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DESCRIPTION

BACKGROUND

[0001] Therapeutic proteins, e.g., therapeutic antibodies, have rapidly become a clinically important drug class for patients with immunological diseases. Numerous autoimmune and alloimmune diseases are mediated by pathogenic antibodies. For example, many fetal and neonatal immune diseases result from the transfer of maternal antibodies from a pregnant subject, especially a pregnant subject with an immunological disease, to the fetus through the human neonatal Fc receptor (FcRn) in the placenta. US2016/194397 discloses proteins that bind to FcRn, e.g., antibodies that inhibit FcRn with high affinity and selectivity. The FcRn-binding proteins can be used to treat variety of disorders including autoimmune disorders. The FcRn-binding proteins can also be used for reducing the risk of developing an autoimmune or alloimmune disorder by administering to a pregnant subject. There exists a need for novel methods of treating immunological diseases.

SUMMARY

[0002] The subject matter for which protection is sought is as defined in the claims. The embodiments and/or examples of the following description which are not covered by the appended claims, when interpreted according to Article 69 EPC and the Protocol on the Interpretation of Article 69 EPC, are not considered to be part of the present invention.

[0003] Any reference as to methods of treatment is considered as a reference to the compounds and compositions of the present invention for use in a method of treatment practised on the human body. In a first aspect, the invention provides an antibody for use in a method of treating a fetal and neonatal alloimmune and/or autoimmune disorder, the method comprising administering the antibody to a pregnant subject, wherein the antibody comprises: a polypeptide having the amino acid sequence of SEQ ID NO: 19 and a polypeptide having the amino cid sequence of SEQ ID NO: 24.

[0004] In a second aspect, the invention provides an antibody for use in a method of treating fetal anemia associated with hemolytic disease of the fetus and newborn, the method comprising administering the antibody to a pregnant subject, wherein the antibody comprises: a polypeptide having the amino acid sequence of SEQ ID NO: 19 and a polypeptide having the amino cid sequence of SEQ ID NO: 24.

[0005] In some embodiments, the subject has a history of having had a previous fetal and neonatal alloimmune and/or autoimmune disorder. In some embodiments, the subject is at risk of having a fetal and neonatal alloimmune and/or autoimmune disorder. In some embodiments, the fetal and neonatal alloimmune and/or autoimmune disorder is selected from the group consisting of fetal and neonatal alloimmune thrombocytopenia, hemolytic disease of the fetus and newborn, alloimmune pan-thrombocytopenia, congenital heart block, fetal arthrogryposis, neonatal myasthenia gravis, neonatal autoimmune hemolytic anemia, neonatal anti-phospholipid syndrome, neonatal polymyositis, dermatomyositis, neonatal lupus, neonatal scleroderma, Behcet's disease, neonatal Graves' disease, neonatal Kawasaki disease, neonatal autoimmune thyroid disease, and neonatal type I diabetes mellitus.

[0006] In some embodiments, the fetal and neonatal autoimmune and/or autoimmune disorder is hemolytic disease of the fetus and newborn. In some embodiments, the fetal and neonatal autoimmune and/or autoimmune disorder is fetal and neonatal alloimmune thrombocytopenia. In some embodiments, the fetal and neonatal autoimmune and/or autoimmune disorder is congenital heart block.

[0007] In some embodiments, treatment reduces the risk of a miscarriage.

[0008] In some embodiments, the method treats the pregnant subject, a fetus of the pregnant subject, and/or a combination thereof.

[0009] In some embodiments, the use reduces the risk of miscarriage/loss of fetus.

[0010] In some embodiments,the use reduces the risk of miscarriage/loss of fetus.

[0011] The light chain variable region of the antibody used in the invention consists of the sequence of QSALTQPASVSGSPGQSITISCTGTGSDVGSYNLVSWYQQHPGKAPKLMIYGDSERPSGVSNRFSGSKS GNTASLTISGLQAEDEADYYCSSYAGSGIYVFGTGTKVTVLGQPKAAPSVTLFPPSSEELQANKATLVCLI SDFYPGAVTVAWKADSSPVKAGVETTTPSKQSNNKYAASSYLSLTPEQWKSHKSYSCQVTHEGSTVEK TVAPTECS (SEQ ID NO: 19); and the heavy chain variable region of the antibody used in the invention consists of the sequence of
EVQLLESGGGLVQPGGSLRLSCAASGFTFSTYAMGWVRQAPGKGLEWVSSIGASGSQTRYADSVKGRF
TISRDNSKNTLYLQMNSLRAEDTAVYYCARLAIGDSYWGQGTMVTVSSASTKGPSVFPLAPSSKSTSGG
TAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVPSSSLGTQTYICNVNHKPSN
TKVDKKVEPKSCDKTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWY
VDGVEVHNAKTKPREEQYASTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQ
VYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSR
WQQGNVFSCSVMHEALHNHYTQKSLSLSPG (SEQ ID NO: 24).

[0012] In some embodiments, the antibody used in the invention binds human FcRn with a K_D of between 1 pM and 100 nM.

[0013] In some embodiments, the antibody used in the invention binds human FcRn with a K_D of less than or equal to that of antibody N026.

[0014] In some embodiments, the antibody used in the invention is a monoclonal antibody.

[0015] In some embodiments, the antibody used in the invention is IgG1 or variant thereof.

[0016] In some embodiments, the antibody used in the invention includes, comprises, consists of, or consists essentially of a λ light chain.

[0017] In some embodiments, the antibody used in the invention recognizes the amino acid sequences a) SEQ ID NO: 25 and b) SEQ ID NO: 26 in the human FcRn.

[0018] In some embodiments, the antibody used in the invention binds to an epitope on FcRn comprising at least one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen, sixteen, seventeen, eighteen, nineteen, or twenty amino acids selected from the group consisting of K80, A81, L82, G83, G84, K85, G86, P87, Y88, L112, N113, E115, G129, D130, W131, P132, E133, L135, A136, and Q139 of SEQ ID NO: 30.

[0019] In some embodiments, the antibody used in the invention binds to an epitope on FcRn comprising at least one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen, sixteen, seventeen, eighteen, nineteen, or twenty amino acids selected from the group consisting of K80, A81, L82, G83, G84, K85, G86, P87, Y88, L112, N113, G129, D130, W131, P132, E133, L135, A136, and Q139 of SEQ ID NO: 30.

[0020] In some embodiments, the epitope on FcRn includes, comprises, consists of, or consists essentially of W131 and/or Y88 of SEQ ID NO: 30.

[0021] In some embodiments, the epitope on FcRn includes, comprises, consists of, or consists essentially of D130W131, W131P132, P87Y88, and/or Y88T89 of SEQ ID NO: 30.

[0022] In some embodiments, the epitope on FcRn includes, comprises, consists of, or consists essentially of G129D130W131, W131P132E133, D130W131P132, P87Y88T89, G86P87Y88, and/or Y88T89L90 of SEQ ID NO:

30.

[0023] In some embodiments, the epitope on FcRn includes, comprises, consists of, or consists essentially of G129D130W131 P132, D130W131P132E133, W131P132E133A134, G128G129D130W131, K85G86P87Y88, G86P87Y88T89, P87Y88T89L90, and/or Y88T89L90Q91 of SEQ ID NO: 30.

[0024] In some embodiments, the epitope on FcRn includes, comprises, consists of, or consists essentially of G129D130W131 P132E133, D130W131P132E133A134, W131P132E133A134L315, G128G129D130W131P132, W127G128G129D130W131, G84K85G86P87Y88, K85G86P87Y88T89, G86P87Y88T89L90, P87Y88T89L90Q91, and/or Y88T89L90T91Q92 of SEQ ID NO: 30.

[0025] In some embodiments, the epitope on FcRn includes, comprises, consists of, or consists essentially of T126W127G128G129D130W131, W127G128G129D130W131P132, G128G129D130W131P132E133, G129D130W131P132E133A134, D130W131P132E133A134L135, W131P132E133A134L135A136, G83G84K85G86P87Y88, G84K85G86P87Y88T89, K85G86P87Y88T89L90, G86P87Y88T89L90Q91, P87Y88T89L90T91Q92, and/or Y88T89L90Q91G92L93 of SEQ ID NO: 30.

[0026] In some embodiments, the epitope on FcRn includes, comprises, consists of, or consists essentially of one or more amino acids within about 3 amino acids or 10 Angstroms of W131, one or more amino acids within about 5 amino acids or 8 Angstroms Y88, or any two sets of amino amino acids, wherein the first set is or includes W131 and the second set is or includes Y88 of SEQ ID NO: 30.

[0027] In some embodiments, the epitope on FcRn includes, comprises, consists of, or consists essentially of K80, A81, L82, G83, G84, K85, G86, P87, Y88, L112, N113, E115, G129, D130, W131, P132, E133, L135, A136, and Q139.

[0028] In some embodiments, the antibody used in the invention binds to an epitope on β2-microglobulin comprising at least one amino acid selected from the group consisting of I1, Q2, P32, and V85 of SEQ ID NO: 31.

[0029] In some embodiments, the antibody used in the invention recognizes an amino acid sequence on FcRn comprising W131 and/or Y88 in SEQ ID NO: 30. In some embodiments, the antibody recognizes an amino acid sequence on FcRn comprising DW, WP, PY, and/or YT in SEQ ID NO: 30.

[0030] In some embodiments, the antibody used in the invention recognizes an amino acid sequence on FcRn comprising GDW, WPE, DWP, PYT, GPY, and/or YTL in SEQ ID NO: 30. In some embodiments, the antibody recognizes an amino acid sequence on FcRn comprising GDWP, DWPE, WPEA, GGDW, KGPY, GPYT, PYTL, and/or YTLQ in SEQ ID NO: 30. In some embodiments, the antibody recognizes an amino acid sequence on FcRn comprising GDWPE, DWPEA, WPEAL, GGDWP, WGGDW, GKGPY, KGPYT, GPYTL, PYTLQ, and/or YTLTQ in SEQ ID NO: 30. In some embodiments, the antibody recognizes an amino acid sequence on FcRn comprising TWGGDW, WGGDWP, GGDWPE, GDWPEA, DWPEAL, WPEALA, GGKGPY, GKGPYT, KGPYTL, GPYTLQ, PYTLTQ, and/or YTLQGL in SEQ ID NO: 30. In some embodiments, the antibody used in the invention recognizes an amino acid sequence on FcRn comprising one or more amino acids within about 3 amino acids or 10 Angstroms of W131, one or more amino acids within about 5 amino acids or 8 Angstroms of Y88, or any two sets of amino acids, wherein the first set is or includes W131 and the second set is or includes Y88 (e.g., Y88 and amino acids around Y88) in SEQ ID NO: 30.

[0031] In another aspect, the antibody used in the invention binds to human FcRn, wherein the antibody binds to an epitope comprising: (a) a first amino acid sequence comprising at least one amino acid of the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25); and (b) a second amino acid sequence comprising at least one amino acid of the sequence of FKALGGKGPYTL (SEQ ID NO: 26), wherein the antibody inhibits the binding of IgG to human FcRn.

[0032] In another aspect, the antibody used in the invention binds to human FcRn, wherein the antibody binds to an epitope comprising at least one amino acid in the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25), wherein

the antibody binds to at least one of amino acid residues 9, 12, or 13 of SEQ ID NO: 25, and wherein the antibody inhibits the binding of IgG to human FcRn.

[0033] In another aspect, the antibody used in the invention binds to human FcRn, wherein the antibody binds to an epitope comprising at least one amino acid in the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25) in FcRn, wherein the antibody does not bind to a peptide consisting of the sequence GEEFMNFDLKQGT (SEQ ID NO: 27) or to the sequence of EEFMNFDL (SEQ ID NO: 28), and wherein the antibody inhibits the binding of IgG to human FcRn.

[0034] In some embodiments, the epitope includes, comprises, consists of, or consists essentially of at least one amino acid in the sequence of WGGDWPEAL (SEQ ID NO: 29) in FcRn.

[0035] In some embodiments, the epitope includes, comprises, consists of, or consists essentially of at least amino acid residue 9 of SEQ ID NO: 25 in FcRn. In some embodiments, the epitope includes, comprises, consists of, or consists essentially of at least amino acid residue 12 of SEQ ID NO: 25 in FcRn. In some embodiments, the epitope includes, comprises, consists of, or consists essentially of at least amino acid residue 13 of SEQ ID NO: 25 in FcRn. In some embodiments, the epitope includes, comprises, consists of, or consists essentially of at least one amino acid of the sequence of FKALGGKGPYTL (SEQ ID NO: 26) in FcRn. In some embodiments, the epitope includes, comprises, consists of, or consists essentially of at least two amino acids of the sequence of FKALGGKGPYTL (SEQ ID NO: 26) in FcRn.

[0036] In some embodiments, the antibody used in the invention binds to an epitope comprising at least one amino acid of the sequence of FKALGGKGPYTL (SEQ ID NO: 26) in FcRn, and wherein the antibody inhibits the binding of IgG to human FcRn. In some embodiments, the epitope includes, comprises, consists of, or consists essentially of at least two amino acids of the sequence of FKALGGKGPYTL (SEQ ID NO: 26) in FcRn.

[0037] In some embodiments, the epitope further includes, comprises, consists of, or consists essentially of at least one amino acid of the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25) in FcRn.

[0038] In some embodiments, the antibody used in the invention binds to at least two amino acids of the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25) in FcRn.

[0039] In some embodiments, the antibody used in the invention binds to at least one of amino acid residues 9, 12, or 13 of SEQ ID NO: 25 in FcRn.

[0040] In some embodiments, the antibody used in the invention binds to at least amino acid residue 9 of SEQ ID NO: 25 in FcRn. In some embodiments, the antibody used in the invention binds to at least amino acid residue 12 of SEQ ID NO: 25 in FcRn. In some embodiments, the antibody used in the invention binds to at least amino acid residue 13 of SEQ ID NO: 25 in FcRn.

[0041] In some embodiments, the antibody is for use in the treatment of a fetal and neonatal alloimmune and/or autoimmune disorder.

[0042] In another aspect, the disclosure provides a nucleic acid molecule encoding an isolated antibody of any of the above aspects. In another aspect, the disclosure provides a vector comprising the nucleic acid molecule. A host cell may express the isolated antibody, wherein the host cell includes, comprises, consists of, or consists essentially of a nucleic acid molecule or a vector, wherein the nucleic acid molecule or vector is expressed in the host cell. The host cell may be a Chinese hamster ovary (CHO) cell.

[0043] In another aspect, the disclosure features a pharmaceutical composition comprising an isolated antibody of any of the above aspects and one or more pharmaceutically acceptable carriers or excipients. The antibody may be formulated in a therapeutically effective amount.

[0044] The anti-FeRn antibodies of the disclosure are also useful in methods of decreasing pathogenic antibody transport across the placenta of a pregnant subject, increasing pathogenic antibody catabolism in a pregnant subject, and treating an antibody-mediated enhancement of viral disease in a fetus or a neonate by administering to a pregnant subject an isolated antibody that binds to FcRn. In some embodiments, the pathogenic antibody in the pregnant subject causes a fetal and neonatal alloimmune and/or autoimmune disorder in a fetus in the pregnant subject.

[0045] In some embodiments, a pathogenic antibody associated with an immune disease is detected in a biological sample (e.g., a blood or urine sample) obtained from the pregnant subject.

Definitions

[0046] The term "antibody" herein is used in the broadest sense and encompasses various antibody structures, including but not limited to monoclonal antibodies, polyclonal antibodies, multispecific antibodies (e.g., bispecific antibodies), and antibody fragments so long as they exhibit FcRn antigen-binding activity.

[0047] "Antibody fragments" comprise a portion of an intact antibody, preferably the antigen binding or variable region of the intact antibody. Examples of antibody fragments include Fab, Fab', $F(ab')_2$, and Fv fragments, diabodies, linear antibodies, single-chain antibody molecules, and multispecific antibodies.

[0048] As used herein, the term "isolated antibody" refers to an antibody which has been separated and/or recovered from a component of its manufacturing host cell environment. Contaminant components of its manufacturing host cell environment are materials which would interfere with research, diagnostic, or therapeutic uses of the antibody. Contaminant components may include enzymes, hormones, and other proteinaceous or nonproteinaceous solutes. In some embodiments, an antibody is purified (1) to greater than 95% by weight of antibody as determined by, for example, the Lowry method, and in some embodiments, to greater than 99% by weight; (2) to a degree sufficient to obtain at least 15 residues of N-terminal or internal amino acid sequence by use of, for example, a spinning cup sequenator, or (3) to homogeneity by SDS-PAGE under reducing or non-reducing conditions using, for example, Coomassie blue or silver stain. An isolated antibody includes the antibody *in situ* within recombinant cells. Ordinarily, however, an isolated antibody will be prepared by at least one purification step. A pharmaceutical preparation of an isolated antibody typically has less than 250 ppm (e.g., less than 200ppm, 150ppm. 100 ppm) of host cell proteins (HCP) as determined by an ELISA based HCP assay performed as recommended by an FDA "Guidance for Industry" document.

[0049] As used herein, the term "monoclonal antibody" refers to an antibody obtained from a population of substantially homogeneous antibodies, i.e., individual antibodies in the population have the same primary sequence except for possible naturally occurring mutations that may be present in minor amounts. Monoclonal antibodies are highly specific and directed against a single antigenic site (i.e., an epitope on human FcRn). In contrast to polyclonal antibody preparations which typically include different antibodies directed against different epitopes, each monoclonal antibody is directed against a single epitope on the antigen. The modifier "monoclonal" indicates the character of the antibody as being obtained from a substantially homogenous population of antibodies, and is not to be construed as requiring production of the antibody by any particular method.

[0050] As used herein, the terms "variable region" and "variable domain" refer to the portions of the light and heavy chains of an antibody that include amino acid sequences of complementary determining regions (CDRs, e.g., CDR L1, CDR L2, CDR L3, CDR H1, CDR H2, and CDR H3) and framework regions (FRs). According to the methods used in this disclosure, the amino acid positions assigned to CDRs and FRs are defined according to Kabat (Sequences of Proteins of Immunological Interest, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD. (1991)). Using this numbering system, the actual linear amino acid sequence may contain fewer or additional amino acids corresponding to a shortening of, or insertion into, a CDR (defined further herein) or FR (defined further herein) of the variable region. For example, a heavy chain variable region may include a single inserted residue (i.e., residue 52a according to Kabat) after residue 52 of CDR H2 and inserted residues (i.e.,

residues 82a, 82b, 82c, etc. according to Kabat) after residue 82 of heavy chain FR. The Kabat numbering of residues may be determined for a given antibody by alignment at regions of homology of the sequence of the antibody with a "standard" Kabat numbered sequence.

[0051] As used herein, the terms "complementary determining regions" and "CDRs" refer to the regions of an antibody variable domain which are hypervariable in sequence and/or form structurally defined loops. A CDR is also known as a hypervariable region. The light chain and heavy chain variable regions each has three CDRs. The light chain variable region contains CDR L1, CDR L2, and CDR L3. The heavy chain variable region contains CDR H1, CDR H2, and CDR H3. Each CDR may include amino acid residues from a complementarity determining region as defined by Kabat (i.e. about residues 24-34 (CDR L1), 50-56 (CDR L2) and 89-97 (CDR L3) in the light chain variable region and about residues 31-35 (CDR H1), 50-65 (CDR H2) and 95-102 (CDR H3) in the heavy chain variable region.

[0052] As used herein, the term "FcRn" refers to a neonatal Fc receptor that binds to the Fc region of an IgG antibody, e.g., an IgG1 antibody. An exemplary FcRn is human FcRn having UniProt ID No. P55899. Human FcRn is believed to be responsible for maintaining the half-life of IgG by binding and trafficking constitutively internalized IgG back to the cell surface for the recycling of IgG.

[0053] As used herein, the terms "affinity" and "binding affinity" refer to the strength of the binding interaction between two molecules. Generally, binding affinity refers to the strength of the sum total of non-covalent interactions between a single binding site of a molecule and its binding partner, such as an isolated antibody and its target (e.g., an isolated anti-FeRn antibody and a human FcRn). Unless indicated otherwise, binding affinity refers to intrinsic binding affinity, which reflects a 1:1 interaction between members of a binding pair. The binding affinity between two molecules is commonly described by the dissociation constant (K_D) or the affinity constant (K_A). Two molecules that have low binding affinity for each other generally bind slowly, tend to dissociate easily, and exhibit a large K_D. Two molecules that have high affinity for each other generally bind readily, tend to remain bound longer, and exhibit a small K_D. One method for determining the K_D of an antibody to human FcRn is described in Example 2 ("the SPR (Surface Plasmon Resonance) method"). Using this method the K_D of N022, N023, N024, N026, and N027 was 31, 31.4, 35.5, 36.5, and 19.3 pM, respectively.

[0054] As used herein, the term "inhibit IgG binding to FcRn" refers to the ability of an anti-FeRn antibody to block or inhibit the binding of IgG (e.g., IgG1) to human FcRn. In some embodiments, an anti-FcRn antibody binds FcRn, for example, at the site on human FcRn to which IgG binds. Thus, the anti-FcRn antibody is able to inhibit the binding of IgG (e.g., a subject's autoantibodies) to FcRn. In some embodiments, the molecule (e.g., an anti-FeRn antibody) substantially or completely inhibits binding to IgG. In some embodiments, the binding of IgG is reduced by 10%, 20%, 30%, 50%, 70%, 80%, 90%, 95%, or even 100%.

[0055] As used herein, the term "inhibit pathogenic antibody binding to FcRn" refers to the ability of an anti-FeRn antibody to block or inhibit the binding of a pathogenic antibody (e.g., pathogenic IgG antibody) to human FcRn. In some embodiments, an anti-FeRn antibody binds FcRn, for example, at the site on human FcRn to which the pathogenic antibody binds. Thus, the anti-FeRn antibody is able to inhibit the binding of pathogenic antibodies (e.g., pathogenic IgG antibodies) to FcRn. In some embodiments, the molecule (e.g., an anti-FeRn antibody) substantially or completely inhibits binding to pathogenic antibodies. In some embodiments, the binding of pathogenic antibodies to FcRn is reduced by 10%, 20%, 30%, 50%, 70%, 80%, 90%, 95%, or even 100%.

[0056] As used herein, the term "hydrophobic amino acid" refers to an amino acid having relatively low-water solubility. Hydrophobic amino acids are glycine, leucine, isoleucine, alanine, phenylalanine, methionine, tryptophan, valine, and proline. Particularly preferred hydrophobic amino acids in the present disclosure are alanine, leucine, isoleucine, and valine.

[0057] As used herein, the term "polar amino acid" refers to an amino acid having a chemical polarity in its side chain induced by atoms with different electronegativity. The polarity of a polar amino acid is dependent on the electronegativity between atoms in the side chain of the amino acid and the asymmetry of the structure of the side

chain. Polar amino acids are serine, threonine, cysteine, histidine, methionine, tyrosine, tryptophan, asparagine, and glutamine. Particularly preferred polar amino acids in the present disclosure are serine, threonine, asparagine, glutamine, cysteine, and tyrosine.

[0058] As used herein, the term "acidic amino acid" refers to an amino acid whose side chain contains a carboxylic acid group having a pKa between 3.5 and 4.5. Acidic amino acids are aspartic acid and glutamic acid.

[0059] As used herein, the term "basic amino acid" refers to an amino acid whose side chain contains an amino group having a pKa between 9.5 and 13. Basic amino acids are histidine, lysine, and arginine.

[0060] As used herein, the term "percent (%) identity" refers to the percentage of amino acid (or nucleic acid) residues of a candidate sequence, e.g., an anti-FeRn antibody, that are identical to the amino acid (or nucleic acid) residues of a reference sequence, e.g., a wild-type anti-FeRn antibody, after aligning the sequences and introducing gaps, if necessary, to achieve the maximum percent identity (i.e., gaps can be introduced in one or both of the candidate and reference sequences for optimal alignment and non-homologous sequences can be disregarded for comparison purposes). Alignment for purposes of determining percent identity can be achieved in various ways that are within the skill in the art, for instance, using publicly available computer software such as BLAST, ALIGN, or Megalign (DNASTAR) software. Those skilled in the art can determine appropriate parameters for measuring alignment, including any algorithms needed to achieve maximal alignment over the full length of the sequences being compared. In some embodiments, the percent amino acid (or nucleic acid) sequence identity of a given candidate sequence to, with, or against a given reference sequence (which can alternatively be phrased as a given candidate sequence that has or includes a certain percent amino acid (or nucleic acid) sequence identity to, with, or against a given reference sequence) is calculated as follows:
100 x (fraction of A/B)
where A is the number of amino acid (or nucleic acid) residues scored as identical in the alignment of the candidate sequence and the reference sequence, and where B is the total number of amino acid (or nucleic acid) residues in the reference sequence. In some embodiments where the length of the candidate sequence does not equal to the length of the reference sequence, the percent amino acid (or nucleic acid) sequence identity of the candidate sequence to the reference sequence would not equal to the percent amino acid (or nucleic acid) sequence identity of the reference sequence to the candidate sequence.

[0061] In particular embodiments, a reference sequence aligned for comparison with a candidate sequence may show that the candidate sequence exhibits from 50% to 100% identity across the full length of the candidate sequence or a selected portion of contiguous amino acid (or nucleic acid) residues of the candidate sequence. The length of the candidate sequence aligned for comparison purpose is at least 30%, e.g., at least 40%, e.g., at least 50%, 60%, 70%, 80%, 90%, or 100% of the length of the reference sequence. When a position in the candidate sequence is occupied by the same amino acid (or nucleic acid) residue as the corresponding position in the reference sequence, then the molecules are identical at that position. A position may be altered by a substitution, deletion, or insertion. A substitution, deletion, or insertion may comprise a certain number of amino acids, (e.g., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or more). When describing a substitution, deletion, or insertion of no more than n amino acids, this is meant that the substitution, deletion, or insertion comprises, e.g., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, ... or n amino acids. The number or substitutions, deletions, or insertions can comprise a percent of the total sequence (e.g., 1%, 5%, 10%, 15%, 20%, or more) where the number of substitutions, deletions, or insertions alters 5%, 10%, 15%, 20% or more, of the amino acids in the total sequence.As used herein, the term "fetal and neonatal alloimmune and/or autoimmune disorder" refers to an immune disorder in a fetus and/or neonate that is caused by the transplacental transfer of maternal antibodies (e.g., pathogenic maternal antibodies) directed against fetal and/or neonate antigens. For example, a pregnant subject's antibodies (e.g., pathogenic antibodies) may react against antigens in the fetus (e.g., antigens the fetus inherited from the fetus' father). Examples of fetal and neonatal alloimmune and/or autoimmune disorders are provided herein.

[0062] As used herein, the term "pathogenic antibody" refers to an antibody that causes one or more immune diseases or disorders in a subject (e.g., a pregnant subject), a fetus in a pregnant subject, and/or a neonate. In some embodiments, pathogenic antibodies are autoantibodies produced in a subject (e.g., a pregnant subject) against one or more of the subject's own proteins, thus causing autoimmune diseases or disorders in the subject. In

some embodiments, pathogenic antibodies in a pregnant subject may transfer through the placenta to the fetus and react against antigens from the fetus (e.g., antigens that the fetus inherited from the fetus' father), thus causing, e.g., fetal and neonatal alloimmune and/or autoimmune disorders.

