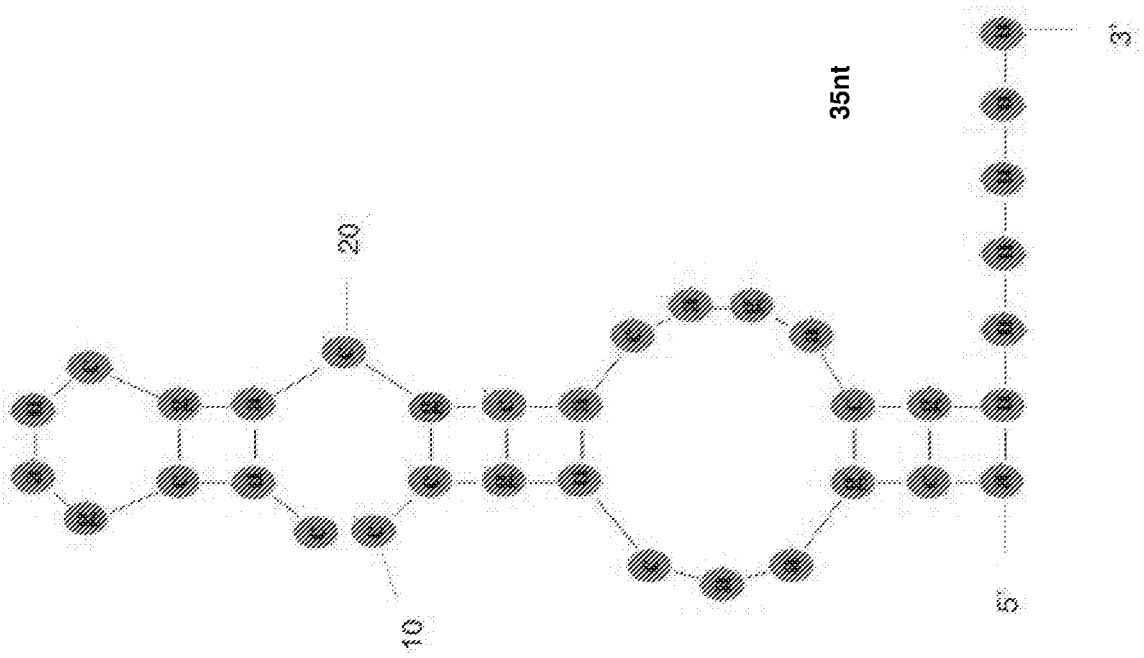
T79; SEQ ID NO: 3



Dots: Antidote: AO55; SEQ ID NO: 157

Figure 3

T79 VRT7; SEQ ID NO: 7



B_{max} = 56%
K_d = 11.2nM

Figure 4

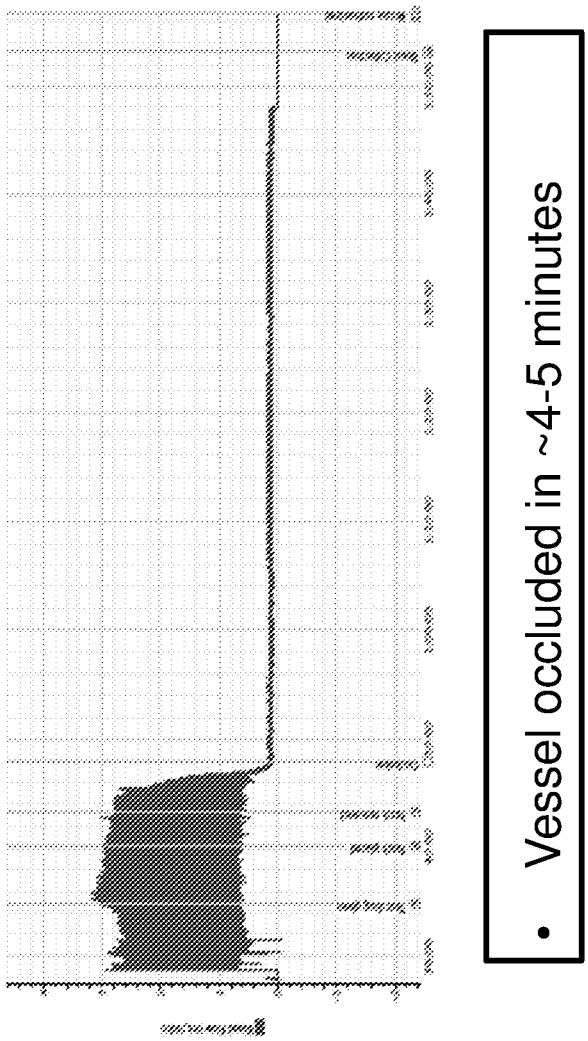


Figure 5

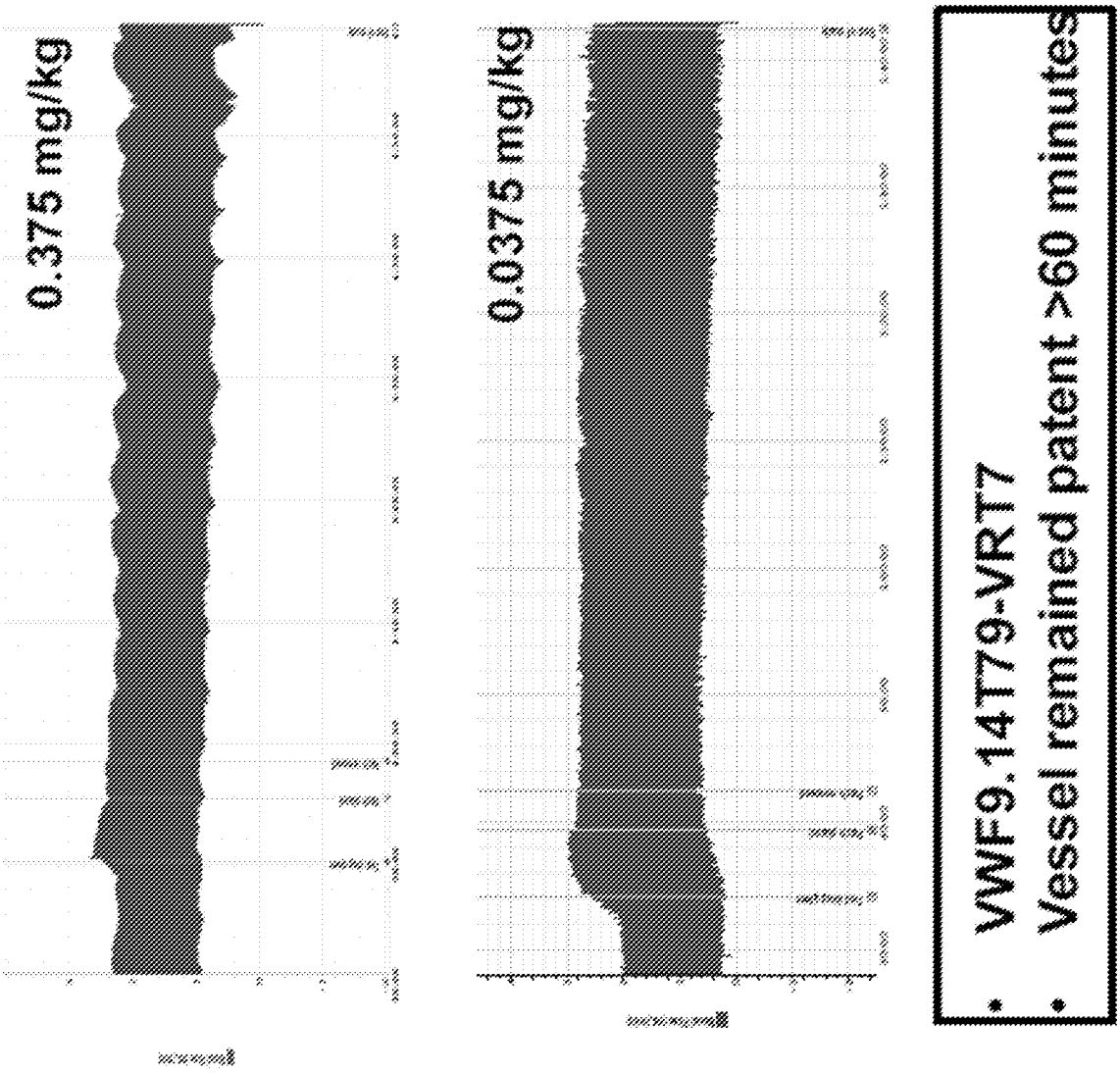

0.375 mg/kg
0.0375 mg/kg
VWF9.14T79-VRT7
Vessel remained patent >60 minutes

Figure 6

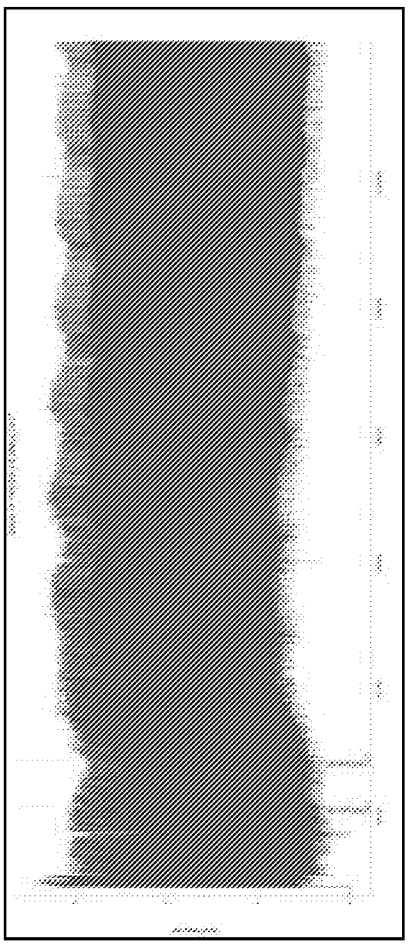
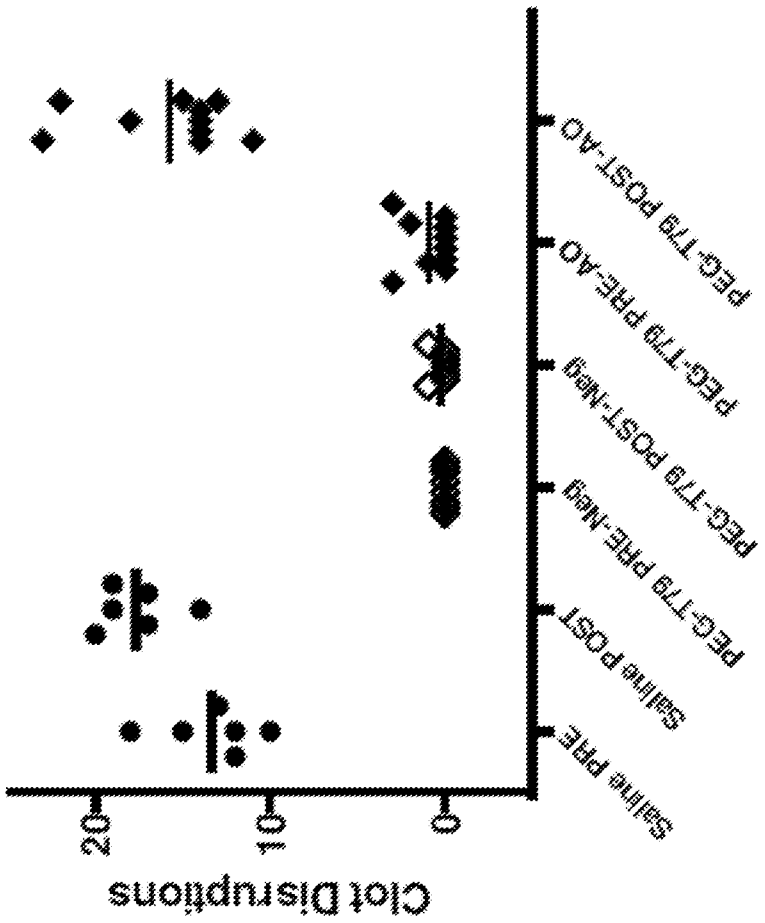


Figure 7

Figure 8


Clot Disruptions
20
10
0
Saline PRE
Saline POST
PEG-TF9 PRE-Aep
PEG-TF9 POST-Aep
PEG-TF9 PRE-AO
PEG-TF9 POST-AO

