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(54) Title: ANTIBODIES DIRECTED AGAINST STAPHYLOCOCCUS AUREUS LEUKOTOXINS

(57) Abstract: The present disclosure is directed to leukotoxin-binding antibodies and antigen-binding fragments thereof. The antibodies and fragments can be used, for example, to detect leukotoxin and/or in methods of treating and preventing Staphylococcus aureus infections.

ANTIBODIES DIRECTED AGAINST STAPHYLOCOCCUS AUREUS LEUKOTOXINS

BACKGROUND

[0001] Infections caused by antimicrobial resistant (AMR) bacterial pathogens are an increasing threat to public health. The ongoing AMR epidemic has been fueled, in part, by empiric broad spectrum antibiotic therapy. This has led to the exploration of pathogen-specific methods, including monoclonal antibodies (mAbs), to prevent or treat serious bacterial infections. Some monoclonal antibodies are currently in development for the prevention or treatment of antibiotic resistant bacterial infections (see, e.g., DiGiandomenico, A., and B.R. Sellman, *Curr. Opin. Microbiol.*, *27*: 78-85 (2015)). Such passive immunization strategies provide an immediate and potent immunoglobulin response against the target pathogen.

[0002] *Staphylococcus aureus* is a bacterial pathogen that causes a wide array of diseases including skin and soft tissue infections, endocarditis, osteomyelitis, pneumonia, and bacteremia (Lowy, F.D., *N. Engl. J. Med.*, *339*(8): 520-32 (1998)). Preclinical studies indicate monoclonal antibody-based approaches hold promise for prophylaxis and adjunctive therapy against *S. aureus* infections (see, e.g., Hazenbos et al., *PLoS Pathog.*, *9*(10):e1003653. doi: 10.1371/journal.ppat.10036532013 (2013); Rouha, H., *MAbs*, *7*(1): 243-254 (2015); Foletti et al., *J. Mol. Biol.*, *425*(10): 1641-1654 (2013); Karauzum et al., *J Biol Chem.*, *287*(30): 25203-15 (2012); and Hua et al., *Antimicrob Agents Chemother.*, *58*(2): 1108-17 (2014)). However, there remains a need for antibodies useful for treating *Staphylococcus aureus* infections, particularly infections that are resistant to currently-available antibiotics. The present disclosure provides such antibodies.

BRIEF SUMMARY OF THE INVENTION

[0003] Provided herein are antibodies and antigen-binding fragments thereof that bind to *Staphylococcus aureus* (*S. aureus*) leukotoxin.

[0004] In certain instances, an antibody or antigen-binding fragment thereof that specifically binds to at least one *S. aureus* leukotoxin comprises a variable heavy chain (VH) complementarity determining region (CDR) 1, a VH CDR2, a VH CDR3, a variable light chain

(VL) CDR1, a VL CDR2, and a VL CDR3, wherein the VH CDR1, VH CDR2, VH CDR3, VL CDR1, VL CDR2, and VL CDR3 comprise sequences selected from the group consisting of: (a) SEQ ID NOs:1, 2, 3, 12, 5, and 6, respectively; (b) SEQ ID NOs:1-6, respectively; (c) SEQ ID NOs:1, 2, 17, 4, 5, and 6, respectively; (d) SEQ ID NOs: 1, 2, 17, 12, 5, and 6, respectively; and (e) SEQ ID NOs: 1, 20, 3, 4, 5, and 6, respectively.

[0005] In certain instances, an antibody or antigen-binding fragment thereof that specifically binds to at least one *S. aureus* leukotoxin comprises the VH CDR1, VH CDR2, VH CDR3, VL CDR1, VL CDR2, and VL CDR3 of SAN481-SYT-YTE. In certain instances, the CDRs are the Kabat-defined CDRs, the Chothia-defined CDRs, or the AbM-defined CDRs.

[0006] In certain instances, the antibody or antigen-binding fragment thereof comprises a VH and a VL, wherein the VH comprises the amino acid sequence of SEQ ID NO:7, 15, 18, 21, or 23. In certain instances, the antibody or antigen-binding fragment thereof comprises a VH and a VL, wherein the VL comprises the amino acid sequence of SEQ ID NO:8 or 13. In certain instances, the antibody or antigen-binding fragment thereof comprises a VH and a VL, wherein the VH and VL comprise sequences selected from the group consisting of: (a) SEQ ID NOs:15 and 13, respectively; (b) SEQ ID NOs:7 and 8, respectively; (c) SEQ ID NOs:7 and 13, respectively; (d) SEQ ID NOs:15 and 8, respectively; (e) SEQ ID NOs:18 and 8, respectively; (f) SEQ ID NOs:18 and 13, respectively; (g) SEQ ID NOs:21 and 8, respectively; and (h) SEQ ID NOs:23 and 13, respectively. In certain instances, the antibody or antigen-binding fragment thereof comprises a VH comprising the sequence of SEQ ID NO:15 and a VL comprising the sequence of SEQ ID NO:13. In certain instances, the antibody or antigen-binding fragment comprises a heavy chain comprising the sequence of SEQ ID NO:16, 9, 11, 22, or 24. In certain instances, the antibody or antigen-binding fragment comprises a light chain comprising the sequence of SEQ ID NO:14 or 10. In certain instances, the antibody comprises a heavy chain and a light chain, wherein the heavy and chains comprise sequences selected from the group consisting of: (a) SEQ ID NOs: 16 and 14, respectively; (b) SEQ ID NOs:9 and 10, respectively; (c) SEQ ID NOs:11 and 10, respectively; (d) SEQ ID NOs:11 and 14, respectively; (e) SEQ ID NOs:16 and 10, respectively; (f) SEQ ID NOs:19and 10, respectively; (g) SEQ ID NOs:19 and 14, respectively; (h) SEQ ID NOs:22 and 10, respectively; and (i) SEQ ID NOs:24 and 14,

respectively. In certain instances, the antibody comprises a heavy comprising the sequence of SEQ ID NO:16 and a light chain comprising the sequence of SEQ ID NO:14.

[0007] In certain instances, an antibody or antigen-binding fragment thereof provided herein binds to the same *S. aureus* leukotoxin epitope as an antibody comprising a VH comprising the amino acid sequence of SEQ ID NO:15 and a VL comprising the amino acid sequence of SEQ ID NO:13.

[0008] In certain instances, an antibody or antigen-binding fragment thereof provided herein competitively inhibits binding of an antibody comprising a VH comprising the amino acid sequence of SEQ ID NO:15 and a VL comprising the amino acid sequence of SEQ ID NO:13 to a *S. aureus* leukotoxin

[0009] In certain instances, the antibody or antigen-binding fragment binds to LukF, LukD, or HlgB and/or the antibody or antigen-binding fragment neutralizes LukF, LukD, or HlgB. In certain instances, the antibody or antigen-binding fragment (a) binds to LukF, LukD, and HlgB and/or (b) neutralizes LukF, LukD, and HlgB.

[0010] In certain instances, the antibody or antigen-binding fragment further comprises a heavy chain constant region. In certain instances, the heavy chain constant region is selected from the group consisting of human immunoglobulin IgG_1, IgG_2, IgG_3, IgG_4, IgA_1, and IgA_2 heavy chain constant regions. In certain instances, the heavy chain constant region is a human IgG_1 constant region.

[0011] In certain instances,the antibody or antigen-binding fragment further comprises a light chain constant region. In certain instances, the light chain constant region is selected from the group consisting of human immunoglobulin IgGκ and IgGλ light chain constant regions. In certain instances, the light chain constant region is a human IgGκ light chain constant region.

[0012] In certain instances, the antibody or antigen-binding fragment thereof is an IgG antibody or antigen-binding fragment thereof.

[0013] In certain instances, the antibody or antigen-binding fragment comprises an Fc region that has been engineered to improve half-life. In certain instances, the antibody or antigen-binding fragment thereof comprises an Fc region with a YTE mutation.

[0014] In certain instances, the antibody or antigen-binding fragment is a monoclonal antibody or antigen-binding fragment.

[0015] In certain instances, the antibody or antigen-binding fragment is a full–length antibody. In certain instances, the antibody or antigen-binding fragment is an antigen-binding fragment. In certain instances, the antigen-binding fragment comprises a Fab, Fab', $F(ab')_2$, single chain Fv (scFv), disulfide linked Fv, intrabody, IgGΔCH2, minibody, $F(ab')_3$, tetrabody, triabody, diabody, DVD-Ig, Fcab, mAb^2, $(scFv)_2$, or scFv-Fc.

[0016] In certain instances, the antibody or antigen-binding fragment thereof has an affinity of less than 75 pM for *S. aureus* LukF, LukD, and HlgB. In certain instances, the antibody or antigen-binding fragment thereof has similar binding affinities for LukF, LukD, and HIgB.

[0017] In certain instances, the antibody or antigen-binding fragment thereof further comprising a detectable label

[0018] Provided herein are also compositions comprising an antibody or antigen-binding fragment thereof provided herein and, optionally, a pharmaceutically-acceptable carrier.

[0019] Provided herein are also methods of using an antibody provided herein. In certain instances, a method of treating or preventing a *Staphylococcus aureus* (*S. aureus*) infection in a subject comprises administering to the subject an antibody or antigen-binding fragment provided herein or a composition provided herein. In certain instances, the *S. aureus* infection is sepsis. In certain instances, the *S. aureus* infection is bacteremia. In certain instances, the *S. aureus* infection is pneumonia. In certain instances, the *S. aureus* infection is ICU pneumonia. In certain instances, the *S. aureus* infection is a skin or soft tissue infection (SSTI). In certain instances, the *S. aureus* infection is a diabetic infection of the lower limbs. In certain instances, the *S. aureus* infection is a diabetic foot ulcer (DFU). In certain instances, the DFU is uninfected. In certain instances, the DFU is infected. In certain instances, the DFU is a grade 1, 2 or 3 DFU. In certain instances, the *S. aureus* infection is a bone or joint infection. In certain instances, the *S. aureus* infection is a joint infection, a device infection, a wound infection, a surgical site infection, or osteomyelitis.

[0020] In certain instances, the subject is a surgical subject.

[0021] In certain instances, the *S. aureus* infection comprises antibiotic-resistant *S. aureus*.

[0022] In certain instances, the subject has diabetes.

[0023] In certain instances, the subject is human.

[0024] In certain instances, the treating or preventing an *S. aureus* infection comprises toxin neutralization, inhibiting cell lysis, inhibiting multi-organ dysfunction, inhibiting *S. aureus*-associated sepsis, or any combination of the foregoing.

[0025] Provided herein are also polynucleotides. In certain instances, an isolated polynucleotide comprises a nucleic acid molecule encoding the VH or heavy chain of an antibody or antigen-binding fragment thereof provided herein. In certain instances, an isolated polynucleotide comprises a nucleic acid molecule encoding the VL or light chain of an antibody or antigen-binding fragment thereof provided herein.

[0026] Also provided herein are vectors. In certain instances, a polynucleotide provided herein.

[0027] Also provided herein are host cells. In certain instances, a host cell comprises a polynucleotide provided herein, a vector provided herein, or a first vector a polynucleotide provided herein and a second vector comprising a polynucleotide provided herein. In certain instances, the host cell is selected from the group consisting of CHO, NS0, PER-C6, HEK-293, and HeLa cells. In certain instances, the host cell is isolated.

[0028] Also provided herein are methods of producing antibodies or antigen-binding fragments. In certain instances, a method of producing an antibody or antigen-binding fragment thereof comprises culturing a host cell provided herein so that the antibody or antigen-binding fragment thereof is produced.

[0029] Also provided herein are methods for detecting detecting *S. aureus* or *S. aureus* leukotoxin. In certain instances, a method for detecting *S. aureus* or *S. aureus* leukotoxin in a sample comprises contacting said sample with an antibody or antigen-binding fragment thereof provided herein.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0030] Figure 1 provides graphs showing the *in vitro* activities of multiple SAN481 variants as compared to SAN481. QD1 = SAN481-YTE; QD2 = SAN481VL26S32Y-YTE; QD3 = SAN481VH28T-YTE; QD4 = SAN481-VH28T100F-YTE; QD5 = SAN481-SY-T-YTE; QD6 = SAN481-SY-TF-YTE; QD11 = SAN481-EG-YTE; and QD12 = SAN481-SY-QFS-YTE. (See Example 2.)