[0063] As used herein, the term "antibody-mediated enhancement of viral disease" refers to a viral disease in which antibodies can facilitate viral entry into host cells, thus leading to increased or enhanced infectivity in the cells. In some embodiments, an antibody may bind to a viral surface protein and the antibody/virus complex may bind to an FcRn receptor on a cell surface through interaction between the antibody and the receptor. Subsequently, the antibody/virus complex may get internalized into the cell.

[0064] As used herein, the term "host cell" refers to a vehicle that includes the necessary cellular components, e.g., organelles, needed to express proteins from their corresponding nucleic acids. The nucleic acids are typically included in nucleic acid vectors that can be introduced into the host cell by conventional techniques known in the art (e.g., transformation, transfection, electroporation, calcium phosphate precipitation, direct microinjection, etc.). A host cell may be a prokaryotic cell, e.g., a bacterial cell, or a eukaryotic cell, e.g., a mammalian cell (e.g., a CHO cell). As described herein, a host cell is used to express one or more polypeptides encoding anti-FeRn antibodies.

[0065] As used herein, the term "vector" refers to a nucleic acid molecule capable of transporting another nucleic acid molecule to which it has been linked. One type of vector is a "plasmid," which refers to a circular double stranded DNA loop into which additional DNA segments may be ligated. Another type of vector is a phage vector. Another type of vector is a viral vector, wherein additional DNA segments may be ligated into the viral genome. Certain vectors are capable of autonomous replication in a host cell into which they are introduced (e.g., bacterial vectors having a bacterial origin of replication and episomal mammalian vectors). Other vectors (e.g., non-episomal mammalian vectors) can be integrated into the genome of a host cell upon introduction into the host cell, and thereby are replicated along with the host genome. Moreover, certain vectors are capable of directing the expression of genes to which they are operatively linked. Such vectors are referred to herein as "recombinant expression vectors" (or simply, "recombinant vectors"). In general, expression vectors of utility in recombinant DNA techniques are often in the form of plasmids.

[0066] As used herein, the term "subject" refers to a mammal, e.g., preferably a human. Mammals include, but are not limited to, humans and domestic and farm animals, such as monkeys (e.g., a cynomolgus monkey), mice, dogs, cats, horses, and cows, etc.

[0067] As used herein, the term "pharmaceutical composition" refers to a medicinal or pharmaceutical formulation that contains an active ingredient as well as one or more excipients and diluents to enable the active ingredient suitable for the method of administration. The pharmaceutical composition includes pharmaceutically acceptable components that are compatible with the anti-FeRn antibody. The pharmaceutical composition may be in aqueous form for intravenous or subcutaneous administration or in tablet or capsule form for oral administration.

[0068] As used herein, the term "pharmaceutically acceptable carrier" refers to an excipient or diluent in a pharmaceutical composition. The pharmaceutically acceptable carrier must be compatible with the other ingredients of the formulation and not deleterious to the recipient. The pharmaceutically acceptable carrier must provide adequate pharmaceutical stability to the Fc construct. The nature of the carrier differs with the mode of administration. For example, for intravenous administration, an aqueous solution carrier is generally used; for oral administration, a solid carrier is preferred.

[0069] As used herein, the term "therapeutically effective amount" refers to an amount, e.g., pharmaceutical dose, effective in inducing a desired biological effect in a subject or patient or in treating a patient having a condition or disorder described herein. It is also to be understood herein that a "therapeutically effective amount" may be interpreted as an amount giving a desired therapeutic effect, either taken in one dose or in any dosage or route, taken alone or in combination with other therapeutic agents.

[0070] As used herein, the term "no more than" refers to an amount that is less than equal to. This may be an amount in integers. For example, no more than two substitutions can refer to 0, 1, or 2 substitutions.

[0071] As used herein, the terms "treatment" or "treating" refer to reducing, decreasing, decreasing the risk of, or decreasing the side effects of a particular disease or condition. Reducing, decreasing, decreasing the risk of, or decreasing the side effects of are relative to a subject who did not receive treatment, e,g, a control, a baseline, or a known control level or measurement.

DESCRIPTION OF THE DRAWINGS

[0072]

FIG. 1 shows two graphs and a table that show IgG competitive binding of antibodies N022-N024, N026, and N027 to human or cynomolgus monkey FcRn at pH 6.0.

FIG. 2 shows graphs that show the effects of antibodies N023, N024, N026, and N027 on IgG catabolism in transgenic mice.

FIG. 3 shows graphs that show the dose-dependent effects of antibody N027 on IgG levels and target occupancy in transgenic mice.

FIGS. 4A-4C show graphs that show the selective induction of IgG catabolism and target occupancy in cynomolgus monkeys following administration of different doses of antibody N027.

FIG. 5 shows a graph that shows the biodistribution of N027 in transgenic mice.

FIG. 6 shows an experimental timeline and a graph that shows the efficacy of N027 in a mouse collagen antibody-induced arthritis model in transgenic mice.

FIG. 7 shows an experimental timeline and two graphs that show the efficacy of N027 in a mouse chronic idiopathic thrombocytopenia purpura (ITP) model in transgenic mice.

FIGS. 8A-8C show graphs that show the dose-dependent FcRn occupancy achieved with N027 in aortic endothelial cells, venous endothelial cells, and placental trophoblast, respectively.

FIGS. 9A-9C show graphs that show 100% FcRn occupancy by N027 results in increased intracellular IgG accumulation in aortic endothelial cells, venous endothelial cells, and placental trophoblast, respectively.

FIG. 10 shows a graph that shows the amount of time it takes to achieve 100% FcRn occupancy by N027.

FIGS. 11A and **11B** show graphs that show N027 treatment does not alter FcRn turnover rates in human endothelial and villous trophoblast cells, respectively.

FIGS. 12A and **12B** show images of FcRn localized in endosomes in human endothelial and villous trophoblast cells.

FIGS. 13A and **13B** show graphs that show the effect of N027 treatment on dynamics of IgG trafficking in human endothelial cells and human placental trophoblasts, respectively.

FIGS. 13C and **13D** show images that show N027 increases intracellular IgG and co-localization of IgG with lysosomes (lysosomal markers: Lamp-1 and Dextran).

FIG. 14 shows images of a comparison of the N027 Fab binding site on FcRn with Fc and albumin binding sites. Fab and Fc binding sites overlap with each other but are distinct from the albumin binding site.

FIG. 15 shows images of the epitope on the N027 Fab surface (left) and paratope on the FcRn surface (right).

FIG. 16 shows the N027 Fab:FcRn epitope and paratope mapped to sequences.

FIG. 17 is a graph that shows transplacental transfer of antipyrine over four hours of perfusion (n=14). The data

represent antipyrine concentrations as mean ± standard deviation (SD) in the fetal (squares) and maternal (circles) circulation after maternal administration of 100µg/ml antipyrine at t=0.

FIG. 18 is a graph that shows transplacental transfer of N027 over four hours of perfusion. The data represent N027 concentrations as mean ± SD in the fetal and maternal circulation after maternal administration of the indicated concentration of N027 at t=0.

FIG. 19 is a graph showing maternal IgG concentrations after treatment with N027 during gestation.

FIG. 20 is a graph showing fetal IgG levels after treatment of mothers with N027 during gestation.

DETAILED DESCRIPTION

[0073] The present disclosure features isolated antibodies that bind to human neonatal Fc receptor (FcRn) with high affinity. The present disclosure features anti-FcRn antibodies, methods and compositions for preparing anti-FcRn antibodies, and methods for blocking FcRn activity, reducing immune complex-based activation of an immune response, and treating immunological diseases. Furthermore, anti-FcRn antibodies can be used to decrease pathogenic antibody transport across the placenta of a pregnant subject, to increase pathogenic antibody catabolism in a pregnant subject, and to treat an antibody-mediated enhancement of viral disease in a fetus or a neonate.

I. Anti-FeRn antibodies

[0074] In general, the disclosure features isolated antibodies that bind to the human FcRn. An anti-FcRn antibody refers to an antibody that can bind to human FcRn and inhibit IgG (e.g., IgG autoantibodies or pathogenic antibodies) binding to FcRn. In some embodiments, the antibody is a monoclonal antibody. In other embodiments, the antibody is a polyclonal antibody. In some embodiment, the antibody is IgG1. In some embodiment, the antibody includes a λ light chain. In some embodiment, the antibody is a sialylated antibody. In some embodiments, the antibody is selected from the group consisting of a chimeric antibody, an affinity matured antibody, a humanized antibody, and a human antibody. In certain embodiments, the antibody is an antibody fragment, e.g., a Fab, Fab', Fab'-SH, $F(ab')_2$, or scFv.

[0075] In some embodiments, the antibody is a chimeric antibody. For example, an antibody contains antigen binding sequences from a non-human donor grafted to a heterologous non-human, human, or humanized sequence (e.g., framework and/or constant domain sequences). In one embodiment, the non-human donor is a mouse. In another embodiment, an antigen binding sequence is synthetic, e.g., obtained by mutagenesis (e.g., phage display screening, etc.). In a further embodiment, a chimeric antibody has non-human (e.g., mouse) variable regions and human constant regions. In one example, a mouse light chain variable region is fused to a human κ light chain. In another example, a mouse heavy chain variable region is fused to a human IgG1 constant region.

[0076] In some embodiments, when describing the CDR sequences of an antibody, the antibody is defined as including a set of 6 CDR sequences. Including a set of CDR sequences describes an antibody that consists of, comprises, or consists essentially of these CDR sequences.

[0077] In one aspect, the disclosure features an isolated antibody that binds to human neonatal Fc receptor (FcRn), the isolated antibody including: (1) a light chain variable region including a CDR L1, a CDR L2, and a CDR L3 and (2) a heavy chain variable region comprising a CDR H1, a CDR H2, and a CDR H3, wherein the CDR L1 includes the sequence SDVGSYNL(SEQ ID NO: 33) or VG_YNL(SEQ ID NO: 34), wherein the "_" can be any amino acid, the CDR L2 includes the sequence GDSE (SEQ ID NO: 35), the CDR L3 includes the sequence YAGSGIY (SEQ ID NO: 36), the CDR H1 includes the sequence TYA(SEQ ID NO: 37), the CDR H2 includes the sequence

SIGASGSQTR (SEQ ID NO: 38) or SI_AS_SQ_R (SEQ ID NO: 39), wherein the "_" can be any amino acid, and the CDR H3 includes the sequence LAI (SEQ ID NO: 40), and, optionally, wherein (a) the CDR L1 has a deletion or has more than two amino acid substitutions relative to the sequence of TGTGSDVGSYNLVS (SEQ ID NO: 1), (b) the CDR L2 has a deletion or has more than one amino acid substitution relative to the sequence of GDSERPS (SEQ ID NO: 2), (c) the CDR L3 has a deletion or has more than one amino acid substitution relative to the sequence of SSYAGSGIYV (SEQ ID NO: 3), (d) the CDR H1 has a deletion or has more than one amino acid substitution relative to each of the sequences of TYAMG (SEQ ID NO: 4), DYAMG (SEQ ID NO: 5), and NYAMG (SEQ ID NO: 6), (e) the CDR H2 has a deletion or has more than two amino acid substitutions relative to each of the sequences of SIGSSGAQTRYADS (SEQ ID NO: 7), SIGASGSQTRYADS (SEQ ID NO: 8), SIGASGAQTRYADS (SEQ ID NO: 9), and SIGASGGQTRYADS (SEQ ID NO: 10), or (f) the CDR H3 has a deletion or has more than one amino acid substitutions relative to the sequence of LAIGDSY (SEQ ID NO: 11). In some embodiments, the isolated antibody comprises the amino acid sequence KSG at Kabat positions 66-68.

[0078] In another aspect, the disclosure features an isolated antibody that binds to human FcRn, wherein the antibody binds to an epitope on FcRn comprising at least one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen, sixteen, seventeen, eighteen, nineteen, or twenty amino acids selected from the group consisting of K80, A81, L82, G83, G84, K85, G86, P87, Y88, L112, N113, E115, G129, D130, W131, P132, E133, L135, A136, and Q139 of SEQ ID NO: 30, which corresponds to amino acids K103, A104, L105, G106, G107, K108, G109, P110, Y111, L135, N136, E138, G152, D153, W154, P155, E156, L158, A159, Q162, respectively, of wildtype FcRn. In some embodiments, the epitope on FcRn does not comprise E115, which corresponds to amino acid E138 of wildtype FcRn.

[0079] In another aspect, the disclosure features an isolated antibody that binds to an epitope on β2-microglobulin comprising at least one amino acid selected from the group consisting of I21, Q22, P52, and V105.

[0080] In another aspect, the disclosure features an isolated antibody that binds to FcRn, wherein the antibody binds to: (a) at least one amino acid of the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25); and (b) a at least one amino acid of the sequence of FKALGGKGPYTL (SEQ ID NO: 26), wherein the antibody inhibits the binding of IgG to human FcRn.

[0081] The disclosure also features an isolated antibody that binds to human FcRn, wherein the antibody binds to at least one amino acid of the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25), wherein the antibody binds to at least one of amino acid residues 5, 12, or 13 of SEQ ID NO: 25, and wherein the antibody inhibits the binding of IgG to human FcRn.

[0082] The disclosure also features an isolated antibody that binds to human FcRn, wherein the antibody binds to at least one amino acid of the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25), wherein the antibody does not bind to a peptide consisting of the sequence EFMNFDLKQGT (SEQ ID NO: 27) or the sequence of EEFMNFDL (SEQ ID NO: 28), and wherein the antibody inhibits the binding of IgG to human FcRn.

[0083] In some embodiments, the anti-FcRn antibody described herein binds to at least one amino acid of the sequence of WGGDWPEAL (SEQ ID NO: 29). In some embodiments, the anti-FcRn antibody binds to at least amino acid residue 5 of SEQ ID NO: 25. In some embodiments, the anti-FcRn antibody binds to at least amino acid residue 12 of SEQ ID NO: 25. In some embodiments, the anti-FcRn antibody binds at least amino acid residue 13 of SEQ ID NO: 25.

[0084] In some embodiments, the anti-FcRn antibody binds to at least one amino acid of the sequence of FKALGGKGPYTL (SEQ ID NO: 26). The anti-FcRn antibody may also bind to t least two amino acids of the sequence of FKALGGKGPYTL (SEQ ID NO: 26).

[0085] In another aspect, the disclosure also features an isolated antibody that binds to human FcRn, wherein the antibody binds to at least one amino acid of the sequence of FKALGGKGPYTL (SEQ ID NO: 26), and wherein the antibody inhibits the binding of IgG to human FcRn.

[0086] In some embodiments of this aspect, the anti-FcRn antibody binds to at least two amino acids of the sequence of FKALGGKGPYTL (SEQ ID NO: 26). In some embodiments, the anti-FcRn antibody further binds to at least one amino acid of the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25). In some embodiments, the anti-FcRn antibody further binds to at least two amino acids of the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25). In some embodiments, the anti-FcRn antibody binds to at least one of amino acid residues 5, 12, or 13 of SEQ ID NO: 25. In some embodiments, the anti-FcRn antibody binds to at least amino acid residue 5 of SEQ ID NO: 25. In some embodiments, the anti-FcRn antibody binds to at least amino acid residue 12 of SEQ ID NO: 25. In some embodiments, the anti-FcRn antibody binds to at least amino acid residue 13 of SEQ ID NO: 25.

[0087] In another aspect, the disclosure features an isolated antibody capable of binding to human FcRn. The isolated antibody contains: (1) a light chain variable region that includes a CDR L1, a CDR L2, and a CDR L3 and (2) a heavy chain variable region that includes a CDR H1, a CDR H2, and a CDR H3, wherein the CDR L1 has a sequence having at least 92% identity to the sequence of TGTGSDVGSYNLVS (SEQ ID NO: 1), the CDR L2 has a sequence having at least 85% identity to the sequence of GDSERPS (SEQ ID NO: 2), the CDR L3 has a sequence having at least 90% identity to the sequence of SSYAGSGIYV (SEQ ID NO: 3), the CDR H1 has a sequence having at least 80% identity to the sequence of TYAMG (SEQ ID NO: 4), DYAMG (SEQ ID NO: 5), or NYAMG (SEQ ID NO: 6), the CDR H2 has a sequence having at least 92% identity to the sequence of SIGSSGAQTRYADS (SEQ ID NO: 7), SIGASGSQTRYADS (SEQ ID NO: 8), SIGASGAQTRYADS (SEQ ID NO: 9), SIGASGGQTRYADS (SEQ ID NO: 10), TIGSSGAQTRYADS (SEQ ID NO: 41), SIGASGSQTRYADS (SEQ ID NO: 42), TIGASGAQTRYADS (SEQ ID NO: 43), or TIGASGGQTRYADS (SEQ ID NO: 32), and the CDR H3 has a sequence having at least 85% identity to the sequence of LAIGDSY (SEQ ID NO: 11). In some embodiments, the antibody binds human FcRn with a K_D of less than 200, 150, 100, 50, or 40 pM. In some embodiments, the antibody binds human FcRn with a K_D that is less than or equal (e.g., less than) to that of an antibody having the light chain variable region and heavy chain variable region of N022, N023, N024, N026, or N027, and further having the same Fc region as the antibody being compared.

[0088] The isolated antibody of the disclosure may have a CDR L1 that comprises, consists of, consists essentially of, or has the sequence of X_1GTGSDVGSYNX_2VS (SEQ ID NO: 12), a CDR L2 that comprises, consists of, consists essentially of, or has the sequence of GDX_3X_4RPS (SEQ ID NO: 13), a CDR L3 that comprises, consists of, consists essentially of, or has the sequence of X_5SYX_6GSGIYV (SEQ ID NO: 14), a CDR H1 that comprises, consists of, consists essentially of, or has the sequence of Z_1YAMG (SEQ ID NO: 15), a CDR H2 that comprises, consists of, consists essentially of, or has the sequence of Z_7IGZ_2SGZ_3QTZ_4YADS (SEQ ID NO: 16), and a CDR H3 that comprises, consists of, consists essentially of, or has the sequence of LAZ_5Z_6DSY (SEQ ID NO: 17), where X_1 is a polar or hydrophobic amino acid (e.g., preferably T, A, S, or I), X_2 is a hydrophobic amino acid (e.g., preferably L or I), X_3 is a polar amino acid (e.g., preferably S, N, or T), X_4 is a polar or acidic amino acid (e.g., preferably Q, E, or N), X_5 is a polar or hydrophobic amino acid (e.g., preferably C, S, I, or Y), X_6 is a hydrophobic amino acid (e.g., preferably A or V), Z_1 is a polar or acidic amino acid (e.g., preferably E, T, D, or N), Z_2 is a polar or hydrophobic amino acid (e.g., preferably S or A), Z_3 is G, S, or A, Z_4 is a basic amino acid (e.g., preferably K or R), Z_5 is a hydrophobic or basic amino acid (e.g., preferably I, L, or H), Z_6 is G, S, D, Q, or H, and Z_7 is S or T, and where the antibody binds human FcRn with a K_D of less than 200, 150, 100, 50, or 40 pM.

The isolated antibody of the disclosure may have a CDR L1 that has the sequence of TGTGSDVGSYNLVS (SEQ ID NO: 1), a CDR L2 that has the sequence of GDSERPS (SEQ ID NO: 2), a CDR L3 that has the sequence of SSYAGSGIYV (SEQ ID NO: 3), a CDR H1 that has the sequence of Z_1YAMG (SEQ ID NO: 15), a CDR H2 that has the sequence of Z_7IGZ_2SGZ_3QTRYADS (SEQ ID NO: 18), and a CDR H3 that has the sequence of LAIGDSY (SEQ ID NO: 11), where Z_1 is T, D, or N, Z_2 is S or A, Z_3 is G, S or A, and Z_7 is S or T.

[0089] Table 1 shows the amino acid sequences of the light and heavy chain complementary determining regions (CDRs) of some exemplary anti-FcRn antibodies.

Table 1

Anti-FcRn antibody	CDR L1	CDR L2	CDR L3	CDR H1	CDR H2	CDR H3
N022	TGTGSDVGSYNLVS (SEQ ID NO: 1)	GDSERPS (SEQ ID NO: 2)	SSYAGSGIYV (SEQ ID NO: 3)	TYAMG (SEQ ID NO: 4)	SIGSSGAQTRYADS (SEQ ID NO: 7)	LAIGDSY (SEQ ID NO: 11)
N023	TGTGSDVGSYNLVS (SEQ ID NO: 1)	GDSERPS (SEQ ID NO: 2)	SSYAGSGIYV (SEQ ID NO: 3)	DYAMG (SEQ ID NO: 5)	SIGASGSQTRYADS (SEQ ID NO: 8)	LAIGDSY (SEQ ID NO: 11)
N024	TGTGSDVGSYNLVS (SEQ ID NO: 1)	GDSERPS (SEQ ID NO: 2)	SSYAGSGIYV (SEQ ID NO: 3)	NYAMG (SEQ ID NO: 6)	SIGASGAQTRYADS (SEQ ID NO: 9)	LAIGDSY (SEQ ID NO: 11)
N026	TGTGSDVGSYNLVS (SEQ ID NO: 1)	GDSERPS (SEQ ID NO: 2)	SSYAGSGIYV (SEQ ID NO: 3)	TYAMG (SEQ ID NO: 4)	SIGASGGQTRYADS (SEQ ID NO: 10)	LAIGDSY (SEQ ID NO: 11)
N027	TGTGSDVGSYNLVS (SEQ ID NO: 1)	GDSERPS (SEQ ID NO: 2)	SSYAGSGIYV (SEQ ID NO: 3)	TYAMG (SEQ ID NO: 4)	SIGASGSQTRYADS (SEQ ID NO: 8)	LAIGDSY (SEQ ID NO: 11)

[0090] Table 2 shows the SEQ ID NOs of the light and heavy chain variable regions of these exemplary anti-FcRn antibodies.

Table 2

Anti-FcRn antibody	Light Chain Variable Region	Heavy Chain Variable Region
N022	SEQ ID NO: 19	SEQ ID NO: 20
N023		SEQ ID NO: 21
N024		SEQ ID NO: 22
N026		SEQ ID NO: 23
N027		SEQ ID NO: 24

[0091] The invention uses an antibody that comprises a polypetide having the amino acid sequence QSALTQPASVSGSPGQSITISCTGTGSDVGSYNLVSWYQQHPGKAPKLMIYGDSERPSGVSNRFSGSKS GNTASLTISGLQAEDEADYYCSSYAGSGIYVFGTGTKVTVLGQPKAAPSVTLFPPSSEELQANKATLVCLI SDFYPGAVTVAWKADSSPVKAGVETTTPSKQSNNKYAASSYLSLTPEQWKSHKSYSCQVTHEGSTVEK TVAPTECS (SEQ ID NO: 19); and a polypeptide having the amino acid sequence EVQLLESGGGLVQPGGSLRLSCAASGFTFSTYAMGWVRQAPGKGLEWVSSIGASGSQTRYADSVKGRF TISRDNSKNTLYLQMNSLRAEDTAVYYCARLAIGDSYWGQGTMVTVSSASTKGPSVFPLAPSSKSTSGG TAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVPSSSLGTQTYICNVNHKPSN TKVDKKVEPKSCDKTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWY VDGVEVHNAKTKPREEQYASTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQ VYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSR WQQGNVFSCSVMHEALHNHYTQKSLSLSPG (SEQ ID NO: 24).

[0092] The antibodies of the disclosure may further contain amino acid substitutions, additions, and/or deletions outside of the CDRs (i.e., in framework regions (FRs)). An amino acid substitution, addition, and/or deletion can be a substitution, addition, and/or deletion of one or more amino acids (e.g., 1, 2, 3, 4, 5, 6, 7, 8, or more). An amino acid substitution, addition, and/or deletion can be a substitution, addition, and/or deletion of eight or fewer, seven or

fewer, six or fewer, five or fewer, four or fewer, three or fewer, or two or fewer single amino acids. In some embodiments, the antibodies may further include any one or more of the following amino acid substitutions: A23V, S30R, L80V, A84T, E85D, A93V, relative to the sequence of any one of SEQ ID NOs: 20-24, and Q38H, V58I, and G99D, relative to the sequence of SEQ ID NO: 19.

[0093] The antibodies of the disclosure may include amino acid substitutions, additions, and/or deletions in the constant regions (e.g., Fc region) of the antibody that, e.g., lead to decreased effector function, e.g., decreased complement-dependent cytolysis (CDC), antibody-dependent cell-mediated cytolysis (ADCC), and/or antibody-dependent cell-mediated phagocytosis (ADCP), and/or decreased B-cell killing. The constant regions are not involved directly in binding an antibody to its target, but exhibit various effector functions, such as participation of the antibody in antibody-dependent cellular toxicity. In some embodiments, the antibodies are characterized by decreased binding (i.e., absence of binding) to human complement factor C1q and/or human Fc receptor on natural killer (NK) cells. In other embodiments, the antibodies are characterized by decreased binding (i.e., absence of binding) to human FcγRI, FcγRIIA, and/or FcγRIIIA. To alter or reduce an antibody-dependent effector function, such as CDC, ADCC, ADCP, and/or B-cell killing, antibodies may be of the IgG class and contain one or more amino acid substitutions E233, L234, G236, D265, D270, N297, E318, K320, K322, A327, A330, P331, and/or P329 (numbering according to the EU index of Kabat (Sequences of Proteins of Immunological Interest, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD. (1991))).

[0094] The antibodies of the disclosure may include those having specific amino acid changes that improve stability of the antibody.

[0095] In any of the anti-FcRn antibodies described herein, in some embodiments, the antibody binds mouse or rat FcRn with a K_D of less than 200, 150, 100, 50, or 40 pM.

[0096] In any of the anti-FcRn antibodies described herein, in some embodiments, the antibody binds to human FcRn with an affinity of between 1-100, 5-150, 5-100, 5-75, 5-50, 10-50, or 10-40 pM.

[0097] The anti-FcRn antibodies may be of immunoglobulin antibody isotype IgG, IgE, IgM, IgA, or IgD. Preferably, the anti-FcRn antibodies are of immunoglobulin antibody isotype IgG. The anti-FcRn antibodies may also be of any immunoglobulin antibody isotype subclasses. For example, the anti-FcRn antibodies may be of IgG subclass IgG1, IgG2, IgG3, or IgG4. Preferably, the anti-FcRn antibodies are of subclass IgG1. In particular, the anti-FcRn antibodies contain an IgG G1m17 or G1m17.1 allotype heavy chain. In some embodiments, the light chain of the anti-FcRn antibodies may be a κ light chain, a λ light chain, or a κ-λ chimeric light chain. In preferred embodiments, the anti-FcRn antibodies contain a full-length λ light chain.

[0098] In some embodiments, the antibodies (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) are monoclonal. The antibodies may also be polyclonal, chimeric, humanized or fully human. In some embodiments, the antibody may be affinity matured. In other embodiments, the antibody may be an antibody fragment.