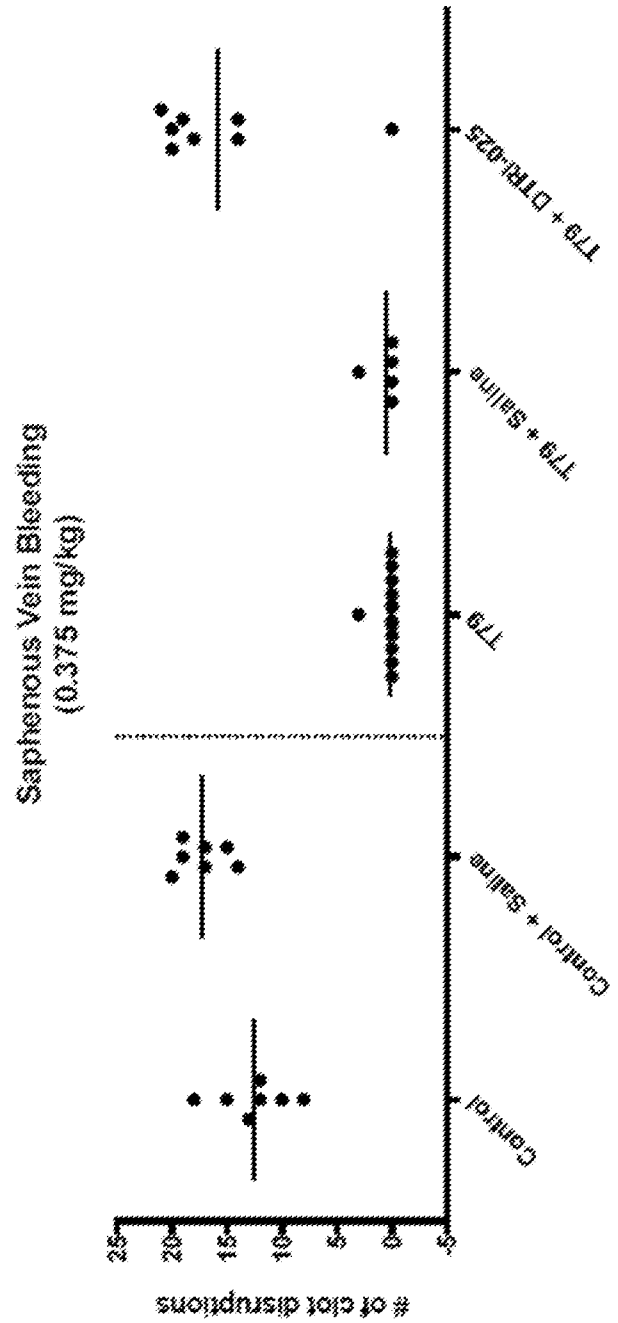


Figure 9A

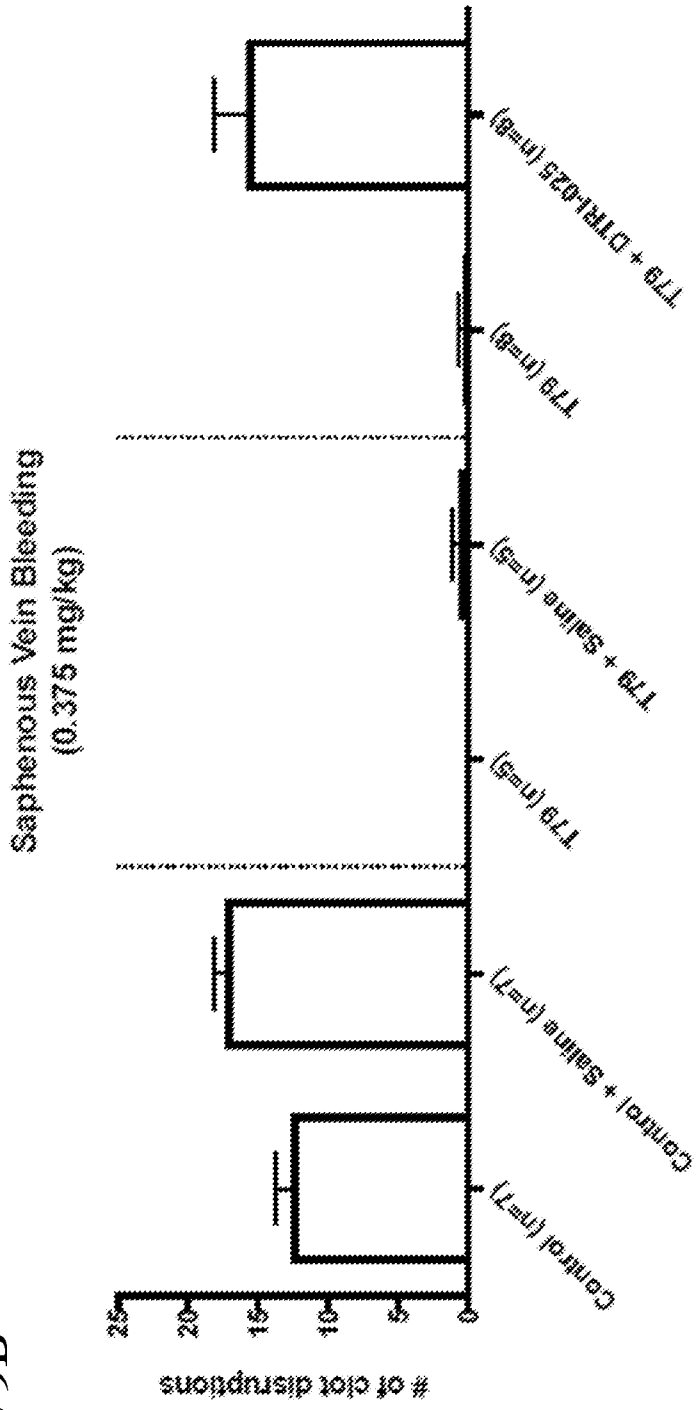


Figure 9B

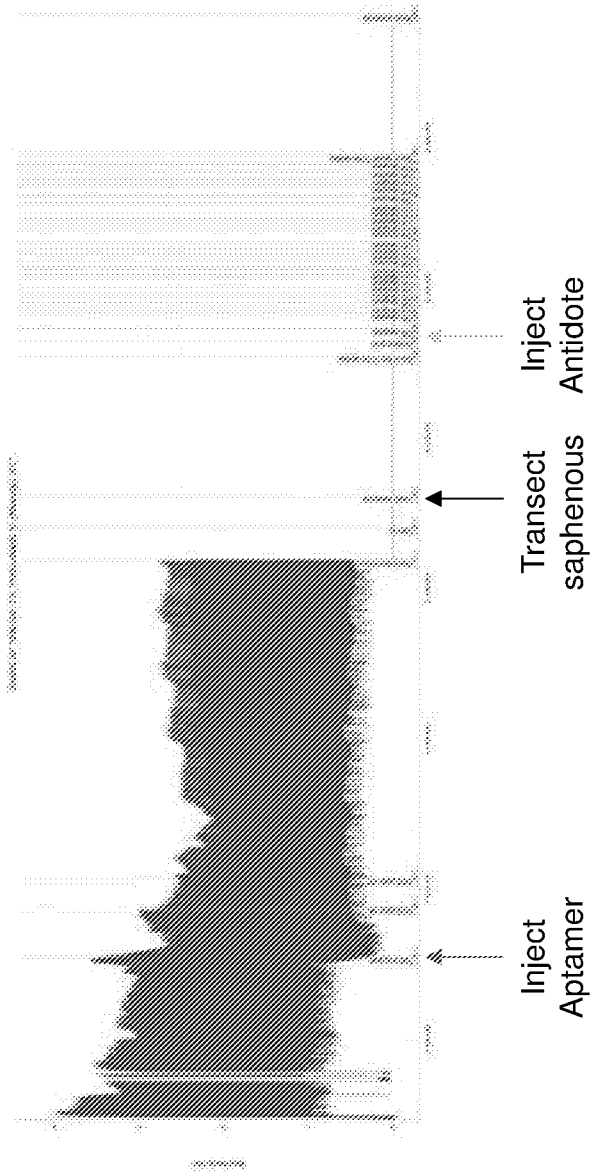


Figure 10

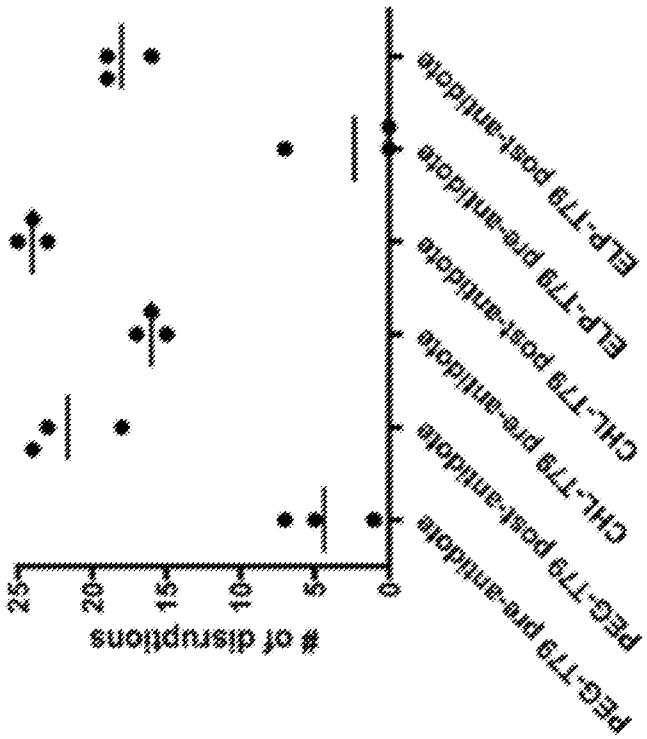
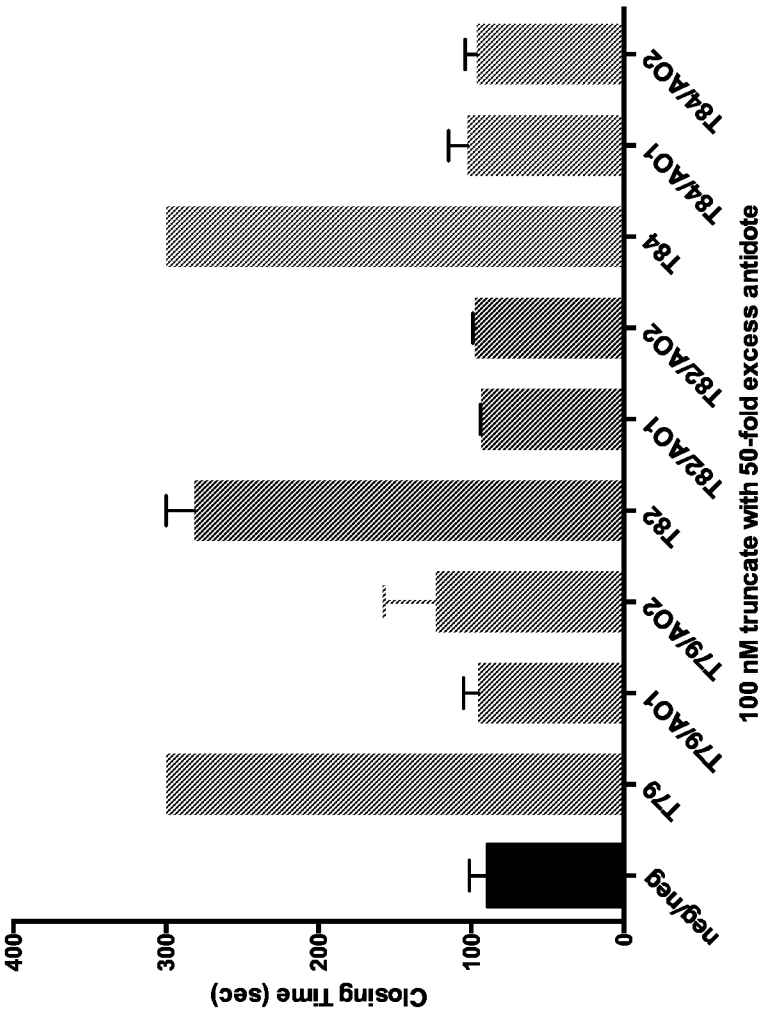


Figure 11

Figure 12


PFA
Closing Time (sec)
0
100
200
300
400
neg/neg
T79
T79/AO1