[0031] Figure 2 provides a graph demonstrating that SAN481-SYT-YTE has similar *in vitro* leukotoxin neutralization activity as SAN481. (See Example 3.)

[0032] Figure 3 provides a sequence alignment of HIgB (SEQ ID NO:27), LukF (SEQ ID NO:25), and LukD (SEQ ID NO:26).

DETAILED DESCRIPTION OF THE INVENTION

[0033] The present disclosure provides antibodies and antigen-binding fragments thereof (e.g., monoclonal antibodies and antigen-binding fragments thereof) that bind to *Staphylococcus aureus* (*S. aureus*) leukotoxins. The present disclosure also provides methods of using such antibodies and antigen-binding fragments, for example, in detecting *Staphylococcus aureus* (*S. aureus*) leukotoxins and in the treatment or prevention of *S. aureus* infections.

I. Definitions

[0034] As used herein, the term "leukotoxin" refers to bacterial leukotoxin polypeptides including, but not limited to, native leukotoxin polypeptides and isoforms of leukotoxin polypeptides. "Leukotoxin" encompasses a full-length, unprocessed leukotoxin polypeptides as well as forms of leukotoxin polypeptides that result from processing within the cell. Leukotoxins include LukSF, leukotoxin ED (LukED), HlgAB, HlgCB), and leukotoxin AB (LukAB, also known as LukGH). As used herein, the term "*S. aureus* LukF" refers to a polypeptide comprising the amino acid sequence of SEQ ID NO:25. As used herein, the term "*S. aureus* LukD" refers to a polypeptide comprising the amino acid sequence of SEQ ID NO:26. As used herein, the term "*S. aureus* HIgB" refers to a polypeptide comprising the amino acid sequence of SEQ ID NO:27. (See Figure 3.) A "leukotoxin polynucleotide," "leukotoxin nucleotide," or "leukotoxin nucleic acid" refer to a polynucleotide encoding a leukotoxin.

[0035] The term "antibody" means an immunoglobulin molecule that recognizes and specifically binds to a target, such as a protein, polypeptide, peptide, carbohydrate, polynucleotide, lipid, or combinations of the foregoing through at least one antigen recognition site within the variable region of the immunoglobulin molecule. As used herein, the term "antibody" encompasses intact polyclonal antibodies, intact monoclonal antibodies, chimeric antibodies, humanized antibodies, human antibodies, fusion proteins comprising an antibody, and any other modified immunoglobulin molecule so long as the antibodies exhibit the desired

biological activity. An antibody can be of any the five major classes of immunoglobulins: IgA, IgD, IgE, IgG, and IgM, or subclasses (isotypes) thereof (e.g. IgG1, IgG2, IgG3, IgG4, IgA1 and IgA2), based on the identity of their heavy-chain constant domains referred to as alpha, delta, epsilon, gamma, and mu, respectively. The different classes of immunoglobulins have different and well known subunit structures and three-dimensional configurations. Antibodies can be naked or conjugated to other molecules such as toxins, radioisotopes, etc.

[0036] The term "monoclonal antibodies," as used herein, refers to antibodies that are produced by a single clone of B-cells and bind to the same epitope. In contrast, the term "polyclonal antibodies" refers to a population of antibodies that are produced by different B-cells and bind to different epitopes of the same antigen.

[0037] The term "antibody fragment" refers to a portion of an intact antibody. An "antigen-binding fragment," "antigen-binding domain," or "antigen-binding region," refers to a portion of an intact antibody that binds to an antigen. An antigen-binding fragment can contain the antigenic determining regions of an intact antibody (e.g., the complementarity determining regions (CDR)). Examples of antigen-binding fragments of antibodies include, but are not limited to Fab, Fab', F(ab')2, and Fv fragments, linear antibodies, and single chain antibodies. An antigen-binding fragment of an antibody can be derived from any animal species, such as rodents (*e.g.*, mouse, rat, or hamster) and humans or can be artificially produced.

[0038] A whole antibody typically consists of four polypeptides: two identical copies of a heavy (H) chain polypeptide and two identical copies of a light (L) chain polypeptide. Each of the heavy chains contains one N-terminal variable (VH) region and three C-terminal constant (CHI , CH2 and CH3) regions, and each light chain contains one N-terminal variable (VL) region and one C-terminal constant (CL) region. The variable regions of each pair of light and heavy chains form the antigen binding site of an antibody. The VH and VL regions have the same general structure, with each region comprising four framework regions, whose sequences are relatively conserved. The term "framework region," as used herein, refers to the relatively conserved amino acid sequences within the variable region which are located between the hypervariable or complementary determining regions (CDRs). There are four framework regions in each variable domain, which are designated FR1, FR2, FR3, and FR4. The framework regions form the β sheets that provide the structural framework of the variable region (see, e.g., C.A.

Janeway et al. (eds.), *Immunobiology*, 5th Ed., Garland Publishing, New York, NY (2001)). The three CDRs, known as CDR1, CDR2, and CDR3, form the "hypervariable region" of an antibody, which is responsible for antigen binding.

[0039] The terms "VL" and "VL domain" are used interchangeably to refer to the light chain variable region of an antibody.

[0040] The terms "VH" and "VH domain" are used interchangeably to refer to the heavy chain variable region of an antibody.

[0041] The term "Kabat numbering" and like terms are recognized in the art and refer to a system of numbering amino acid residues in the heavy and light chain variable regions of an antibody or an antigen-binding fragment thereof. In certain aspects, CDRs can be determined according to the Kabat numbering system (see, *e.g.*, Kabat EA & Wu TT (1971) Ann NY Acad Sci 190: 382-391 and Kabat EA *et al.*, (1991) Sequences of Proteins of Immunological Interest, Fifth Edition, U.S. Department of Health and Human Services, NIH Publication No. 91-3242). Using the Kabat numbering system, CDRs within an antibody heavy chain molecule are typically present at amino acid positions 31 to 35, which optionally can include one or two additional amino acids, following 35 (referred to in the Kabat numbering scheme as 35A and 35B) (CDR1), amino acid positions 50 to 65 (CDR2), and amino acid positions 95 to 102 (CDR3). Using the Kabat numbering system, CDRs within an antibody light chain molecule are typically present at amino acid positions 24 to 34 (CDR1), amino acid positions 50 to 56 (CDR2), and amino acid positions 89 to 97 (CDR3). In a specific embodiment, the CDRs of the antibodies described herein have been determined according to the Kabat numbering scheme.

[0042] Chothia refers instead to the location of the structural loops (Chothia and Lesk, J. Mol. Biol. 196:901-917 (1987)). The end of the Chothia CDR-H1 loop when numbered using the Kabat numbering convention varies between H32 and H34 depending on the length of the loop (this is because the Kabat numbering scheme places the insertions at H35A and H35B; if neither 35A nor 35B is present, the loop ends at 32; if only 35A is present, the loop ends at 33; if both 35A and 35B are present, the loop ends at 34). The AbM hypervariable regions represent a compromise between the Kabat CDRs and Chothia structural loops, and are used by Oxford Molecular's AbM antibody modeling software.

Loop	Kabat	AbM	Chothia
L1	L24-L34	L24-L34	L24-L34
L2	L50-L56	L50-L56	L50-L56
L3	L89-L97	L89-L97	L89-L97
H1	H31-H35B	H26-H35B	H26-H32..34
		(Kabat Numbering)	
H1	H31-H35	H26-H35	H26-H32
		(Chothia Numbering)	
H2	H50-H65	H50-H58	H52-H56
H3	H95-H102	H95-H102	H95-H102

[0043] As used herein, the term "constant region" or "constant domain" are interchangeable and have its meaning common in the art. The constant region is an antibody portion, *e.g.*, a carboxyl terminal portion of a light and/or heavy chain which is not directly involved in binding of an antibody to antigen but which can exhibit various effector functions, such as interaction with the Fc receptor. The constant region of an immunoglobulin molecule generally has a more conserved amino acid sequence relative to an immunoglobulin variable domain.

[0044] As used herein, the term "heavy chain" when used in reference to an antibody can refer to any distinct type, *e.g.*, alpha (α), delta (δ), epsilon (ε), gamma (γ), and mu (μ), based on the amino acid sequence of the constant domain, which give rise to IgA, IgD, IgE, IgG, and IgM classes of antibodies, respectively, including subclasses of IgG, *e.g.*, IgG_1, IgG_2, IgG_3, and IgG_4. Heavy chain amino acid sequences are well known in the art. In specific embodiments, the heavy chain is a human heavy chain.

[0045] As used herein, the term "light chain" when used in reference to an antibody can refer to any distinct type, *e.g.*, kappa (κ) or lambda (λ) based on the amino acid sequence of the constant domains. Light chain amino acid sequences are well known in the art. In specific embodiments, the light chain is a human light chain.

[0046] A "chimeric" antibody refers to an antibody or fragment thereof comprising both human and non-human regions. A "humanized" antibody is a antibody comprising a human antibody scaffold and at least one CDR obtained or derived from a non-human antibody. Non-human antibodies include antibodies isolated from any non-human animal, such as, for example, a rodent (e.g., a mouse or rat). A humanized antibody can comprise, one, two, or three CDRs

obtained or derived from a non-human antibody. A fully human antibody does not contain any amino acid residues obtained or derived from a non-human animal. It will be appreciated that fully human and humanized antibodies carry a lower risk for inducing immune responses in humans than mouse or chimeric antibodies (see, e.g., Harding et al., *mAbs*, *2*(3): 256-26 (2010)).

[0047] As used herein, an "epitope" is a term in the art and refers to a localized region of an antigen to which an antibody or antigen-binding fragment thereof can specifically bind. An epitope can be, for example, contiguous amino acids of a polypeptide (linear or contiguous epitope) or an epitope can, for example, come together from two or more non-contiguous regions of a polypeptide or polypeptides (conformational, non-linear, discontinuous, or non-contiguous epitope). In certain embodiments, the epitope to which an antibody or antigen-binding fragment thereof binds can be determined by, *e.g.*, NMR spectroscopy, X-ray diffraction crystallography studies, ELISA assays, hydrogen/deuterium exchange coupled with mass spectrometry (e.g., liquid chromatography electrospray mass spectrometry), array-based oligo-peptide scanning assays, and/or mutagenesis mapping (*e.g.*, site-directed mutagenesis mapping). For X-ray crystallography, crystallization can be accomplished using any of the known methods in the art (*e.g.*, Giegé R *et al.,* (1994) Acta Crystallogr D Biol Crystallogr 50(Pt 4): 339-350; McPherson A (1990) Eur J Biochem 189: 1-23; Chayen NE (1997) Structure 5: 1269-1274; McPherson A (1976) J Biol Chem 251: 6300-6303). Antibody/antigen-binding fragment thereof:antigen crystals can be studied using well known X-ray diffraction techniques and can be refined using computer software such as X-PLOR (Yale University, 1992, distributed by Molecular Simulations, Inc.; *see*, e.g., Meth Enzymol (1985) volumes 114 & 115, eds Wyckoff HW *et al.,*; U.S. 2004/0014194), and BUSTER (Bricogne G (1993) Acta Crystallogr D Biol Crystallogr 49(Pt 1): 37-60; Bricogne G (1997) Meth Enzymol 276A: 361-423, ed Carter CW; Roversi P *et al.,* (2000) Acta Crystallogr D Biol Crystallogr 56(Pt 10): 1316-1323). Mutagenesis mapping studies can be accomplished using any method known to one of skill in the art. *See*, *e.g.*, Champe M *et al.,* (1995) J Biol Chem 270: 1388-1394 and Cunningham BC & Wells JA (1989) Science 244: 1081-1085 for a description of mutagenesis techniques, including alanine scanning mutagenesis techniques.

[0048] An antibody that "binds to the same epitope" as a reference antibody refers to an antibody that binds to the same amino acid residues as the reference antibody. The ability of an

antibody to bind to the same epitope as a reference antibody can determined by a hydrogen/deuterium exchange assay (see Coales et al. Rapid Commun. Mass Spectrom. 2009; 23: 639–647) or x-ray crystallography.

