

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
21 September 2006 (21.09.2006)

PCT

(10) International Publication Number
WO 2006/099174 A2

(51) International Patent Classification:
A01N 1/02 (2006.01)

(21) International Application Number:
PCT/US2006/008658

(22) International Filing Date: 10 March 2006 (10.03.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/660,571 11 March 2005 (11.03.2005) US
11/368,935 6 March 2006 (06.03.2006) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: ORGAN TRANSPLANT SOLUTIONS AND METHOD FOR TRANSPLANTING ORGANS

(57) Abstract: A preservation solution for organs waiting to be transplanted is disclosed; the method of using the solution in a transplantation procedure is also disclosed. The preservation solutions comprise a balanced isotonic aqueous solution comprising sodium, potassium, calcium, magnesium and bicarbonate ions in a physiologically acceptable amount, together with an effective amount of a mutein of the C5a anaphylatoxin which is a C5a receptor antagonist wherein the amino acid residue naturally occurring at sequence position (69) is mutated.



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ORGAN TRANSPLANT SOLUTIONS AND METHOD FOR TRANSPLANTING ORGANS

Jörg Köhl and Prasad Devarajan

CROSS-REFERENCE TO RELATED APPLICATION

- [0001] This application is related to and claims priority from U.S. Provisional Patent Application No. 60/660,571, Köhl et al., filed March 11, 2005, incorporated herein by reference.

TECHNICAL FIELD

- [0002] The present invention relates to organ preservation solutions and to methods for transplanting organs. More particularly, this invention relates to preservation solutions for perfusing and storing an organ while awaiting implantation and to methods of using the preservation solution during transplantation of the organ.

BACKGROUND OF THE INVENTION

- [0003] A great deal of research progress has been made over the years in understanding cellular mechanisms, as well as developing new transplantation techniques, for keeping organs viable not only during storage but also after reperfusion of these organs (e.g., minimization of ischemia/reperfusion injury). As a result, organ transplantation has become an established and effective technique. A significant factor limiting clinical application of organ transplantation is decrease in viability of the organ after removal from the donor.
- [0004] Generally, the two most frequently used methods for preserving organs after removal from the donor are simple hypothermic storage and continuous pulsatile perfusion. With simple hypothermic storage, the organ is removed from the donor and cooled rapidly. This is usually achieved by a combination of cooling and short periods of perfusion to drop the organ temperature as quickly as possible to a temperature between 0°C and 4°C, where it may be held for up to about six hours. While cold storage enables organs to be transplanted, the time during which the organ is viable is short. Cold storage decreases the rate at which intracellular enzymes, essential cellular

components necessary for organ viability, degrade but does not stop metabolism entirely.

[0005] The second method of organ preservation which has undergone extensive investigation, continuous pulsatile perfusion, utilizes the following elements: (1) pulsatile flow, (2) hypothermia, (3) membrane oxygenation, and (4) a perfusate containing both albumin and lipids. Although being more technically complex and costly, continuous pulsatile perfusion provides significantly longer viability of the organ when compared to simple hypothermia.

[0006] Preserving organs at between 0°C and 4°C can result in damage to the organ during storage and upon reperfusion with a warm reperfusion solution. Injury to the organ occurs through damage to epithelial and endothelial cells. Although some of the solutions of the prior art have been useful to extend the storage time of donor organs and lessen injury to the organ upon reperfusion, cell injury still does occur frequently. It is desirable to extend the viable organ life and improve the quality of the transplanted organ. For example, using preservation solutions of the prior art, kidneys that have been in cold storage beyond 48 hours frequently cannot be used and must be discarded. Extending organ viability allows sufficient time for compatibility testing of the donor and recipient, and increased organ availability. It is also desirable to minimize damage to the organ upon reperfusion. Ischemia-reperfusion injury to transplanted organs preserved in solutions of the prior art commonly results in delayed graft function, and predisposes the graft to acute and chronic rejection.

[0007] A storage solution for preserving organs which can be used at temperatures from 0°C to 37°C is disclosed in U.S. Patent 5,145,771, Lemasters et al., issued September 8, 1992. The solution requires the use of a colloid, hydroxyethyl starch for osmotic support against interstitial edema.

[0008] U.S. Patents 4,879,283 and 4,798,824, Belzer et al., issued November 7, 1989 and January 17, 1989, respectively, relate to organ preservation/storage solutions containing a specifically defined synthetic hydroxyethyl starch in place of human serum albumin. These patents cover the widely used organ preservation solution commercially available under the trade name VIASPAN™, marketed by Barr Laboratories.