T79/AO2
T82
T82/AO1
T82/AO2
T84
T84/AO1
T84/AO2
100 nM truncate with 50-fold excess antidote

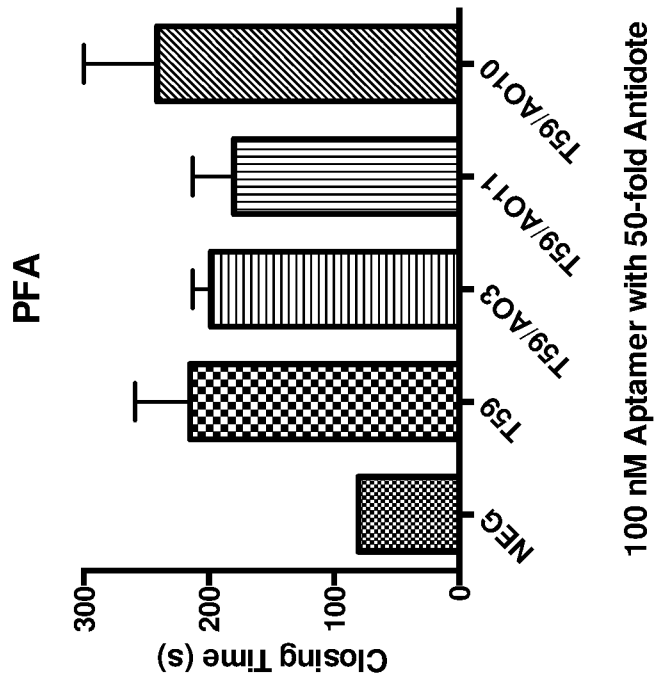

PFA
Closing Time (s)
0
100
200
300
NEG
T59
T59/AO3
T59/AO11
T59/AO10
100 nM Aptamer with 50-fold Antidote

Figure 13

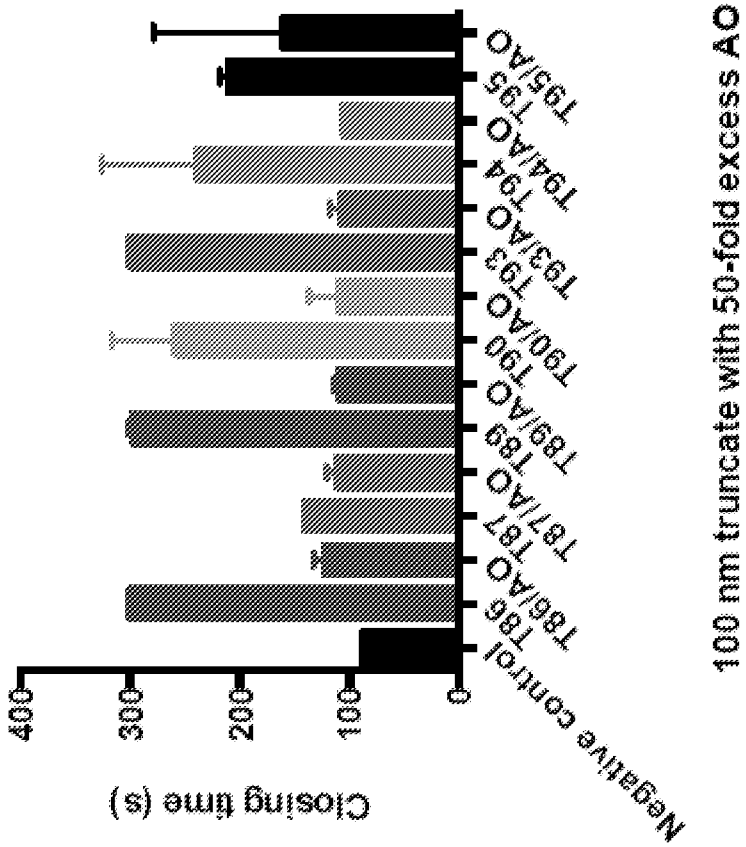
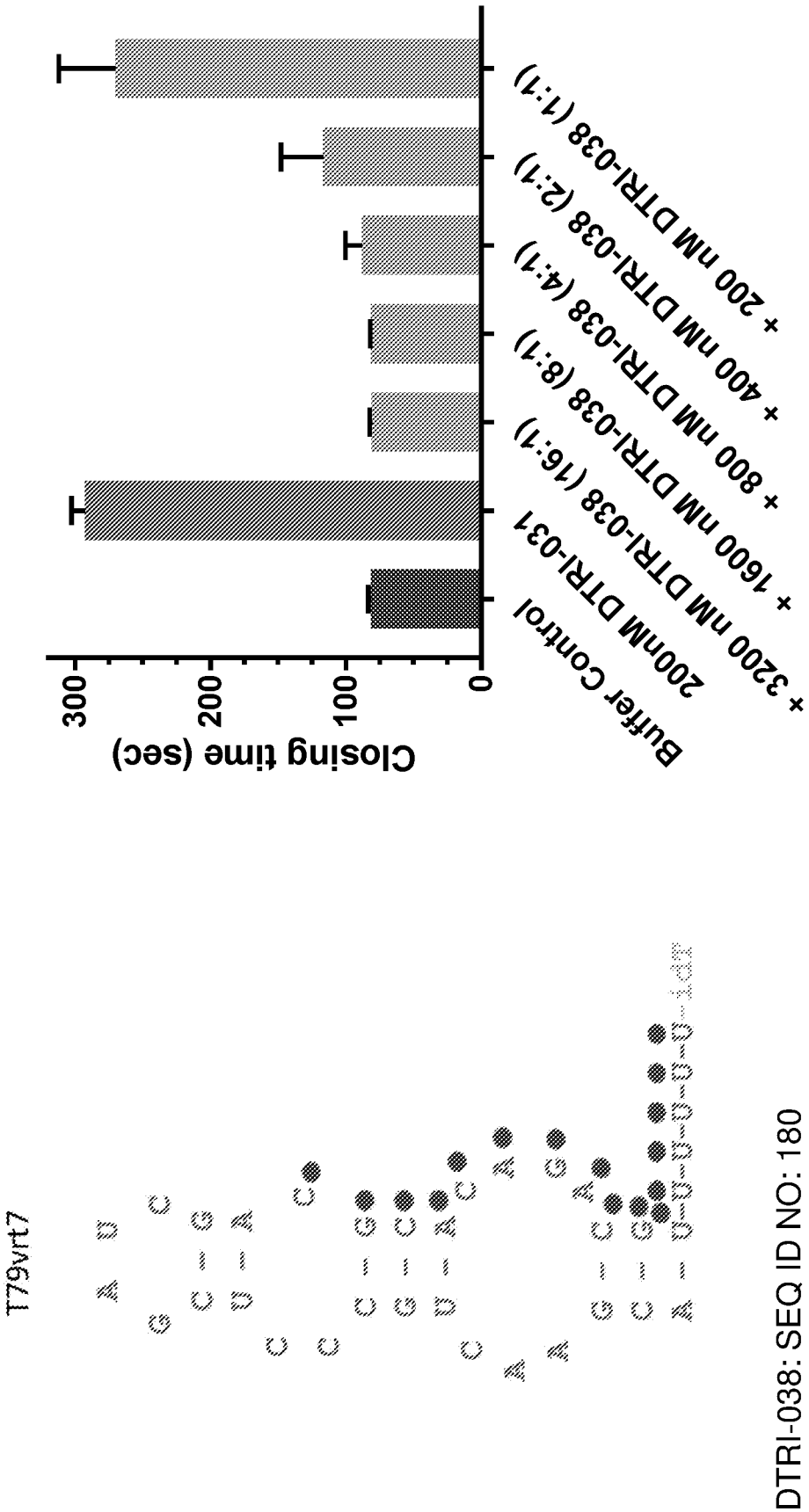