[0049] As used herein, the terms "immunospecifically binds," "immunospecifically recognizes," "specifically binds," and "specifically recognizes" are analogous terms in the context of antibodies or antigen-binding fragments thereof. These terms indicate that the antibody or antigen-binding fragment thereof binds to an epitope via its antigen-binding domain and that the binding entails some complementarity between the antigen binding domain and the epitope. Accordingly, for example, an antibody that "specifically binds" to a first *S. aureus* leukotoxin may also bind to other *S. aureus* leukotoxins, but the extent of binding to an un-related, non-leukotoxin protein is less than about 10% of the binding of the antibody to the first *S. aureus* leukotoxin as measured, e.g., by a radioimmunoassay (RIA), enzyme-linked immunosorbent assay (ELISA), BiaCore or an octet binding assay.

[0050] An antibody is said to "competitively inhibit" binding of a reference antibody to a given epitope if it preferentially binds to that epitope or an overlapping epitope to the extent that it blocks, to some degree, binding of the reference antibody to the epitope. Competitive inhibition may be determined by any method known in the art, for example, competition ELISA assays. An antibody may be said to competitively inhibit binding of the reference antibody to a given epitope by at least 90%, at least 80%, at least 70%, at least 60%, or at least 50%.

[0051] The term "nucleic acid sequence" is intended to encompass a polymer of DNA or RNA, i.e., a polynucleotide, which can be single-stranded or double-stranded and which can contain non-natural or altered nucleotides. The terms "nucleic acid" and "polynucleotide" as used herein refer to a polymeric form of nucleotides of any length, either ribonucleotides (RNA) or deoxyribonucleotides (DNA). These terms refer to the primary structure of the molecule, and thus include double- and single-stranded DNA, and double- and single-stranded RNA. The terms include, as equivalents, analogs of either RNA or DNA made from nucleotide analogs and modified polynucleotides such as, though not limited to, methylated and/or capped polynucleotides. Nucleic acids are typically linked via phosphate bonds to form nucleic acid sequences or polynucleotides, though many other linkages are known in the art (e.g., phosphorothioates, boranophosphates, and the like).

[0052] An *S. aureus* infection can occur, for example, as a skin or soft tissue infection (SSTI) or bacteremia. *S. aureus* bacteria can travel through the bloodstream and infect a site in the body, resulting in pneumonia, ICU pneumonia, a diabetic infection of the lower limbs, diabetic foot ulcer (DFU), a bone or joint infection, a device infection, a wound infection, a surgical site infection, or osteomyelitis.

[0053] "Transfection," "transformation," or "transduction," as used herein, refer to the introduction of one or more exogenous polynucleotides into a host cell by using physical or chemical methods. Many transfection techniques are known in the art and include, for example, calcium phosphate DNA co-precipitation (see, e.g., Murray E.J. (ed.), *Methods in Molecular Biology, Vol. 7, Gene Transfer and Expression Protocols*, Humana Press (1991)); DEAE-dextran; electroporation; cationic liposome-mediated transfection; tungsten particle-facilitated microparticle bombardment (Johnston, *Nature*, *346*: 776-777 (1990)); and strontium phosphate DNA co-precipitation (Brash et al, *Mol. Cell Biol.*, *7*: 2031-2034 (1987)). Phage or viral vectors can be introduced into host cells, after growth of infectious particles in suitable packaging cells, many of which are commercially available.

[0054] As used herein, the terms "treatment," "treating," and the like, refer to obtaining a desired pharmacologic and/or physiologic effect. In one embodiment, the effect is therapeutic, i.e., the effect partially or completely cures a disease and/or adverse symptom attributable to the disease.

[0055] A "therapeutically effective amount" refers to an amount effective, at dosages and for periods of time necessary, to achieve a desired therapeutic result (e.g., treatment of *S. aureus* infection). The therapeutically effective amount may vary according to factors such as the disease state, age, sex, and weight of the individual, and the ability of the antibody or antigen-binding fragment to elicit a desired response in the individual.

[0056] A "prophylactically effective amount" refers to an amount effective, at dosages and for periods of time necessary, to achieve a desired prophylactic result (e.g., prevention of *S. aureus* infection or disease onset).

[0057] The terms "administer", "administering", "administration", and the like, as used herein, refer to methods that may be used to enable delivery of a drug, e.g., a leukotxin-binding antibody or antigen-binding fragment thereof to the desired site of biological action (e.g.,

intravenous administration). Administration techniques that can be employed with the agents and methods described herein are found in *e.g.*, Goodman and Gilman, *The Pharmacological Basis of Therapeutics*, current edition, Pergamon; and Remington's, *Pharmaceutical Sciences*, current edition, Mack Publishing Co., Easton, Pa.

[0058] As used in the present disclosure and claims, the singular forms "a," "an," and "the" include plural forms unless the context clearly dictates otherwise.

[0059] Unless specifically stated or obvious from context, as used herein, the term "or" is understood to be inclusive. The term "and/or" as used in a phrase such as "A and/or B" herein is intended to include both "A and B," "A or B," "A," and "B." Likewise, the term "and/or" as used in a phrase such as "A, B, and/or C" is intended to encompass each of the following embodiments: A, B, and C; A, B, or C; A or C; A or B; B or C; A and C; A and B; B and C; A (alone); B (alone); and C (alone).

II. Anti-leukotoxin antibodies

[0060] Provided herein are antibodies and antigen-binding fragments thereof that bind to at least one *S. aureus* leukotoxin.

[0061] Leukotoxins are *S. aureus* virulence factor. Leukotoxins target a broad range of immune cells for destruction. Leukotoxins include Panton–Valentine leukocidin (LukSF-PV also known as LukSF), leukotoxin ED (LukED), gamma hemolysin (which exists as two toxins: HlgAB and HlgCB), and leukotoxin AB (LukAB, also known as LukGH). In certain instances, an antibody or antigen-binding fragment thereof that binds to at least one leukotoxin binds to LukF, LukD, and/or HIgB. In certain instances, an antibody or antigen-binding fragment thereof that binds to at least one leukotoxin binds to LukF, LukD, and HIgB.

[0062] In one instance, an antibody or antigen-binding fragment (e.g., monoclonal antibody or fragment) that specifically binds to at least one *S. aureus* leukotoxin comprises, consists essentially of, or consists of (i) a heavy chain polypeptide comprising a CDR1 amino acid sequence of SEQ ID NO:1, a CDR2 amino acid sequence of SEQ ID NO:2, and a CDR3 amino acid sequence of SEQ ID NO:3, and (ii) a light chain polypeptide comprising a CDR1 amino acid sequence of SEQ ID NO:12, a CDR2 amino acid sequence of SEQ ID NO:5, and a CDR3 amino acid sequence of SEQ ID NO:6. In another instance, the heavy chain polypeptide of an

antibody or antigen-binding fragment (e.g., monoclonal antibody or fragment) that specifically binds to at least one *S. aureus* leukotoxin comprises, consists essentially of, or consists of a variable region amino acid sequence of SEQ ID NO:15. In another instance, the light chain polypeptide of an antibody or antigen-binding fragment (e.g., monoclonal antibody or fragment) that specifically binds to at least one *S. aureus* leukotoxin comprises, consists essentially of, or consists of a variable region amino acid sequence of SEQ ID NO:13. In another instance, an antibody or antigen-binding fragment (e.g., monoclonal antibody or fragment) that specifically binds to at least one *S. aureus* leukotoxin comprises, consists essentially of, or consists of a variable heavy chain comprising, consisting essentially of, or consisting of the amino acid sequence of SEQ ID NO:15 and a variable light chain comprising, consisting essentially of, or consisting of the amino acid sequence of SEQ ID NO:13. In another instance, an antibody or antigen-binding fragment (e.g., monoclonal antibody or fragment) that specifically binds to at least one *S. aureus* leukotoxin comprises, consists essentially of, or consists of a variable heavy chain comprising, consisting essentially of, or consisting of the amino acid sequence of SEQ ID NO:16 and/or a variable light chain comprising, consisting essentially of, or consisting of the amino acid sequence of SEQ ID NO:14.

[0063] Sequences of exemplary anti-leukotoxin antibodies are provided below. In certain instances, an antibody or antigen-binding fragment thereof described herein binds to at least one leukotoxin and comprises six CDRs (i.e., a VH CDR1, a VH CDR2, a VH CDR3, a VL CDR1, a VL CDR2, and VL CDR3) from Tables 1 and 2 below.

[0064] The SAN481-SYT-YTE antibody comprises the VH CDRs of SEQ ID NOs:1-3 and the VL CDRs of SEQ ID NOs:12, 5, and 6.

Table 1: VH CDR Amino Acid Sequences

Antibody Name	VH CDR1 (SEQ ID NO:)	VH CDR2 (SEQ ID NO:)	VH CDR3 (SEQ ID NO:)
SAN481	TYAMH (SEQ ID NO:1)	VTSFDGSNEYYIDSVKG (SEQ ID NO:2)	DEYTGGWYSVGY (SEQ ID NO:3)

SAN481-TF	TYAMH (SEQ ID NO:1)	VTSFDGSNEYYIDSV KG (SEQ ID NO:2)	DEYTGG**F**YSVGY (SEQ ID NO:17)
SAN481-EG	TYAMH (SEQ ID NO:1)	VTSF**E**GSNEYYIDSV KG (SEQ ID NO:20)	DEYTGGWYSVGY (SEQ ID NO:3)

Table 2: VL CDR Amino Acid Sequences

Antibody	**VL CDR1 (SEQ ID NO:)**	**VL CDR2 (SEQ ID NO:)**	**VL CDR3 (SEQ ID NO:)**
SAN481	SGNSYNIGSNSVY (SEQ ID NO:4)	RSIQRPS (SEQ ID NO:5)	AAWDDSLRAWV (SEQ ID NO:6)
SAN481-SY	SG**S**SYNIGSN**Y**VY (SEQ ID NO:12)	RSIQRPS (SEQ ID NO:5)	AAWDDSLRAWV (SEQ ID NO:6)

[0065] In certain instances, an antibody or antigen-binding fragment thereof described herein binds to at least one leukotoxin and comprises the VH of an antibody listed in the following table, e.g., in combination with a VL.

Table 3: Variable Heavy Chain (VH) Amino Acid Sequence

Antibody	**VH Amino Acid Sequence (SEQ ID NO)**
SAN481	QLQLVESGGGAVQPGRSLKLSCAASGFNFSTYAMHWVRQAPGRGLEW VAVTSFDGSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGGWYSVGYWGQGTLVTVSS (SEQ ID NO:7)
SAN481-T	QLQLVESGGGAVQPGRSLKLSCAASGF**T**FSTYAMHWVRQAPGRGLEW VAVTSFDGSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGGWYSVGYWGQGTLVTVSS (SEQ ID NO:15)
SAN481-TF	QLQLVESGGGAVQPGRSLKLSCAASGF**T**FSTYAMHWVRQAPGRGLEW VAVTSFDGSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGG**F**YSVGYWGQGTLVTVSS (SEQ ID NO:18)
SAN481-EG	QLQLVESGGGAVQPGRSLKLSCAASGFNFSTYAMHWVRQAPGRGLEW VAVTSF**E**GSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC

	ARDEYTGGWYSVGYWGQGTLVTVSS (SEQ ID NO:21)
SAN481-QFS	QLQLVESGGGAVQPGRSLKLSCAASGF**Q**FSTYAMHWVRQAPGRGLEW VAVTSFDGSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGGWYSVGYWGQGTLVTVSS (SEQ ID NO:23)

[0066] In certain instances, an antibody or antigen-binding fragment thereof described herein binds to at least one leukotoxin and comprises the VL of an antibody listed in the following table, e.g., in combination with a VH, optionally a VH listed in the preceding table.