[0099] Without being bound by theory, it is believed that the anti-FcRn antibodies compete with and inhibit the binding of IgG to human FcRn. Epitope mapping by hydrogen-deuterium exchange of the antibodies indicates that the antibodies bind to an epitope on FcRn located in and/or adjacent to the Fc-FcRn interaction interface, which suggests that the antibodies block IgG binding to FcRn by direction inhibition. Furthermore, the epitope-mapped binding site is distant from the albumin-binding site of FcRn.

[0100] In some embodiments, serum albumin binding is not inhibited. In some cases serum albumin levels are not decreased after anti-FcRn antibody administration.

III. FcRn inhibition

[0101] Human neonatal Fc receptor (FcRn) is a type I transmembrane protein that functions as an IgG- and serum albumin-binding, intracellular-IgG trafficking protein. FcRn is expressed in endothelial cells, luminal epithelial cells, hepatocytes, podocytes, granulocytes, monocytes, macrophages, dendritic cells, and NK cells, but not on B or T cells. FcRn maintains the half-life of IgG by binding and trafficking constitutively internalized IgG back to the cell surface. Binding of both Fc and serum albumin by FcRn occurs in the early endosome at pH 6.0, followed by sorting of the FcRn into vesicles, which traffic the FcRn-bound IgG and/or albumin back to the cell surface where FcRn rapidly releases the IgG and/or albumin at pH 7.4. This trafficking cycle maintains the half-life of IgG and albumin by recycling both into the circulation and preventing trafficking to the lysosomes for degradation. FcRn also captures internalized IgG Fc in epithelial cells and transports them bidirectionally to the opposing apical or basolateral membranes. This function allows IgG to traffic to the lumen of organs such as the gastrointestinal tract or the transport of IgG or IgG-antigen complexes from the lumen to the vasculature or lymphoid tissues in the stromal layers.

[0102] In order to study the contribution of FcRn to IgG homeostasis, mice have been engineered so that parts of the light and heavy chains of FcRn have been "knocked out" so that these proteins are not expressed (Junghans et al., Proc Natl Acad Sci USA 93:5512, 1996). In these mice, the serum half-life and concentrations of IgG were dramatically reduced, suggesting an FcRn-dependent mechanism of IgG homeostasis. Studies in rodent models, such as the one discussed above, suggest that blockage of FcRn function can increase IgG catabolism, including that of pathogenic autoantibodies, thereby inhibiting disease (e.g., an autoimmune disease) development. FcRn may also contribute to antigen presentation through trafficking of immune complexes to antigen degradation and MHC loading compartments.

[0103] Placental transfer of maternal IgG antibodies to the fetus is an important FcRn-dependent mechanism that provides protection to the neonate while his/her humoral response is inefficient. During fetal life, FcRn in the syncytiotrophoblast layers of the placenta is responsible for the transfer of maternal IgG antibodies to the fetus. Pathogenic maternal antibodies (e.g., pathogenic maternal IgG antibodies) may also cross the placenta by binding to FcRn and cause alloimmune disorders and/or autoimmune disorders in the fetus and neonate. In some embodiments, pathogenic antibodies in the pregnant subject cause a fetal and neonatal alloimmune and/or autoimmune disorder in a fetus in the pregnant subject. The anti-FcRn antibodies described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) may compete with and inhibit the binding of maternal pathogenic antibodies (e.g., maternal pathogenic IgG antibodies) to FcRn, thereby increasing the catabolism and decreasing the half-life of these pathogenic antibodies.

[0104] The present disclosure provides isolated anti-FcRn antibodies that bind to human FcRn. The anti-FcRn antibodies may compete with and inhibit the binding of other anti-FcRn antibodies (e.g., IgG, IgG autoantibodies) to FcRn, thereby increasing the catabolism and decreasing the half-life of other anti-FcRn antibodies (e.g., IgG, IgG autoantibodies). The anti-FcRn antibodies may be used in a method of treating or reducing immune complex-based activation of an immune response in a subject, such as an immune response caused by autoantibodies in an autoimmune disease. Reducing an immune response may be described as reducing an immune response relative to a subject who does not receive treatment (e.g., a control subject). The anti-FcRn antibodies may also be used in methods of decreasing pathogenic antibody transport (e.g., pathogenic maternal IgG antibody transport) across the placenta of a pregnant subject, increasing pathogenic antibody catabolism in a pregnant subject, and treating an antibody-mediated enhancement of viral disease in a fetus or a neonate by administering to a pregnant subject an isolated antibody that binds to human FcRn. Decreasing pathogenic antibody transport across the placenta of a pregnant subject, may be described as decreasing pathogenic antibody transport relative to a subject who does not receive treatment (e.g., a control subject).

IV. Vectors, host cells, and antibody production

[0105] The anti-FcRn antibodies can be produced from a host cell. A host cell refers to a vehicle that includes the necessary cellular components, e.g., organelles, needed to express the polypeptides and constructs described herein from their corresponding nucleic acids. The nucleic acids may be included in nucleic acid vectors that can be

introduced into the host cell by conventional techniques known in the art (e.g., transformation, transfection, electroporation, calcium phosphate precipitation, direct microinjection, infection, etc.). The choice of nucleic acid vectors depends in part on the host cells to be used. Generally, preferred host cells are of either prokaryotic (e.g., bacterial) or eukaryotic (e.g., mammalian) origin.

Nucleic acid vector construction and host cells

[0106] A nucleic acid sequence encoding the amino acid sequence of an anti-FcRn antibody may be prepared by a variety of methods known in the art. These methods include, but are not limited to, oligonucleotide-mediated (or site-directed) mutagenesis and PCR mutagenesis. A nucleic acid molecule encoding an anti-FcRn antibody may be obtained using standard techniques, e.g., gene synthesis. Alternatively, a nucleic acid molecule encoding a wild-type anti-FcRn antibody may be mutated to contain specific amino acid substitutions using standard techniques in the art, e.g., QuikChange™ mutagenesis. Nucleic acid molecules can be synthesized using a nucleotide synthesizer or PCR techniques.

[0107] Nucleic acid sequences encoding anti-FcRn antibodies may be inserted into a vector capable of replicating and expressing the nucleic acid molecules in prokaryotic or eukaryotic host cells. Many vectors are available in the art and can be used. Each vector may contain various components that may be adjusted and optimized for compatibility with the particular host cell. For example, the vector components may include, but are not limited to, an origin of replication, a selection marker gene, a promoter, a ribosome binding site, a signal sequence, the nucleic acid sequence encoding protein of interest, and a transcription termination sequence.

[0108] The disclosure also provides that mammalian cells are used as host cells. Examples of mammalian cell types include, but are not limited to, human embryonic kidney (HEK) (e.g., HEK293, HEK 293F), Chinese hamster ovary (CHO), HeLa, COS, PC3, Vero, MC3T3, NS0, Sp2/0, VERY, BHK, MDCK, W138, BT483, Hs578T, HTB2, BT20, T47D, NS0 (a murine myeloma cell line that does not endogenously produce any immunoglobulin chains), CRL7O3O, and HsS78Bst cells. In other embodiments, *E. coli* cells are used as host cells. Examples of *E. coli* strains include, but are not limited to, *E. coli* 294 (ATCC® 31,446), *E. coli* λ 1776 (ATCC® 31,537, *E. coli* BL21 (DE3) (ATCC® BAA-1025), and *E. coli* RV308 (ATCC® 31 ,608). Different host cells have characteristic and specific mechanisms for the posttranslational processing and modification of protein products. Appropriate cell lines or host systems may be chosen to ensure the correct modification and processing of the anti-FcRn antibody expressed. The above-described expression vectors may be introduced into appropriate host cells using conventional techniques in the art, e.g., transformation, transfection, electroporation, calcium phosphate precipitation, and direct microinjection. Once the vectors are introduced into host cells for protein production, host cells are cultured in conventional nutrient media modified as appropriate for inducing promoters, selecting transformants, or amplifying the genes encoding the desired sequences. Methods for expression of therapeutic proteins are known in the art, see, for example, Paulina Balbas, Argelia Lorence (eds.) Recombinant Gene Expression: Reviews and Protocols (Methods in Molecular Biology), Humana Press; 2nd ed. 2004 (July 20, 2004) and Vladimir Voynov and Justin A. Caravella (eds.) Therapeutic Proteins: Methods and Protocols (Methods in Molecular Biology) Humana Press; 2nd ed. 2012 (June 28, 2012).

Protein production, recovery, and purification

[0109] Host cells used to produce the anti-FcRn antibodies may be grown in media known in the art and suitable for culturing of the selected host cells. Examples of suitable media for mammalian host cells include Minimal Essential Medium (MEM), Dulbecco's Modified Eagle's Medium (DMEM), Expi293™ Expression Medium, DMEM with supplemented fetal bovine serum (FBS), and RPMI-1640. Examples of suitable media for bacterial host cells include Luria broth (LB) plus necessary supplements, such as a selection agent, e.g., ampicillin. Host cells are cultured at suitable temperatures, such as from about 20 °C to about 39 °C, e.g., from 25 °C to about 37 °C, preferably 37 °C, and CO_2 levels, such as 5 to 10% (preferably 8%). The pH of the medium is generally from about

6.8 to 7.4, e.g., 7.0, depending mainly on the host organism. If an inducible promoter is used in the expression vector, protein expression is induced under conditions suitable for the activation of the promoter.

[0110] Protein recovery typically involves disrupting the host cell, generally by such means as osmotic shock, sonication, or lysis. Once the cells are disrupted, cell debris may be removed by centrifugation or filtration. The proteins may be further purified. An anti-FcRn antibody may be purified by any method known in the art of protein purification, for example, by protein A affinity, other chromatography (e.g., ion exchange, affinity, and size-exclusion column chromatography), centrifugation, differential solubility, or by any other standard technique for the purification of proteins, (see Process Scale Purification of Antibodies, Uwe Gottschalk (ed.) John Wiley & Sons, Inc., 2009). In some instances, an anti-FcRn antibody can be conjugated to marker sequences, such as a peptide to facilitate purification. An example of a marker amino acid sequence is a hexa-histidine peptide (His-tag), which binds to nickel-functionalized agarose affinity column with micromolar affinity. Other peptide tags useful for purification include, but are not limited to, the hemagglutinin "HA" tag, which corresponds to an epitope derived from the influenza hemagglutinin protein.

[0111] Alternatively, anti-FcRn antibodies can be produced by the cells of a subject (e.g., a human), e.g., in the context of therapy, by administrating a vector (e.g., a retroviral vector, adenoviral vector, poxviral vector (e.g., vaccinia viral vector, such as Modified Vaccinia Ankara (MVA)), adeno-associated viral vector, and alphaviral vector) containing a nucleic acid molecule encoding the anti-FcRn antibody. The vector, once inside a cell of the subject (e.g., by transformation, transfection, electroporation, calcium phosphate precipitation, direct microinjection, infection, etc.) will promote expression of the anti-FcRn antibody, which is then secreted from the cell. If treatment of a disease or disorder is the desired outcome, no further action may be required. If collection of the protein is desired, blood may be collected from the subject and the protein purified from the blood by methods known in the art.

V. Pharmaceutical compositions and preparations

[0112] The disclosure features pharmaceutical compositions that include one or more anti-FcRn antibodies described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024). In some embodiments, pharmaceutical compositions contain one or more antibodies as the therapeutic proteins. In other embodiments, pharmaceutical compositions containing one or more antibodies may be used in combination with other agents (e.g., therapeutic biologics and/or small molecules) or compositions in a therapy. In addition to a therapeutically effective amount of the antibody, the pharmaceutical compositions may contain one or more pharmaceutically acceptable carriers or excipients, which can be formulated by methods known to those skilled in the art.

[0113] Acceptable carriers and excipients in the pharmaceutical compositions are nontoxic to recipients at the dosages and concentrations employed. Acceptable carriers and excipients may include buffers, antioxidants, preservatives, polymers, amino acids, and carbohydrates. Pharmaceutical compositions can be administered parenterally in the form of an injectable formulation. Pharmaceutical compositions for injection (i.e., intravenous injection) can be formulated using a sterile solution or any pharmaceutically acceptable liquid as a vehicle. Pharmaceutically acceptable vehicles include, but are not limited to, sterile water, physiological saline, and cell culture media (e.g., Dulbecco's Modified Eagle Medium (DMEM), α-Modified Eagles Medium (α-MEM), F-12 medium). Formulation methods are known in the art, see e.g., Banga (ed.) Therapeutic Peptides and Proteins: Formulation, Processing and Delivery Systems (2nd ed.) Taylor & Francis Group, CRC Press (2006).

[0114] The pharmaceutical composition may be formed in a unit dose form as needed. The amount of active component, e.g., one or more anti-FcRn antibodies (e.g., N022-N024, N026, and N027, preferably N027 and/or N024), included in the pharmaceutical preparations is such that a suitable dose within the designated range is provided (e.g., a dose within the range of 0.01-500 mg/kg of body weight).

VI. Routes, dosage, and administration

[0115] Pharmaceutical compositions that contain one or more anti-FcRn antibodies described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) as the therapeutic proteins may be formulated for intravenous administration, parenteral administration, subcutaneous administration, intramuscular administration, intra-arterial administration, intrathecal administration, or intraperitoneal administration. In particular, intravenous administration is preferred. The pharmaceutical composition may also be formulated for, or administered via, oral, nasal, spray, aerosol, rectal, or vaginal administration. For injectable formulations, various effective pharmaceutical carriers are known in the art.

[0116] The dosage of the pharmaceutical compositions depends on factors including the route of administration, the disease to be treated, and physical characteristics, e.g., age, weight, general health, of the subject. Typically, the amount of an anti-FcRn antibody described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) contained within a single dose may be an amount that effectively prevents, delays, or treats the disease without inducing significant toxicity. A pharmaceutical composition may include a dosage of an anti-FcRn antibody ranging from 0.01 to 500 mg/kg (e.g., 0.01, 0.1, 0.2, 0.3, 0.4, 0.5, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 100, 150, 200, 250, 300, 350, 400, 450, or 500 mg/kg) and, in a more specific embodiment, about 1 to about 100 mg/kg and, in a more specific embodiment, about 1 to about 50 mg/kg. The dosage may be adapted by the physician in accordance with conventional factors such as the extent of the disease and different parameters of the subject.

[0117] The pharmaceutical compositions are administered in a manner compatible with the dosage formulation and in such amount as is therapeutically effective to result in an improvement or remediation of the symptoms. The pharmaceutical compositions are administered in a variety of dosage forms, e.g., intravenous dosage forms, subcutaneous dosage forms, and oral dosage forms (e.g., ingestible solutions, drug release capsules). Generally, therapeutic proteins are dosed at 1-100 mg/kg, e.g., 1-50 mg/kg. Pharmaceutical compositions that contain an anti-FcRn antibody described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) may be administered to a subject in need thereof, for example, one or more times (e.g., 1-10 times or more) daily, weekly, monthly, biannually, annually, or as medically necessary. Dosages may be provided in either a single or multiple dosage regimens. The timing between administrations may decrease as the medical condition improves or increase as the health of the patient declines.

VII. Methods of Treatment and Indications

[0118] The blockade of human FcRn by anti-FcRn antibodies may be of therapeutic benefit in diseases that are driven by IgG autoantibodies. The ability of FcRn blockade to induce overall pathogenic antibody (e.g., an IgG antibody) catabolism and removal of multiple species of autoantibodies without perturbing serum albumin, small circulating metabolites, or lipoproteins offers a method to expand the utility and accessibility of an autoantibody removal strategy to patients with autoantibody-driven autoimmune disease pathology. While this disclosure is not bound by theory, the dominant mechanism of action of an anti-FcRn antibody may be to increase the catabolism of pathogenic autoantibodies in circulation and decrease autoantibody and immune complex deposition in affected tissues.

[0119] The pharmaceutical compositions and methods containing one or more anti-FcRn antibodies described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) are useful to promote catabolism and clearance of pathogenic antibodies, e.g., IgG and IgG autoantibodies in a subject, to reduce the immune response, e.g., to block immune complex-based activation of the immune response in a subject, and to treat immunological conditions or diseases in a subject. In particular, the pharmaceutical compositions and methods are useful to reduce or treat an immune complex-based activation of an acute or chronic immune response. The acute immune response may be activated by a medical condition selected from the group consisting of pemphigus vulgaris, lupus nephritis, myasthenia gravis, Guillain-Barré syndrome, antibody-mediated rejection, catastrophic anti-phospholipid antibody syndrome, immune complex-mediated vasculitis, glomerulitis, a channelopathy, neuromyelitis optica, autoimmune hearing loss, idiopathic thrombocytopenia purpura (ITP), autoimmune haemolytic anaemia (AIHA),

immune neutropenia, dialated cardiomyopathy, and serum sickness. The chronic immune response may be activated by a medical condition selected from the group consisting of chronic inflammatory demyelinating polyneuropathy (CIDP), systemic lupus, a chronic form of a disorder indicated for acute treatment, reactive arthropathies, primary biliary cirrhosis, ulcerative colitis, and antineutrophil cytoplasmic antibody (ANCA)-associated vasculitis.

[0120] In some embodiments, the pharmaceutical compositions and methods are useful to decrease the risk of or decrease the risk of developing anemia in the fetus. In some embodiments, the pharmaceutical compositions and methods are useful to decrease or obviate the need for IUT (intrauterine transfusion).

[0121] In some embodiments, the pharmaceutical compositions and methods are useful to decrease or obviate the need for antenatal PP + IVIg, postnatal transfusion, IVIg, and/or phototherapy. In some embodiments, the pharmaceutical compositions and methods are useful to reduce or treat an immune response activated by an autoimmune disease. The autoimmune disease may be selected from the group consisting of alopecia areata, ankylosing spondylitis, antiphospholipid syndrome, Addison's disease, hemolytic anemia, autoimmune hepatitis, hepatitis, Behcets disease, bullous pemphigoid, cardiomyopathy, celiac sprue-dermatitis, chronic fatigue immune dysfunction syndrome, chronic inflammatory demyelinating polyneuropathy, Churg-Strauss syndrome, cicatricial pemphigoid, limited scleroderma (CREST syndrome), cold agglutinin disease, Crohn's disease, dermatomyositis, discoid lupus, essential mixed cryoglobulinemia, fibromyalgia, fibromyositis, Graves' disease, Hashimoto's thyroiditis, hypothyroidism, inflammatory bowel disease, autoimmune lymphoproliferative syndrome, idiopathic pulmonary fibrosis, IgA nephropathy, insulin dependent diabetes, juvenile arthritis, lichen planus, lupus, Ménière's Disease, mixed connective tissue disease, multiple sclerosis, pernicious anemia, polyarteritis nodosa, polychondritis, polyglandular syndromes, polymyalgia rheumatica, polymyositis, primary agammaglobulinemia, primary biliary cirrhosis, psoriasis, Raynaud's phenomenon, Reiter's syndrome, rheumatic fever, rheumatoid arthritis, sarcoidosis, scleroderma, Sjögren's syndrome, stiff-man syndrome, Takayasu arteritis, temporal arteritis, ulcerative colitis, uveitis, vitiligo, and Wegener's granulomatosis.

[0122] In particular, the pharmaceutical compositions and methods are useful to reduce or treat an immune response activated by systemic lupus erythematosus, antiphospholipid syndrome, pemphigus vulgaris/bullous pemphigoid, antineutrophil cytoplasmic antibody (ANCA)-associated vasculitis, myasthenia gravis, or neuromyelitis optica.

[0123] The pharmaceutical compositions and methods are useful in methods of decreasing pathogenic antibody transport (e.g., pathogenic maternal IgG antibody transport) across the placenta of a pregnant subject, increasing pathogenic antibody catabolism in a pregnant subject, and treating an antibody-mediated enhancement of viral disease in a fetus or a neonate by administering to a pregnant subject an isolated antibody that binds to human FcRn. Diseases and disorders that may benefit from FcRn inhibition by the isolated anti-FcRn antibodies described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) include diseases and disorders in a fetus and/or neonate that are caused by the transfer of maternal pathogenic antibodies (e.g., maternal pathogenic IgG antibodies) across the placenta from a pregnant subject to the fetus and/or neonate.

[0124] In some embodiments, the diseases and disorders that may benefit from FcRn inhibition by the isolated anti-FcRn antibodies described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) are fetal and neonatal alloimmune and/or autoimmune disorders. Fetal and neonatal alloimmune disorders are disorders in a fetus and/or neonate that is caused by pathogenic antibodies in the pregnant subject. The pathogenic antibodies in the pregnant subject may attack the antigens of the fetus (e.g., antigens the fetus inherited from the fetus' father), causing the fetus or the neonate to have a fetal and neonatal alloimmune and/or autoimmune disorder.

[0125] Examples of fetal and neonatal alloimmune and/or autoimmune disorders that may be treated by the methods described herein include, but are not limited to, fetal and neonatal alloimmune thrombocytopenia (FNAIT), hemolytic disease of the fetus and newborn (HDFN), alloimmune pan-thrombocytopenia, congenital heart block, fetal arthrogryposis, neonatal myasthenia gravis, neonatal autoimmune hemolytic anemia, neonatal anti-phospholipid syndrome, neonatal polymyositis, dermatomyositis, neonatal lupus, neonatal scleroderma. Behcet's disease, neonatal Graves' disease, neonatal Kawasaki disease, neonatal autoimmune thyroid disease, and

neonatal type I diabetes mellitus.

[0126] Other diseases and disorders that may benefit from FcRn inhibition by the isolated anti-FcRn antibodies described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) are viral diseases wherein antibodies facilitate viral entry into host cells, leading to increased or enhanced infectivity in the cells, e.g., antibody-mediated enhancement of viral disease. An antibody may bind to a viral surface protein and the antibody/virus complex may bind to an FcRn on a cell surface through interaction between the antibody and the receptor. Subsequently, the antibody/virus complex may get internalized into the cell. For example, a virus may gain entry into the cells and/or tissues of a fetus through forming a complex with a maternal IgG antibody. A maternal IgG antibody may bind to a viral surface protein and the IgG/virus complex may bind to an FcRn in the syncytiotrophoblasts of the placenta, which then transfers the complex into the fetus.

[0127] The methods described herein may be used to treat an antibody-mediated enhancement of viral disease. The viral diseases that may be enhanced by pathogenic antibodies (e.g., pathogenic IgG antibodies) include, but are not limited to, viral diseases caused by an alpha virus infection, flavivirus infection, Zika virus infection, Chikungunya virus infection, Ross River virus infection, severe acute respiratory syndrome coronavirus infection, Middle East respiratory syndrome, avian influenza infection, influenza virus infection, human respiratory syncytial virus infection, Ebola virus infection, yellow fever virus infection, dengue virus infection, human immunodeficiency virus infection, respiratory syncytial virus infection, Hantavirus infection, Getah virus infection, Sindbis virus infection, Bunyamwera virus infection, West Nile virus infection, Japanese encephalitis virus B infection, rabbitpox virus infection, lactate dehydrogenase elevating virus infection, reovirus infection, rabies virus infection, foot-and-mouth disease virus infection, porcine reproductive and respiratory syndrome virus infection, simian hemorrhagic fever virus infection, equine infectious anemia virus infection, caprine arthritis virus infection, African swine fever virus infection, lentivirus infection, BK papovavirus infection, Murray Valley encephalitis virus infection, enterovirus infection, cytomegalovirus infection, pneumovirus infection, morbillivirus infection, and measles virus infection.

[0128] The blockade of human FcRn by anti-FcRn antibodies may be of therapeutic benefit in diseases that are driven by pathogenic antibodies (e.g., pathogenic IgG antibodies). The ability of FcRn blockade to induce overall pathogenic antibody catabolism and removal of multiple species of pathogenic antibodies without perturbing serum albumin, small circulating metabolites, or lipoproteins offers a method to expand the utility and accessibility of a pathogenic antibody removal strategy to patients with pathogenic antibody-driven autoimmune disease pathology. While not bound by theory, the dominant mechanism of action of an anti-FcRn antibody may be to increase the catabolism of pathogenic antibodies in circulation and decrease pathogenic antibody and immune complex deposition in affected tissues.

[0129] The anti-FcRn antibodies described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) may be administered to a pregnant subject who has or is at risk of having a medical condition that activates an immune response in the pregnant subject. In some embodiments, the pregnant subject may have had, in the past, a medical condition that activated an immune response in the pregnant subject. In some embodiments, the pregnant subject has a history of having had a previous fetus or neonate that had a fetal and neonatal alloimmune and/or autoimmune disorder. In some embodiments, the anti-FcRn antibodies described herein may be administered to a pregnant subject if a pathogenic antibody associated with an immune disease is detected in a biological sample (e.g., a blood or urine sample) obtained from the pregnant subject. In some embodiments, the pathogenic antibody detected in the biological sample of the pregnant subject is known to bind to an antigen from the fetus in the pregnant subject (e.g., an antigen that the fetus inherited from the fetus' father).

[0130] In some embodiments, the anti-FcRn antibodies described herein (e.g., N022-N024, N026, and N027, preferably N027 and/or N024) may be administered to a subject who is planning to become pregnant and who has or is at risk of having a medical condition that activates an immune response in the pregnant subject, and/or who has had, in the past, a medical condition that activated an immune response in the pregnant subject. In some embodiments, a subject is planning to become pregnant and has a history of having had a previous fetus or neonate that had a fetal and neonatal alloimmune and/or autoimmune disorder. In some embodiments, the anti-FeRn antibodies described herein may be administered to a subject who is planning to become pregnant and

whose biological sample contains a pathogenic antibody associated with an immune disease.

[0131] The anti-FcRn antibodies described herein may be administered to a subject (e.g., a pregnant subject) to reduce or treat an immune complex-based activation of an acute or chronic immune response in the subject. The acute immune response may be activated by a medical condition (e.g., pemphigus vulgaris, lupus nephritis, myasthenia gravis, Guillain-Barré syndrome, antibody-mediated rejection, catastrophic anti-phospholipid antibody syndrome, immune complex-mediated vasculitis, glomerulitis, a channelopathy, neuromyelitis optica, autoimmune hearing loss, idiopathic thrombocytopenia purpura, autoimmune haemolytic anaemia, immune neutropenia, dialated cardiomyopathy, serum sickness, chronic inflammatory demyelinating polyneuropathy, systemic lupus, reactive arthropathies, primary biliary cirrhosis, ulcerative colitis, or antineutrophil cytoplasmic antibody (ANCA)-associated vasculitis).