100 nm truncate with 50-fold excess AO
Negative control
T86
T86/AO
T87
T87/AO
T89
T89/AO
T90
T90/AO
T93
T93/AO
T94
T94/AO
T95
T95/AO
Closing time (s)
0
100
200
300
400

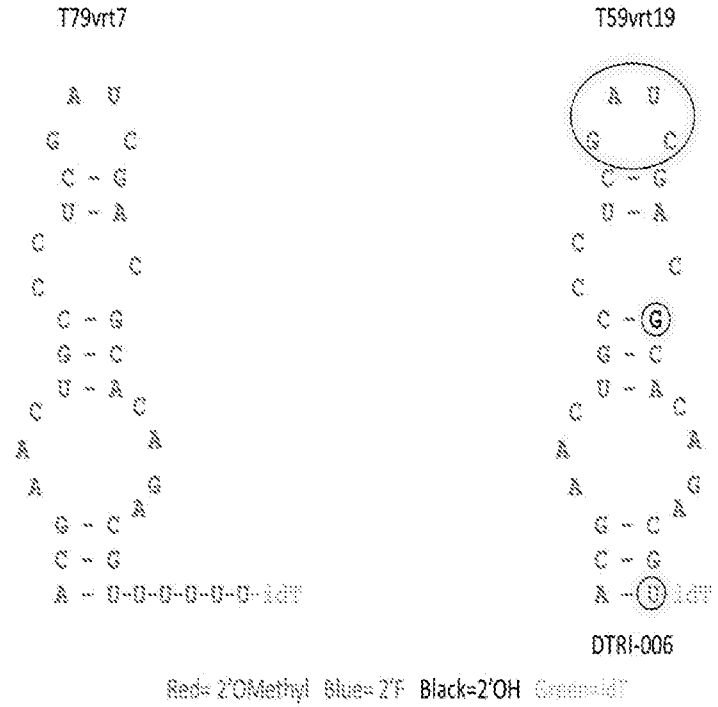
Figure 14



DTRI-038: SEQ ID NO: 180

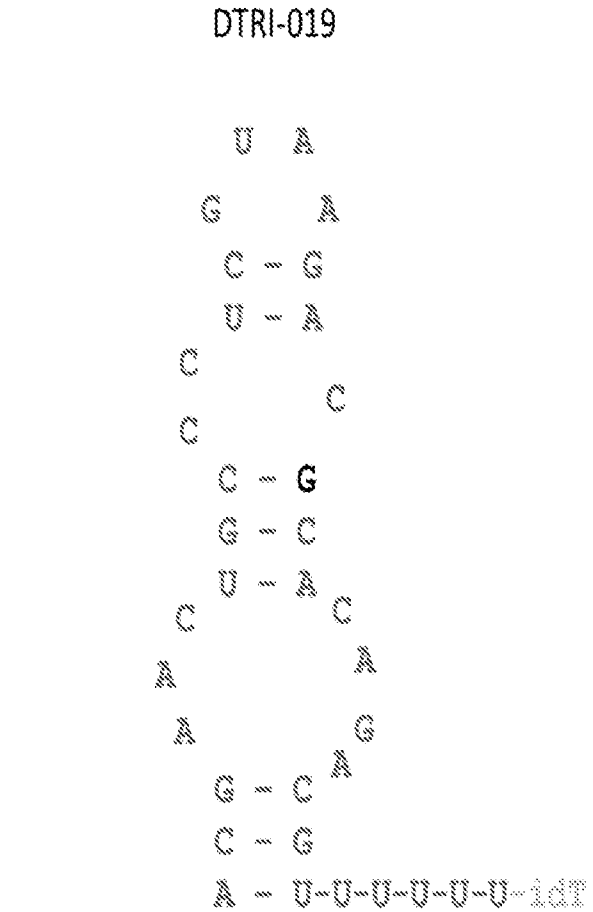
5' mAmAmAmAmAmCmGmUmCmUmGmUmGmCmG 3'

Figure 15

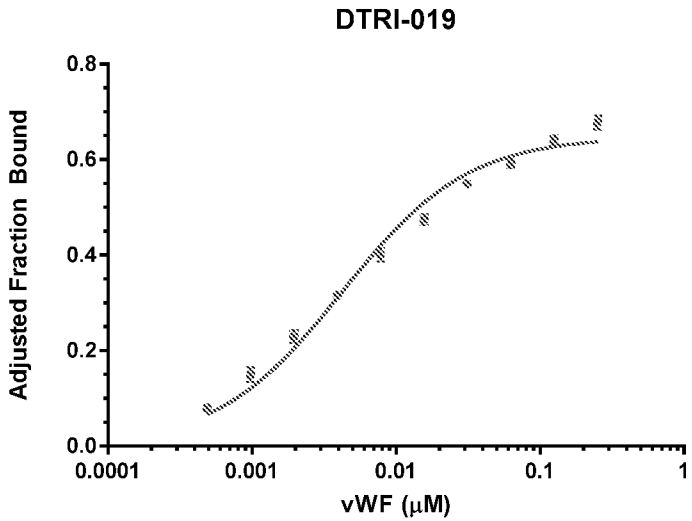


Sequence ID	Target	Description	Sequence
DTRI-006	VWF	T59VRT19	mAmCmGmAmAmCmUmGfCfCfCmUmCmGmAmUmCmGmAfCrGfCmAmCmAmGmAmCmGfUidT
DTRI-007	VWF	DTRI006 S2fG	mAmCmGmAmAmCmUmGfCfCfCmUmCmGmAmUmCmGmAfCfGfCmAmCmAmGmAmCmGfUidT
DTRI-008	VWF	DTRI006 S1mU	mAmCmGmAmAmCmUmGfCfCfCmUmCmGmAmUmCmGmAfCrGfCmAmCmAmGmAmCmGmUidT
DTRI-009	VWF	DTRI006 L3spacer	mAmCmGmAmAmCmUmGfCfCfCmUmC(c6spacer)mGmAfCrGfCmAmCmAmGmAmCmGfUidT
DTRI-010	VWF	DTRI006 S2dG	mAmCmGmAmAmCmUmGfCfCfCmUmCmGmAmUmCmGmAfCdGfCmAmCmAmGmAmCmGfUidT
DTRI-011	VWF	DTRI006 L3 GUAA	mAmCmGmAmAmCmUmGfCfCfCmUmCmGmUmAmAmGmAfCrGfCmAmCmAmGmAmCmGfUidT
DTRI-012	VWF	DTR1011 3'5U tail	mAmCmGmAmAmCmUmGfCfCfCmUmCmGmUmAmAmGmAfCrGfCmAmCmAmGmAmCmGfUmUmUmUmUidT
DTRI-013	VWF	DTRI006 s1 b1 sub	mCmCmGmAmAmCmUmGfCfCfCmUmCmGmAmUmCmGmAfCrGfCmAmCmAmGmAmCmGmGidT