[0009] International Published Patent Application WO 03/078457, published September 25, 2003, describes muteins of the C5a anaphylatoxin, which are taught to be C5a receptor antagonists. The materials are taught to be useful for the treatment of C5a-mediated disease or inflammatory conditions, such as asthma, adult respiratory distress syndrome, ischemia/reperfusion injury, chronic progressive pulmonary cystic fibrosis, and rheumatoid arthritis. It is also taught that the C5a muteins can be used to treat patients suffering from organ transplant rejection.

[0010] The present invention provides preservation solutions useful for storing organs while awaiting implantation which extend the vitality of the organ and reduce damage to organ cells. The present invention also provides method for preserving organs which extend the maximum life of the organ during transplantation.

SUMMARY OF THE INVENTION

[0011] In accordance with these objectives, there are disclosed preservation solutions for use in the transplantation of organs, and to methods for transplanting organs using those solutions, which methods increase storage times and lessen injury to the organs. The preservation solutions of the present invention comprise:

- (a) a balanced isotonic solution comprising sodium, potassium, calcium, magnesium and bicarbonate ions in a physiologically acceptable amount;
- (b) a safe and effective amount of a mutein of the C5a anaphylatoxin which is a C5a receptor antagonist, wherein the amino acid residue naturally occurring at sequence position 69 is mutated; and
- (c) water.

[0012] The present invention also relates to a method for preservation, storage and reperfusion of organs intended for implantation, said method comprising:

preserving or perfusing said organ with a solution comprising:

- (a) a balanced isotonic solution comprising sodium, potassium, calcium, magnesium and bicarbonate ions in a physiologically acceptable amount;

- (b) a safe and effective amount of a mutein of the C5a anaphylatoxin which is a C5a receptor antagonist, wherein the amino acid residue naturally occurring at sequence position 69 is mutated; and
- (c) water.

[0013] Finally, the present invention relates to a method of preserving organs intended for implantation, said method comprising perfusing the body of the dead organ donor, prior to removal of the organs, with the preservation solution defined above.

[0014] The preservation solution in one embodiment includes at least one antioxidant, such as dimethyl thiourea (DMTU), catalase as a hydrogen peroxide scavenger, and apoferritin to decrease iron content within the preservation solution. In addition, the preservation solutions optionally may include hormones, such as insulin and prostaglandin, and antibiotics.

[0015] All patents and publications cited in this patent are fully incorporated by reference herein.

DETAILED DESCRIPTION OF THE INVENTION

[0016] The present invention is directed to new preservation solutions for storing and perfusing organs intended for implantation in a patient requiring such implant. Suitable organs on which the solutions of this invention may be used include, for example, heart, liver, kidney, lungs, intestines, and pancreas.

[0017] The individual components of the present invention are all nontoxic and have been found to be stable during storage.

[0018] The preservation solutions of the present invention are based on a balanced isotonic solution including sodium, potassium, calcium and magnesium ions, as well as glucose and sodium bicarbonate, in a physiologically acceptable amount. Certain of these types of solutions are well known, such as the one described below, known as Krebs-Henseleit-bicarbonate solution, which has the following composition:

Table 1

Concentration ranges in 1 Liter			
NaCl	85.0 mM	to	145 mM
KCl	3.0 mM	to	30 mM
CaCl ₂	0.5 mM	to	2.5 mM
KH ₂ PO ₄	0.7 mM	to	1.3 mM
MgSO ₄	0.9 mM	to	4.8 mM
NaHCO ₃	15.0 mM	to	35 mM
Glucose	1.0 mM	to	50 mM

[0019] Isotonic preservation solutions are also described in U.S. Patent 5,693,462, Raymond, issued December 2, 1997, incorporated herein by reference.

[0020] The preservation solutions are designed to prevent or inhibit various mechanisms which cause injury to the organ, and thus should be a composition that performs one or more (and preferably all) of the following functions: (1) prevents or restricts intracellular acidosis, (2) prevents the expansion of intracellular space, (3) prevents injury from oxygen-derived free radicals, especially during reperfusion, (4) enables the regeneration of high-energy phosphate compounds during reperfusion, (5) sustains appropriate metabolic requirements and prevents the rapid changes in intracellular $\text{Na}^+ - \text{H}^+ - \text{Ca}^{++}$ following reperfusion.