[0132] The anti-FcRn antibodies described herein may be administered to a subject (e.g., a pregnant subject) to reduce or treat an immune response activated by an autoimmune disease. The autoimmune disease may be, for example, alopecia areata, ankylosing spondylitis, antiphospholipid syndrome, Addison's disease, hemolytic anemia, warm autoimmune hemolytic anemia (wAIHA), anti-factor antibodies, heparin induced thrombocytopenia (HICT), sensitized transplant, autoimmune hepatitis, hepatitis, Behcet's disease, bullous pemphigoid, cardiomyopathy, celiac sprue-dermatitis, chronic fatigue immune dysfunction syndrome, chronic inflammatory demyelinating polyneuropathy, Churg-Strauss syndrome, cicatricial pemphigoid, limited scleroderma (CREST syndrome), cold agglutinin disease, Crohn's disease, dermatomyositis, discoid lupus, essential mixed cryoglobulinemia, fibromyalgia, fibromyositis, Graves' disease, Hashimoto's thyroiditis, hypothyroidism, inflammatory bowel disease, autoimmune lymphoproliferative syndrome, idiopathic pulmonary fibrosis, IgA nephropathy, insulin dependent diabetes, juvenile arthritis, lichen planus, lupus, Ménière's Disease, mixed connective tissue disease, multiple sclerosis, pernicious anemia, polyarteritis nodosa, polychondritis, polyglandular syndromes, polymyalgia rheumatica, polymyositis, primary agammaglobulinemia, primary biliary cirrhosis, psoriasis, Raynaud's phenomenon, Reiter's syndrome, rheumatic fever, rheumatoid arthritis, sarcoidosis, scleroderma, Sjögren's syndrome, stiff-man syndrome, Takayasu arteritis, temporal arteritis, ulcerative colitis, uveitis, vitiligo, or Wegener's granulomatosis.

EXAMPLES

Example 1 - Antibody production

[0133] IgG heavy and light chain nucleic acid molecules were cloned in vector pCDNA 3.3 using osteonectin secretion signals. HEK 293F cells were grown in Expi293 media at 37 °C with 8% CO_2. Cells were transfected at a density of 3×10^6/ml with 1 mg total DNA per liter. Enhancers were added on days 2 and 3 following manufacturer's directions and the cells were cultured until day 5 or 6 before cell viability dropped to below 50% to 60%. The cells were then spun out by centrifugation and the spent media was sterile filtered and stored at 4 °C until antibody purification. Antibodies were purified by a two-column procedure: POROS Protein A chromatography followed by POROS HS-50 cation exchange chromatography. The former separated most of the host cell proteins from the expressed antibodies while the latter removed the heavy chain dimers, light chain dimers, and half antibodies, as well as higher molecular weight species. The fractions from the HS-50 cation exchange column were pooled based on an SDS-PAGE gel analysis to maximize purity of the full-length antibodies. The collected fractions were put over a Sephadex G50 buffer exchange column equilibrated in PBS at pH 7.2. The peak fractions were pooled and concentrated to greater than 10 mg/ml using 30 kDa spin concentrators and frozen at - 30 °C in 2 mg and 5 mg aliquots. The final protein samples were checked for purity by SDS-PAGE.

Example 2 - Binding affinities

[0134] Through affinity maturation, we identified more than 100 anti-FeRn antibodies having binding affinities to human FcRn with a K_D in the sub-micromolar range. Five antibodies (N022-N024, N026, and N027) were selected for further characterization. Surface Plasmon Resonance (SPR) was used to determine the on- and off-rates (k_a and k_d, respectively) for each of these five antibodies. Briefly, a Bio-Rad GLC sensor chip was inserted into the ProteOn XPR 36 and air initialized. After initialization the running buffer was switched to freshly prepared buffer, either HBSP+ (0.01 M HEPES, 0.15 M NaCl, 0.05% P20, pH 7.4) or Sodium Phosphate Buffer (0.02 M Sodium Phosphate, 0.15 M NaCl, 0.05% P20, pH 6.0) as appropriate, which was used for the remainder of the assay and for all dilutions. The chip was preconditioned using one injection each of 0.5% SDS, 50mM NaOH and 10mM HCl at 30 µl/min for 60 seconds (s). A mouse anti-Human Fc mAb from GE Healthcare (BR100839) was diluted to 10 µg/ml in 10 mM acetate buffer pH 5.0 and approximately 5,700 response units (RU) was immobilized using standard amine coupling chemistry in the horizontal orientation onto a GLC sensor chip. The anti-hFcRn mAbs to be tested were captured onto the surface in the vertical orientation, with the goal of immobilizing approximately 200 response units (RU) per interaction spot. The rhFcRn was diluted in a five-point threefold dilution series starting at 1.25 µg/ml, leaving one lane as buffer-only for a double reference. The analyte was flowed across the sensor surface in the horizontal orientation at 100 µl/min for 240 s with a 3,600 s dissociation time. Regeneration was accomplished by injecting 3M MgCl2 at 100 µl/min for 30 s in both the horizontal and vertical directions. These procedures were repeated for all ligands.

[0135] Data analysis was conducted using the ProteOn Manager software. Each interaction step was adjusted for the Y and X direction using the Auto Process tool, followed by interspot channel referencing to remove non-specific interactions and blank lane double referencing to remove assay drift. The data was fit using the Langmuir 1:1 kinetic model with a grouped Rmax. The k_a, k_d and K_D values obtained from ProteOn Manager in a single run were averaged and their percent CV was calculated in Microsoft Excel when the N was three or greater.

[0136] Table 3 shows that five anti-FcRn antibodies, N022, N023, N024, N026, and N027, all bind with high affinity to human FcRn at pH 7.4. The equilibrium dissociation constant, K_D, of the anti-FcRn antibodies ranged from 19.4 pM (N027) to 36.5 pM (N026) for binding to human FcRn at pH 7.4, 298K. Table 3 also shows the rapid on-rates and slow off-rates of the five anti-FeRn antibodies. At pH 7.4, 298K, the on-rates were in the range of 0.93-1.42 × 10^6 1/Ms for binding to human FcRn. The off-rates were in the range of 2.31-4.44 × 10^6 1/s.

Table 3

	k_a (1/Ms)	k_d (1/s)	K_D (M)	R_{max}	Chi2	K_D (pM)
N022	1.42E+06	4.42E-05	3.10E-11	146.93	7.65	31
N023	9.27E+05	2.91 E-05	3.14E-11	193.43	5.26	31.4
N024	1.13E+06	4.03E-05	3.55E-11	181.17	6.12	35.5
N026	1.22E+06	4.44E-05	3.65E-11	163.9	5.68	36.5
N027	1.19E+06	2.31E-05	1.94E-11	211.33	7.81	19.4

Example 3 - IgG competition

[0137] The ability of anti-FcRn antibodies to compete with IgG for binding to human or cynomolgus monkey FcRn was evaluated on human embryonic kidney (HEK) 293 cells ectopically expressing cell surface, glycophosphatidylinositol (GPI)-linked FcRn. Human and cynomolgus monkey FcRn alpha amino acid sequences exhibit 97.5% sequence identity. Nine amino acid residues of 355 are different between human and cynomolgus monkey FcRn alpha, but none are in the epitope-mapped binding region. The level of cell-bound IgG was determined using 66 nM of fluorescent probe-labeled, non-specific IgG. The binding of IgG to cell surface FcRn was done at pH 6.0, which allows the Fc portion of IgG to interact with FcRn. As shown in FIG. 1, the amount of cell-bound IgG significantly decreased as the concentration of the anti-FcRn antibody (N022-N024, N026, or N027) increased. The binding of IgG was inhibited in a concentration- and saturation-dependent manner by each of the five exemplary anti-FcRn antibodies , demonstrating the ability of the anti-FcRn antibodies, N022-N024, N026, and

N027, to effectively compete with and inhibit binding of IgG to FcRn at pH 6.0. The EC50 values of the antibodies ranged between 2 and 6 nM.

Example 4 - Effect of anti-FeRn antibodies on IgG catabolism in mice

[0138] To measure the effect of the anti-FcRn antibodies on IgG catabolism *in vivo,* human FcRn transgenic mouse strain, homozygous B6.Cg-*Fcgrt*^{tm1Dcr}Tg(FCGRT)32Dcr/DcrJ mice, which lacks mouse FcRn but expresses human FcRn in a tissue distribution similar to the endogenous mouse and human FcRn, was used. FcRn-/-hFcRn (32) Tg mice injected with 500 mg/kg human IVIG tracer on day 0 were administered a single dose of an anti-FcRn antibody at 10 mg/kg on days 1 and 4. As shown in FIG. 2, the catabolism of IgG was increased by the administration of anti-FcRn antibodies as seen by lower levels of IgG measured over time in anti-FcRn antibody-treated mice. The activities of N024 (K_D = 35.5 pM), N026 (K_D = 36.5 pM), and N027 (K_D = 19.4 pM) appeared to be similar at 10 mg/kg.

Example 5 - *In vitro* characterizations of anti-FeRn antibodies

[0139] Cellular binding affinities of the antibodies were measured on human embryonic kidney (HEK) 293 cells ectopically expressing cell surface, glycophosphatidylinositol (GPI)-linked human or cynomolgus monkey FcRn. FcRn is a type I transmembrane protein with the IgG and albumin binding domains oriented to the luminal side of endosomal membranes or to the cell surface when transported to the plasma membrane. The binding of anti-FcRn antibodies to cell surface, membrane-associated FcRn on HEK293 cells at pH 7.4 mimics binding in a physiologically-relevant environment and at the pH where only the Fab domain and not the Fc domain of the antibodies interact with FcRn. The FcRn extracellular domain was displayed on the cell surface at high density through a C-terminal engineered GPI linkage. The anti-FeRn antibodies were labeled with a fluorescent probe. The antibodies were allowed to bind for 30 minutes on ice. Cells were then washed at 4 °C and bound antibodies were detected using a fluorophore-labeled secondary antibody, e.g., a goat anti-human IgG $F(ab)_2$. The binding to human FcRn was concentration dependent and antibodies displayed EC50 values ranging from 4 to 7 nM.

[0140] Cellular binding affinities of the antibodies were also measured on endogenously expressed human FcRn. Monocytes express the highest levels of FcRn and show the highest percent positivity for FcRn expression in mouse and human blood. Monocytic cell line THP-1 was used to evaluate binding of anti-FcRn antibodies to endogenous human FcRn at pH 7.4. Since endogenous FcRn is primarily in intracellular endosomal vesicles, the THP-1 cells were first fixed and then permeablized with a mild detergent and fixed prior to incubation for 30 minutes at 4 °C with anti-FcRn antibodies in the presence of bovine serum to block non-specific Fc receptor binding. This assay was able to distinguish antibodies with better binding to endogenous human FcRn. The binding of anti-FeRn antibodies to THP-1 cells is concentration dependent. All antibodies, e.g., N022-N024, N026, and N027, showed better binding affinities than IgG1. Antibody N027 displayed the highest binding affinity with an EC50 value of 3.0 nM.

[0141] Epitope mapping by hydrogen-deuterium exchange of the antibodies indicated that the antibodies bind to an epitope that comprises at least a portion of two amino acid sequences on human FcRn. One amino acid sequence includes at least one amino acid of the sequence of KQGTWGGDWPEAL (SEQ ID NO: 25), located in and/or adjacent to the Fc-FcRn interaction interface, which suggests that the antibodies block IgG binding to FcRn by direction inhibition. The first amino acid sequence comprises W131 of FcRn (SEQ ID NO: 30). The second amino acid sequence includes at least one amino acid of the sequence of FKALGGKGPYTL (SEQ ID NO: 26). The second amino acid sequence comprises Y88 of FcRn (SEQ ID NO: 30). The epitope of the anti-FcRn antibody includes one or both of a) an amino acid sequence comprising W131 of FcRn and b) an amino acid sequence comprising Y88 of FcRn. In some embodiments, the epitope comprises at least a) an amino acid sequence comprising W131 of FcRn and b) an amino acid sequence comprising Y88 of FcRn. In some embodiments, the epitope comprises either a) an amino acid sequence comprising W131 of FcRn or b) an amino acid sequence comprising Y88 of FcRn. The

epitope-mapped binding sites are distant from the albumin-binding site of FcRn. Thus, serum albumin-binding should not be inhibited and serum albumin levels should not be decreased. An enzyme-linked immunosorbent assay (ELISA) was used to confirm that the antibodies do not inhibit serum albumin binding to FcRn. Soluble His-tagged extracellular domain of human FcRn was bound to the plate surface and pre-incubated with increasing concentrations of anti-FcRn antibody at pH 6.0. Horseradish peroxidase (HRP)-conjugated human serum albumin was allowed to bind to the soluble, His-tagged FcRn. None of the antibodies inhibited albumin binding to FcRn. Furthermore, *in vivo* experimental evidence also showed that cynomolgus monkey albumin levels remained constant after anti-FcRn antibody administration, indicating that albumin recycling was not disturbed by antibody binding to FcRn (FIG. 4C).

Example 6 - Effect of anti-FeRn antibodies on IgG levels and target occupancy in mice

[0142] N027 was dosed intravenously (i.v.) 24 hrs after administration of 500 mg/kg human IVIg (tracer) to homozygous B6.Cg-*Fcgrt*^{tm1Dcr} Tg(FCGRT)32Dcr/DcrJ mice. Circulating human IgG was detected by ELISA on each day. Target occupancy was measured on each day in monocytes from RBC-lysed whole blood by fluorescence-activated cell sorting (FACS), after incubation of cells with immunophenotyping cell surface markers followed by fixation and permeabilization. Unoccupied FcRn was measured by staining with Dy650-labeled N027 (n = 4 males per group). As shown in FIG. 3, IgG levels and the percentage of unoccupied FcRn were decreased by the administration of N027 in a dose-dependent manner.

Example 7 - Selective induction of IgG catabolism and target occupancy in cynomolgus monkeys

[0143] To study the effect of N027 on induction of IgG catabolism and target receptor occupancy, N027 was dosed i.v. on day 0 in cynomolgus monkeys. Circulating endogenous IgG and albumin was detected by ELISA. Target occupancy was measured in monocytes from RBC-lysed whole blood by FACS, after incubation of cells with immunophenotyping cell surface markers followed by fixation and permeabilization. Unoccupied FcRn was measured by staining with Dy650-labeled N027. (n = 3 males per group). As shown in FIGS. 4A-4C, IgG level and the percentage of unoccupied FcRn were decreased by the administration of N027 in a dose-dependent manner, while plasma albumin levels stayed unchanged.

Example 8 - Biodistribution of N027 in mice

[0144] To compare the biodistribution of N027 and a human IgG with no target mediated distribution, N027 or human IgG1 isotype control antibody labeled with fluorophore (VivoTag 680) were administered i.v. to homozygous B6.Cg-*Fcgrt*^{tm1Dcr} Tg(FCGRT)32Dcr/DcrJ mice at 30 mg/kg. Levels of labeled antibody were measured in individual organs by quantitative ex vivo fluorescence imaging. As shown in FIG. 5, the biodistribution of N027 in various organs in mice is similar to that of an isotype control antibody.

Example 9 - Efficacy of N027 in mouse collagen antibody-induced arthritis

[0145] Collagen antibody-induced arthritis was induced in homozygous B6.Cg-*Fcgrt*^{tm1Dcr} Tg(FCGRT)32Dcr/DcrJ mice by intraperitoneal (i.p.) injection of ArthritoMab™ cocktail (MD Biosciences) on day 1 and inflammatory disease activity induced with 100 µg LPS dosed i.p. on day 4. N027 was dosed therapeutically i.v. at 5 mg/kg (arrow), on day 6 post disease induction and randomization. IVIG at 1 g/kg (positive control group) or vehicle-PBS (negative control) were dosed on day 6 after randomization (n = 5 per group). As shown in FIG. 6, N027 potently inhibits collagen antibody-induced arthritis in human transgenic FcRn mice when dosed therapeutically.

Example 10 - Efficacy of N027 in mouse chronic idiopathic thrombocytopenia purpura (ITP)

[0146] Thrombocytopenia was induced in homozygous B6.Cg-*Fcgrt*^{tm1Dcr} Tg(FCGRT)320cr/OcrJ mice by continuous subcutaneous infusion of anti-platelet antibody (anti-CD41 , MWReg30) *via* a miniosmotic pump. Circulating platelet levels were decreased to 300 × 10^9/L or less by 72 hrs (Day 3) after pump implantation. N027 was dosed therapeutically i.v. 72 hrs (day 3) and 120 hrs (Day 5) post-pump implantation (A, n = 4 per group; B, n = 7 per group). FIG. 7 shows that N027 when dosed therapeutically, can effectively restore platelet levels in mice having thrombocytopenia.

Example 11- Concentration dependent FcRn occupancy was achieved with N027 in target cell types

[0147] The receptor occupancy by N027 was compared across different cell types such as primary human aortic endothelial cells (HAECs), human umbilical vein endothelial cells (HUVECs) cells and placental trophoblasts (HVTs). Cells were grown to confluency in complete EBM-2 media (Lonza, Waterville) or in trophoblast media (ScienCell). Cell monolayers were incubated in 1 ml of media with different concentrations of unlabeled N027 for 1 hour at 37 °C. After washing, cells were harvested with cold HyQTase, fixed and permeabilized before incubation with VivoTag645-labeled N027 (10 µg/ml), for 30 minutes at 4 °C in the dark. Following incubation, cells were washed with permeabilization buffer before resuspending in FACS buffer. Cell-associated VivoTag645-N027 was measured by flow cytometry. The values represent geometric mean fluorescence intensity (gMFI) ± SD (n=2). FIGS. 8A, 8B, and 8C show the FcRn occupancy across N027 concentrations for the HAECs, HUVECs and HVTs, respectively. The results as summarized in Table 4 show that human ECs (HAECs, HUVECs) as well as placental HVTs exhibit similar concentration dependence receptor occupancy by N027.

Table 4

Human Primary Cells	IC_{50}	100% FcRn occupancy dose
Aortic endothelial cells (HAECs)	0.23 µg/mL	2.43 µg/mL
Venous endothelial cells (HUVECs)	0.15 µg/mL	4.99 µg/mL
Placental trophoblast cells (HVTs)	0.15 µg/mL	2.43 µg/mL

Example 12 - N027 concentrations achieving 100% receptor occupancy result in increased intracellular IgG accumulation

[0148] The relation between levels of receptor occupancy and alterations in IgG intracellular trafficking by N027 was compared across different cell types. Human endothelial cells (HAECs and HUVECs) were cultured in endothelial cell culture (EBM-2, Lonza) while human placental trophoblasts (HVTs) were cultured in trophoblast media (ScienCell). Cell monolayers were then pulsed for 4-5 hours at 37 °C in 1 mL media containing either:

1. 1. varying concentrations of N027 + VivoTag645-IgG (50 µg/mL); or
2. 2. varying concentrations of Isotype control IgG + VivoTag645-IgG (50 µg/mL)

[0149] Cell monolayers were then washed in cold media followed by cell detachment by HyQtase treatment. Cell associated VivoTag645-N027 was measured by flow cytometry. Values represent geometric mean fluorescence intensity (gMFI) ± SD (n=2). FIGS. 9A, 9B, and 9C show the intracellular IgG levels for the HAECs, HUVECs and HVTs, respectively, corresponding to various doses of N027. N027 doses corresponding to >100% FcRn occupancy resulted in significantly higher IgG accumulation compared to isotype controls. The results demonstrate that the effective N027 concentrations needed to achieve saturating levels of IgG accumulation is similar in these target cell types and ranges from 4.99 to 2.43 µg/mL as summarized in Table 5

Table 5

Human Primary Cells	~IC_{50}	100% FcRn occupancy dose
Aortic endothelial cells (HAECs)	0.12 µg/mL	2.43 µg/mL
Venous endothelial cells (HUVECs)	0.15 µg/mL	4.99 µg/mL
Placental trophoblast cells (HVTs)	0.07 µg/mL	3.68 µg/mL

Example 13 - Measurement of time to 100% FcRn-occupancy

[0150] To determine the time taken by N027 to saturate FcRn and block IgG trafficking, confluent vascular endothelial cell (HUVEC) monolayers were incubated with or without a saturating concentration of N027 (16.6 µg/ml) in EBM-2 media for the indicated times at 37 °C (FIG. 10). Upon completion of incubation, cells were washed and harvested with cold HyQtase, followed by fixing and permeabilization. These cells were then incubated in permeabilization buffer + 10% human serum and VivoTag645-labeled N027 (10 µg/mL) for 30 minutes at 4 °C in the dark. The cells were then washed with permeabilization buffer, resuspended in FACS buffer and cell-associated VivoTag645-N027 was measured by FACS. Values represent mean gMFI ± SD (n=2). The results shown in FIG.. 10 indicates that 100% FcRn-occupancy by N027 was achieved in about 30 minutes in this endothelial cell type.

Example 14 - Human vascular endothelial cells and placental trophoblasts exhibit similar FcRn turnover rates which are unaltered by N027

[0151] The FcRn turnover rates of human vascular endothelial cells (HUVECs) and placental trophoblasts (HVTs) were compared in the presence and absence of N027. Cells were cultured in 75 cm^2 flask in 25% D_2O (Deuterium Oxide, from Aldrich) containing media for three days. After three days, the media was replaced with normal media containing N027 (100 µg/mL) or control IgG (100 µg/ml) or mock treatment. Cells were then harvested from the flasks at indicated times post media change (FIGS. 11A and 11B). The cell monolayers were washed; cells were harvested, pelleted, and individual pellets were lysed and digested separately. Shotgun proteomics and targeted proteomics were performed. Using Qual Browser, isotopic relative intensities were extracted and fractional abundances were calculated for each isotopomer by dividing each intensity by the total. Fractional abundance values were used to calculate the percentage of D_2O-labeled FcRn remaining in the system. FIGS. 11A and 11B show that FcRn turnover rates are similar between human vascular endothelial cells (HUVECs) and placental trophoblasts (HVTs). Furthermore, treatment with N027 did not change the FcRn turnover rates.

Example 15 - FcRn localization in target cells

[0152] The localization of N027 was compared in human vascular endothelial cells (HUVECs) and placental trophoblasts (HVTs). Cells were grown on glass coverslips in EBM-2/TM media. Live cells were incubated in media containing DyLight594-N027 (2 µg/mL) for 1 hour at 37 °C. Cells were then washed and imaged live on fluorescence microscope in confocal mode with 60X dry objective using appropriate filters. Representative single cell images show similar localization pattern of N027 bound to the endocytic pool of FcRn in both cell types (FIGS. 12A and 12B). The circle in the center of the cell indicates the location of the nucleus.

Example 16 - Effect of N027 treatment on dynamics of IgG trafficking: Intracellular IgG accumulation and co-localization with lysosomes

[0153] The effect of N027 treatment on dynamics of intracellular IgG accumulation was compared across FcRn expressing target cell types such as human vascular endothelial cells (HUVECs) and placental trophoblasts (HVTs).

Cells were grown to confluency in EBM-2 media (Lonza, Waterville) or TM1 media (ScienCell). Confluent cell monolayers were then pulsed in 1 ml media containing either N027 (2 µg/ml) + VivoTag645-IgG (50 µg/mL) or isotype control IgG (2 µg/mL) + VivoTag645-IgG (50 µg/ml) for 20 hours at 37 °C. Cell monolayers were then washed and then chased for 0 min, 30 min, and 90 min at 37 °C in chase media containing either N027 (2 µg/mL) or Isotype control (2 µg/ml). After each chase period, cells were washed, detached, and collected by HyQtase treatment. Cell- associated VivoTag645-N027 was measured by flow cytometry. Values represent geometric mean fluorescence intensity (gMFI) ± SD (n=2). Cells treated with N027 showed higher levels of intracellular IgG. Further, the effect of N027 on the dynamics of intracellular IgG accumulation was similar between the two cells types tested as shown in FIGS. 13A and 13B.

[0154] We also determined whether N027 increases intracellular IgG and co-localization of IgG with lysosomes in primary human umbilical vein endothelial cells (HUVECs). Cells were grown on glass coverslips and incubated in media containing 10 µg/ml Alexa Fluor 594 Dextran (10,000 MW, anionic, fixable) for 2 hours at 37 °C. Following incubation cells were washed and pulsed at 37 °C for 20 hours in either N027 (2 µg/ml) + DyLight 488-IgG (50 µg/ml) containing media or Isotype control IgG (2 µg/ml) + DyLight 488-IgG (50 µg/ml) containing media; or in media without any IgG-treatments. The plates were washed in cold media and then chased for 0 min or 30 min at 37 °C. The following chase conditions were used: the N027+DyLight 488-IgG pulsed set was chased in the presence of N027 (2 µg/mL); the Isotype+DyLight 488-IVIG pulsed set was chased in the presence of isotype control IgG (2 µg/mL) and the set without any IgG-treatments was chased in media only. Cells were washed, incubated in BD Cytofix/Cytoperm solution for 30 min at 4 °C in the dark, washed with perm wash buffer followed by incubation in perm wash buffer + 10% normal mouse serum + 5 µg/ml mouse anti-human Lamp1 antibody for overnight at 4 °C in the dark. Cells were then washed with perm wash buffer and PBS, and then mounted on glass slides. Cell imaging was done using confocal mode on Olympus fluorescence microscope with a 60X dry objective with 2X optical magnification. As presented in FIGS. 13C and 13D, it was shown that N027 treatment increases the accumulation of IgG in the lysosomal compartment as compared to isotype control IgG-treated cells.

Example 17 - Determination and Analysis of a structure of FcRn (a heterodimer comprised of FcRn/p51 and β2-microglobulin/p14) in complex with the N027 Fab

[0155] The complex of N027 Fab:FcRn was purified and concentrated to about 9 mg/ml in a buffer composed of 30 mM HEPES (pH 7.5), 200 mM NaCl, 3% glycerol. This complex was set up in sitting drop vapor diffusion crystallization experiments. Drops consisting of 0.3 µl protein solution plus 0.3 µl reservoir solution were mixed over a reservoir of 80 µl of the reservoir solution. The plates were sealed and allowed to equilibrate at 4°C.

[0156] Plate-like crystals grew in several conditions over the course of 4 days to 7 weeks. The crystal that ultimately led to the structure of the complex grew in a mother liquor consisting of 10% PEG 1000, 10% PEG 8000. The crystal was cryoprotected by soaking for about 2 minutes in a solution of 25% PEG 1000, 10% PEG 8000, 100 mM NaCl before mounting in a cryoloop and plunge-freezing in liquid nitrogen.

[0157] X-ray diffraction data were collected at the Stanford Synchrotron Radiation Lightsource (SSRL) on beamline BL9-2, using a Dectris Pilatus 6M detector and a wavelength of 0.97946 Å. The diffraction images were processed to a resolution of 2.7Å using HKL-2000 followed by various programs in the CCP4 (Collaborative Computational Project, Number 4) software suite. Details of data collection and processing are contained in Table 6.

[0158] The 27Å structure of the N027 Fab:FcRn complex was solved by molecular replacement using search models consisting of a complete FcRn (heterodimer of large and small subunits, p51 and p14, respectively) from Protein Data Bank (PDB) ID No. 4k71 and individual heavy and light chains of human Fab from PDB ID No. 5v7u with the program Phaser. There is one complete complex in the asymmetric unit with a solvent content of approximately 65%. The structure was subsequently completed and refined by successive rounds of manual building and real space refinement in the program Coot followed by restrained refinement against the X-ray data using the program Refmac5 and validation using the program Molprobity and various tools within Coot. The last several rounds of refinement in Refmac5 included TLS refinement with each chain defined as an individual TLS

group. Details of structure solution and refinement are contained in Table 7.