Table 4: Variable Light Chain (VL) Amino Acid Sequence

Antibody	VL Amino Acid Sequence (SEQ ID NO)
SAN481	QSVLTQPPSASGTPGQRVTISCSGNSYNIGSNSVYWYQQFPGTAPKLLIS RSIQRPSGVPDRFSGSKSVTSASLAISGLRSEDEADYYCAAWDDSLRAW VFGGGTKLTVL (SEQ ID NO:8)
SAN481-SY	QSVLTQPPSASGTPGQRVTISCSG**S**SYNIGSN**Y**VYWYQQFPGTAPKLLIS RSIQRPSGVPDRFSGSKSVTSASLAISGLRSEDEADYYCAAWDDSLRAW VFGGGTKLTVL (SEQ ID NO:13)

[0067] In certain instances, an antibody or antigen-binding fragment thereof described herein binds at least one leukotoxin and comprises the heavy chain of an antibody listed in the following table, e.g., in combination with a light chain.

Table 5: Full-length heavy chain amino acid sequences

Antibody	Full-Length Heavy Chain Amino Acid Sequence (SEQ ID NO)
SAN481	QLQLVESGGGAVQPGRSLKLSCAASGFNFSTYAMHWVRQAPGRGLEW VAVTSFDGSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGGWYSVGYWGQGTLVTVSSASTKGPSVFPLAPSSKSTSGGTA ALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVP SSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELLGGP SVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHN AKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIE KTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWE SNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHE ALHNHYTQKSLSLSPGK (SEQ ID NO:9)
SAN481-YTE	QLQLVESGGGAVQPGRSLKLSCAASGFNFSTYAMHWVRQAPGRGLEW VAVTSFDGSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGGWYSVGYWGQGTLVTVSSASTKGPSVFPLAPSSKSTSGGTA ALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVP SSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELLGGP SVFLFPPKPKDTL**YITRE**PEVTCVVVDVSHEDPEVKFNWYVDGVEVHN

	AKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIE KTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWE SNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHE ALHNHYTQKSLSLSPGK (SEQ ID NO:11)
SAN481-T-YTE	QLQLVESGGGAVQPGRSLKLSCAASGF**T**FSTYAMHWVRQAPGRGLEW VAVTSFDGSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGGWYSVGYWGQGTLVTVSSASTKGPSVFPLAPSSKSTSGGTA ALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVP SSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELLGGP SVFLFPPKPKDTL**Y**I**T**R**E**PEVTCVVVDVSHEDPEVKFNWYVDGVEVHN AKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIE KTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWE SNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHE ALHNHYTQKSLSLSPGK (SEQ ID NO:16)
SAN481-TF-YTE	QLQLVESGGGAVQPGRSLKLSCAASGF**T**FSTYAMHWVRQAPGRGLEW VAVTSFDGSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGG**F**YSVGYWGQGTLVTVSSASTKGPSVFPLAPSSKSTSGGTA ALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVP SSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELLGGP SVFLFPPKPKDTLYITREPEVTCVVVDVSHEDPEVKFNWYVDGVEVHN AKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIE KTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWE SNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHE ALHNHYTQKSLSLSPGK (SEQ ID NO:19)
SAN481-EG-YTE	QLQLVESGGGAVQPGRSLKLSCAASGFNFSTYAMHWVRQAPGRGLEW VAVTSF**E**GSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGGWYSVGYWGQGTLVTVSSASTKGPSVFPLAPSSKSTSGGTA ALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVP SSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELLGGP SVFLFPPKPKDTL**Y**I**T**R**E**PEVTCVVVDVSHEDPEVKFNWYVDGVEVHN AKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIE KTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWE SNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHE ALHNHYTQKSLSLSPGK (SEQ ID NO:22)
SAN481-QFS-YTE	QLQLVESGGGAVQPGRSLKLSCAASGF**Q**FSTYAMHWVRQAPGRGLEW VAVTSFDGSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGGWYSVGYWGQGTLVTVSSASTKGPSVFPLAPSSKSTSGGTA ALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVP SSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELLGGP SVFLFPPKPKDTL**Y**I**T**R**E**PEVTCVVVDVSHEDPEVKFNWYVDGVEVHN AKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIE KTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWE SNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHE ALHNHYTQKSLSLSPGK (SEQ ID NO:24)
SAN481-T	QLQLVESGGGAVQPGRSLKLSCAASGF**T**FSTYAMHWVRQAPGRGLEW

	VAVTSFDGSNEYYIDSVKGRFTISRDNTKNTLYLQMTGLRVEDTALYFC ARDEYTGGWYSVGYWGQGTLVTVSSASTKGPSVFPLAPSSKSTSGGTA ALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVP SSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELLGGP SVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHN AKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIE KTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWE SNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHE ALHNHYTQKSLSLSPGK (SEQ ID NO:28)

[0068] In certain instances, an antibody or antigen-binding fragment thereof described herein binds to at least one leukotoxin and comprises the light chain of an antibody listed in the following table, e.g., in combination with a heavy chain, optionally a heavy chain listed in the preceding table.

Table 6: Full-length light chain amino acid sequences

Antibody	Full-Length Light Chain Amino Acid Sequence (SEQ ID NO)
SAN481	QSVLTQPPSASGTPGQRVTISCSGNSYNIGSNSVYWYQQFPGTAPKLLIS RSIQRPSGVPDRFSGSKSVTSASLAISGLRSEDEADYYCAAWDDSLRAW VFGGGTKLTVLGQPKAAPSVTLFPPSSEELQANKATLVCLISDFYPGAV TVAWKADSSPVKAGVETTTPSKQSNNKYAASSYLSLTPEQWKSHRSYS CQVTHEGSTVEKTVAPTECS (SEQ ID NO:10)
SAN481-SY	QSVLTQPPSASGTPGQRVTISCSG**S**SYNIGSN**Y**VYWYQQFPGTAPKLLIS RSIQRPSGVPDRFSGSKSVTSASLAISGLRSEDEADYYCAAWDDSLRAW VFGGGTKLTVLGQPKAAPSVTLFPPSSEELQANKATLVCLISDFYPGAV TVAWKADSSPVKAGVETTTPSKQSNNKYAASSYLSLTPEQWKSHRSYS CQVTHEGSTVEKTVAPTECS (SEQ ID NO:14)

[0069] The sequences of antibodies used in the Examples below are summarized in Table 7.

Table 7: SEQ ID NOs of Antibody CDR, Variable Regions, and Heavy and Light Chains

Antibody	H CDRs	L CDRs	VH	VL	H	L
SAN481	1-3	4-6	7	8	9	10
SAN481-YTE	1-3	4-6	7	8	11	10
SAN481-	1-3	12, 5, 6	7	13	11	14

SY-YTE						
SAN481-T-YTE	1-3	4-6	15	8	16	10
SAN481-TF-YTE	1, 2, 17	4-6	18	8	19	10
SAN481-SYT-YTE	1-3	12, 5, 6	15	13	16	14
SAN481-SY-TF-YTE	1, 2, 17	12, 5, 6	18	13	19	14
SAN481-EG-YTE	1, 20, 3	4-6	21	8	22	10
SAN481-SY-QFS-YTE	1-3	12, 5, 6	23	13	24	14
SAN481-SYT*	1-3	12, 5, 6	15	13	28	14

[0070] In certain aspects, the CDRs of an antibody or antigen-binding fragment thereof can be determined according to the Chothia numbering scheme, which refers to the location of immunoglobulin structural loops (*see*, *e.g.*, Chothia C & Lesk AM, (1987), J Mol Biol 196: 901-917; Al-Lazikani B *et al.*, (1997) J Mol Biol 273: 927-948; Chothia C *et al.*, (1992) J Mol Biol 227: 799-817; Tramontano A *et al.*, (1990) J Mol Biol 215(1): 175-82; and U.S. Patent No. 7,709,226). Typically, when using the Kabat numbering convention, the Chothia CDR-H1 loop is present at heavy chain amino acids 26 to 32, 33, or 34, the Chothia CDR-H2 loop is present at heavy chain amino acids 52 to 56, and the Chothia CDR-H3 loop is present at heavy chain amino acids 95 to 102, while the Chothia CDR-L1 loop is present at light chain amino acids 24 to 34, the Chothia CDR-L2 loop is present at light chain amino acids 50 to 56, and the Chothia CDR-L3 loop is present at light chain amino acids 89 to 97. The end of the Chothia CDR-H1 loop when numbered using the Kabat numbering convention varies between H32 and H34 depending on the length of the loop (this is because the Kabat numbering scheme places the insertions at

H35A and H35B; if neither 35A nor 35B is present, the loop ends at 32; if only 35A is present, the loop ends at 33; if both 35A and 35B are present, the loop ends at 34).

[0071] In certain aspects, provided herein antibodies and antigen-binding fragments thereof that comprise the Chothia VH and VL CDRs of the SAN481 or SAN481-SYT antibody. In certain embodiments, antibodies or antigen-binding fragments thereof comprise one or more CDRs, in which the Chothia and Kabat CDRs have the same amino acid sequence. In certain embodiments, provided herein are antibodies and antigen-binding fragments thereof comprise combinations of Kabat CDRs and Chothia CDRs.

[0072] In certain aspects, the CDRs of an antibody or antigen-binding fragment thereof can be determined according to the IMGT numbering system as described in Lefranc M-P, (1999) The Immunologist 7: 132-136 and Lefranc M-P *et al.*, (1999) Nucleic Acids Res 27: 209-212. According to the IMGT numbering scheme, VH-CDR1 is at positions 26 to 35, VH-CDR2 is at positions 51 to 57, VH-CDR3 is at positions 93 to 102, VL-CDR1 is at positions 27 to 32, VL-CDR2 is at positions 50 to 52, and VL-CDR3 is at positions 89 to 97. In a particular embodiment, provided herein are antibodies and antigen-binding fragments thereof that comprise the IMGT VH and VL CDRs of the SAN481 or SAN481-SYT-YTE antibody, for example, as described in Lefranc M-P (1999) *supra* and Lefranc M-P *et al.*, (1999) *supra*).

[0073] In certain aspects, the CDRs of an antibody or antigen-binding fragment thereof can be determined according to MacCallum RM *et al.*, (1996) J Mol Biol 262: 732-745. *See also*, *e.g.*, Martin A. "Protein Sequence and Structure Analysis of Antibody Variable Domains," in *Antibody Engineering*, Kontermann and Dübel, eds., Chapter 31, pp. 422-439, Springer-Verlag, Berlin (2001). In a particular embodiment, provided herein are antibodies or antigen-binding fragments thereof that comprise the VH and VL CDRs of the SAN481 or SAN481-SYT-YTE antibody determined by the method in MacCallum RM *et al.*

[0074] In certain aspects, the CDRs of an antibody or antigen-binding fragment thereof can be determined according to the AbM numbering scheme, which refers AbM hypervariable regions which represent a compromise between the Kabat CDRs and Chothia structural loops, and are used by Oxford Molecular's AbM antibody modeling software (Oxford Molecular Group, Inc.). In a particular embodiment, provided herein are antibodies or antigen-binding

fragments that comprise the VH and VL CDRs of the SAN481 or SAN481-SYT-YTE antibody as determined by the AbM numbering scheme.

[0075] In another aspect, the antibody or antigen-binding fragment thereof (e.g., monoclonal antibody or fragment) described herein can comprise a constant region (Fc) of any suitable class (e.g., IgG, IgA, IgD, IgM, and IgE) that has been modified in order to improve the half-life of the antibody or antigen-binding fragment (e.g., monoclonal antibody or fragment). For example, the antibody or antigen-binding fragment thereof (e.g., monoclonal antibody or fragment) described herein can comprise an Fc that comprises a mutation that extends half-life relative to the same antibody without the mutation.

[0076] Fc region engineering is widely used in the art to extend the half-life of therapeutic antibodies and protect from degradation *in vivo*. In some embodiments, the Fc region of an IgG antibody or antigen-binding fragment can be modified in order to increase the affinity of the IgG molecule for the Fc Receptor-neonate (FcRn), which mediates IgG catabolism and protects IgG molecules from degradation. Suitable Fc region amino acid substitutions or modifications are known in the art and include, for example, the triple substitution M252Y/S254T/T256E (referred to as "YTE") (see, e.g., U.S. Patent 7,658,921; U.S. Patent Application Publication 2014/0302058; and Yu et al., *Antimicrob. Agents Chemother.*, *61*(1): e01020-16 (2017)). In certain aspects, an antibody or antigen-binding binding fragment (e.g., monoclonal antibody or fragment) that binds to at least one *S. aureus* leukotoxin comprises an Fc region comprising the YTE mutation.