Figure 16

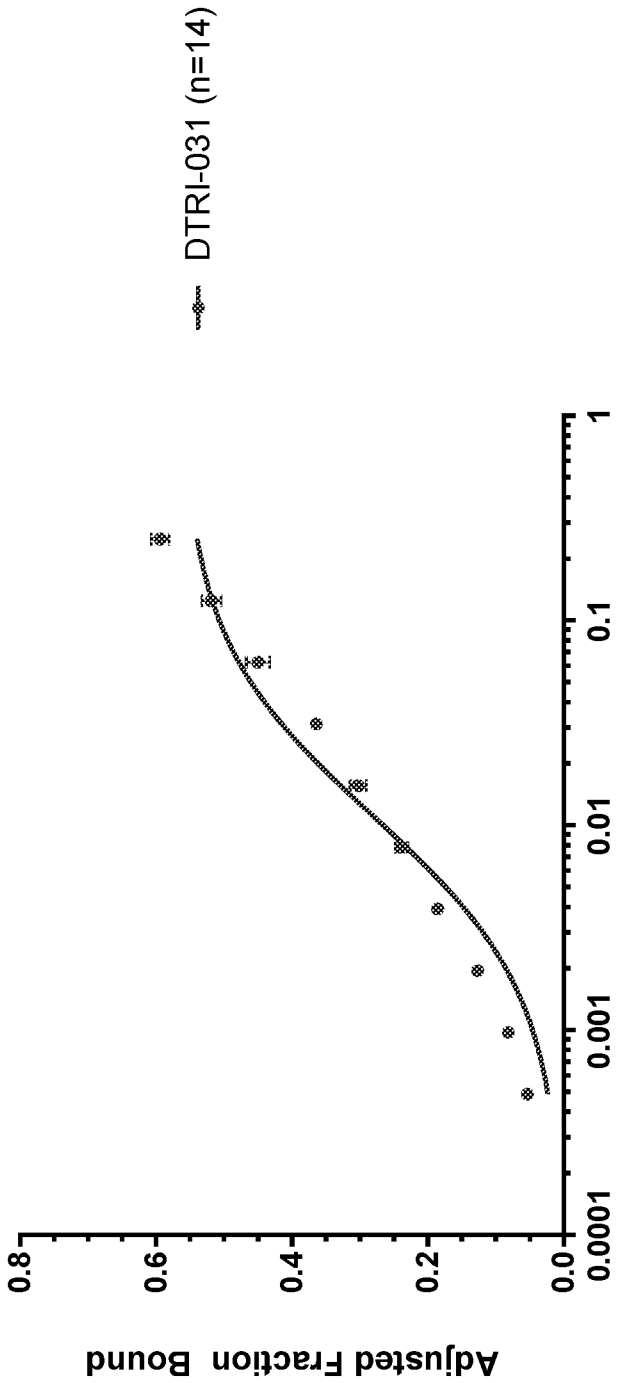


Red= 2'OMethyl Blue= 2'F Black=2'OH Green=idT



One site binding (hyperbola)	
Best-fit values	
Bmax	0.6483
Kd	0.004258

Figure 17



One site binding (hyperbola)	
Best-fit values	
Bmax	0.5639
Kd	0.01119

Figure 18

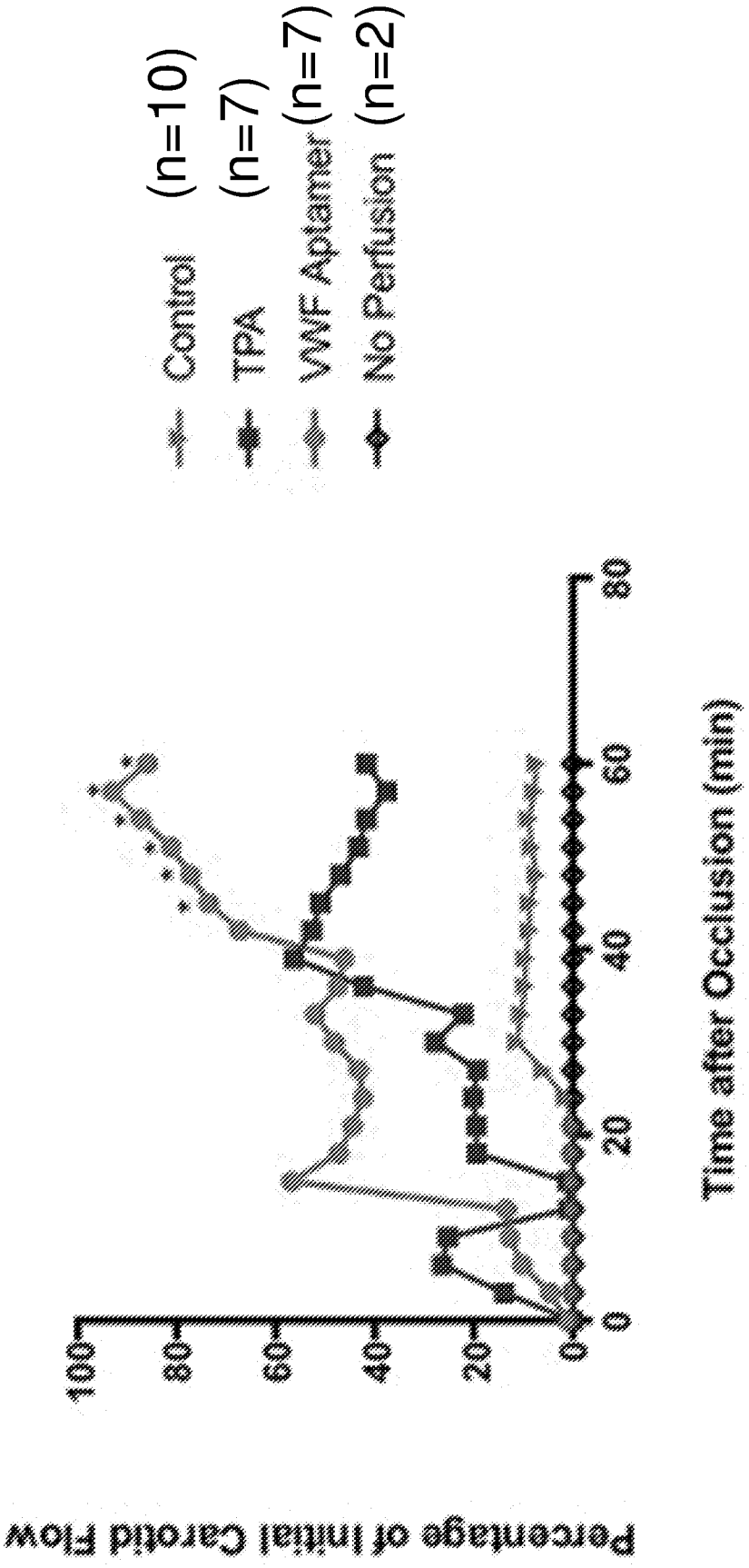

Control (n=10)
TPA (n=7)
VWF Aptamer (n=7)
No Perfusion (n=2)
Percentage of Initial Carotid Flow
100
80
60
40
20
0
0
20
40
60
80
Time after Occlusion (min)

Figure 19

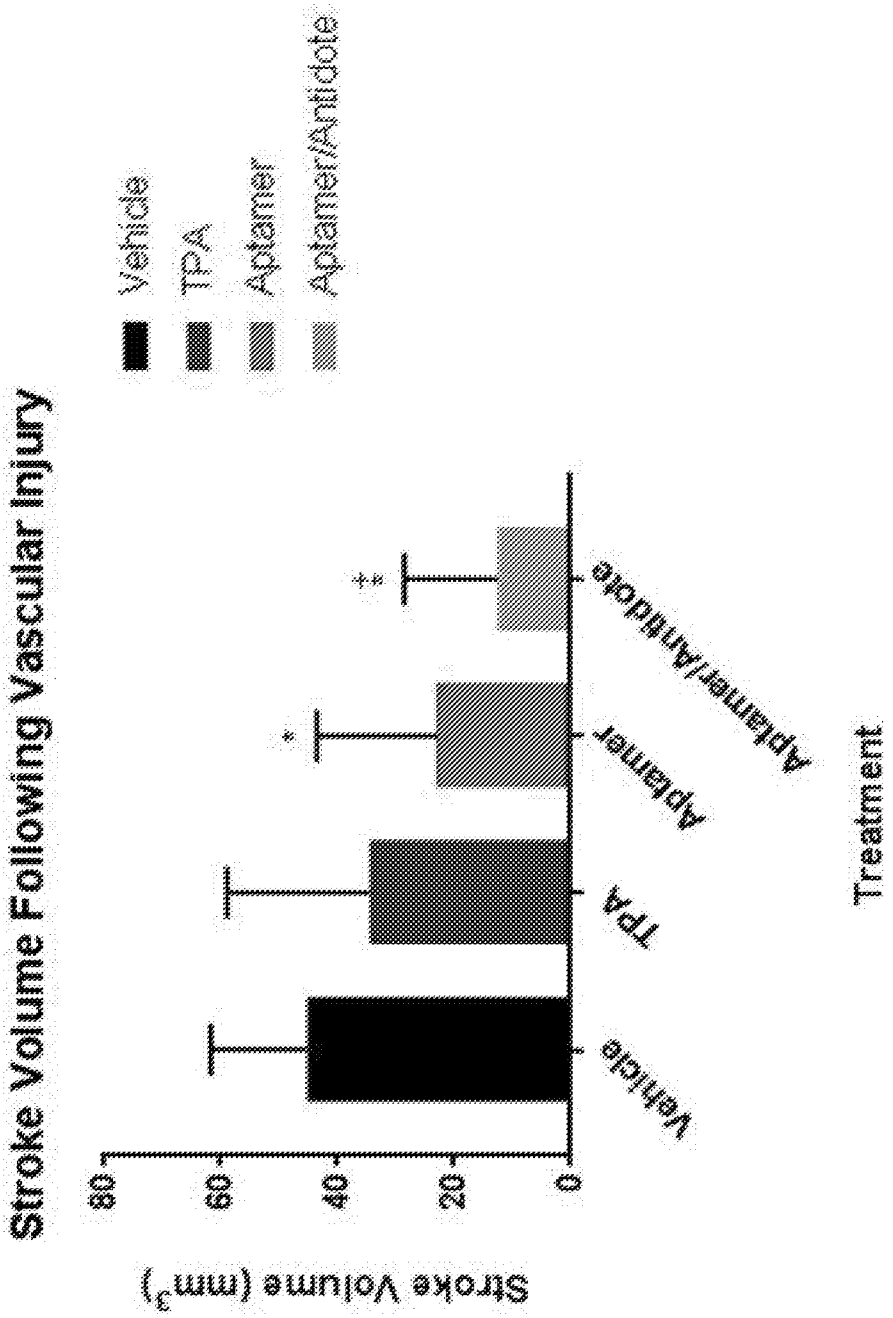

Stroke Volume Following Vascular Injury
Vehicle
TPA
Aptamer
Aptamer/Antidote
Stroke Volume (mm3)
80
60
40
20
0
*
**
Vehicle
TPA
Aptamer
Aptamer/Antidote
Treatment