Table 6

Parameter		Value*
Space group		C121
Unit cell parameters		
	a, b, c (Å)	183.2, 67.6, 105.2
	α, β, γ (°)	90.0, 104.9, 90.0
Resolution range (Å)		41.5-2.7 (2.75-2.70)
No. of reflections		115,072
No. of unique reflections		33,982
Completeness (%)		98.1 (96.4)
Multiplicity		3.4 (3.2)
(I/σ(I))		7.4 (1.0)
R_{merge} (%)		13.5 (75.7)
R_{pim} (%)		8.6 (48.2)
Overall B from Wilson plot (Å^2)		40.8
*values in parentheses are for the highest resolution shell		

Table 7

Parameter		Value*
Resolution range (Å)		41.5-2.7
Fraction of test reflections (%)		4.9
Final R_{work} (%)		21.5
Final R_{free} (%)		26.3
Mean B value (overall, Å^2)		28.6
R.m.s. deviations		
	Bonds (Å)	0.01
	Angles (°)	1.50
Ramachandran plot		
	Most favored (%)	95.39
	Allowed (%)	4.35
	Outliers (%)	0.26

Structural Analysis of the FcRn epitope

[0159] The epitope of FcRn defined by the crystal structure is composed primarily of amino acids on the FcRn/p51 subunit but four amino acids from the β2-microglobulin/p14 subunit are also involved. Overall, the interaction between the N027 Fab and FcRn buries approximately 1020 Å^2, with 470 Å^2 between the light chain and FcRn, 414 Å^2 between the heavy chain and FcRn, and 136 Å^2 between the light chain and β2-microglobulin. All three CDR loops from both chains of the N027 Fab are involved in the paratope with CDR H2 and CDR L1 together contributing about half of the interacting amino acid with eight apiece. CDRs H1, H3, and L2 contribute three amino acids each and CDR L3 contributes five. Three amino acids (KSG) at positions 66-68 Kabat in the light chain framework between CDRs L2 and L3 are also involved in binding. The epitope/paratope interface is fully defined by the electron density and has been fully modeled unambiguously. The Fab binding epitope on FcRn overlaps the

canonical Fc binding site so tight binding by the FcRn antibodies is expected to block Fc binding. Additionally, the albumin binding site remains accessible. Additionally, a N-acetylglucosamine is present on Gln102 of FcRn that is well-defined by the electron density. An overview of the epitope as defined by the crystal structure is depicted and are mapped onto the sequence in FIGS. 14-16. The W131 and Y88 residues on FCGRT appear to be the most significant residues that bind through H-bonding to the CDR L3 (YAGSGIY) and CDR H2 (R58) on the anti-FcRn N027 molecule.

Example 18 - Suppression Of Endogenous Maternal And Fetal IgG In Cynomolgus Monkeys By N027 And Lack Of N027 Transfer To Fetal Circulation

[0160] Pregnant female cynomolgus monkeys were dosed weekly from Gestation Day 45 (GD45) to C-section at GD100 (mid-gestation) or GD140 (late gestation). A cohort of animals was also included in the study that were allowed to deliver their infants (birth day [BD1]). The design study is depicted in Table 8.

Table 8: Study Design

Group No.	Test Material	Dose Level (mg/kg)	Dose Volume (mL/kg)	Dose Concentration (mg/mL)	No. of Females for C-section[a]		Live Birth BD1
					GD100 ± 2	GD140 ± 2	
1	Control	0	10	0	4	4	3
2	N027	100	10	10	4	4	-
3	N027	300	10	30	4	4	3

[a] Twenty-four (24) pregnant females were initially enrolled on study (8 per group). Four pregnancies per group were assigned to the GD140 ± 2 C-section cohort, and the remaining 4 pregnancies per group were assigned to the GD100 ± 2 cohort.

IgG concentrations were measured in maternal and neonatal blood samples using a standard validated total IgG ELISA (Table 9). Briefly, polystyrene plates (96-well) were coated with commercially available anti-human IgG antigen. The coated plate(s) were washed to remove unbound sample and then blocked using with blocking buffer followed by a wash to remove the residual blocking buffer. Serum samples were diluted and added to the anti-human IgG coated wells and incubated at room temperature for 60 ± 5 minutes. Each well was washed before addition of secondary (detection) antibody conjugated to horseradish peroxidase (HRP) and incubated at room temperature for 60 ± 5
minutes. Tetramethylbenzidine (TMB) substrate was subsequently added to each well and incubated at room temperature for 20 ± 5 minutes on a plate shaker, before addition of 2N H_2SO4 to stop the enzymatic reaction. The absorbance of each well was read at 450 nm using the SpectraMax® 190 microplate reader. Any commercially available or proprietary pair of anti-human IgG capture antibody and HRP conjugated anti-human IgG detection antibody that recognizes total IgG and is cross-reactive with cynomolgus monkey IgG can be used to measure total cynomolgus monkey IgG in an ELISA. The IgG detection antibody can be, for example, intact IgG, polyclonal serum antibody, monoclonal antibody, or a Fab(2) fragment.

Table 9: Methods

Assay	Method	
Total IgG ELISA		1. Coat immunoassay plate with anti-human IgG.
		2. Incubate with sample
		3. Detect with HRP labeled and addition of TMB substrate
Receptor Occupancy by Fluorescence Activated Cell Sorting (FACS)		1. Whole blood was treated with ammonium chloride to lyse RBC
		2. Cells were spun, washed with PBS, stained with viability dye and incubated with Fc receptor blocking solution

Assay	Method	
		3. Cells were washed with Perm/Wash buffer, suspended in buffer and incubated with fluor labeled N027 for 20 mins
		4. Cells were then washed and resuspended in FACS buffer before analysis by FACS

[0161] For all pregnant adult females assigned to study, blood was collected by venipuncture from the femoral vein (preferred) or cephalic/saphenous veins according to Table 10. For all fetuses obtained by C-section on GD100 ± 2 or GD140 ± 2, blood was collected from the umbilical cord according to Table 10. Samples (1 mL) were allowed to clot for at least 60 minutes; centrifuged and the resultant serum was separated, transferred to appropriately labeled (e.g., IgG) polypropylene tubes, and frozen immediately in a freezer set to maintain -80°C.

Table 10: Sample Collection Timepoints for Evaluation

Gestation Day[b]	**Time Points Relative to Dosing**	**Samples Collected**
GD38±1 (prestudy)	Prestudy	Adult female: IgG
GD44-46 (first dose)	Predose	Adult female: IgG
GD44-46 (first dose)	Postdose: 2 hr	Adult female: IgG
GD44-46	Postdose: 4hr	-
GD45-47	GD45: 24hr	Adult female: IgG
GD47-49	GD45: 72hr	Adult female: IgG
GD48-50	GD45: 96hr	Adult female: IgG
GD51-53	GD52: Predose	Adult female: IgG
GD58-60	GD59:Predose	Adult female: IgG
GD65-67	GD66: Predose	Adult female: IgG
GD72-74	GD73:Predose	Adult female: IgG
GD79-81	GD80: Predose	Adult female: IgG
GD86-88	GD87: Predose	Adult female: IgG
GD93-95	GD94: Predose	Adult female: IgG
GD93-95[a]	GD94: 2hr	Adult female: IgG
GD93-95[a]	GD94: 4hr	-
GD94-96[a]	GD94: 24hr	Adult female: IgG
GD96-98[a]	GD94: 72hr	Adult female: IgG
GD97-99[a]	GD94: 96hr	Adult female: IgG
GD100 ± 2 (1st C-section cohort)	NA	Adult female: IgG; Fetus: IgG
GD100-102	GD101: Predose	Adult female: IgG
GD107-109	GD108: Predose	Adult female: IgG
GD114-116	GD115: Predose	Adult female: IgG
GD121-123	GD122: Predose	Adult female: IgG
GD128-130	GD129: Predose	Adult female: IgG
GD135-137 (last dose)	GD136: Predose	Adult female: IgG
GD135-137	GD136: 2hr	Adult female:IgG
GD135-137	GD136: 4hr	-

Gestation Day[b]	Time Points Relative to Dosing	Samples Collected
GD136-138	GD136: 24hr	Adult female: IgG
GD138-140	GD 136: 72hr	Adult female: IgG
GD139-141	GD136: 96hr	Adult female: IgG
GD140 ± 2 (2nd C-section cohort)	NA	Adult female: IgG
		Fetus: IgG total
Day of parturition (Maternal: PPD1) (Neonate: BD1)	NA	Adult female: IgG
		Neonate: IgG
[a] Time points were only collected from animals in the GD100 C-section cohorts. [b] Collection ranges listed based on potential dose days of GD44 to 46. All time points were based off of the dose day.		

Suppression of Endogenous Maternal IgG

[0162] N027 administration resulted in dose-independent reductions in serum IgG levels in adult females beginning 72 hours postdose, and the greatest reductions in serum IgG concentrations were observed for both the 100 and 300 mg/kg dosed animals at the GD51-53: predose time point (FIG. 19). The serum IgG values for Group 2 (100 mg/kg) trended toward predose levels in a dose-dependent manner, beginning at the GD65-67: predose time point and continuing until the next dose administrations on GD93-95 and GD135-137, after which, reductions of a similar magnitude were present within 72 hours of dosing. Group 3 animals (300 mg/kg) remained at a nadir IgG value at all pre-dose timepoints (as referred to in Table 10) throughout the dosing period. No change in IgG from baseline was observed in animals treated with vehicle (Group 1).

[0163] Dose-dependent increases in serum IgG concentrations were present 2 hours after dose administration on GD44-46, GD93-95, and GD135-137. These increases were likely the result of the detection of N027 by the total IgG assay and were not considered to be related to the pharmacology of N027. Dose-dependent reductions in fetal serum IgG levels were present relative to control values at the GD100 and GD140, and in neonates at the BD1 time point (FIG. 20).

Lack of N027 Transfer from Maternal to Fetal Circulation

[0164] The transfer of N027 from maternal circulation to fetal circulation was evaluated by measuring the level of N027 FcRn occupancy in fetal circulating monocytes. N027 receptor occupancy was assessed on monocytes, granulocytes, B-lymphocytes, and T-lymphocytes using a flow cytometric (FACS) assay to measure the binding of fluorescent-labeled N027 to free/unbound FcRn in the presence and absence of saturating concentrations of N027. The unsaturated samples demonstrated the percentages of free or unbound FcRn receptor present on each leukocyte subset at each predose and postdose time point. The saturated samples were spiked with concentrations of unlabeled N027 that were determined to completely saturate any FcRn receptors that remained free/unbound at each postdose time point. N027 receptor occupancy was not detected in the whole blood of fetuses on day GD100 and GD140, or in neonates on BD1, in the context of the unsaturated sample analysis as described above.

Example 19 - Evaluation of the transplacental transfer of N027

[0165] Human placenta obtained from uncomplicated term pregnancies were utilized in an ex-vivo dual perfusion single placental lobule method to evaluate the transplacental transfer of N027. Briefly, each placenta was examined

for tears, and two chorionic vessels (one artery and vein) supplying a single intact peripheral cotyledon were cannulated with 3F and 5F umbilical catheters, respectively. The cotyledon was trimmed and placed in the perfusion chamber with the maternal surface upward. The intervillous space on the maternal side was perfused by two catheters piercing the basal plate. The flow rate of the perfusate medium in the fetal and maternal circuits was 3.0 and 12 mL/min, respectively. The maternal perfusate was equilibrated with a gas mixture made of 95% O_2 and 5% CO_2, and the fetal perfusate with a mixture of 95% N_2 and 5% CO_2. All experiments were carried out at a temperature of 37°C.

[0166] Each placental lobule was perfused for an initial control period of one hour to allow the tissue to stabilize to its new environment using an open-open configuration of the perfusion system. Perfusion was terminated if one of the following occurred during the control period: a volume loss in the fetal circuit in an excess of 3 mL/h, or a pOz difference between the fetal vein and the artery less than 60 mmHg, indicating inadequate perfusion overlap between the two circuits. The control period was followed by an experimental period of four hours using a closed-closed configuration (i.e., re-circulation of the medium) of the perfusion system. The latter was initiated by replacing the medium of the maternal and fetal reservoirs and the addition of 3 mg/ml of BSA.

[0167] The transfer of N027 across the human placental lobule was tested for three different concentrations: 0.3 mg/ml, 3 mg/ml, and 30 mg/ml. Fourteen individual placentae were perfused for four hours with N027 being added to the maternal perfusate at 0.3 mg/ml, 3 mg/ml, and 30 mg/ml. Samples from the maternal artery and fetal vein, in 0.5 mL aliquots, were taken at 0, 15, 30, 60, 90, 120, 150, 180, 210 and 240 minutes during the experimental period. Antipyrine was employed as a positive control to validate the integrity of the circuits (FIGS. 17-18). Concentrations of N027 in maternal and fetal samples were determined using a sensitive meso scale discovery (MSD) immunoassay with a lower limit of quantification of 5 ng/ml. This assay involved a sandwich format using an anti-idiotypic antibody pair; wherein the MSD plate was coated with an anti-idiotypic Ab followed by incubation with sample and revealed with the second biotinylated anti-idiotypic Ab followed by detection with MSD tagged streptavidin and addition of read buffer. The concentration of antipyrine was determined using a HPLC assay with UV detection at 260 nm after a liquid-liquid extraction. The mean fetal transfer rate for antipyrine across fourteen experiments was 41±2.8 %. The mean fetal transfer rate for N027 across fourteen experiments was 0.0027±0.0021 % indicating very low levels of transfer. The results suggest that N027 could be used in methods of treating pregnant patients without causing fetal exposure.

REFERENCES CITED IN THE DESCRIPTION

Cited references

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US2016194397A [0001]

Non-patent literature cited in the description

- **KABAT**Sequences of Proteins of Immunological InterestPublic Health Service, National Institutes of Health19910000 [0050] [0093]
- **JUNGHANS et al.**Proc Natl Acad Sci USA, 1996, vol. 93, 5512- [0102]
- Recombinant Gene Expression: Reviews and ProtocolsMethods in Molecular BiologyHumana Press20040720 [0108]
- Therapeutic Proteins: Methods and ProtocolsMethods in Molecular BiologyHumana Press20120628 [0108]
- Process Scale Purification of AntibodiesJohn Wiley & Sons, Inc.20090000 [0110]
- Therapeutic Peptides and Proteins: Formulation, Processing and Delivery SystemsTaylor & Francis Group, CRC Press20060000 [0113]

PATENTKRAV

1. Antistof til anvendelse i en fremgangsmåde til behandling af en føtal og neonatal alloimmun og/eller autoimmun lidelse, fremgangsmåden omfatter administration af antistoffet til et gravid individ, hvor antistoffet omfatter: et polypeptid med aminosyresekvensen SEQ ID NO: 19 og et polypeptid med aminosyresekvensen SEQ ID NO: 24.

2. Antistof til anvendelse ifølge krav 1, hvor individet har en historie med at have haft en tidligere føtal og neonatal alloimmun og/eller autoimmun lidelse.

3. Antistof til anvendelse ifølge krav 1 eller krav 2, hvor individet er i risiko for at have en føtal og neonatal alloimmun og/eller autoimmun lidelse.

4. Antistof til anvendelse ifølge et hvilket som helst af de foregående krav, hvor den føtale og neonatale alloimmune og/eller autoimmune lidelse er udvalgt blandt gruppen bestående af føtal og neonatal alloimmun trombocytopeni, hæmolytisk sygdom hos fosteret og nyfødt, alloimmun pan-thrombocytopeni, kongenit hjerteblok, fetal arthrogryposi, neonatal myasthenia gravis, neonatal autoimmune hæmolytisk anæmi, neonatal anti-phospholipid syndrom, neonatal polymyositis, dermatomyositis, neonatal lupus, neonatal scleroderma, Behcet's sygdom, neonatal Graves' sygdom, neonatal Kawasaki sygdom, neonatal autoimmune skjoldbruskkirtelsygdom og neonatal type I diabetes mellitus.

5. Antistof til anvendelse ifølge krav 4, hvor den føtale og neonatale alloimmune og/eller autoimmune lidelse er hæmolytisk sygdom hos fosteret og den nyfødte.

6. Antistof til anvendelse ifølge krav 4, hvor den føtale og neonatale alloimmune og/eller autoimmune lidelse er føtal og neonatal alloimmun trombocytopeni.

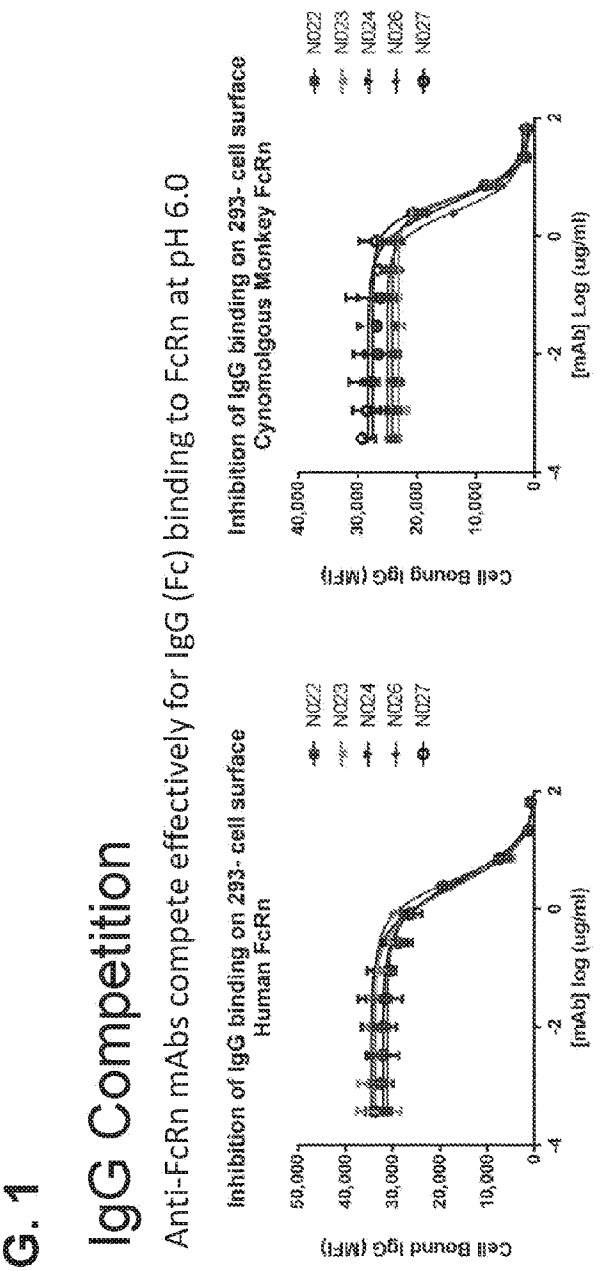
7. Antistof til anvendelse ifølge krav 4, hvor den føtale og neonatale alloimmune og/eller autoimmune lidelse er kongenit hjerteblok.

8. Antistof til anvendelse ifølge et hvilket som helst af de foregående krav, hvor behandling reducerer risikoen for abort.

9. Antistof til anvendelse i en fremgangsmåde til behandling af føtal anæmi forbundet med hæmolytisk sygdom hos fosteret og nyfødte, fremgangsmåden omfatter administration af antistoffet til et gravidt individ, hvor antistoffet omfatter: et polypeptid med aminosyresekvensen SEQ. ID NO: 19 og et polypeptid med aminosyresekvensen SEQ ID NO: 24.

DRAWINGS

FIG. 1



EC50 (nM)	N022	N023	N024	N026	N027
Human FcRn	2.93	2.48	2.48	3.24	3.25
Cynomolgus FcRn	4.80	5.16	3.51	2.68	4.46

FIG. 2 Human IgG Catabolism

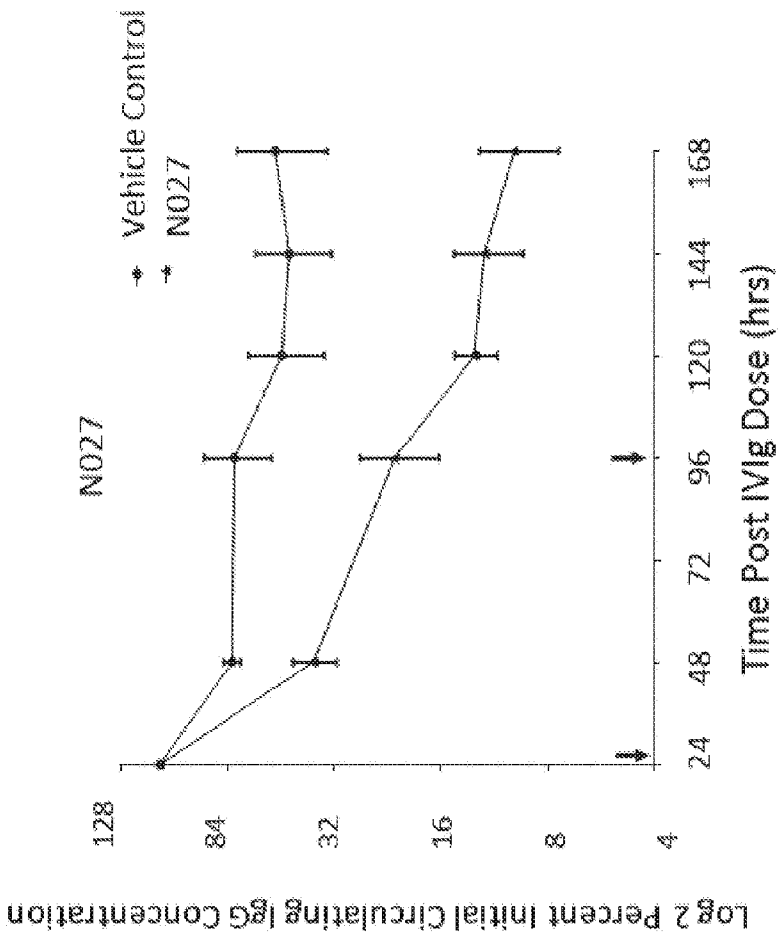


FIG. 2 cont. Human IgG Catabolism

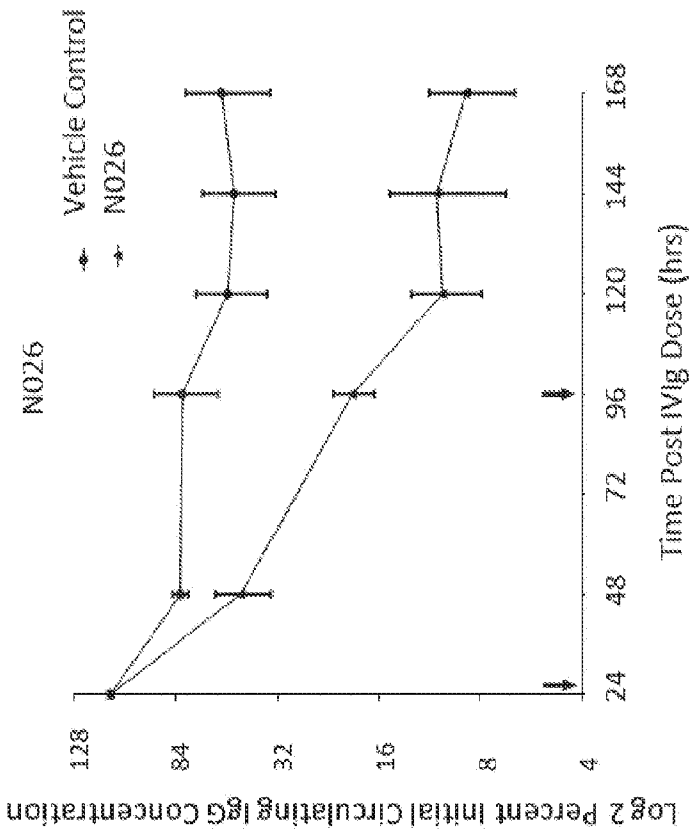


FIG. 2 cont. Human IgG Catabolism

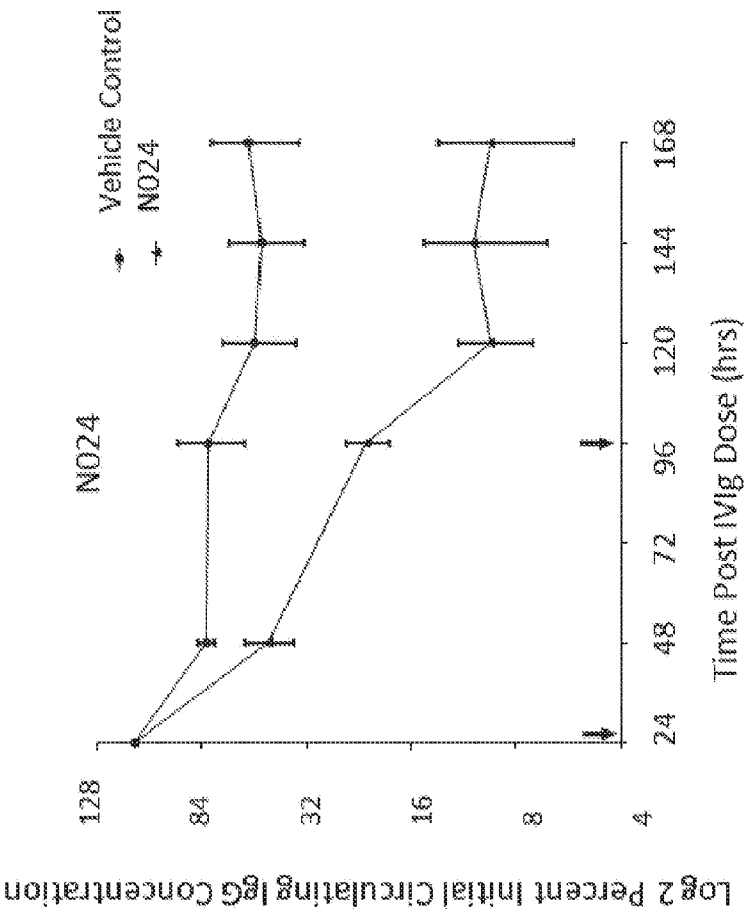


FIG. 2 cont. Human IgG Catabolism

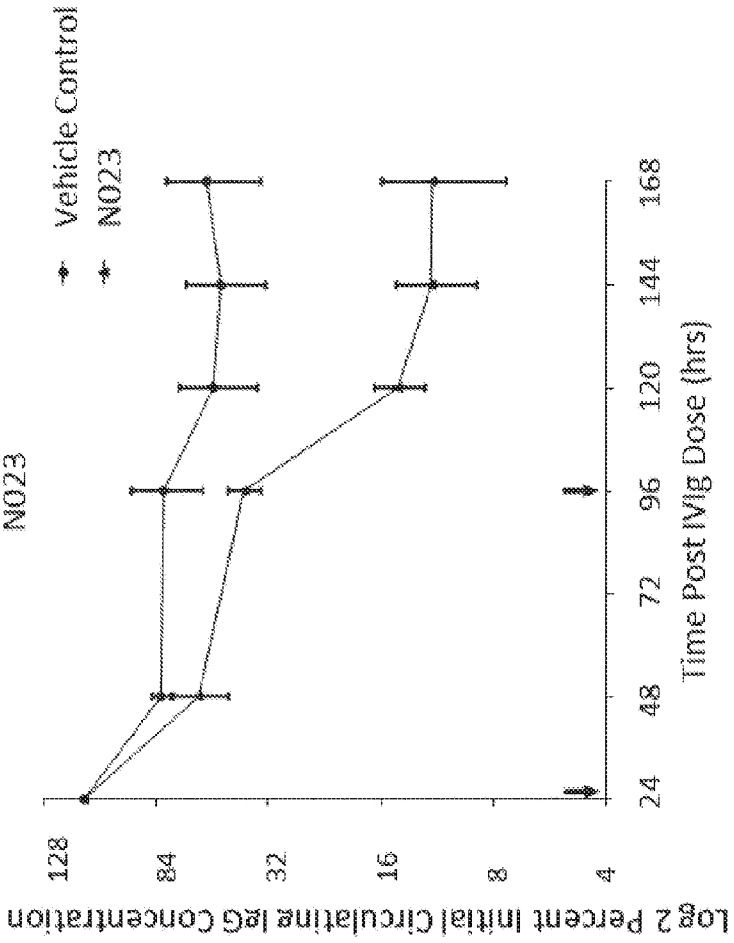
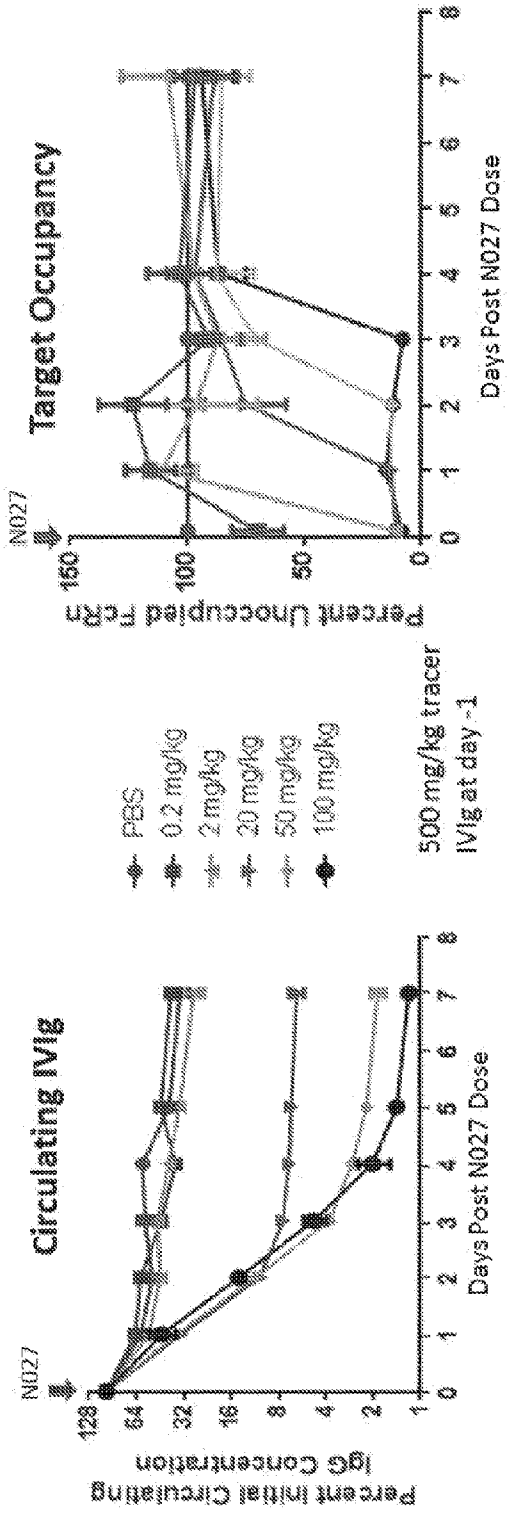