[0077] An antibody or antigen-binding fragment (e.g. monoclonal antibody or fragment) described herein can be, or can be obtained from, a human antibody, a humanized antibody, a non-human antibody, or a chimeric antibody. In one aspect, an antibody described herein, or antigen-binding fragment thereof, is a fully human antibody.

[0078] A human antibody, a non-human antibody, a chimeric antibody, or a humanized antibody can be obtained by any means, including via *in vitro* sources (e.g., a hybridoma or a cell line producing an antibody recombinantly) and *in vivo* sources (e.g., rodents, human tonsils). Methods for generating antibodies are known in the art and are described in, for example, Köhler and Milstein, *Eur. J. Immunol.*, *5*: 511-519 (1976); Harlow and Lane (eds.), *Antibodies: A Laboratory Manual*, CSH Press (1988); and Janeway et al. (eds.), *Immunobiology, 5th Ed.*,

Garland Publishing, New York, N.Y. (2001)). In certain embodiments, a human antibody or a chimeric antibody can be generated using a transgenic animal (e.g., a mouse) wherein one or more endogenous immunoglobulin genes are replaced with one or more human immunoglobulin genes. Examples of transgenic mice wherein endogenous antibody genes are effectively replaced with human antibody genes include, but are not limited to, the Medarex HUMAB-MOUSE™, the Kirin TC MOUSE™, and the Kyowa Kirin KM-MOUSE™ (see, e.g., Lonberg, *Nat. Biotechnol.*, *23*(9): 1117-25 (2005), and Lonberg, *Handb. Exp. Pharmacol.*, *181*: 69-97 (2008)). A humanized antibody can be generated using any suitable method known in the art (see, e.g., An, Z. (ed.), *Therapeutic Monoclonal Antibodies: From Bench to Clinic*, John Wiley & Sons, Inc., Hoboken, N.J. (2009)), including, e.g., grafting of non-human CDRs onto a human antibody scaffold (see, e.g., Kashmiri et al., *Methods*, *36*(1): 25-34 (2005); and Hou et al., *J. Biochem.*, *144*(1): 115-120 (2008)). In one embodiment, a humanized antibody can be produced using the methods described in, e.g., U.S. Patent Application Publication 2011/0287485 A1.

[0079] In certain aspects, an antibody or antigen-binding fragment provided herein has similar binding affinities for LukF, LukD, and HIgB.

III. Nucleic acids, vectors, and host cells

[0080] Also provided herein are one or more isolated nucleic acid sequences that encode the antibody or antigen-binding fragment thereof that binds to at least one leukotoxin (optionally wherein the antibody or antigen-binding fragment thereof is a monoclonal antibody or fragment).

[0081] The disclosure further provides one or more vectors comprising one or more nucleic acid sequences encoding an antibody or antigen-binding fragment thereof that binds to at least one leukotoxin (optionally wherein one or more of the antibodies or antigen-binding fragments thereof is a monoclonal antibody or fragment). The vector can be, for example, a plasmid, episome, cosmid, viral vector (e.g., retroviral or adenoviral), or phage. Suitable vectors and methods of vector preparation are well known in the art (see, e.g., Sambrook et al., *Molecular Cloning, a Laboratory Manual, 3rd edition*, Cold Spring Harbor Press, Cold Spring Harbor, N.Y. (2001), and Ausubel et al., *Current Protocols in Molecular Biology*, Greene Publishing Associates and John Wiley & Sons, New York, N.Y. (1994)).

[0082] In addition to the nucleic acid sequence encoding the antibody or antigen-binding fragment thereof that binds to at least one leukotoxin (optionally wherein the antibody or antigen-binding fragments thereof is a monoclonal antibody or fragment), the vector desirably comprises expression control sequences, such as promoters, enhancers, polyadenylation signals, transcription terminators, internal ribosome entry sites (IRES), and the like, that provide for the expression of the coding sequence in a host cell. Exemplary expression control sequences are known in the art and described in, for example, Goeddel, *Gene Expression Technology: Methods in Enzymology*, Vol. 185, Academic Press, San Diego, Calif. (1990).

[0083] The vector(s) comprising the nucleic acid(s) the antibody or antigen-binding fragment thereof that binds to at least one leukotoxin (optionally wherein one or more of the antibodies or antigen-binding fragments thereof is a monoclonal antibody or fragment) can be introduced into a host cell that is capable of expressing the polypeptides encoded thereby, including any suitable prokaryotic or eukaryotic cell. As such, the present disclosure provides an isolated cell comprising the vector. Host cells that may be used include those that can be easily and reliably grown, have reasonably fast growth rates, have well characterized expression systems, and can be transformed or transfected easily and efficiently. Examples of suitable prokaryotic cells include, but are not limited to, cells from the genera *Bacillus* (such as *Bacillus subtilis* and *Bacillus brevis*), *Escherichia* (such as *E. coli*), *Pseudomonas*, *Streptomyces*, *Salmonella*, and *Erwinia*. Particularly useful prokaryotic cells include the various strains of *Escherichia coli* (e.g., K12, HB101 (ATCC No. 33694), DH5a, DH10, MC1061 (ATCC No. 53338), and CC102). Suitable eukaryotic cells are known in the art and include, for example, yeast cells, insect cells, and mammalian cells. In one embodiment, the vector is expressed in mammalian cells. A number of suitable mammalian host cells are known in the art, and many are available from the American Type Culture Collection (ATCC, Manassas, VA). Examples of suitable mammalian cells include, but are not limited to, Chinese hamster ovary cells (CHO) (ATCC No. CCL61), CHO DHFR- cells (Urlaub et al, *Proc. Natl. Acad. Sci. USA*, *97*: 4216-4220 (1980)), human embryonic kidney (HEK) 293 or 293T cells (ATCC No. CRL1573), and 3T3 cells (ATCC No. CCL92). Other suitable mammalian cell lines are the monkey COS-1 (ATCC No. CRL1650) and COS-7 cell lines (ATCC No. CRL1651), as well as the CV-1 cell line (ATCC No. CCL70). The mammalian cell desirably is a human cell. For example, the mammalian cell

can be a human lymphoid or lymphoid derived cell line, such as a cell line of pre-B lymphocyte origin, a PER.C6® cell line (Crucell Holland B.V., The Netherlands), or human embryonic kidney (HEK) 293 or 293T cells (ATCC No. CRL1573).

[0084] A nucleic acid sequence encoding amino acids of any of the antibodies or antigen-binding fragments (optionally monoclonal antibodies or fragments) described herein can be introduced into a cell by transfection, transformation, or transduction.

IV. Pharmaceutical compositions and methods of using anti-Staphylococcus aureus leukotoxin antibodies

[0085] The present disclosure provides compositions comprising an antibody or antigen-binding fragment thereof described herein and a pharmaceutically acceptable carrier.

[0086] The present disclosure also provides compositions comprising one or more nucleic acid sequences encoding an antibody or antigen-binding fragment thereof provided herein, or one or more vectors comprising such nucleic acid sequences.

[0087] A composition provided herein (e.g., comprising an antibody or antigen-binding fragment thereof, one or more nucleic acid sequences, or one or more vectors) can be a pharmaceutically acceptable (e.g., physiologically acceptable) composition, which comprises a carrier, such as a pharmaceutically acceptable (e.g., physiologically acceptable) carrier and the antibody or antigen-binding fragment, nucleic acid sequence(s), or vector(s).

[0088] Any suitable carrier can be used within the context of the disclosure, and such carriers are well known in the art. The choice of carrier will be determined, in part, by the particular site to which the composition may be administered and the particular method used to administer the composition. The composition optionally can be sterile. The composition can be frozen or lyophilized for storage and reconstituted in a suitable sterile carrier prior to use. The compositions can be generated in accordance with conventional techniques described in, e.g., *Remington: The Science and Practice of Pharmacy*, 21st Edition, Lippincott Williams & Wilkins, Philadelphia, PA (2001).

[0089] The composition desirably comprises the antibody or antigen-binding fragment in an amount that is effective to treat and/or prevent a *S. aureus* infection. To this end, the disclosed method comprises administering a therapeutically effective amount or prophylactically effective

amount of a leukotoxin-binding antibody or antigen-binding fragment thereof or a composition comprising the aforementioned antibody or antigen-binding fragment thereof (including monoclonal antibodies or fragments).

[0090] The disclosure provides a method of treating or preventing a *Staphylococcus aureus* (*S. aureus*) infection in a subject (e.g., a human), which comprises administering the leukotoxin-binding antibody or antigen-binding fragment described herein to a subject in need thereof, whereupon the *S. aureus* infection is treated or prevented in the subject. The disclosure also provides use of the leukotoxin-binding antibody or antigen-binding fragment, described herein, or the composition comprising the antibodies or fragments thereof described herein, in the manufacture of a medicament for treating or preventing a *S. aureus* infection.

[0091] As discussed herein, *Staphylococcus aureus* is a major human pathogen that causes a wide range of clinical infections. *S. aureus* is a leading cause of bacteremia and infective endocarditis as well as osteoarticular, skin and soft tissue, pleuropulmonary, and device-related infections. Approximately 30% of the human population is colonized with *S. aureus* (Wertheim et al., *Lancet Infect. Dis.*, *5*: 751-762 (2005)). The symptoms of *S. aureus* skin infections include, for example, boils, cellulits, and impetigo. *S. aureus* also may cause food poisoning, blood poisoning (also known as bacteremia), toxic shock syndrome, and septic arthritis. The epidemiology, pathophysiology, and clinical manifestations of *S. aureus* infections are described in detail in, e.g., Tong et al., *Clin. Microbiol. Rev.*, *28*(3): 603-661 (2015), and the genomes of several different *S. aureus* strains have been sequenced (see, e.g., GenBank/EMBL Accession Nos. BX571856, BX571857, BX571858, FN433596, FN433597, FN433598, HE681097, FR821777, FR821778, FR821779, and FR821780). As discussed herein, the subject (e.g., human subject) can have diabetes.

[0092] In certain instances, a therapeutically effective amount of the leukotoxin-binding antibody or antigen-binding fragment, is an amount which inhibits *S. aureus*-associated sepsis, neutralizes toxins, inhibits cell lysis, inhibits multi-organ dysfunction or any combination of the foregoing, e.g., in a human.

[0093] Alternatively, the pharmacologic and/or physiologic effect may be prophylactic, i.e., the effect completely or partially prevents a disease or symptom thereof. In this respect, the disclosed method comprises administering a "prophylactically effective amount" of the

leukotoxin-binding antibody or antigen-binding fragment, (including monoclonal antibodies or fragments).

[0094] Therapeutic or prophylactic efficacy can be monitored by periodic assessment of treated patients. For repeated administrations over several days or longer, depending on the condition, the treatment can be repeated until a desired suppression of disease symptoms occurs. However, other dosage regimens can be useful and are within the scope of the present disclosure. The desired dosage can be delivered by a single bolus administration of the composition, by multiple bolus administrations of the composition, or by continuous infusion administration of the composition.

[0095] The composition(s) comprising an effective amount of an antibody or antigen-binding fragment thereof described herein, nucleic acid sequence(s) encoding any of the foregoing, or vector(s) comprising the nucleic acid sequence can be administered to a subject, such as a human, using standard administration techniques, including intravenous, intraperitoneal, subcutaneous, and intramuscular administration routes. The composition may be suitable for parenteral administration. The term "parenteral," as used herein, includes intravenous, intramuscular, subcutaneous, and intraperitoneal administration. In some embodiments, the composition is administered to a subject using peripheral systemic delivery by intravenous, intraperitoneal, or subcutaneous injection.

[0096] The leukotoxin-binding antibody or antigen-binding fragment or composition comprising the same, can be administered alone or in combination with other drugs (e.g., as an adjuvant) conventionally used for treating *S. aureus* infections. The composition comprising the leukotoxin-binding antibody or antigen-binding fragment can be used in combination with, for example, one or more antibiotics, such as a penicillinase-resistant β-lactam antibiotic (e.g., oxacillin or flucloxacillin). Gentamicin can be used to treat serious infections, such as endocarditis. Most strains of *S. aureus*, however, are now resistant to penicillin, and two in 100 people carry methicillin-resistant strains of *S. aureus* (MRSA). MRSA infections typically are treated with vancomycin, and minor skin infections can be treated with triple antibiotic ointment.