Figure 20A-E

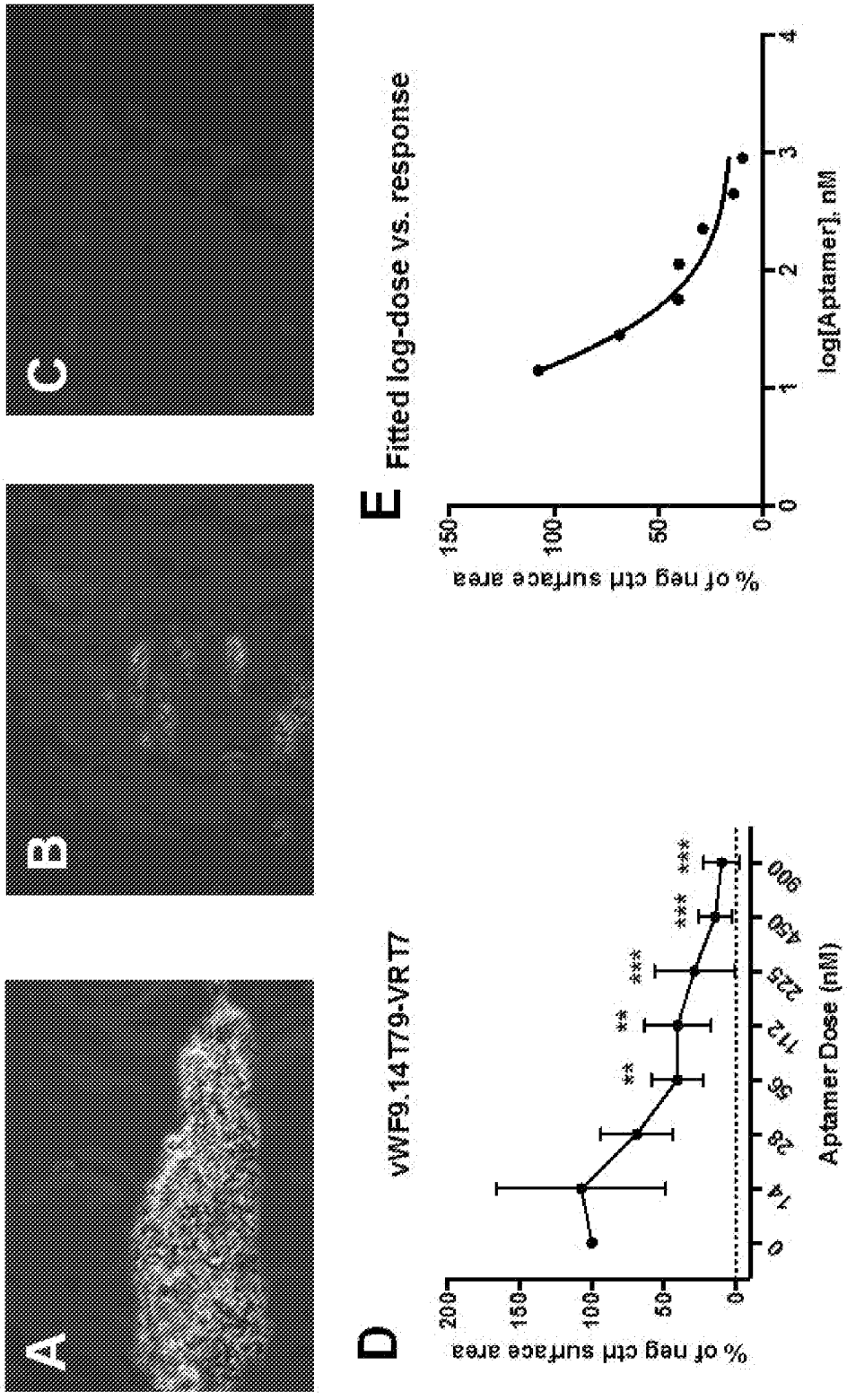

A
Buffer Only
B
56nM
C
900nM
D
vWF9.14T79-VRT7
% of neg ctrl surface area
Aptamer Dose (nM)
E
Fitted log-dose vs. response
% of neg ctrl surface area
log[Aptamer], nM

Figure 21

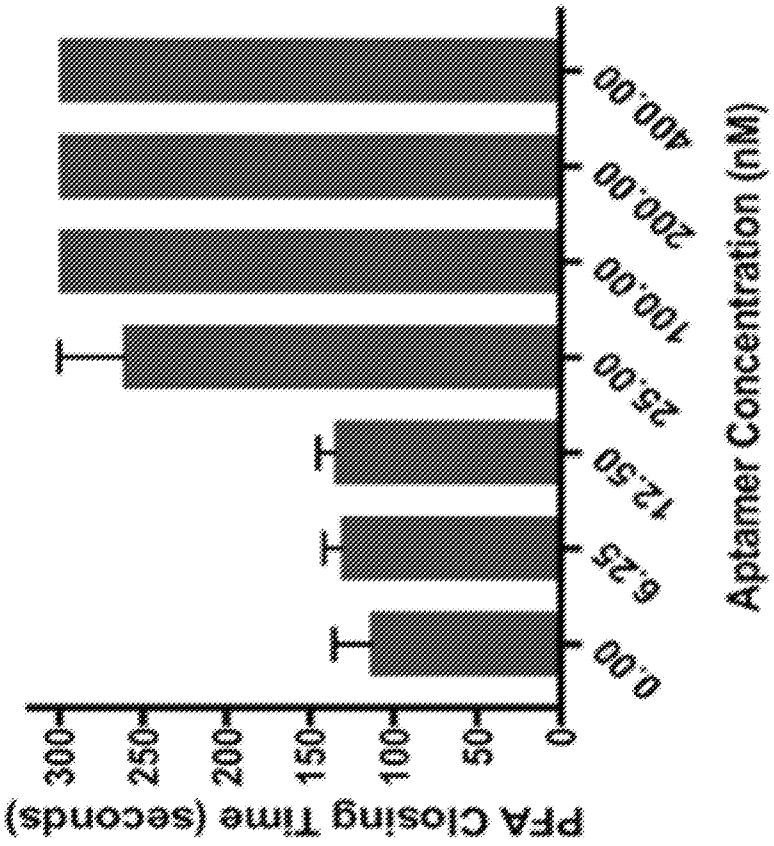

PFA Closing Time (seconds)
300
250
200
150
100
50
0
0.00
6.25
12.50
25.00
100.00
200.00
400.00
Aptamer Concentration (nM)

Figure 22

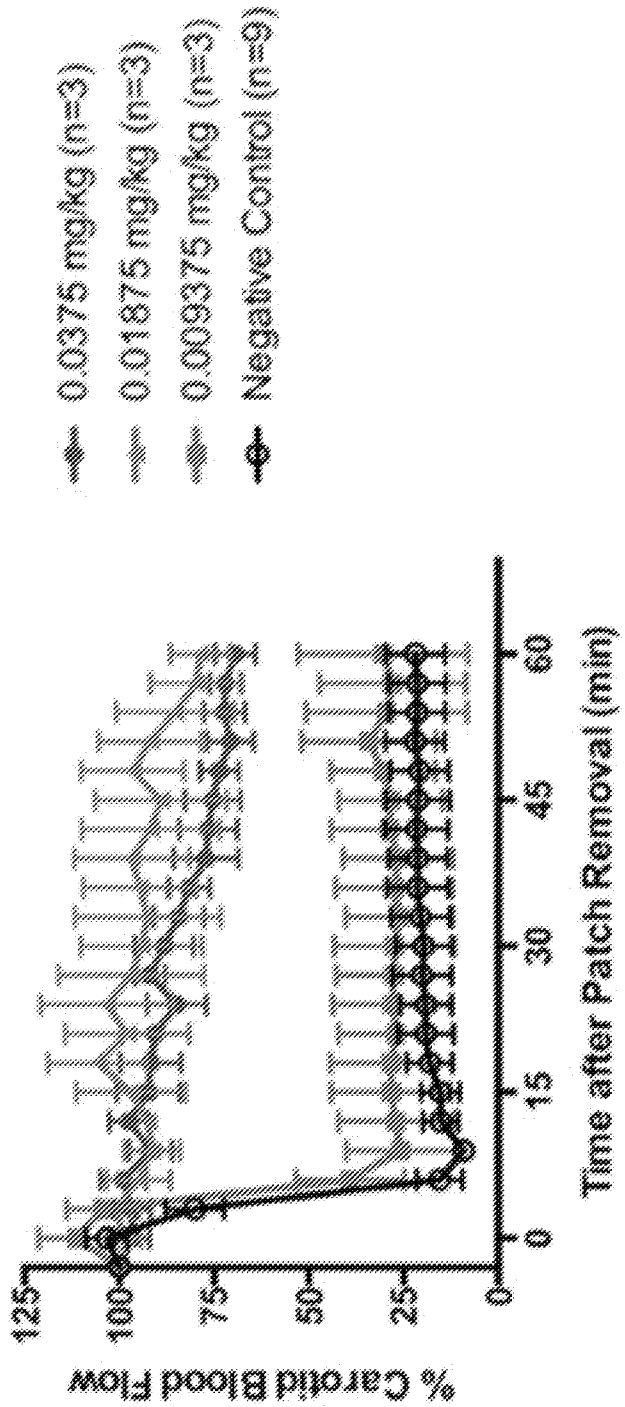

0.0375 mg/kg (n=3)
0.01875 mg/kg (n=3)
0.009375 mg/kg (n=3)
Negative Control (n=9)
% Carotid Blood Flow
125
100
75
50
25
0
0
15
30
45
60
Time after Patch Removal (min)