[0021] While the preservation solution begins with the balanced isotonic solution described above, there may be significant differences in the final compositions. For example, the preservation solution begins with the isotonic solution, wherein the potassium concentration is maintained at preferably from about 3.0 mM to about 8.0 mM. Magnesium chloride may be used in place of potassium chloride.

[0022] To the balanced isotonic solution is added a safe and effective amount of the C5a mutein which is described in International Published Patent Application WO 03/078457, published September 25, 2003, incorporated herein by reference. By "safe and effective amount" is meant that amount of C5a mutein which provides the beneficial preservation effect and minimization of ischemic perfusion injury, but not so much as to cause damage to the organ or desired side effects to the organ recipient. The C5a mutein is preferably incorporated in the composition at a concentration of from about 0.1 μM to about 10 μM . While not intending to be bound by theory, it is

believed that the C5a mutein binds to the C5a receptor sites on the organ thereby reducing ischemic perfusion injury and, as a result, reducing the potential for rejection of the organ upon transplantation.

[0023] The mutein used in the present invention can be derived from the natural C5a sequence of mammal and non-mammal species. It can, for instance be of human, porcine, murine, bovine or rat origin. In one embodiment, the mutein is a mutant protein of the human C5a protein.

[0024] In one embodiment, the positively charged amino acid residue at sequence position 69 of the C5a mutein is Arg or Lys.

[0025] In a further embodiment used in the invention, the mutein comprises a hydrophobic amino acid residue at sequence position 67. The aromatic hydrophobic amino acids Trp, Phe and Tyr are particularly preferred as residues at sequence position 67.

[0026] Also preferred antagonists are muteins which comprise a hydrophobic amino acid residue at one or more of the sequence positions 70, 71 or 72. Such hydrophobic amino acid residues can be selected independently from each other, they can be identical or different. Preferred hydrophobic residues are Leu, Ile and Ala.

[0027] Such muteins preferably comprise, at sequence position 70, an amino acid residue which is selected from Ala or Leu. Other preferred muteins comprise Ser at sequence position 70.

[0028] A preferred amino acid at sequence position 71 is Leu. The antagonistic mutein disclosed can also preferably comprise a Leu residue at sequence position 72.

[0029] In a particularly preferred embodiment, the mutein comprises Leu at all of the sequence positions 70, 71, and 72.

[0030] If present, i.e., not deleted, in the C5a mutant, the sequence position 73 is preferably occupied by a Cys, Tyr, Arg or Ser residue. In preferred embodiments the mutein has a length of 70, 71, 72 or 73 amino acid residues. In general, Arg, Cys, Tyr or Ser are also preferred as C-terminal amino acid residues of a truncated mutein, i.e., a mutein having 70, 71, 72, or 73 amino acid residues. An example of a mutein having

a length of 70 amino acids is the mutein C5a-(1-66, Cys27Ala)-FKRS-70 (cf. Table 1, SEQ ID NO: 21).

[0031] Further, muteins are also within the scope of the invention in which the positively charged amino acid at position 69 is the C-terminal (last) residue. Accordingly, such muteins can have a length of 69 amino acids. However, it is also possible to introduce deletions, for example, into the N-terminal region of the protein so that an antagonistic protein used herein can comprise fewer than 69 amino acid residues. For clarity reasons it is noted once again that such deletions can, of course, also be present in muteins of the invention in which residues at sequence positions 70 to 74 are not or only partly deleted.

[0032] The mutein used in the present invention preferably comprises or has as C-terminal sequence a sequence selected from the group consisting of 67-FKRSLLR-73 (cf. mutein A8B; SEQ ID NO: 14), 67-FKRLLLR-73 (cf. mutein A8B-Leu-70; SEQ ID NO: 15), 67-FKRSC-71 (cf. mutein Ab8-Cys71, SEQ ID NO: 16), 67-FKRSLLC-73 (cf. mutein Ab8-Cys73, SEQ ID NO: 17), 67-FKRLLLY-73 (cf. mutein A8B-Leu70-Tyr73, SEQ ID NO: 18), 67-FKKALLR-73 (cf. mutein A8B-Lys69Ala70; SEQ ID NO: 19), 67-FKRS-70 (cf. A8B-Del.71-73, SEQ ID NO: 21) and 67-FKLLLLY-73 (cf. A5a, SEQ ID NO: 39). For the sake of clarity, the numbering refers to the amino acid position of C5a, i.e., 67-F means that phenylalanine is present as amino acid at sequence position 67.