[0097] In addition to therapeutic and prophylactic uses, any antibody or antigen-binding fragment thereof described herein can be used in diagnostic or research applications. In this respect, the leukotoxin-binding antibody or antigen-binding fragment can be used in an assay to

monitor *S. aureus* infection in a subject. Research applications include, for example, methods that utilize the leukotoxin-binding antibody or antigen-binding fragment and a label to detect *S. aureus* in a sample, e.g., in a human body fluid or in a cell or tissue extract. The leukotoxin-binding antibody or antigen-binding fragment can be used with or without modification, such as covalent or non-covalent labeling with a detectable moiety. For example, the detectable moiety can be a radioisotope (e.g., ^{3}H, ^{14}C, ^{32}P, ^{35}S, or ^{125}I), a fluorescent or chemiluminescent compound (e.g., fluorescein isothiocyanate, rhodamine, or luciferin), an enzyme (e.g., alkaline phosphatase, beta-galactosidase, or horseradish peroxidase), or prosthetic groups. Any method known in the art for separately conjugating an antibody or antigen-binding fragment thereof to a detectable moiety can be employed in the context of the present disclosure (see, e.g., Hunter et al., *Nature*, *194*: 495-496 (1962); David et al., *Biochemistry*, *13*: 1014-1021 (1974); Pain et al., *J. Immunol. Meth.*, *40*: 219-230 (1981); and Nygren, J., *Histochem. And Cytochem.*, *30*: 407-412 (1982)).

[0098] Any antibody or antigen-binding fragment thereof described herein (e.g., monoclonal antibodies or fragments), the nucleic acid sequence(s) encoding any of the foregoing, the vector(s) comprising the nucleic acid sequence(s), or the composition(s) comprising any of the foregoing, can be provided in a kit, i.e., a packaged combination of reagents in predetermined amounts with instructions for performing a diagnostic assay. If the leukotoxin-binding antibody or antigen-binding fragment is labeled with an enzyme, the kit desirably includes substrates and cofactors required by the enzyme (e.g., a substrate precursor which provides a detectable chromophore or fluorophore). In addition, other additives may be included in the kit, such as stabilizers, buffers (e.g., a blocking buffer or lysis buffer), and the like. The relative amounts of the various reagents can be varied to provide for concentrations in solution of the reagents which substantially optimize the sensitivity of the assay. The reagents may be provided as dry powders (typically lyophilized), including excipients which on dissolution will provide a reagent solution having the appropriate concentration.

[0099] The following examples further illustrate the invention but, of course, should not be construed as in any way limiting its scope.

EXAMPLE 1

[00100] The anti-leukotoxin antibody SAN481 comprises a heavy chain with the amino acid sequence of SEQ ID NO:9 and a light chain with the amino acid sequence of SEQ ID NO:10. Several sequence liabilities were identified in these sequences. For example, oxidation of heavy chain W100a (inVH-CDR3) and M256 (in the Fc domain) were observed. In addition, a glycosylation site (NFS) in the variable heavy chain was 70% glycosylated. Two NS deamidation sites were identified in VL-CDR1, and a DG/DS isomerization site was identified in VH-CDR2. Furthermore, light sensitivity resulted in a 3.5% increase in aggregation of SAN481 upon 1 wk CWL-2kLux.

[00101] In order to achieve an improved SAN481 antibody variant, a series of sequence variants were designed and tested. The variants were designed to remove these liabilities and to increase half-life without impacting the leukotoxin neutralization activity of the antibody. (Initial attempts to remove sequence liabilities resulted in the loss of binding and neutralizing activity to LukSF. These initial attempts included mutating W102 to F, Y, A, L, I, G, and V in a construct containing the N28T mutation.) A YTE mutation was used for half-life extension, and this same mutation also removes the methionine oxidation site (residue M256) in the Fc region.

[00102] These variants were then tested for the binding and neutralizing potency against LukSF, for their photo-stability, and for their developability. The results are summarized in Table 8 below, and additional information is found in the following Examples.

Table 8: SAN481 and SAN481 Variants

Variant	IC50 (LukSF) HL-60 µg/mL	IC50 (HIgAB) HL-60 µg/mL	Kd LukF M	Titer Mg/L	% mon. Prot. A	% mon. loss (stability)	1 Wk Photo Stability % agg. change
SAN481	0.16	0.57	1.63E-10		99.1%	2.19	3.54%
SAN481-YTE	0.15	0.54	1.48E-11	475	99.8%	-0.05	0.48%
SAN481-SY-YTE	0.18	0.55	1.01E-10	834	99.7%	0.18	0.00%
SAN481	0.17	0.54	<1.0E-	800	99.4%	-0.02	0.49%

-T-YTE			12				
SAN481-TF-YTE	0.81	0.44	1.21E-09	778	99.2%	3.92	Not tested
SAN481-SYT-YTE	0.16	0.54	1.01E-10	694	99.5%	0.27	0.18%

"mon." = monomer

"agg." = aggregation

[00103] SAN481-SYT-YTE was selected as a particular advantageous variant in view of the fact that it had similar IC50s for LukSF, LukED, and HIgAB as SAN481, had minimal aggregation increase under light exposure, had no significant CDR deamidation and isomerization (1.1%) detected, no stability issues, no self-association, and no non-specific binding.

EXAMPLE 2

[00104] This example demonstrates that, unlike other SAN481-variants, the SAN481-SYT-YTE antibody maintains the *in vitro* activity of SAN481.

[00105] *In vitro* assays were conducted in order to evaluate the activity of SAN481 variants. In these assays, differentiated HL60 human monocytic cells (2.5e4 well/25 µl) were incubated for 2 hours at 37°C with 50 µl of a mixture of LukSF (100 ng/ml each) or HIgAB (400 ng/ml each) and serial dilutions of each mAb mutant (25 µl) as indicated on Figure 1.

The percentage of cell viability was measured using a Cell Glo assay and calculated as follows: 100*[(OD450 cells+toxin+mAb)/(OD450 cells alone)]. The concentration of mAb required to achieve 50% inhibition of viability (IC_{50}) was calculated, and reported on Table 9.

Table 9: LukSF and HIgAB Activity of SAN481 Variants

Variant	IC_{50} for LukSF (µg/ml)	IC_{50} Fold loss vs. WT	IC_{50} for HIgAB (µg/ml)	IC_{50} Fold loss vs. WT
SAN481-YTE (QD1)	0.1499	0.9375	0.5399	0.9497
SAN481-SY-YTE (QD2)	0.1826	1.1420	0.5513	0.9697
SAN481-T-YTE (QD3)	0.1656	1.0356	0.5388	0.9478

SAN481-TF-YTE (QD4)	0.8109	5.0713	0.4406	0.7750
SAN481-SYT-YTE (QD5)	0.1617	1.0113	0.5404	0.9506
SAN481-SYTF-YTE (QD6)	1.369	8.5616	0.4929	0.8670
SAN481-EG-YTE (QD11)	0.2006	1.2545	0.503	0.8848
SAN481-SY-QFS-YTE (QD12)	0.1579	0.9875	0.5513	0.9698
SAN481	0.1599		0.5685	

[00106] SAN481-TF-YTE and SAN481-SYTF-YTE antibodies lost respectively 5.07 and 8.56 fold potency against LukSF as compared to SAN481. However, the SAN481-SYT-YTE antibody did not.

EXAMPLE 3

[00107] This example demonstrates that the SAN481-SYT-YTE antibody has similar *in vitro* leukotoxin neutralization as the SAN481 antibody.

[00108] The *in vitro* leukotoxin neutralization activity was tested by an assay measuring cell viability. More specifically, differentiated HL60 human monocytic cells (2.5e4 well/25 µl) were incubated for 2 hours at 37°C with 50µl of a mixture of LukSF (100 ng/ml each), LukED (2000ng/ml each), HlgCB (200ng/ml each) or HIgAB (400 ng/ml each) and serial dilutions of SAN481 or SAN481_SYT-YTE (25µl) as indicated on Figure 2. The percentage of cell viability was measured using a Cell Glo assay and calculated as follows: 100*[(OD450 cells+toxin+mAb)/(OD450 cells alone)], and graphed on Figure 2.

[00109] The results, shown in Figure 2, demonstrate that SAN481-SYT-YTE and SAN481 have similar *in vitro* neutralization activity against all of LukSF, HIgAB, HIgBC, and LukED.

EXAMPLE 4

[00110] This example demonstrates that the SAN481-SYT-YTE demonstrates superior photostability.

[00111] The photostability of SAN481 variants was tested. In these assays, the binding affinities of mAb variants to recombinant antigens were measured by Bio-layer Interferometry on an Octet384 instrument (ForteBio, Menlo Park, CA). For determination the intrinsic binding affinity, antibodies at 2 μg/mL in PBS pH 7.2, 3 mg/mL BSA, 0.05% (v/v) tween 20 (1× Kinetics Buffer, ForteBio) were captured by anti-human IgG Fc biosensors (ForteBio). Following washing, association and dissociation measurements were carried out using serial dilutions of the antigen protein. The dissociation constant (KD), was deduced as the ratio of the two rate constants (koff/kon) from a non-linear fit of the data using the Octet384 software v.7.2..

[00112] The results are shown in Tables 10 and 11 below.

Table 10: One-Week Photostability of SAN481 Variants

Variant		% agg	% mon	% frag	IC_{50} (LukSF) HL-60 (ug/mL)	IC_{50} (HlgAB) HL-60 (ug/mL)
SAN481	Light	4.18	94.96	0.84		
SAN481	Dark	0.70	98.76	0.52	0.16	0.569
SAN481-YTE (QD1)	Light	0.7	98.46	0.83	0.233	0.821
SAN481-YTE (QD1)	Dark	0.22	99.24	0.53	0.209	0.704
SAN481-SY-YTE (QD2)	Light	0.46	99.2	0.32	0.241	0.736
SAN481-SY-YTE (QD2)	Dark	0.47	99.19	0.33	0.221	0.721
SAN481-T-YTE (QD3)	Light	1.32	98.04	0.62	0.205	0.624
SAN481-T-YTE (QD3)	Dark	0.83	98.71	0.44	0.193	0.707
SAN481-SYT-YTE (QD5)	Light	0.37	99.23	0.39	0.184	0.645
SAN481-SYT-YTE (QD5)	Dark	0.19	99.47	0.33	0.163	0.576

Table 11: Octet Binding Activity of Light Stressed SAN481, SAN481-YTE, and SAN481-SYT-YTE

Antigen	Antibody/Condition	KD (M)	Kon (1/Ms)	koff (1/s)
LukD	SAN481	<1.0E-12	3.48E+05	<1.0E-07
	SAN481-YTE (QD1) / Dark	<1.0E-12	2.77E+05	<1.0E-07
	SAN481-YTE (QD1) / Light	<1.0E-12	294200	<1.0E-07
	SAN481-SYT-YTE (QD5) / Dark	<1.0E-12	2.79E+05	<1.0E-07
	SAN481-SYT-YTE (QD5) / Light	<1.0E-12	2.63E+05	<1.0E-07
Luk F	SAN481	9.93E-11	4.02E+05	3.99E-05
	SAN481-YTE (QD1) / Dark	2.32E-10	2.83E+05	6.55E-05
	SAN481-YTE (QD1) / Light	2.26E-10	2.87E+05	6.47E-06
	SAN481-SYT-YTE (QD5) / Dark	1.01E-10	3.65E+05	3.69E-05
	SAN481-SYT-YTE (QD5) / Light	<1.0E-12	2.57E+05	<1.0E-07
HIgB	SAN481	1.51E-10	2.90E+05	4.38E-05
	SAN481-YTE (QD1) / Dark	<1.0E-12	2.40E+05	<1.0E-07
	SAN481-YTE (QD1) / Light	<1.0E-12	2.65E+05	<1.0E-07
	SAN481-SYT-YTE (QD5) / Dark	1.91E-11	2.55E+05	4.88E-06
	SAN481-SYT-YTE (QD5) / Light	<1.0E-12	2.44E+05	<1.0E-07

[00113] The results demonstrate the superior photostability of SAN481-SYT-YTE and that there is no loss of binding for light stress samples of SAN481-SYT-YTE.