Figure 23A-D

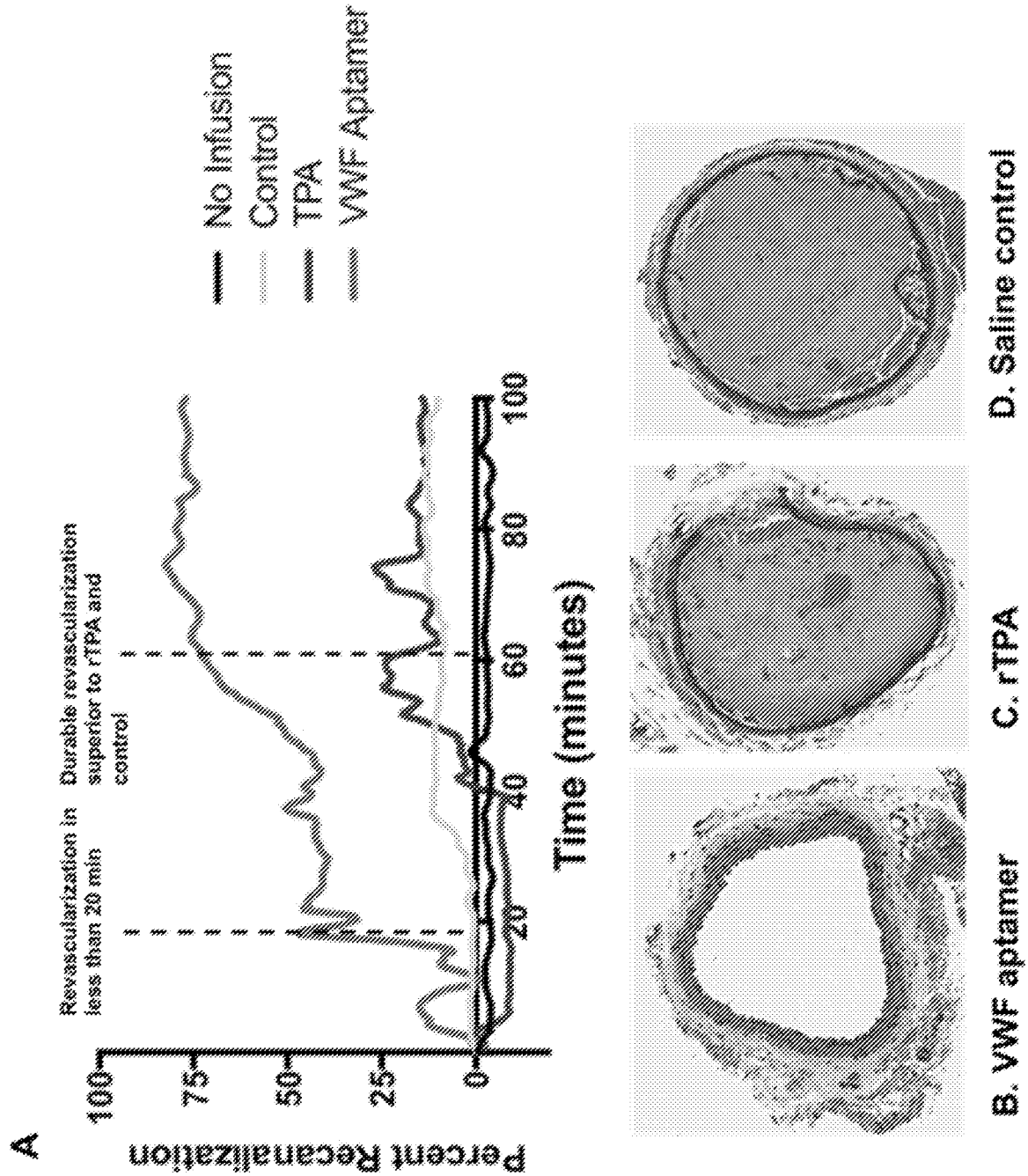

A
Percent Recanalization
100
75
50
25
0
20
40
60
80
100
Time (minutes)
Revascularization in less than 20 min
Durable revascularization superior to rTPA and control
No Infusion
Control
TPA
VWF Aptamer
B. VWF aptamer
C. rTPA
D. Saline control

Figure 24A-B

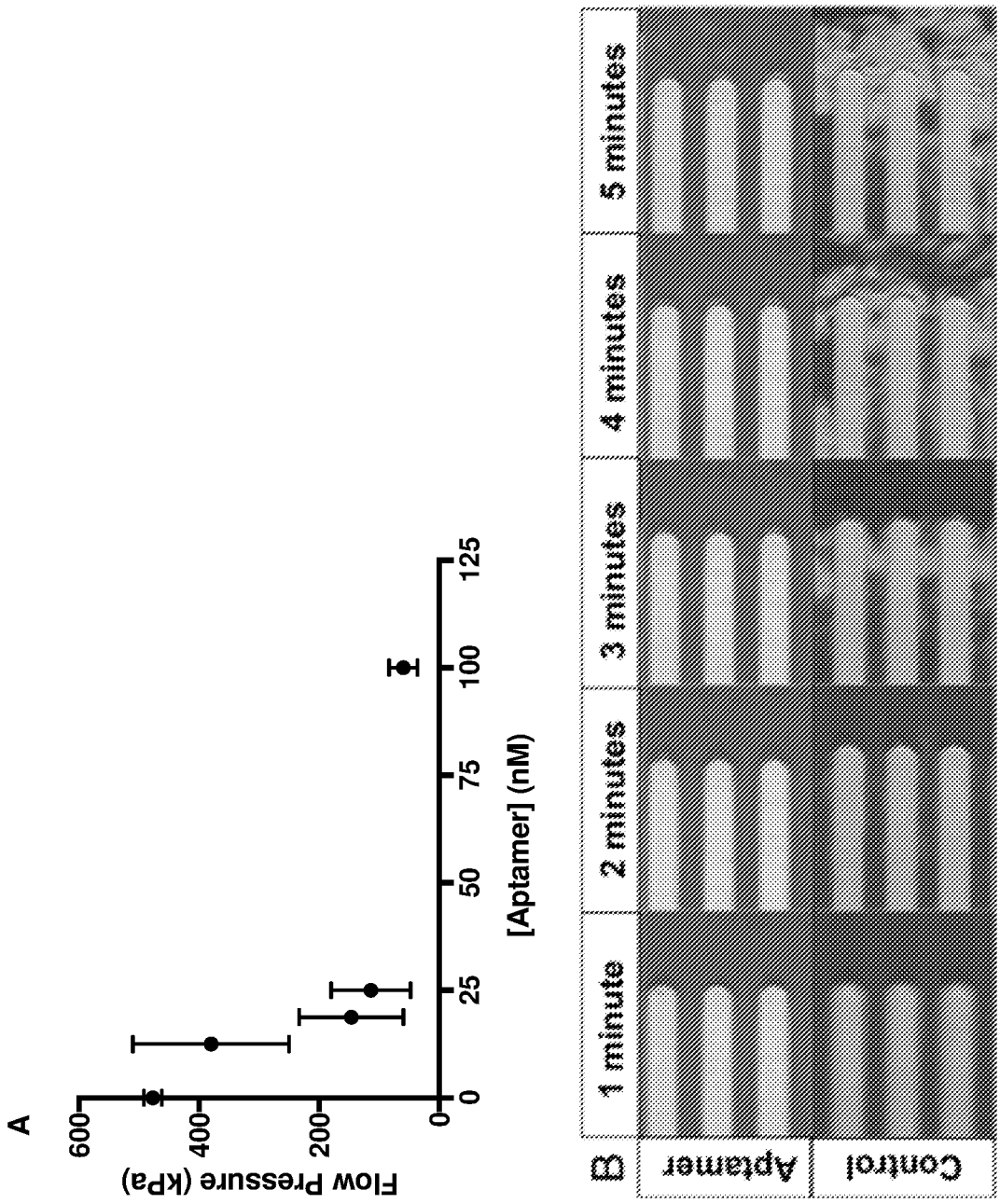
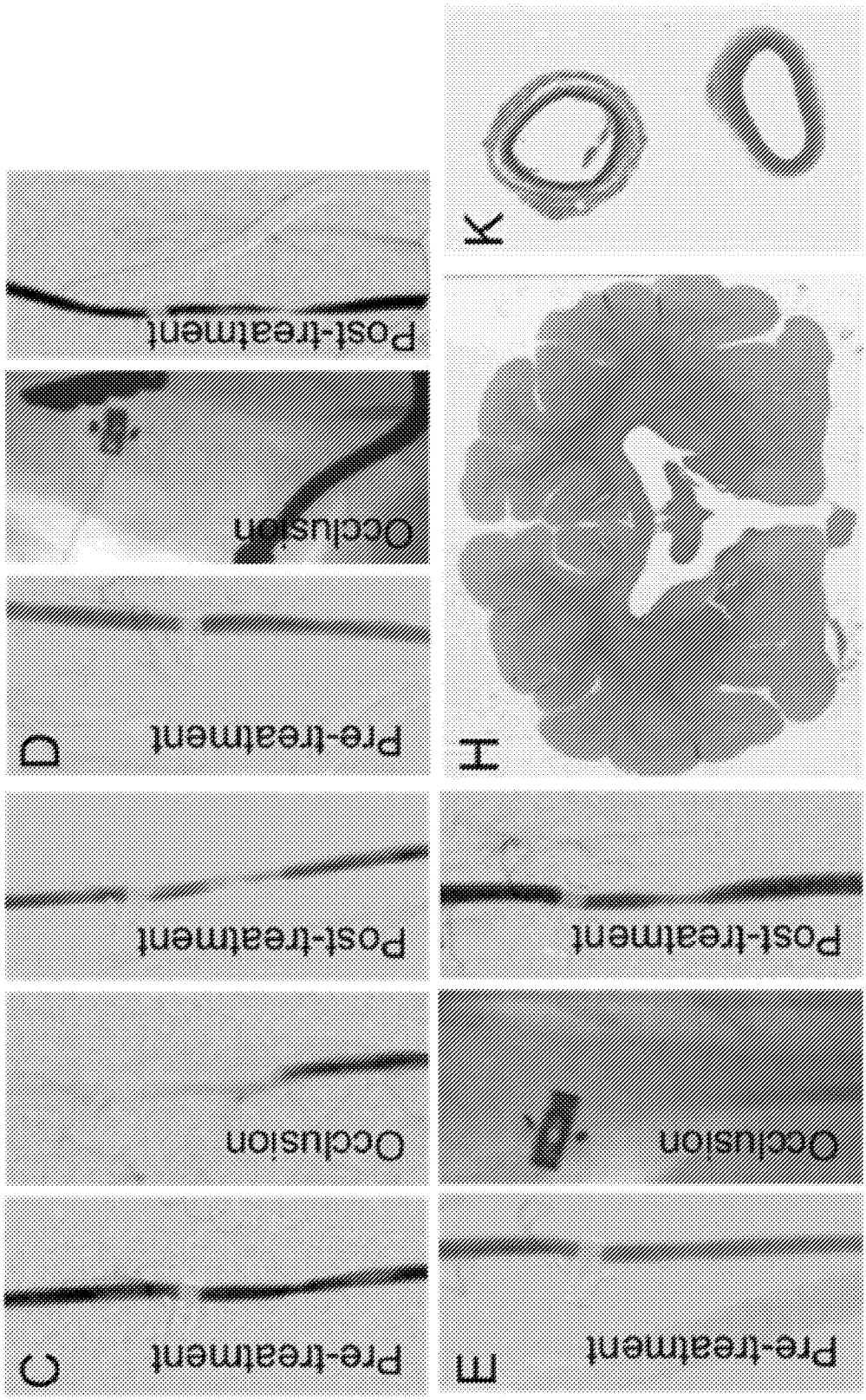

A
Flow Pressure (kPa)
600
400
200
0
0
25
50
75
100
125
[Aptamer] (nM)
B
1 minute
2 minutes
3 minutes
4 minutes
5 minutes
Aptamer
Control