[0033] The mutein can further comprise an Arg residue at sequence position 27, see, for example, mutein C5a-(1-66,Cys27Arg)-FKRSLLR (A8B-Arg27, SEQ ID NO: 20). In fact, Arg at position 27 is found in porcine and bovine C5a. In addition, muteins of human C5a with a Cys27Arg replacement were selected from C5a mutant phage library (Cain, S., et al. "Analysis of receptor/ligand interactions using whole-molecule randomly-mutated ligand libraries," *J. Immunol. Methods*. 2000. pp 139-145. 245), incorporated herein by reference. Muteins of C5a with only a Cys27Arg replacement are agonists of the C5a receptor (*Ibid.*).

[0034] Particularly preferred is a mutein of the human C5a anaphylatoxin having or comprising the amino acid sequence of SEQ ID NO: 14, i.e., C5a-(1-66, Cys27Ala)-A8B; SEQ ID NO: 15, i.e., C5a-(1-66, Cys27Ala)-A8B-Leu 70; SEQ ID NO: 16, i.e., C5a-(1-66, Cys27Ala)-Ab8-Cys71; SEQ ID NO: 17, i.e., C5a-(1-66, Cys27Ala)-A8B-Cys73; SEQ ID NO: 18; i.e., C5a-(1-66, Cys27Ala)-A8B-Leu70-

Tyr73); SEQ ID NO: 19, i.e., C5a-(1-66, Cys27Ala)-A8B-Lys69-Ala70); SEQ ID NO: 20; i.e., C5a-(1-66, Cys27Arg)-A8B; SEQ ID NO: 21, i.e., C5a-(1-66, Cys27Ala)-A8B-Del.71-73); SEQ ID NO: 22, i.e., C5a-(1-66, Cys-3, Gly-2, -1, Cys27Ala)-A8B; and SEQ ID NO: 39, i.e., C5a-(1-66, Cys27Ala)A5a.

[0035] A mutant C5a antagonist of the present invention cannot only be present as the isolated (recombinant) protein but it can also be modified. In one embodiment, a mutein of the invention can be dimerized either with the same or a different mutein to form a homo- or heterodimer. For this purpose the mutein can comprise an N-terminal linker sequence which is capable of dimerizing the C5a mutein. One example of a preferred linker sequence linked to the N-terminus comprises the sequence Cys-Gly-Gly which can be used for spontaneous dimerization of the C5a mutein A8B in the course of the recombinant production of the mutant protein (cf. the mutein C5a-(1-66; Cys-3, Gly-2, -1; Cys27Ala)-A8B). Another example of such a suitable linker is Cys-(Gly-Gly-Gly-Gly-Ser)₂.

[0036] If the mutein carries a cysteine as C-terminal residue (cf. the muteins A8B-Cys71 and A8B-Cys73), the dimerization can also occur by coupling of two muteins via these C-terminal cysteine residues as described by Pellas et al., "Novel C5a receptor antagonists regulate neutrophil functions in vitro and in vivo," *Journal of Immunology*, June 1, 1998, pp 5616-5621, vol. 160, no. 11, incorporated herein by reference. The dimerization can also be achieved by linking a nucleotide sequence encoding a mutein in an appropriate reading frame with the nucleotide sequence coding for a protein which forms a homodimer in its native fold. Subsequent expression of the nucleic acid molecule yields a fusion protein consisting of the dimerization module linked to the C5a mutant polypeptide, which then dimerizes spontaneously. Examples of such proteins which can be used as dimerization modules are alkaline phosphatase, superoxide-dismutase or glutathione-S-transferase. The use of these proteins is in particular useful because the respective functional fusion protein can readily be obtained by periplasmic expression in bacterial expression systems such as *E. coli*. The use of dimerization modules such as alkaline phosphatase or superoxide-dismutase provides the further advantage that such a fusion protein can easily be detected using a chromogenic reaction which is catalyzed, e.g., by alkaline phosphatase. Suitable chromogenic substrates for these enzymes, such as 5-bromo-4-chloro-3-indolylphosphate for alkaline phosphatase, are

well known to the person skilled in the art. Those fusion proteins are therefore suitable as diagnostic reagents.