[00114] All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

[00115] The use of the terms "a" and "an" and "the" and "at least one" and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The use of the term "at least one" followed by a list of one or more items (for example, "at least one of A and B") is to be construed to mean one item selected from the listed items (A or B) or any combination of two or more of the listed items (A and B), unless otherwise indicated herein or clearly contradicted by context. The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted. 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. 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 better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[00116] Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations

thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

CLAIM(S):

1. An antibody or antigen-binding fragment thereof that specifically binds to at least one *S. aureus* leukotoxin wherein the antibody or antigen-binding fragment comprises a variable heavy chain (VH) complementarity determining region (CDR) 1, a VH CDR2, a VH CDR3, a variable light chain (VL) CDR1, a VL CDR2, and a VL CDR3, wherein the VH CDR1, VH CDR2, VH CDR3, VL CDR1, VL CDR2, and VL CDR3 comprise sequences selected from the group consisting of: (a) SEQ ID NOs:1, 2, 3, 12, 5, and 6, respectively; (b) SEQ ID NOs:1-6, respectively; (c) SEQ ID NOs:1, 2, 17, 4, 5, and 6, respectively; (d) SEQ ID NOs: 1, 2, 17, 12, 5, and 6, respectively; and (e) SEQ ID NOs: 1, 20, 3, 4, 5, and 6, respectively.

2. An antibody or antigen-binding fragment thereof that specifically binds to at least one *S. aureus* leukotoxin wherein the antibody or antigen-binding fragment comprises the VH CDR1, VH CDR2, VH CDR3, VL CDR1, VL CDR2, and VL CDR3 of SAN481-SYT-YTE.

3. The antibody or antigen-binding fragment thereof of claim 2, wherein the CDRs are the Kabat-defined CDRs, the Chothia-defined CDRs, or the AbM-defined CDRs.

4. The antibody or antigen-binding fragment thereof of any one of claims 1-3, wherein the antibody or antigen-binding fragment thereof comprises a VH and a VL, wherein the VH comprises the amino acid sequence of SEQ ID NO:7, 15, 18, 21, or 23.

5. The antibody or antigen-binding fragment thereof of any one of claims 1-4, wherein the antibody or antigen-binding fragment thereof comprises a VH and a VL, wherein the VL comprises the amino acid sequence of SEQ ID NO:8 or 13.

6. The antibody or antigen-binding fragment thereof of any one of claims 1-5, wherein the antibody or antigen-binding fragment thereof comprises a VH and a VL, wherein the VH and VL comprise sequences selected from the group consisting of: (a) SEQ ID NOs:15 and 13, respectively; (b) SEQ ID NOs:7 and 8, respectively; (c) SEQ ID NOs:7 and 13, respectively; (d) SEQ ID NOs:15 and 8, respectively; (e) SEQ ID NOs:18 and 8, respectively; (f) SEQ ID NOs:18 and 13, respectively; (g) SEQ ID NOs:21 and 8, respectively; and (h) SEQ ID NOs:23 and 13, respectively.

7. The antibody or antigen-binding fragment thereof of any one of claims 1-5, wherein the antibody or antigen-binding fragment thereof comprises a VH comprising the sequence of SEQ ID NO:15 and a VL comprising the sequence of SEQ ID NO:13.

8. The antibody or antigen-binding fragment thereof of any one of claims 1-7, wherein the antibody or antigen-binding fragment comprises a heavy chain comprising the sequence of SEQ ID NO:16, 9, 11, 22, or 24.

9. The antibody or antigen-binding fragment thereof of any one of claims 1-8, wherein the antibody or antigen-binding fragment comprises a light chain comprising the sequence of SEQ ID NO:14 or 10.

10. The antibody or antigen-binding fragment thereof of any one of claims 1-9, wherein the antibody comprises a heavy chain and a light chain, wherein the heavy and chains comprise sequences selected from the group consisting of: (a) SEQ ID NOs: 16 and 14, respectively; (b) SEQ ID NOs:9 and 10, respectively; (c) SEQ ID NOs:11 and 10, respectively; (d) SEQ ID NOs:11 and 14, respectively; (e) SEQ ID NOs:16 and 10, respectively; (f) SEQ ID NOs:19and 10, respectively; (g) SEQ ID NOs:19 and 14, respectively; (h) SEQ ID NOs:22 and 10, respectively; and (i) SEQ ID NOs:24 and 14, respectively.

11. The antibody or antigen-binding fragment thereof of any one of claims 1-9, wherein the antibody comprises a heavy comprising the sequence of SEQ ID NO:16 and a light chain comprising the sequence of SEQ ID NO:14.

12. An antibody or antigen-binding fragment thereof that binds to the same *S. aureus* leukotoxin epitope as an antibody comprising a VH comprising the amino acid sequence of SEQ ID NO:15 and a VL comprising the amino acid sequence of SEQ ID NO:13.

13. An antibody or antigen-binding fragment thereof that competitively inhibits binding of an antibody comprising a VH comprising the amino acid sequence of SEQ ID NO:15 and a VL comprising the amino acid sequence of SEQ ID NO:13 to a *S. aureus* leukotoxin

14. The antibody or antigen-binding fragment thereof of any one of claims 1-13, wherein (a) the antibody or antigen-binding fragment binds to LukF, LukD, or HlgB and/or (b) the antibody or antigen-binding fragment neutralizes LukF, LukD, or HlgB.

15. The antibody or antigen-binding fragment thereof of any one of claims 1-14, wherein the antibody or antigen-binding fragment (a) binds to LukF, LukD, and HlgB and/or (b) neutralizes LukF, LukD, and HlgB.

16. The antibody or antigen-binding fragment thereof of any one of claims 1-15, wherein the antibody or antigen-binding fragment further comprises a heavy chain constant region.

17. The antibody or antigen-binding fragment thereof of claim 16, wherein the heavy chain constant region is selected from the group consisting of human immunoglobulin IgG_1, IgG_2, IgG_3, IgG_4, IgA_1, and IgA_2 heavy chain constant regions.

18. The antibody or antigen-binding fragment thereof of claim 17, wherein the heavy chain constant region is a human IgG_1 constant region.

19. The antibody or antigen-binding fragment thereof of any one of claims 1-18, wherein the antibody or antigen-binding fragment further comprises a light chain constant region.

20. The antibody or antigen-binding fragment thereof of claim 19, wherein the light chain constant region is selected from the group consisting of human immunoglobulin IgGκ and IgGλ light chain constant regions.

21. The antibody or antigen-binding fragment thereof of claim 20, wherein the light chain constant region is a human IgGκ light chain constant region.

22. The antibody or antigen-binding fragment thereof of any one of claims 1-21, wherein the antibody or antigen-binding fragment thereof is an IgG antibody or antigen-binding fragment thereof.

23. The antibody or antigen-binding fragment thereof of any one of claims 1-22, wherein the antibody or antigen-binding fragment thereof comprises an Fc region that has been engineered to improve half-life.

24. The antibody or antigen-binding fragment thereof of any one of claims 1-23, wherein the antibody or antigen-binding fragment thereof comprises an Fc region with a YTE mutation.

25. The antibody or antigen-binding fragment thereof of any one of claims 1-24, wherein the antibody or antigen-binding fragment is a monoclonal antibody or antigen-binding fragment.

26. The antibody or antigen-binding fragment thereof of any one of claims 1-25, wherein the antibody or antigen-binding fragment is a full–length antibody.

27. The antibody or antigen-binding fragment thereof of any one of claims 1-9 and 12-26, wherein the antibody or antigen-binding fragment is an antigen-binding fragment.

28. The antigen-binding fragment of claim 27, wherein the antigen-binding fragment comprises a Fab, Fab', $F(ab')_2$, single chain Fv (scFv), disulfide linked Fv, intrabody, IgGΔCH2, minibody, $F(ab')_3$, tetrabody, triabody, diabody, DVD-Ig, Fcab, mAb^2, $(scFv)_2$, or scFv-Fc.

29. The antibody or antigen-binding fragment thereof of any one of claims 1-28, wherein the antibody or antigen-binding fragment thereof has an affinity of less than 75 pM for *S. aureus* LukF, LukD, and HlgB.

30. The antibody or antigen-binding fragment thereof of any one of claims 1-29, wherein the antibody or antigen-binding fragment thereof has similar binding affinities for LukF, LukD, and HIgB.

31. The antibody or antigen-binding fragment thereof of any one of claims 1-30, further comprising a detectable label

32. A composition comprising the antibody or antigen-binding fragment thereof of any one of claims 1-31 and, optionally, a pharmaceutically-acceptable carrier.

33. A method of treating or preventing a *Staphylococcus aureus* (*S. aureus*) infection in a subject comprising administering to the subject the antibody or antigen-binding fragment of any one of claims 1-31 or the composition of claim 32.

34. The method of claim 33, wherein the *S. aureus* infection is sepsis.

35. The method of claim 33, wherein the *S. aureus* infection is bacteremia

36. The method of claim 33, wherein the *S. aureus* infection is pneumonia.

37. The method of claim 33, wherein the *S. aureus* infection is ICU pneumonia.

38. The method of claim 33, wherein the *S. aureus* infection is a skin or soft tissue infection (SSTI).

39. The method of claim 33, wherein the *S. aureus* infection is a diabetic infection of the lower limbs.

40. The method of claim 33, wherein the *S. aureus* infection is a diabetic foot ulcer (DFU).

41. The method of claim 40, wherein the DFU is uninfected.

42. The method of claim 40, wherein the DFU is infected.

43. The method of claim 40, wherein the DFU is a grade 1, 2 or 3 DFU.

44. The method of claim 33, wherein the *S. aureus* infection is a bone or joint infection.

45. The method of claim 33, wherein the *S. aureus* infection is a joint infection, a device infection, a wound infection, a surgical site infection, or osteomyelitis.

46. The method of any one of claims 33-45, wherein the subject is a surgical subject.

47. The method of any one of claims 33-46, wherein the *S. aureus* infection comprises antibiotic-resistant *S. aureus*.

48. The method of any one of claims 33-47, wherein the subject has diabetes.

49. The method of any one of claims 33-48, wherein the subject is human.

50. The method of any one of claims 33-49, wherein the treating or preventing an *S. aureus* infection comprises toxin neutralization, inhibiting cell lysis, inhibiting multi-organ disfunction, inhibiting *S. aureus*-associated sepsis, or any combination of the foregoing.

51. An isolated polynucleotide comprising a nucleic acid molecule encoding the VH or heavy chain of the antibody or antigen-binding fragment thereof of any one of claims 1-30.

52. An isolated polynucleotide comprising a nucleic acid molecule encoding the VL or light chain of the antibody or antigen-binding fragment thereof of any one of claims 1-30.

53. An isolated vector comprising the polynucleotide of claim 51 and/or claim 52.

54. A host cell comprising the polynucleotide of claim 51 and/or 52, the vector of claim 53, or a first vector comprising the polynucleotide of claim 51 and a second vector comprising the polynucleotide of claim 52.

55. The host cell of claim 54, wherein the host cell is selected from the group consisting of CHO, NS0, PER-C6, HEK-293, and HeLa cells.

56. The host cell of claim 54 or 55, wherein the host cell is isolated.

57. A method of producing an antibody or antigen-binding fragment thereof comprising culturing the host cell of any one of claims 54-56 so that the antibody or antigen-binding fragment thereof is produced.

58. A method for detecting *S. aureus* or *S. aureus* leukotoxin in a sample comprising contacting said sample with the antibody or antigen-binding fragment thereof of any one of claims 1-31.