FIG. 3


Target Occupancy
Percent Unoccupied FcRn
150
100
50
0
N027
0 1 2 3 4 5 6 7 8
Days Post N027 Dose
PBS
0.2 mg/kg
2 mg/kg
20 mg/kg
50 mg/kg
100 mg/kg
500 mg/kg tracer
IVIg at day -1
Circulating IVIg
Percent Initial Circulating
IgG Concentration
128
64
32
16
8
4
2
1
N027
0 1 2 3 4 5 6 7 8
Days Post N027 Dose

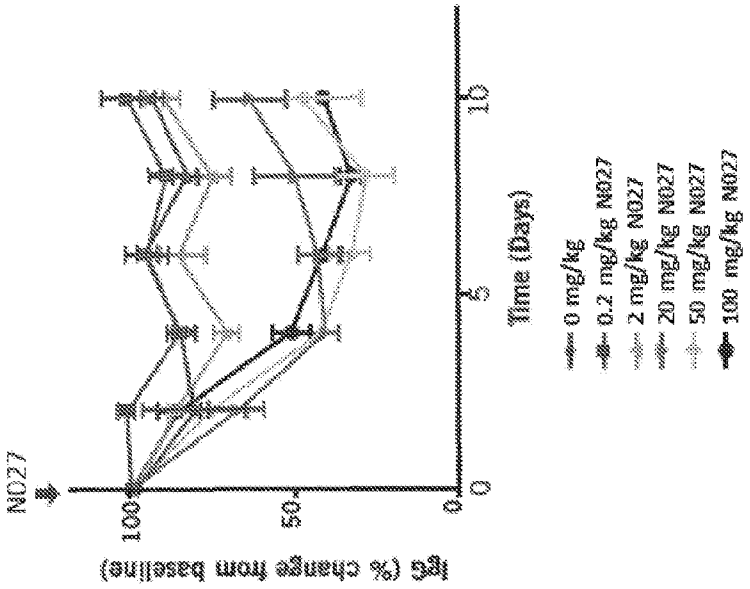

Circulating IgG
IgG (% change from baseline)
100
50
0
N027
0
5
10
Time (Days)
0 mg/kg
0.2 mg/kg N027
2 mg/kg N027
20 mg/kg N027
50 mg/kg N027
100 mg/kg N027

FIG. 4A

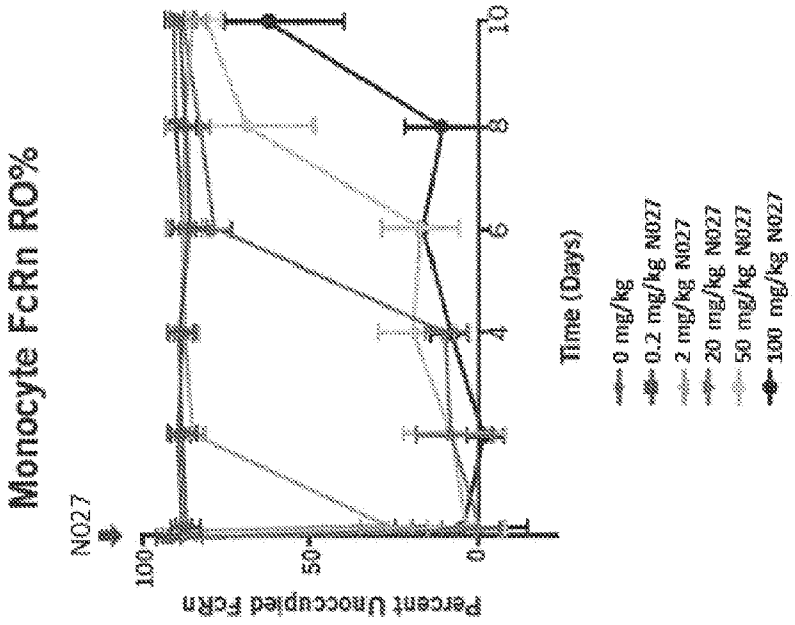

Monocyte FcRn RO%
N027
100
50
0
Percent Unoccupied FcRn
0
4
6
8
10
Time (Days)
0 mg/kg
0.2 mg/kg N027
2 mg/kg N027
20 mg/kg N027
50 mg/kg N027
100 mg/kg N027

FIG. 4B

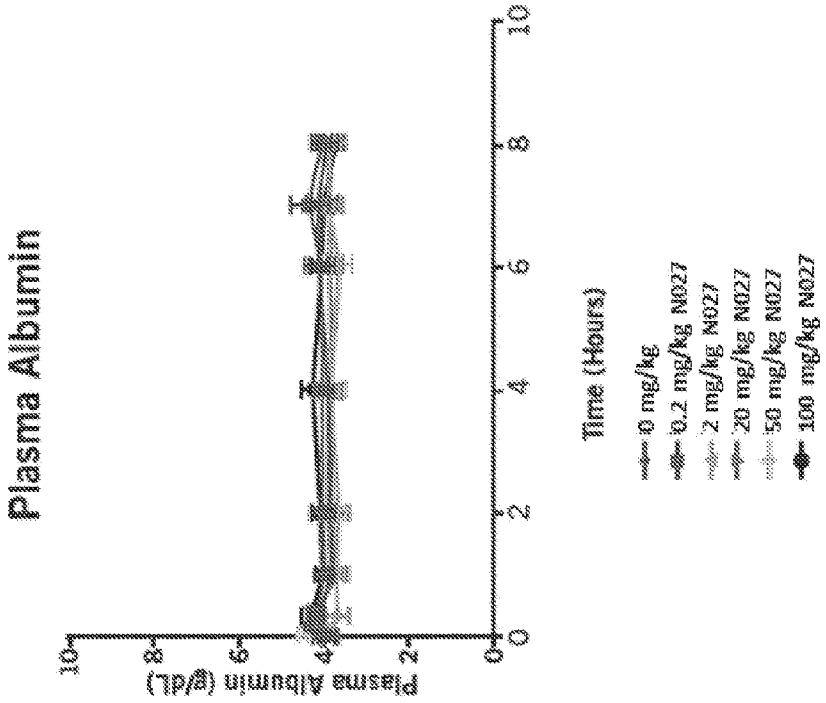

Plasma Albumin
Plasma Albumin (g/dL)
10
8
6
4
2
0
0
2
4
6
8
10
Time (Hours)
0 mg/kg
0.2 mg/kg N027
2 mg/kg N027
20 mg/kg N027
50 mg/kg N027
100 mg/kg N027

FIG. 4C

FIG. 5

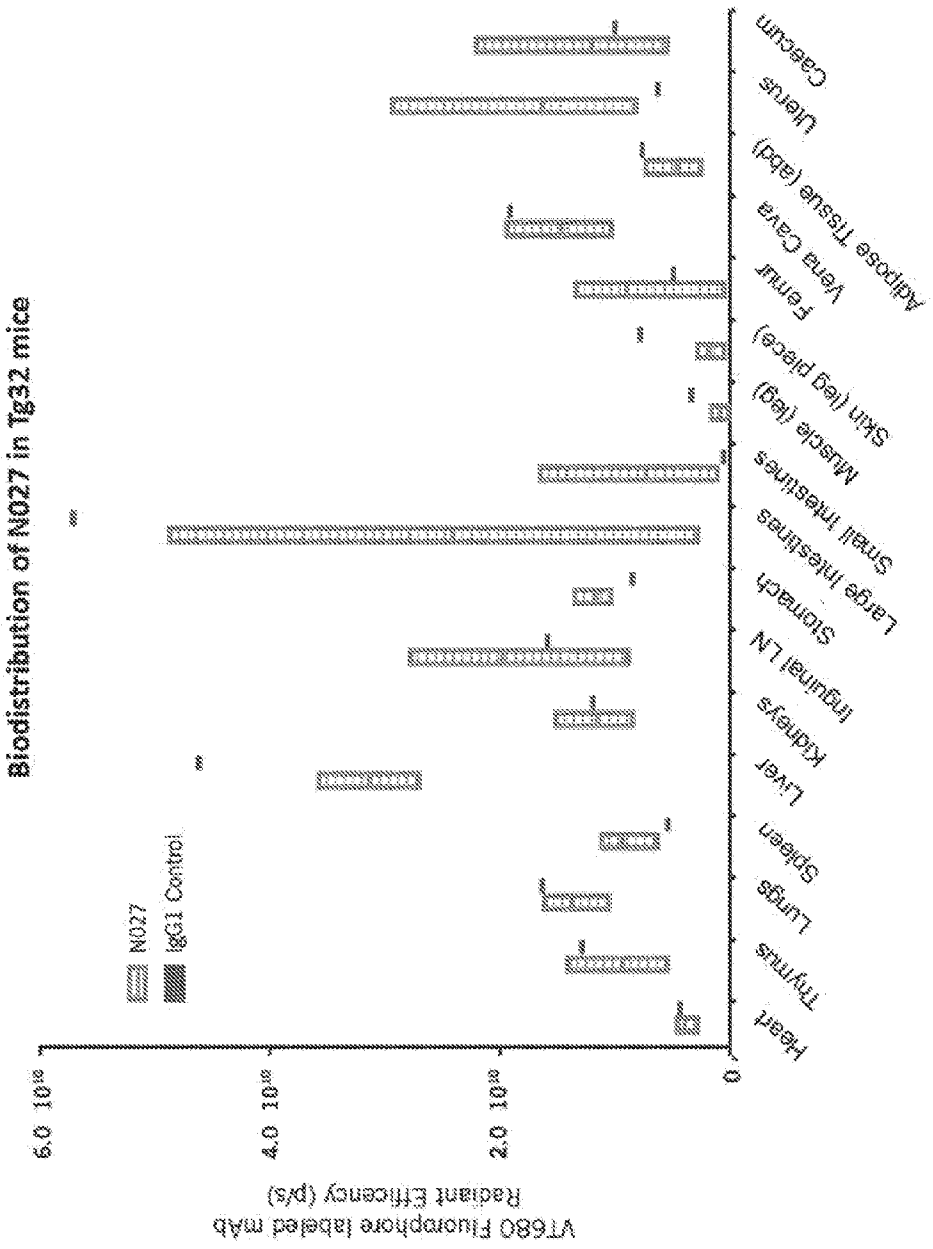

Biodistribution of N027 in Tg32 mice
VT680 Fluorophore labeled mAb
Radiant Efficency (p/s)
6.0 10⁸
4.0 10⁸
2.0 10⁸
0
N027
IgG1 Control
Heart
Thymus
Lungs
Spleen
Liver
Kidneys
Inguinal LN
Stomach
Large Intestines
Small Intestines
Muscle (leg)
Skin (leg piece)
Femur
Vena Cava
Adipose Tissue (abd)
Uterus
Caecum

FIG. 6

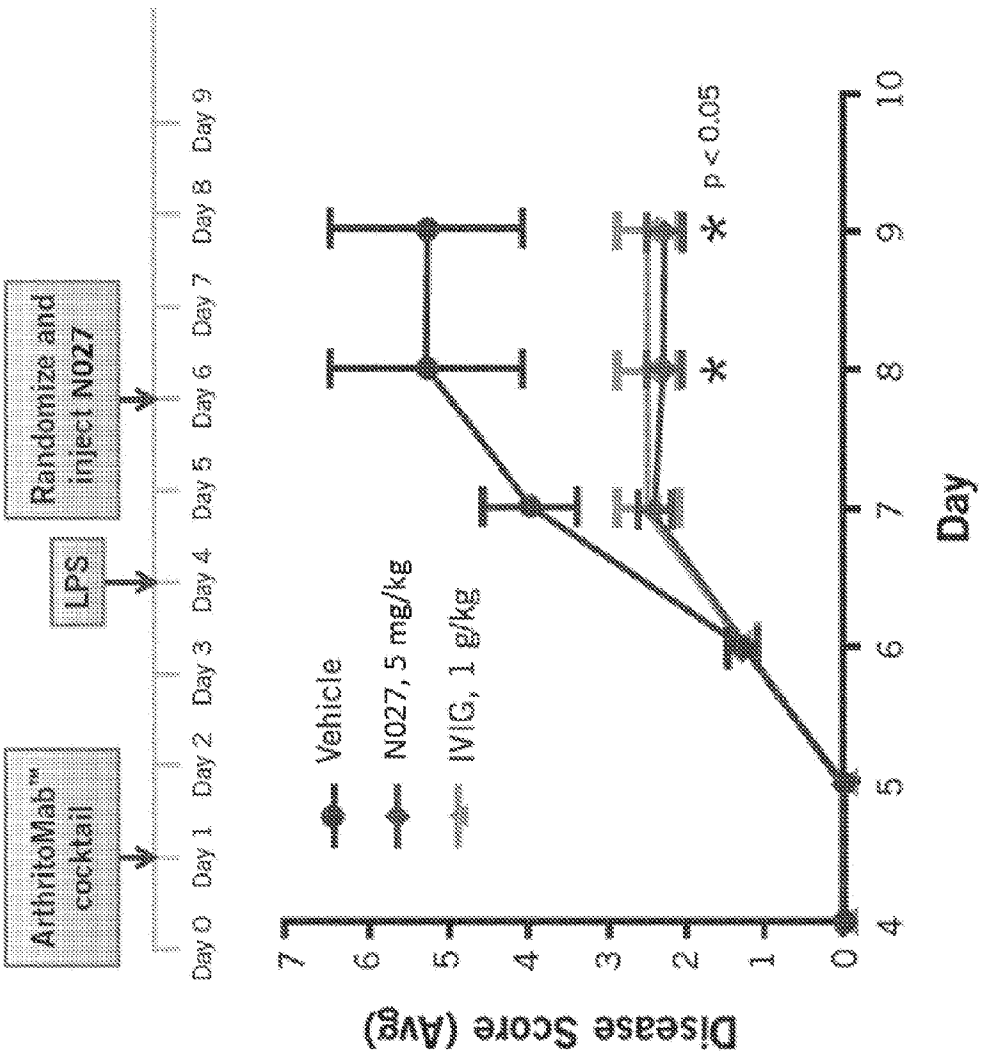
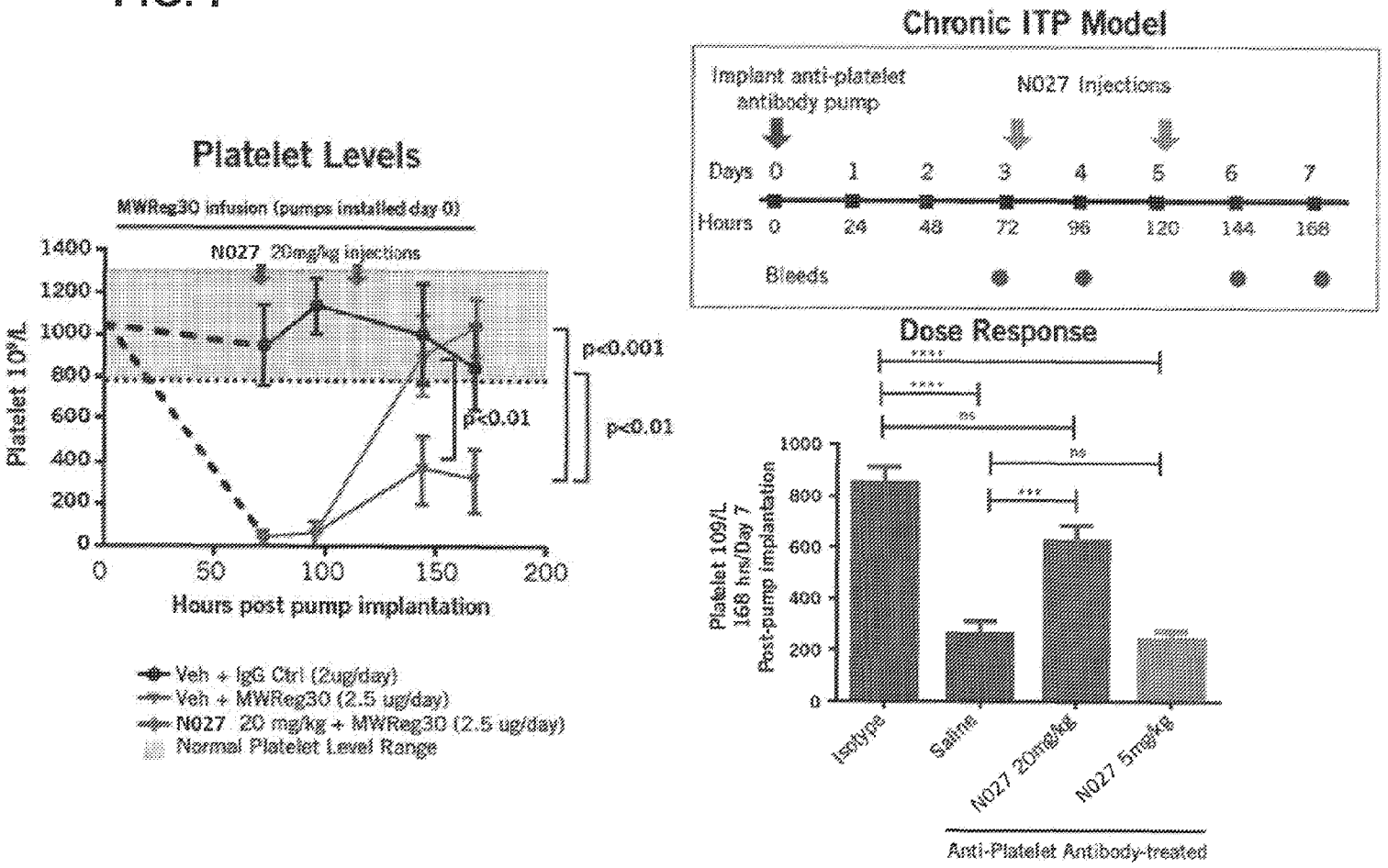

ArthritoMab™ cocktail
LPS
Randomize and inject N027
Day 0
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Day 8
Day 9
Vehicle
N027, 5 mg/kg
IVIG, 1 g/kg
p < 0.05
*
*
Disease Score (Avg)
Day
0
1
2
3
4
5
6
7
4
5
6
7
8
9
10

FIG. 7



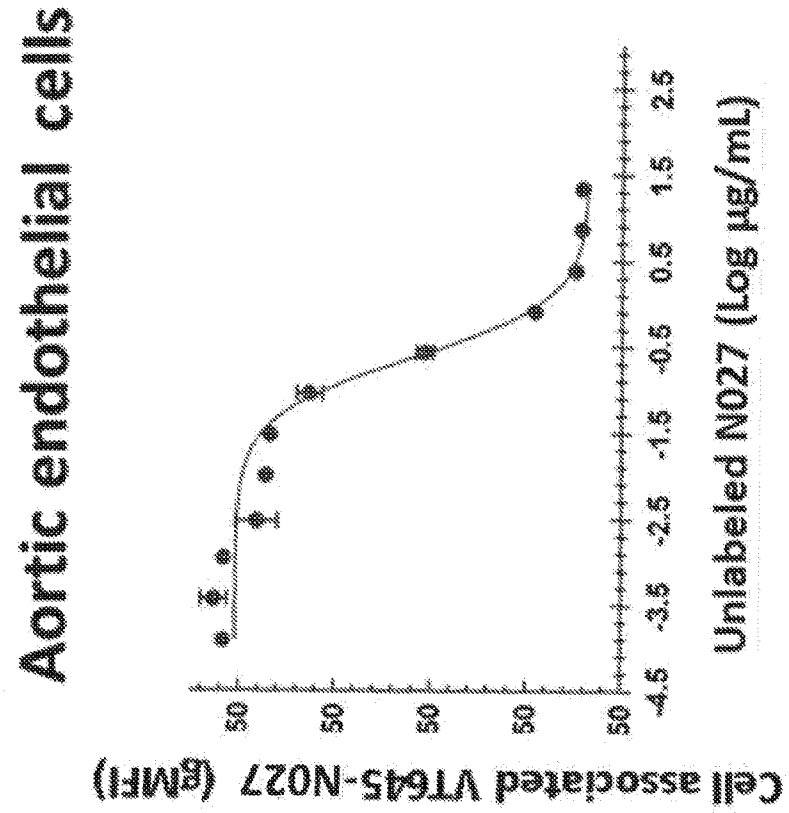

Aortic endothelial cells
Cell associated VT645-N027 (gMFI)
50
50
50
50
50
-4.5
-3.5
-2.5
-1.5
-0.5
0.5
1.5
2.5
Unlabeled N027 (Log µg/mL)

FIG. 8A

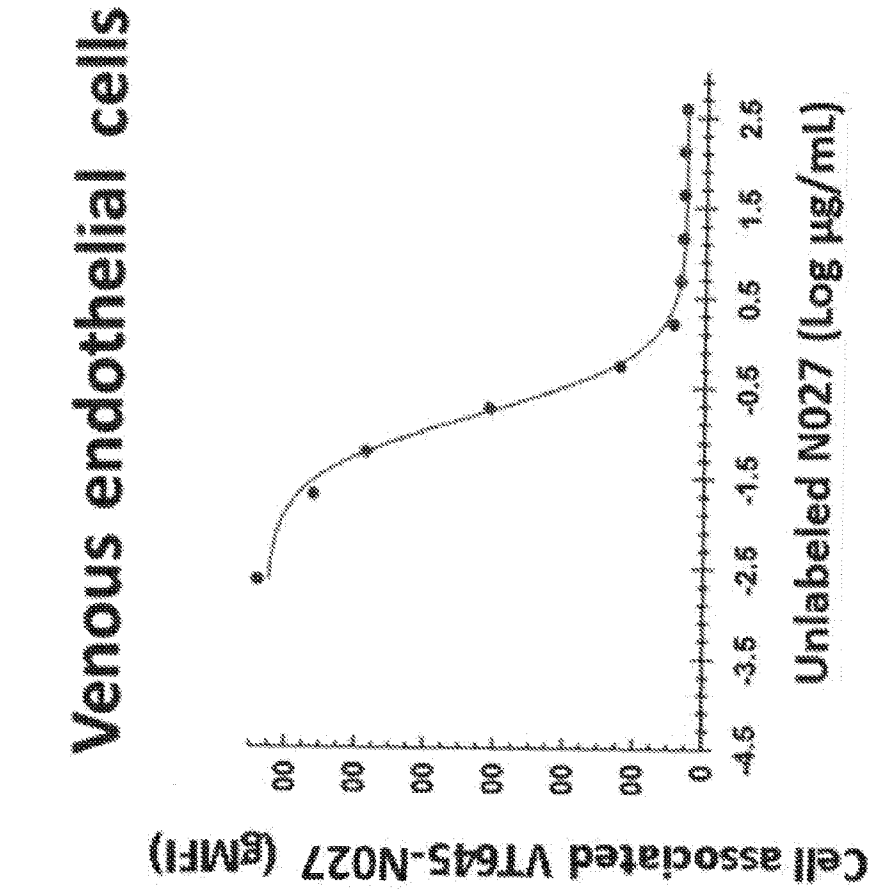

Venous endothelial cells
Cell associated VT64S-N027 (gMFI)
80
60
40
20
0
-4.5
-3.5
-2.5
-1.5
-0.5
0.5
1.5
2.5
Unlabeled N027 (Log µg/mL)