[0037] In accordance with the disclosure of the above paragraph, the mutein of the invention is in a further embodiment linked to a protein or a peptide tag, i.e., in which a fusion protein containing the C5a mutein is also part of the invention. However, the fusion proteins of the mutein A8B with Jun/Fos alone, and, with Jun/Fos and the minor coat protein (pIII) of the filamentous M13 phage fused to the N-terminus of the mutein A8B, which are known from Heller et al, "Selection of a C5a receptor antagonist from phage libraries attenuating the inflammatory response in immune complex disease and ischemia/reperfusion injury," *Journal of Immunology*, July 15, 1999, pp 985-994, vol. 163, no. 2, are excluded from the invention. The same applies to the mutein A8B that has a hexahistidine tag directly fused to the N-terminus, because this polypeptide is known from Hennecke, Untersuchung zur C5a-C5a Rezeptor-Interaktion unter Verwendung des Phage-Displays, PhD thesis, 1998, Medical School Hannover, Germany.

[0038] A fusion protein of the invention can comprise any suitable fusion partner, e.g., alkaline phosphatase or the green fluorescent protein (GFP) as long as the fusion partner does not interfere with the antagonistic properties of the mutein disclosed here and converts the mutein into an agonist when given to a patient, for example. A fusion partner appropriate for therapeutic purpose is a protein such as albumin which can enhance the *in vivo* (circulation) half-life of a mutein of the invention. The fusion partner can be fused to the N-terminus of the C5a mutein. Likewise, any peptide tag can be fused to the N-terminus of the mutein as long as its antagonistic property is maintained. Examples of suitable affinity tags are the STREP-TAG® which has specific binding affinity for streptavidin or mutants thereof as STREP-TACTIN® (see U.S. Patents 5,506,121, Skerra et al., issued April 9, 1996, and 6,022,951, Sano et al., issued February 8, 2000, both incorporated by reference herein), the Flag-tag or the myc-tag, all of which can be used for purification of the mutein by affinity chromatography.

[0039] It should, however, be noted that in the event of, e.g., inventive C5a muteins conjugated or fused to a partner that confers agonistic properties, the antagonistic muteins can be readily generated/released from its (fusion) partner by treatment such as limited proteolysis or cleavage, for example enzymatic or chemical cleavage, of a

(peptide) bond which links the C5a mutein to the (fusion) partner. Accordingly, it is also within the scope of the present invention, to use a fusion partner, for example, for improved purification of the mutein, for example, even if this fusion partner confers an agonistic activity as long as this activity can be eliminated before (and thus the antagonistic activity of the inventive mutein is generated) the muteins is used, for instance, in a desired therapeutic application. It is also possible to use a mutein the antagonistic activity of which is reduced by the (fusion) partner but not completely abolished. In this case, it is thus not necessary to deliberate the mutein of the invention by cleavage from its (fusion) partner. Rather, the fusion protein or the conjugate as explained in the following can be used in a desired application.

[0040] The mutein used in the present invention can also be conjugated to a protein or a different chemical (macromolecular) moiety via a suitable peptidic or non-peptidic linker that can be attached to any suitable residue within the primary sequence of the mutein. A protein can, for instance, be conjugated with the C5a mutein using solvent exposed α -amino groups of lysine residues and glutaraldehyde as linker. Another suitable coupling chemistry is amine-amine crosslinking using bis(succinimidylesters) of 5,5'-dithiobis-(2-nitrobenzoic acid) (DTNB) as described in Haugland, R. Handbook of Fluorescent Probes and Research Chemicals, 6th Ed. 1996, Molecular Probes, Eugene, OR, on page 96, incorporated herein by reference. Any protein can be coupled to the C5a mutein, depending on the desired application. For example, a conjugate with streptavidin, horseradish peroxidase or green fluorescent protein might be used as a diagnostic reagent or research tool for visualizing a C5a receptor on the surface or within different compartments of a cell.

[0041] In a preferred embodiment a mutein of the invention is conjugated to a moiety which enhances the *in vivo* half-life of the mutein. Such a conjugate is particularly useful when a present C5a receptor antagonist is used for the treatment of the organ recipient where a long term presence of the antagonist within the graft is desired. Suitable moieties are proteins such as human serum albumin. It is also possible to use anon-protein (macromolecular) moiety such as polyethylene glycol.

[0042] The C5a muteins including conjugates or fusion proteins thereof are useful in the treatment and/or prevention or prophylaxis of a variety of injurious conditions or diseases in which the complement system, and more particularly C5a and the C5a receptor, are involved. They are therapeutically very suitable when administered to

any mammal such as cats, dogs, monkeys, rabbits, mice, rats and, of course, especially humans that face a high risk of C5a-mediated tissue destruction and death. In general, the conditions or diseases are usually those such as inflammatory disorders where C5a is generated proteolytically in serum or tissue.