Figure 24C, 24D, 24E, 24H, 24K



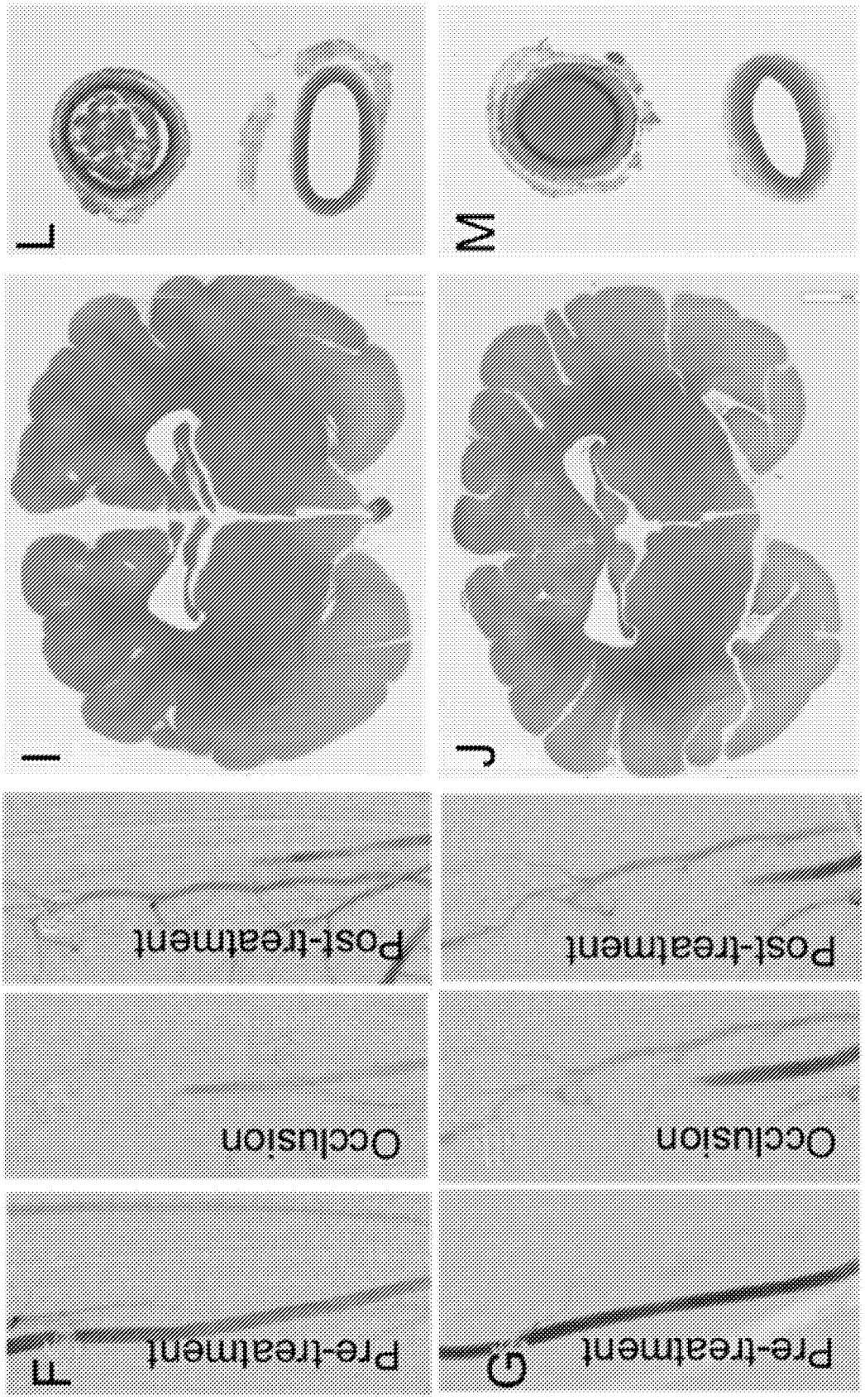
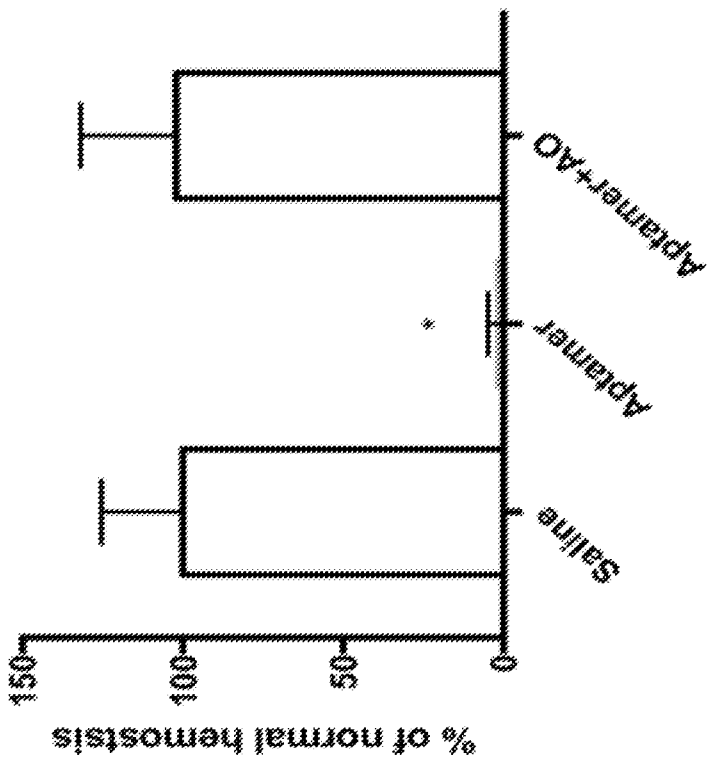


Figure 24F, 24G, 24I, 24J, 24L, 24M

Figure 25



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 17/52063

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61K 31/7088, A61K 31/711, A61K 38/17 (2017.01)
CPC - C12N 15/113, A61K 38/177, C12N 15/115, C12N 2310/11

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- A	US 2012/0264815 A1 (SULLENGER et al.) 18 October 2012 (18.10.2012) para [0008]; [0105]; Table 4.	1, 2 --- 3
A	Genbank Accession No. CP000494 " Bradyrhizobium sp. BTAi1, complete genome" 28 January 2014 [located online 1/3/2018 at https://www.ncbi.nlm.nih.gov/nuccore/CP000494] DNA sequence nts 2456644-2456610.	3

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 January 2018	30 JAN 2018
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 17/52063

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4-18, 20-24, 27-31, 33, 34
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I+, claims 1-3, directed to an aptamer comprising a VWF-targeting polynucleotide. The aptamer will be searched to the extent that the polynucleotide encompasses SEQ ID NO: 3 (SEQ ID NO: 3 comprises both sequences SEQ ID NOs: 1 and 2). It is believed that claims 1-3 encompass this first named invention, and thus these claims will be searched without fee to the extent that the polynucleotide encompasses SEQ ID NO: 3. Additional aptamer(s) will be searched upon the payment of additional fees. Applicants must specify the claims that encompass any additionally elected aptamer(s). Applicants must further indicate, if applicable, the claims which encompass the first named invention, if different than what was indicated above for this group. Failure to clearly identify how any paid additional invention fees are to be applied to the "+" group(s) will result in only the first claimed invention to be searched. An exemplary election would be an aptamer SEQ ID NO: 4 (claims 1-3).

--continued on first extra sheet--

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-3 limited to SEQ ID NOs: 1-3

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

--continued from Box III: Observations where unity of invention is lacking--

Group II+, claim 19, directed to an antidote that is capable of hybridizing to a VWF-targeting aptamer. Group II+ will be searched upon payment of additional fees. The antidote may be searched, for example, to encompass polynucleotide SEQ ID NO: 103 for an additional fee and election as such. It is believed that claim 19 reads on this exemplary invention. Additional antidote(s) will be searched upon the payment of additional fees. Applicants must specify the claims that encompass any additionally elected antidote(s). Failure to clearly identify how any paid additional invention fees are to be applied to the"+" group(s) will result in only the first claimed invention to be searched. Another exemplary election would be an antidote of SEQ ID NO: 104 (claim 19).

Group III, claims 25, 26 and 32, directed to a method/use of a VWF-targeting agent for treating a blood clot in a subject .

The inventions listed as Group I+, II+ and III do not relate to a single special technical feature under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Group I+ has the special technical feature of a composition of an aptamer, that is not required by Groups II+ or III.

Group II+ has the special technical feature of a composition an antidote, that is not required by Groups I+ or III.

Group III has the special technical feature of use of a VWF-targeting agent for treating a blood clot in a subject, that is not required by Groups I+ or II+.

No technical features are shared between the aptamer polynucleotide sequences of Group I+ and, accordingly, these groups lack unity a priori.

No technical features are shared between the antidote polynucleotide sequences of Group II+ and, accordingly, these groups lack unity a priori.

Additionally, even if Group I+ and Group II+ were considered to share the technical features of including: a VWF-targeting aptamer polynucleotide and an antidote that is capable of hybridizing to a VWF-targeting aptamer, respectively. These shared technical features are previously disclosed by US 2012/0264815 A1 to Sullenger et al., (hereinafter Sullenger).

Sullenger teaches an aptamer comprising a polynucleotide comprising a VWF-targeting sequence with 100% sequence identity to SEQ ID NO: 1 and SEQ ID NO: 2 (para [0008] "the invention relates to RNA ligands or aptamers that can inhibit the activity of a receptor, such as gpIIb/IIIa, as well as aptamers that inhibit VWF, and to methods of using same"; TABLE 4 "Sequences and binding properties of VWF aptamer truncates" [Aptamer 9.14 T8] "GGGAGGATGCGGTGGACGAACTGCCCTCAGCTACTTTCATGTTGCTGACGCACAGACGACTCGCTG". This sequence (nts 17-28) displays 100% identity to RNA sequence SEQ ID NO: 1. This sequence (nts 47-58) displays 100% identity to RNA sequence SEQ ID NO: 2).

Sullenger further teaches an antidote comprising a polynucleotide sequence that is complementary to a VWF-targeting sequence (para [0008] "The invention additionally relates to agents (antidotes) that can reverse the inhibitory effect of such ligands/aptamers"; [0035] "the antidote oligonucleotide comprises a sequence complementary to 6-25 consecutive nucleotides of the targeted aptamer").

The inventions of Group I+ and III further share the technical feature of a VWF-targeting aptamer polynucleotide, which is previously disclosed by Sullenger, as above (para [0008], Table 4).

As the technical features were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

Therefore, Group I+, II+ and III inventions lack unity under PCT Rule 13 because they do not share the same or corresponding special technical feature.

NOTE, claims 4-18, 20-24, 27-31, 33, 34 are held unsearchable because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).