Figure 1

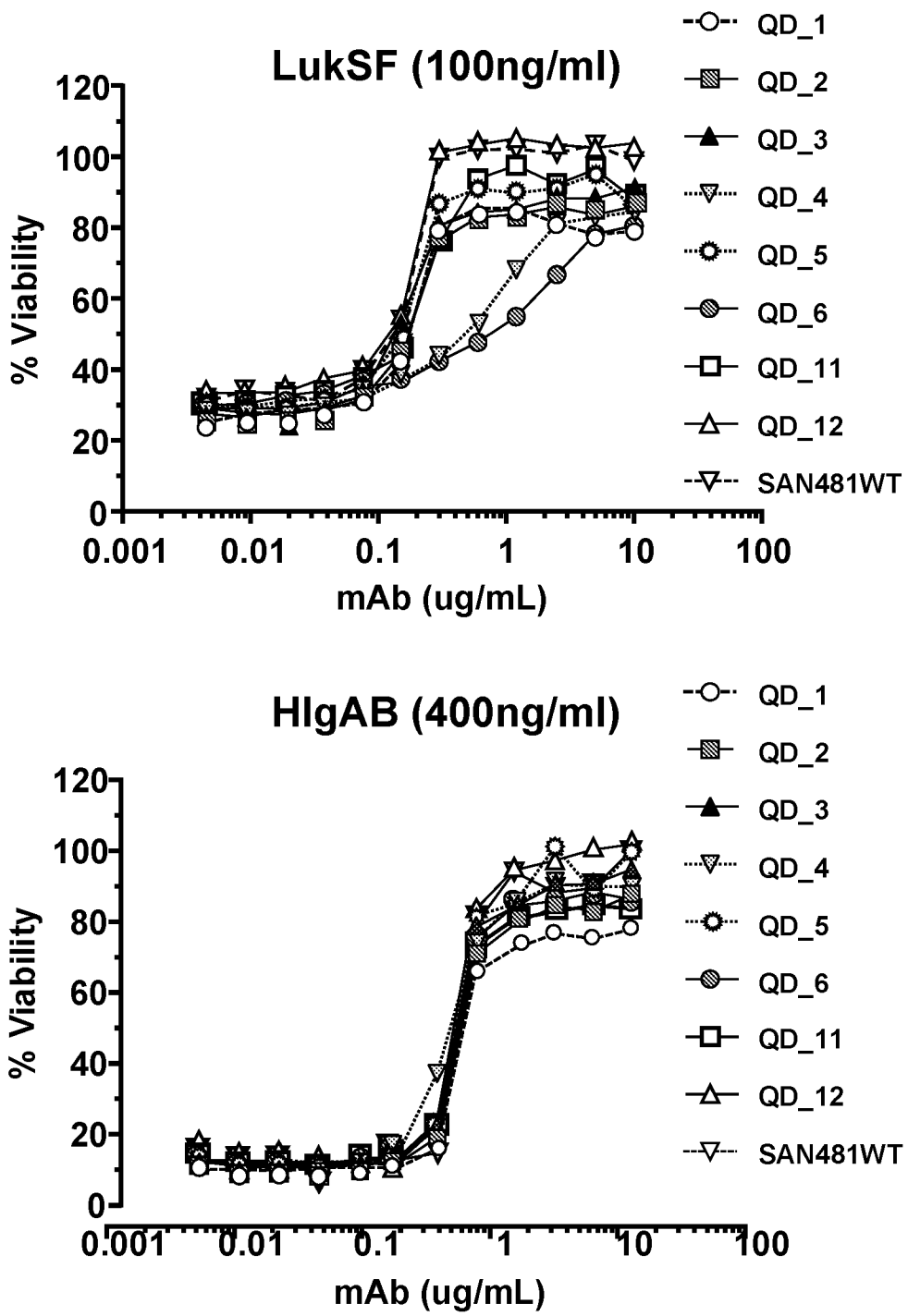

LukSF (100ng/ml)
% Viability
120
100
80
60
40
20
0
0.001
0.01
0.1
1
10
100
mAb (ug/mL)
QD_1
QD_2
QD_3
QD_4
QD_5
QD_6
QD_11
QD_12
SAN481WT
HlgAB (400ng/ml)
% Viability
120
100
80
60
40
20
0
0.001
0.01
0.1
1
10
100
mAb (ug/mL)
QD_1
QD_2
QD_3
QD_4
QD_5
QD_6
QD_11
QD_12
SAN481WT

Figure 2

in vitro

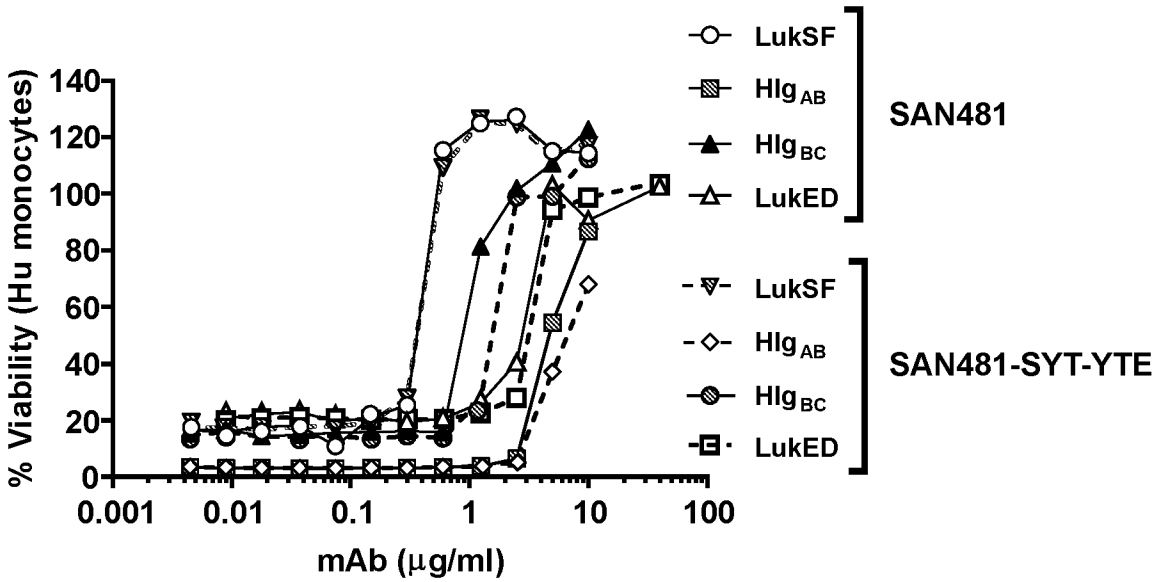
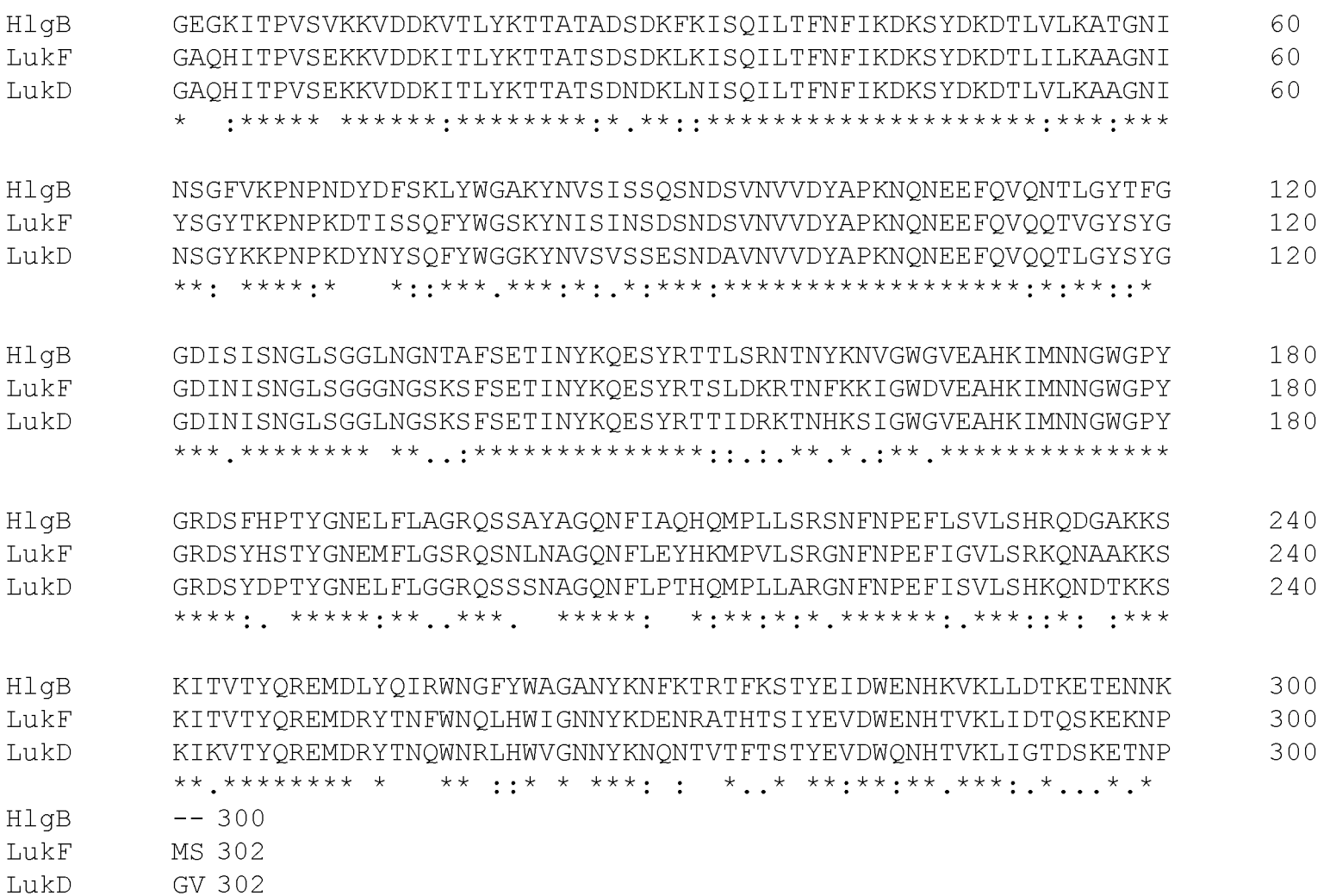


Figure 3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LukD GAQHITPVSEKKVDDKITLYKTTATSDNDKLNISQILTFNFIKDKSYDKDTLVLKAAGNI 60
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LukF YSGYTKPNPKDTISSQFYWGSKYNISINSDSNDSVNVVDYAPKNQNEEFQVQQTVGYSYG 120
LukD NSGYKKPNPKDYNYSQFYWGGKYNVSVSSESNDAVNVVDYAPKNQNEEFQVQQTLGYSYG 120
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LukD GRDSYDPTYGNELFLGGRQSSSNAGQNFLPTHQMPLLARGNFNPEFISVLSHKQNDTKKS 240
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LukF KITVTYQREMDRYTNFWNQLHWIGNNYKDENRATHTSIYEVDWENHTVKLIDTQSKEKNP 300
LukD KIKVTYQREMDRYTNQWNRLHWVGNNYKNQNTVTFTSTYEVDWQNHTVKLIGTDSKETNP 300
HlgB -- 300
LukF MS 302
LukD GV 302

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/055144

A. CLASSIFICATION OF SUBJECT MATTER
INV. C07K16/12 A61K39/085 A61P31/00 A61K39/00
ADD.

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)
C07K A61K A61P

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data, BIOSIS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015/055814 A1 (ARSANIS BIOSCIENCES GMBH [AT]) 23 April 2015 (2015-04-23) abstract, p. 4 line 29 - p. 22 line 31, examples 1-6, fig. 1-6 and claims ----- -/--	1-58

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 December 2019	20/01/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hermann, Patrice

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	B.-J. LAVENTIE ET AL: "Heavy chain-only antibodies and tetravalent bispecific antibody neutralizing Staphylococcus aureus leukotoxins", PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES, vol. 108, no. 39, 27 September 2011 (2011-09-27), pages 16404-16409, XP055059913, ISSN: 0027-8424, DOI: 10.1073/pnas.1102265108 the whole document -----	1-58
A	US 2011/274693 A1 (TORRES VICTOR J [US] ET AL) 10 November 2011 (2011-11-10) the whole document -----	1-58

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Information on patent family members

International application No
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