FIG. 8B

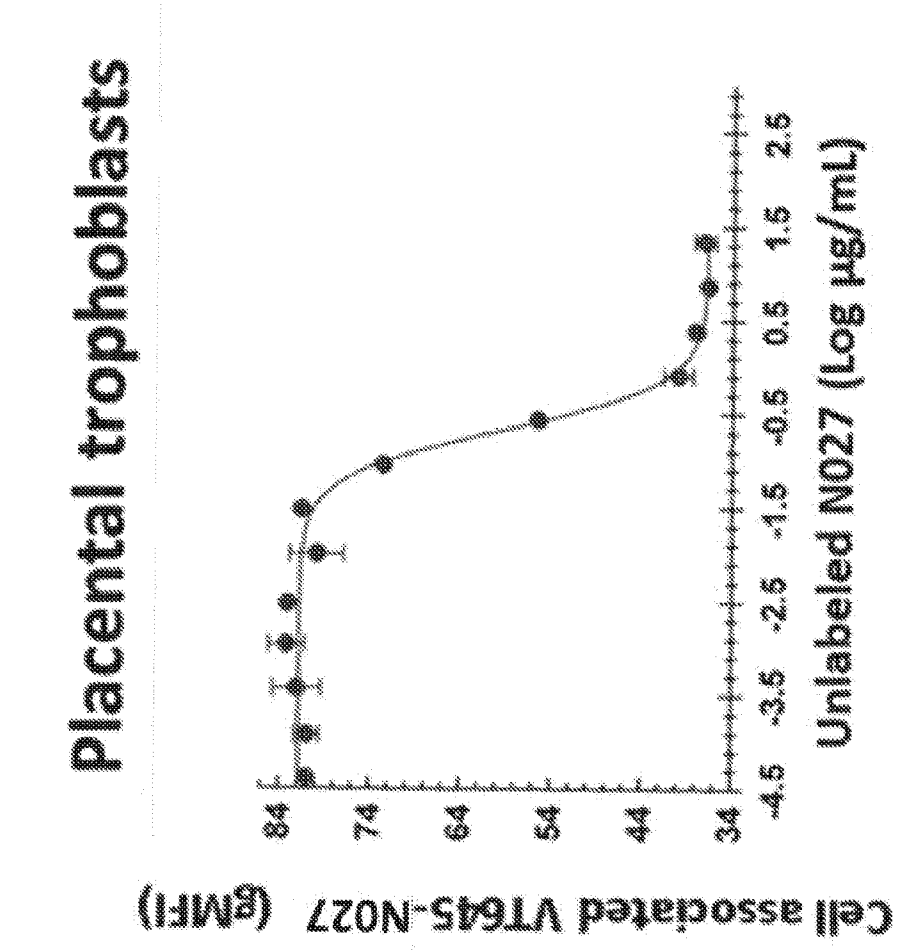

Placental trophoblasts
Cell associated VT64S-N027 (gMFI)
84
74
64
54
44
34
-4.5
-3.5
-2.5
-1.5
-0.5
0.5
1.5
2.5
Unlabeled N027 (Log µg/mL)

FIG. 8C

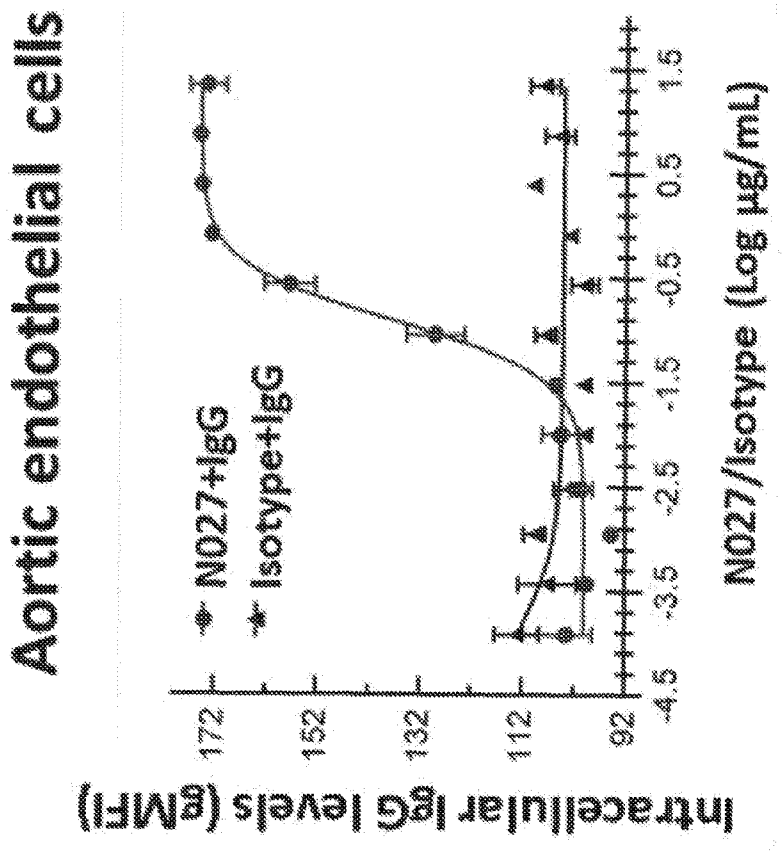

Aortic endothelial cells
N027+IgG
Isotype+IgG
Intracellular IgG levels (gMFI)
172
152
132
112
92
-4.5
-3.5
-2.5
-1.5
-0.5
0.5
1.5
N027/Isotype (Log µg/mL)

FIG. 9A

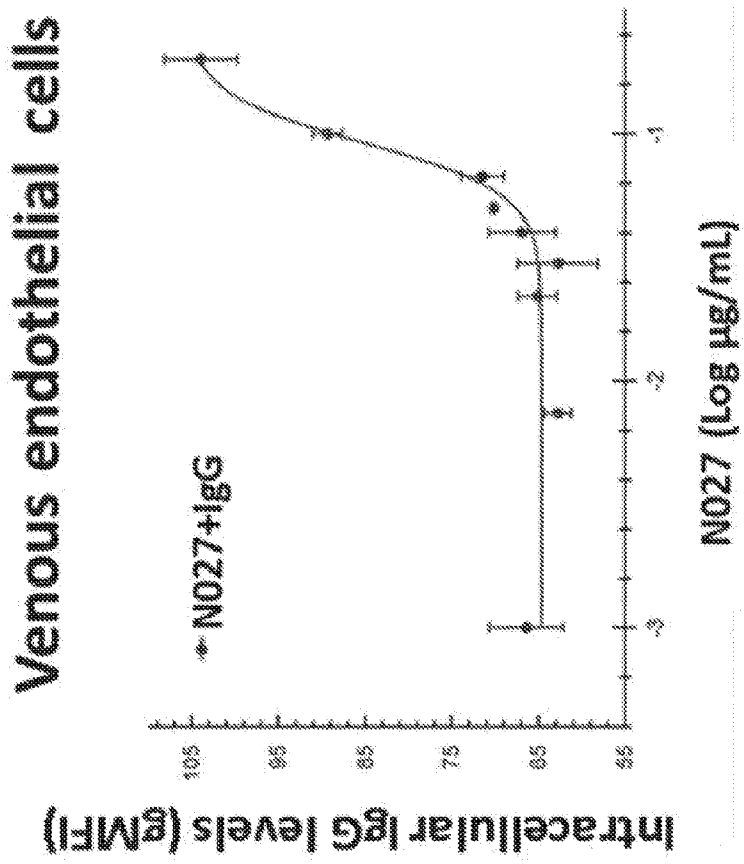

Venous endothelial cells
+ N027+IgG
Intracellular IgG levels (gMFI)
105
95
85
75
65
55
1
-1
-2
-3
N027 (Log µg/mL)

FIG. 9B

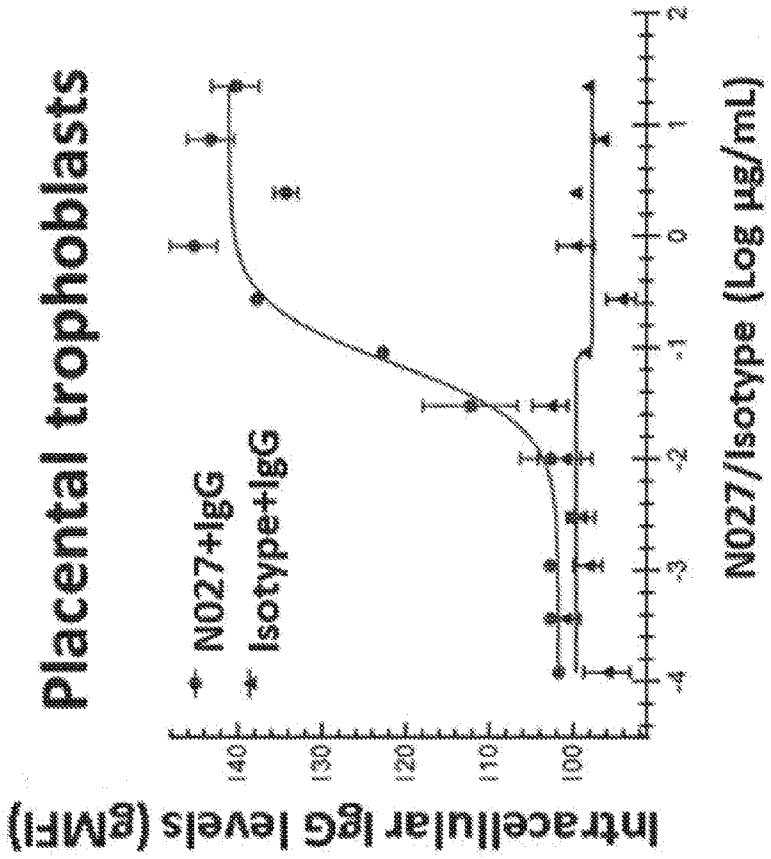

Placental trophoblasts
N027+IgG
Isotype+IgG
Intracellular IgG levels (gMFI)
140
130
120
110
100
2
1
0
-1
-2
-3
-4
N027/Isotype (Log µg/mL)

FIG. 9C

FIG. 10

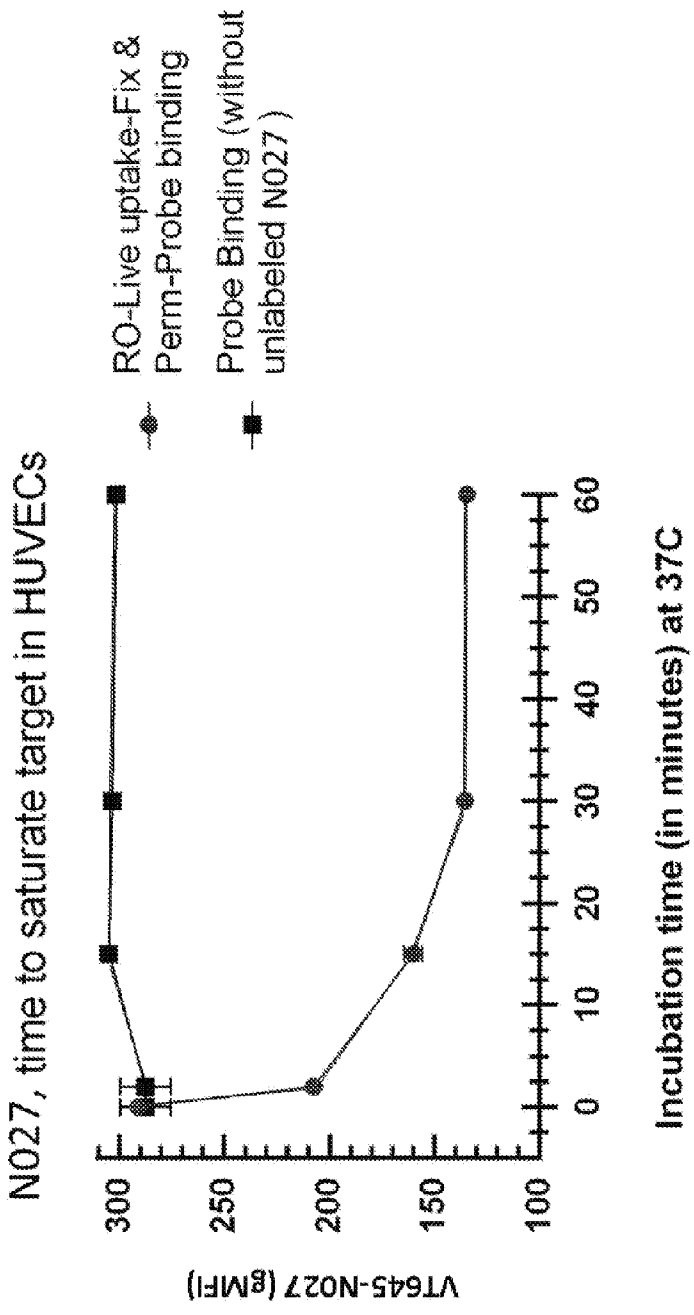

N027, time to saturate target in HUVECs
RO-Live uptake-Fix & Perm-Probe binding
Probe Binding (without unlabeled N027)
VT645-N027 (gMFI)
300
250
200
150
100
0
10
20
30
40
50
60
Incubation time (in minutes) at 37C

FIG. 11A

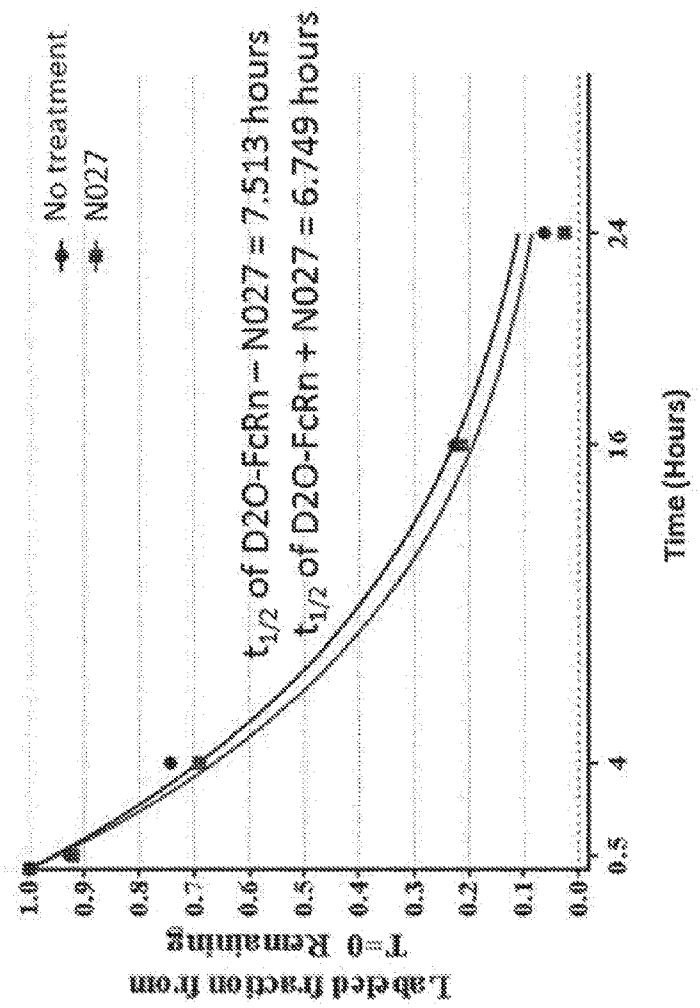
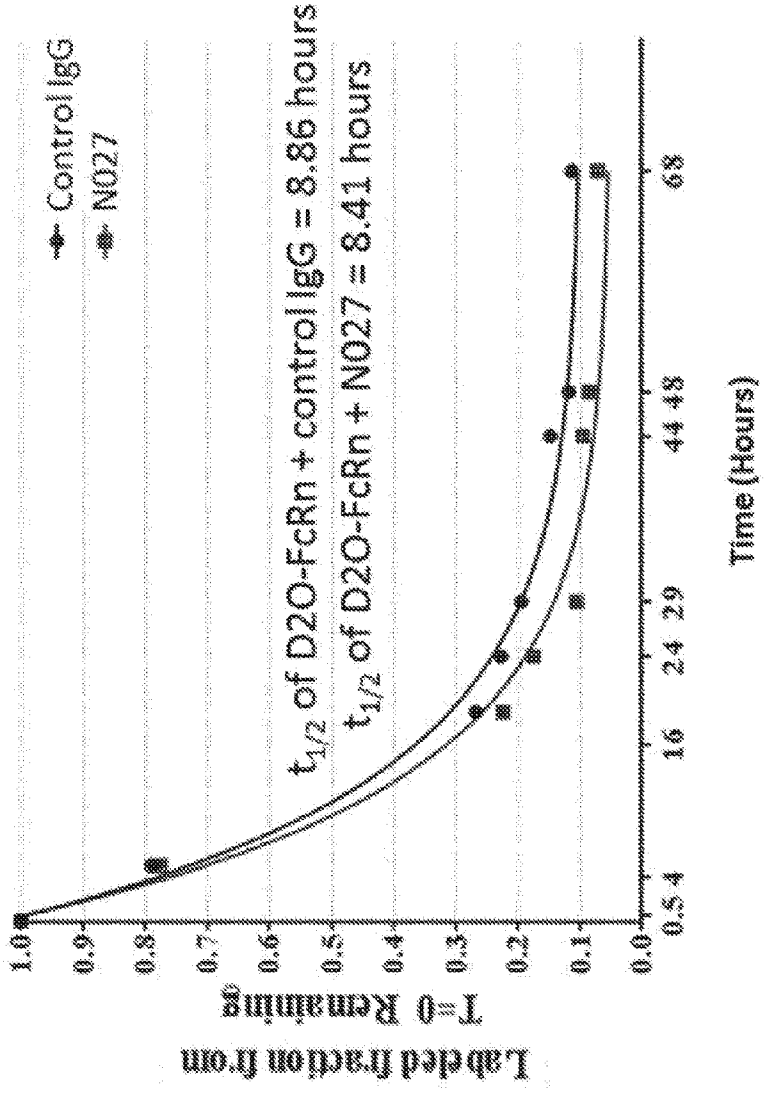
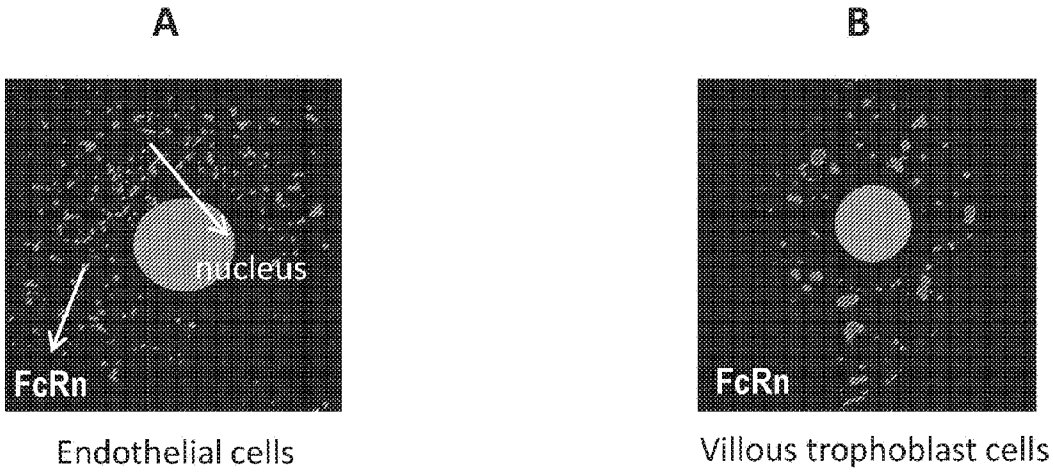

Endothelial cells
No treatment
N027
$t_{1/2}$ of D2O-FcRn – N027 = 7.513 hours
$t_{1/2}$ of D2O-FcRn + N027 = 6.749 hours
Labeled fraction from T=0 Remaining
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.5
4
16
24
Time (Hours)

FIG. 11B


Villous trophoblast cells
Control IgG
N027
$t_{1/2}$ of D2O-FcRn + control IgG = 8.86 hours
$t_{1/2}$ of D2O-FcRn + N027 = 8.41 hours
Labeled fraction from T=0 Remaining
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.5 4
16
24 29
44 48
68
Time (Hours)

FIGS. 12A-12B


A
B
nucleus
FcRn
FcRn
Endothelial cells
Villous trophoblast cells

FIGS. 13A-13B

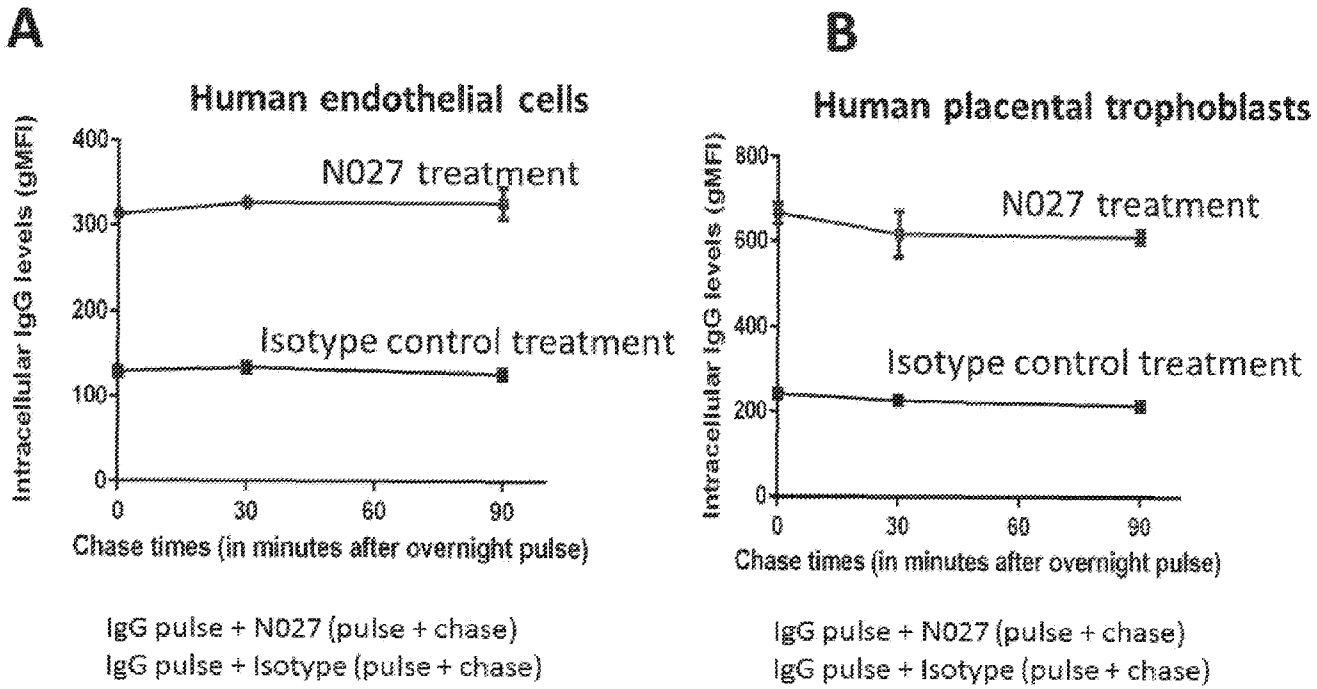

A
Human endothelial cells
Intracellular IgG levels (gMFI)
400
300
200
100
0
N027 treatment
Isotype control treatment
0
30
60
90
Chase times (in minutes after overnight pulse)
IgG pulse + N027 (pulse + chase)
IgG pulse + Isotype (pulse + chase)
B
Human placental trophoblasts
Intracellular IgG levels (gMFI)
800
600
400
200
0
N027 treatment
Isotype control treatment
0
30
60
90
Chase times (in minutes after overnight pulse)
IgG pulse + N027 (pulse + chase)
IgG pulse + Isotype (pulse + chase)

FIG. 13C

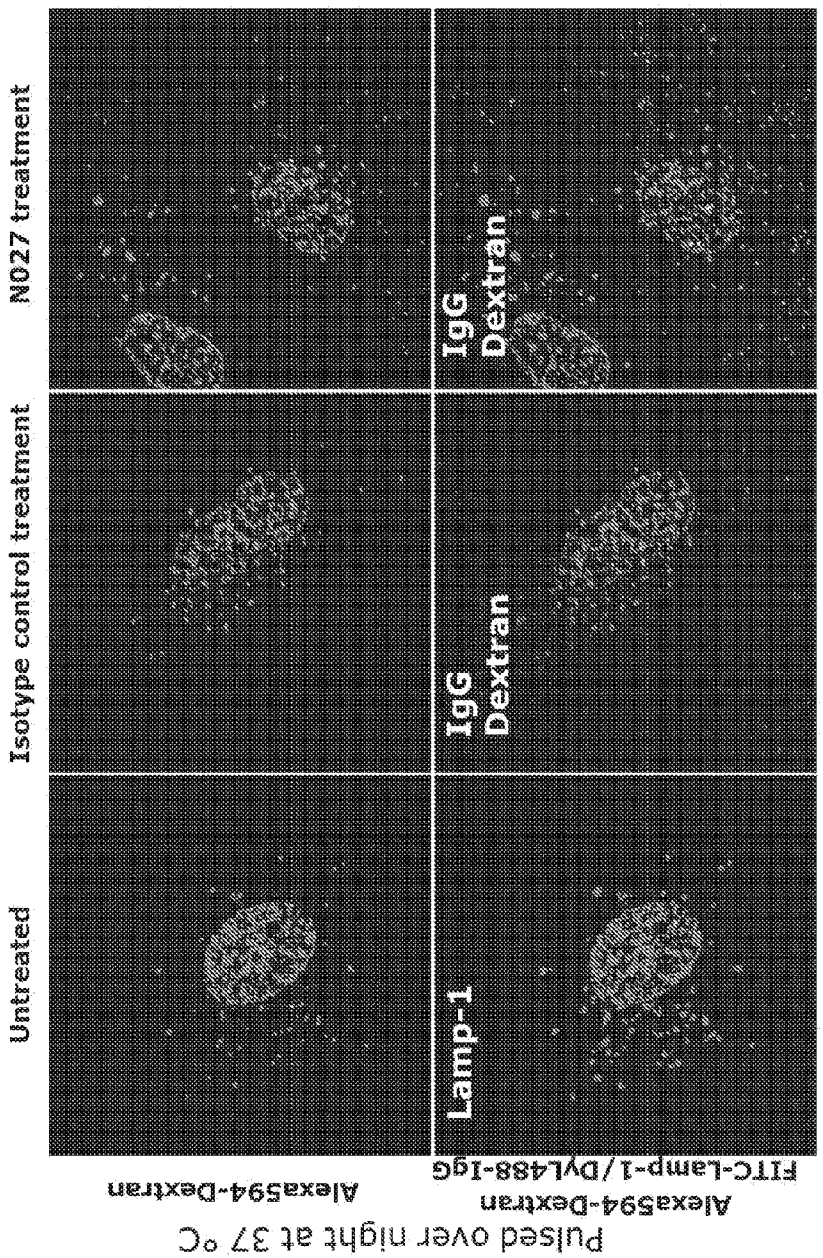

Untreated
Isotype control treatment
N027 treatment
Lamp-1
IgG
Dextran
IgG
Dextran
Alexa594-Dextran
FITC-Lamp-1/DyL488-IgG
Alexa594-Dextran
Pulsed over night at 37 °C

FIG. 13D

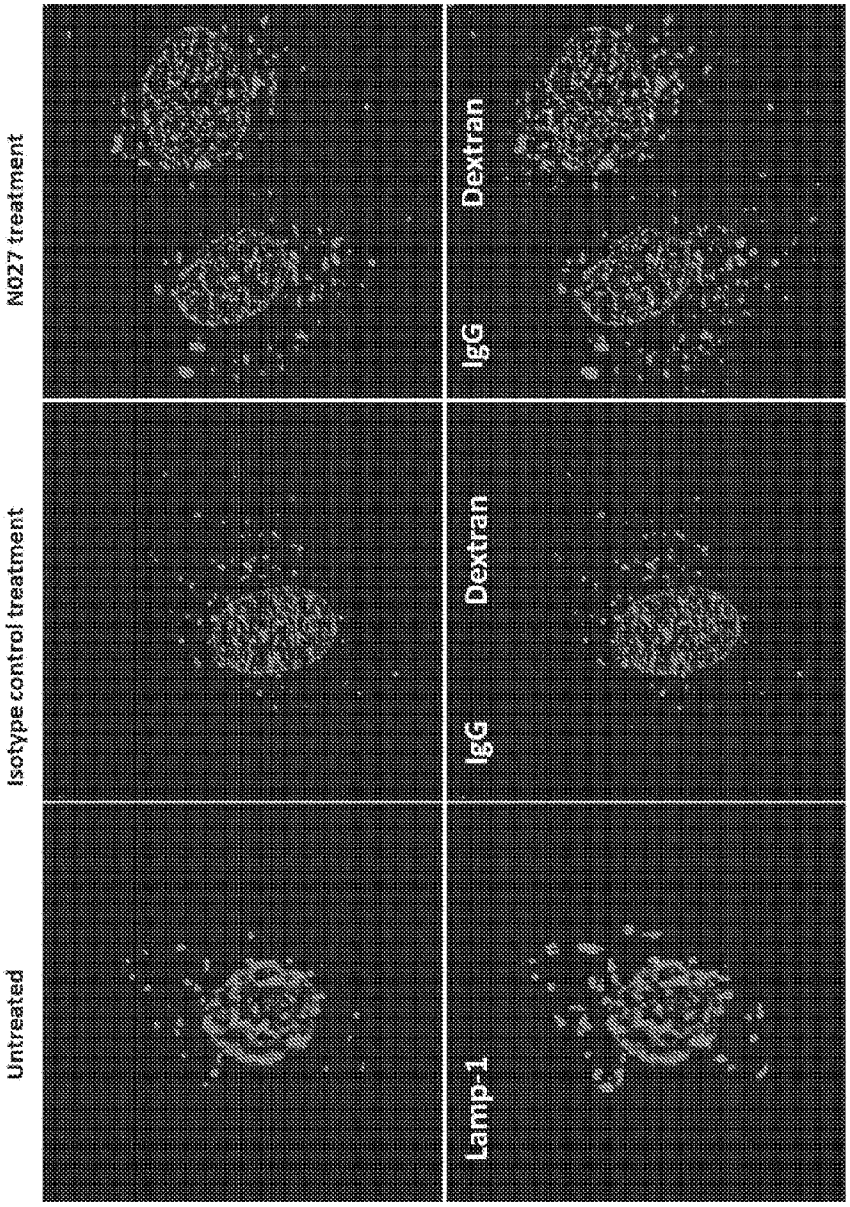

Untreated
Isotype control treatment
N027 treatment
Lamp-1
IgG
Dextran
IgG
Dextran
Alexa594-Dextran
FITC-Lamp-1/DyL488-IgG
Alexa594-Dextran
Chased at 37 °C for 30 min

FIG. 14

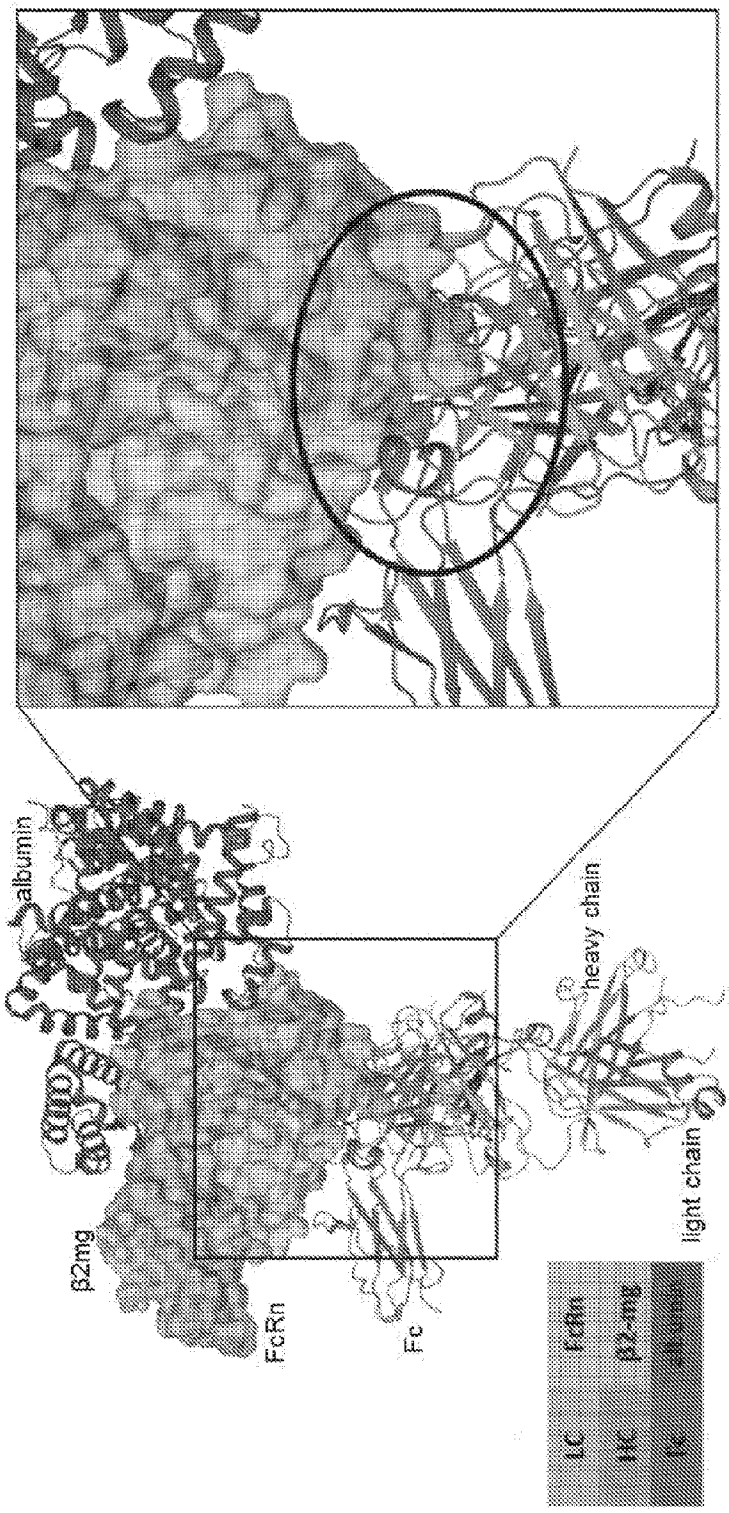

albumin
β2mg
FcRn
Fc
heavy chain
light chain
LC
HC
fc/fm
β2-mg
albumin

FIG. 15

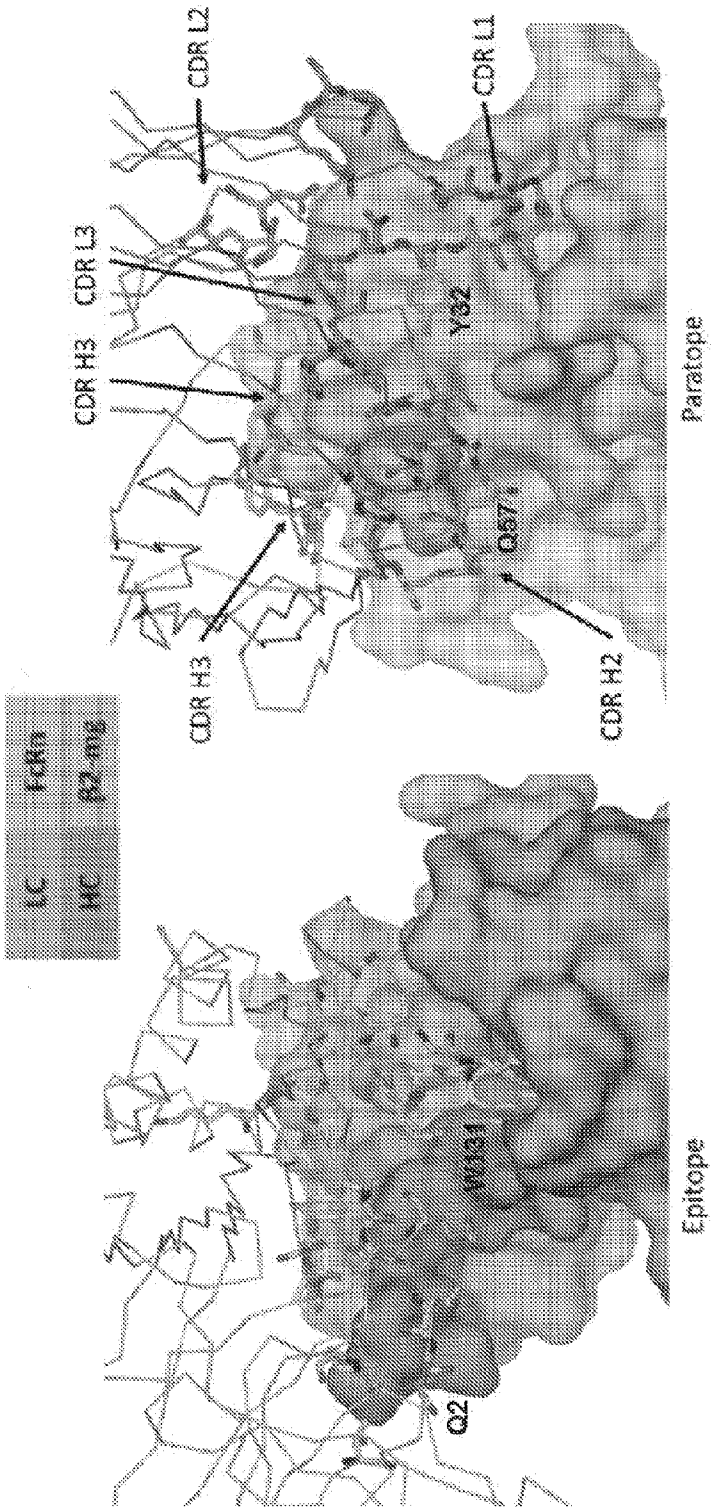

LC
HC
FcRn
β2-m
CDR L2
CDR L1
CDR L3
CDR H3
Y32
Q57
CDR H3
CDR H2
Paratope
Epitope
W131
Q2

FIG. 16

>FcRn-6xHis chain A (SEQ ID NO: 30)

AESHLSLLYHLTAVSSPAPGTPAFWVSGWLGPQQYLSYNSLRGEAEPCGAWVWENQVSWY
WEKETTDLRIKEKLFLEAF[redacted]TLQGLLGCELGPDNTSVPTAKFA[redacted]EFMNF
DLKQGTWG[redacted]A[redacted]ISRWQQQDKAANKELTFLLFSCPHRLREHLERGRGNLEWKEPP
SMRLKARpsspGFSVLTCSAFSFYPPELQLRFLRNGLAAGTGQGDFGPNSDGSFHASSSL
TVKSGDEHHYCCIVQHAGLAQPLRVELESPAKSSHHHHHH

>β2-microglobulin chain B (SEQ ID NO: 31)

[redacted]RTPKIQVYSRHPAENGKSNFLNCYVSGFH[redacted]SDIEVDLLKngeRIEKVEHSDLSFSKDW
SFYLLYYTEFTPTEKDeYaCrVNH[redacted]TLSqpKiVkWDRDM

>N027 Fab_HC chain H (SEQ ID NO: 32)

EVQLLESGGGLVQPGGSLRLSCAASGFTFS[redacted]MGWVRQAPGKGLEWVS[redacted]G[redacted]T[redacted]Y
ADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCAR[redacted]GDSYWGQGTMVTVSSASTK
GPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYS
LSSVVTVPSSSLGTQTYICNVNHKPSNTKVDKKVEPKSCD

>N027 Fab_LC chain L (SEQ ID NO: 33)

QSALTQPASVSGSPGQSITISCTGTG[redacted]VSWYQQHPGKAPKLMIY[redacted]S[redacted]RPSGV
SNRFSGS[redacted]NTASLTISGLQAEDEADYYCSS[redacted]I[redacted]VFGTGTKVTVLGQPkAAPSVT
LFPPSSEELQANKATLVCLISDFYPgaVtVAWKADssPvkaGVETTTPSKQSNNKYAASS
YLSLTPEQWKSHKSYSCQVtHegstVEKTVAPTEcS

Crystal structure-determined epitope is highlighted - FcRn

Crystal structure-determined epitope is highlighted – β2-m

Crystal structure-determined paratope is highlighted - HC

Crystal structure-determined paratope is highlighted - LC

Key

- Amino acids involved in "dimer" interface are lower case and underlined
- Bold amino acids have not been modeled in the crystal structure due to weak or absent electron density

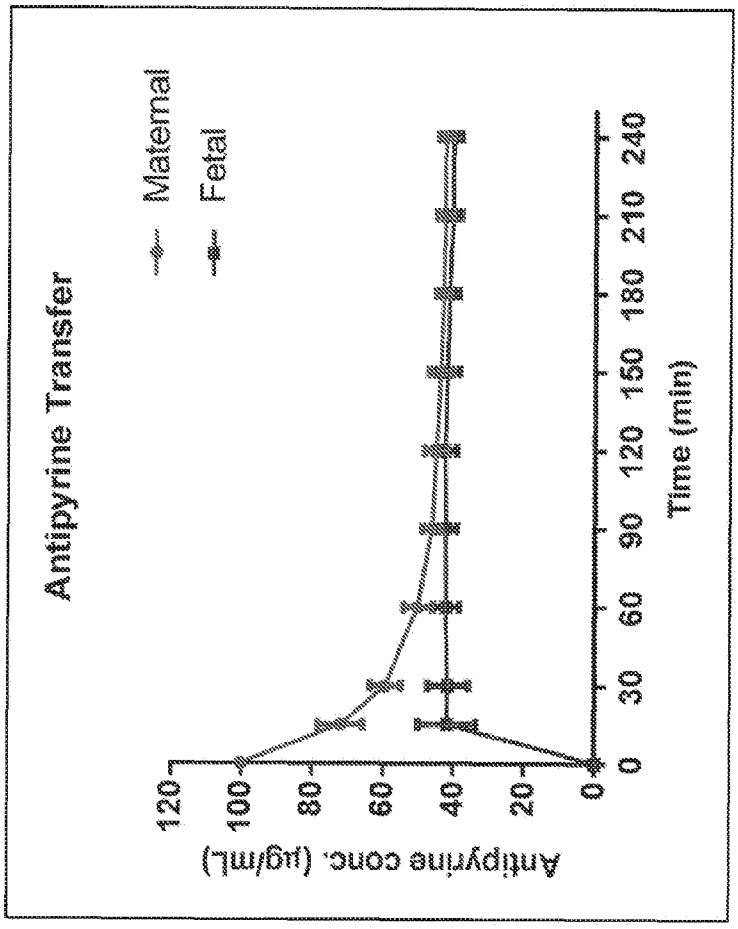

Antipyrine Transfer
Maternal
Fetal
Antipyrine conc. (μg/mL)
120
100
80
60
40
20
0
0
30
60
90
120
150
180
210
240
Time (min)

FIG. 17

FIG. 18

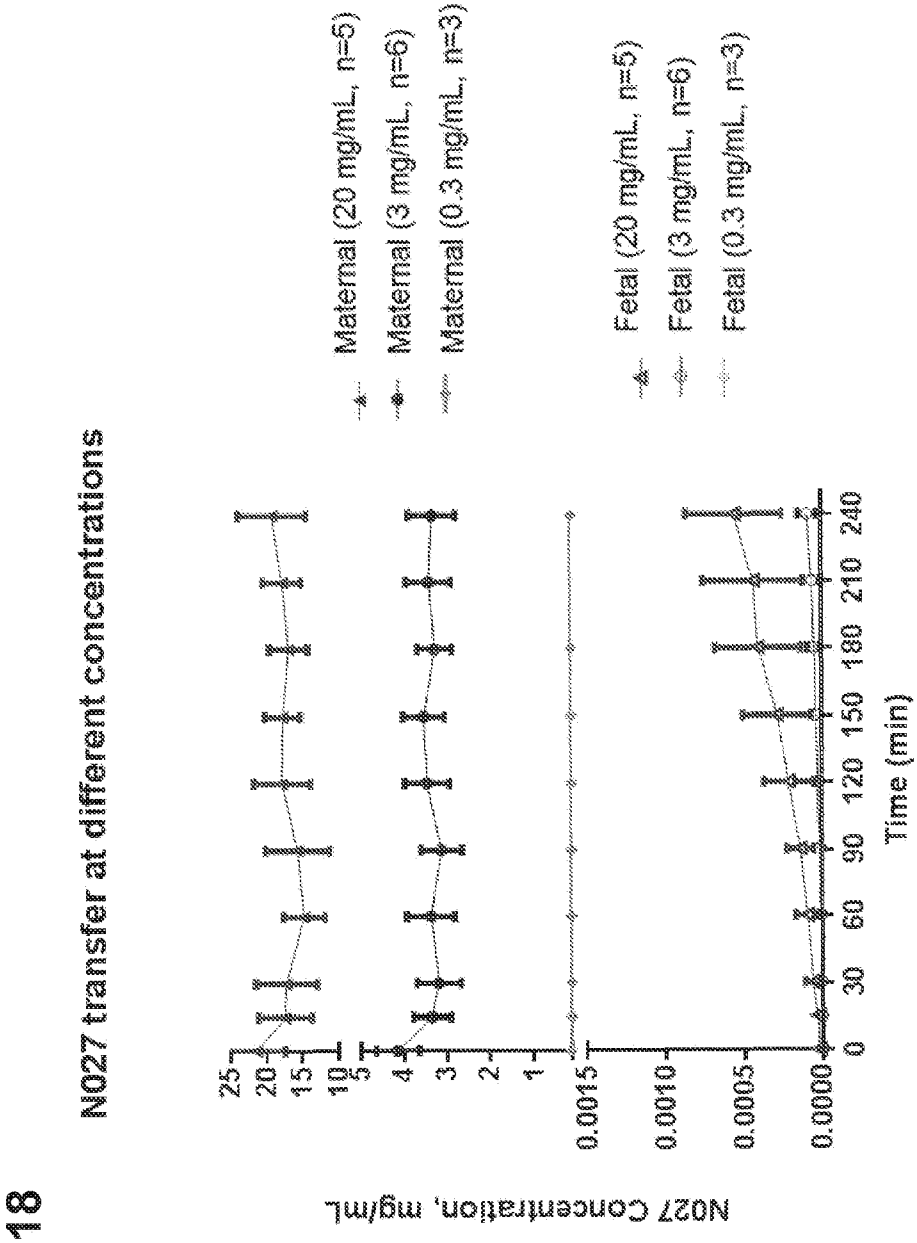

N027 transfer at different concentrations
N027 Concentration, mg/mL
Time (min)
Maternal (20 mg/mL, n=5)
Maternal (3 mg/mL, n=6)
Maternal (0.3 mg/mL, n=3)
Fetal (20 mg/mL, n=5)
Fetal (3 mg/mL, n=6)
Fetal (0.3 mg/mL, n=3)
25
20
15
10
5
4
3
2
1
0.0015
0.0010
0.0005
0.0000
0
30
60
90
120
150
180
210
240

FIG. 19

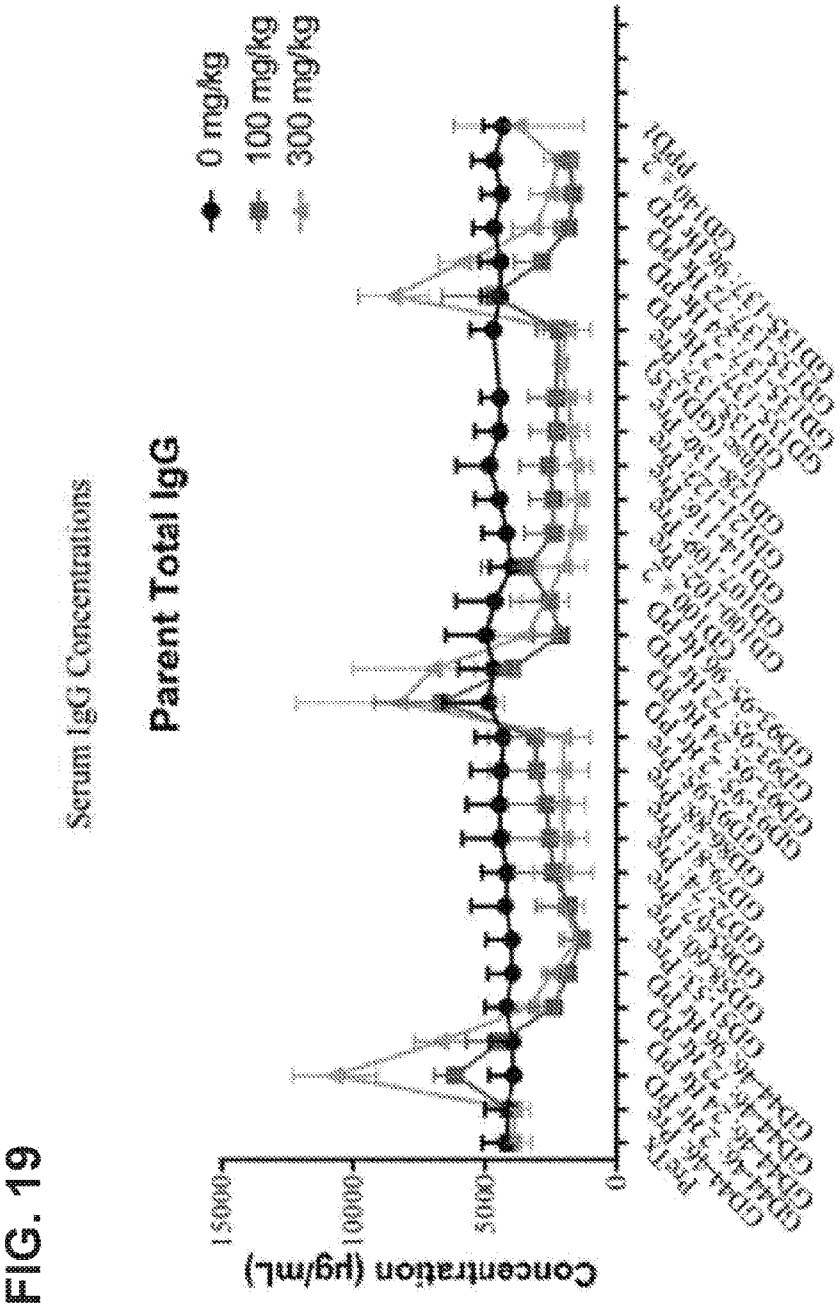
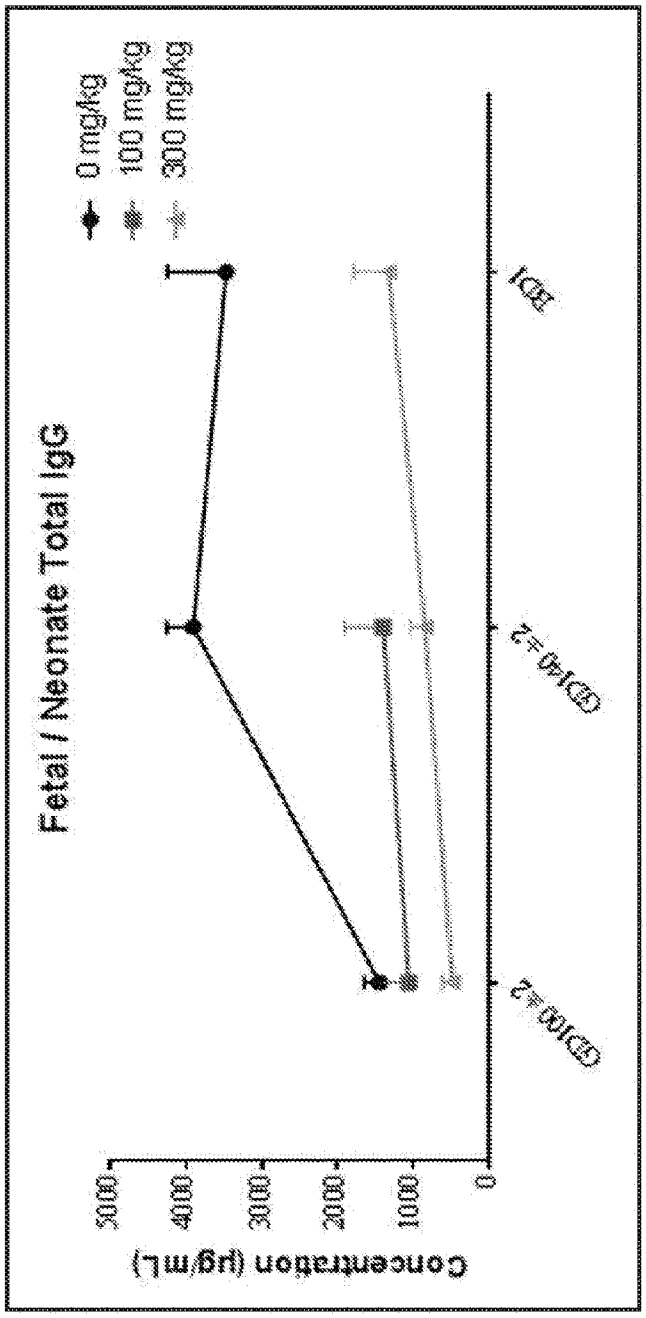

Serum IgG Concentrations
Parent Total IgG
0 mg/kg
100 mg/kg
300 mg/kg
Concentration (µg/mL)
150000
100000
50000
0

FIG. 20


Fetal / Neonate Total IgG
0 mg/kg
100 mg/kg
300 mg/kg
Concentration (µg/mL)
5000
4000
3000
2000
1000
0
GD100 ± 2
GD140 ± 2
1 CD