[0043] The preservation solution also preferably includes pharmaceutically-acceptable adjunct materials, such as ethylene diaminetetraacetic acid (EDTA) in an amount from 0.5 μM to about 1.5 μM as a chelating agent (or other chelating agents known in the art may also be used). It has also been found desirable to add from 10 ηM to about 100 ηM of caprylic acid which helps the solution to bypass blocked fatty acid utilization and from 10 $\mu\text{g/L}$ to 100 $\mu\text{g/L}$ of apoferritin which serves to eliminate iron (Fe^{++}) which causes breakdown of the cells. Desferrioxamine may also be used to chelate the iron. Dichloroacetic acid may be employed to reduce lactate.

[0044] Suitable pharmaceutically acceptable antioxidants include, but are not limited to, allopurinol, glutathione, beta-carotene, catalase, superoxide dismutase, dimethyl thiourea (DMTU), diphenyl phenylene diamine (DPPD), mannitol or cyanidanol in an amount effective to inhibit the generation of oxygen-derived free radicals. The antioxidants are present generally in an amount from about 1 ηM to 10 ηM . Antibiotics may be added for transplantable organs, but are not generally added during acute studies.

[0045] The transplantation method of the present invention is to preserve and store the organ with the preservation solution and reperfuse with preservation solution prior to implantation. In a preferred method, the surgeon removes the organ and connects it to a perfusion apparatus comprising tubing and pumps. The preservation solution is then perfused through the organ while gassed with oxygen and carbon dioxide while it is awaiting implantation into a patient. A perfusion rate of from about 25 to about 150 mL/hour, preferably about 50 mL/hour, at 1°C has been found to be effective. This organ perfusion can occur at either a constant flow or pressure. In a variation of this method, after the donor has died, but before the organs have been removed from the donor, the donor's body can be perfused with the preservation solution of the present invention in order to provide the beneficial effects of the solution to the organs at the earliest possible time. Once the organs are removed, they are then perfused with the preservation solution as described above.

[0046] The preservation solution can be used at all temperatures ranging from 0°C to normal body temperature, 37°C. At temperatures of from about 12°C to about 37°C, the solution is particularly effective.

[0047] The following example is provided to further illustrate the present invention and is not intended to be construed as limiting the invention in any manner.

[0048] EXAMPLE

A liter of preservation solution having the following composition is prepared.

Table 2

Component	Concentration
NaCl	118 mM
KCl	30 mM
CaCl ₂	1.75 mM
KH ₂ PO ₄	1.2 mM
MgSO ₄	1.2 mM
NaHCO ₃	25 mM
Glucose	11 mM
Adenosine	10 μ M
EDTA	1.0 mM
DMA	1.0 μ M
Heparin	1000 units
Distilled, deionized water	q.s.

[0049] To this solution is added the C5a mutein in sterile water or other sterile injectable medium to reach a final concentration in the preservation solution of from about 0.1 to about 10 μ M. The C5a mutein used has the following structure:

SEQ ID NO: 21 (C5a-(1-66,Cys27Ala)-A8B-Del. 71-73).

[0050] The preservation solution defined above is perfused through a kidney or a heart, at a rate of about 50 mL per hour, after removal from the donor and prior to implantation. Similar results are obtained when the specific C5a mutein component utilized is replaced, in whole or in part, with the following:

SEQ ID NO: 14 (C5a-(1-66, Cys27Ala)-A8B);

SEQ ID NO: 15 (C5A-(1-66, Cys27Ala)-A8B-Leu 70);
SEQ ID NO: 16 (C5a-(1-66, Cys27Ala)-Ab8-Cys71);
SEQ ID NO: 17 (C5a-(1-66, Cys27Ala)-A8B-Cys73);
SEQ ID NO: 18 (C5a-(1-66, Cys27Ala)-A8B-Leu70-Tyr73);
SEQ ID NO: 19 (C5a-(1-66, Cys27Ala)-A8B-Lys69-Ala70);
SEQ ID NO: 20 (C5a-(1-66, Cys27Arg)-A8B);
SEQ ID NO: 22 (C5a-(1-66, Cys-3,Gly-2,-1,Cys27Ala)-A8B); and
SEQ ID NO: 39 (C5a-(1-66, Cys27Ala)A5a).

[0051] The present invention has been described in detail and with particular reference to the preferred embodiments. Those skilled in the art will appreciate that changes can be made without departing from the spirit and scope thereof. Accordingly, the present invention is to be defined by the following claims, with equivalents of the claims to be included therein.

What is claimed is:

1. A preservation solution for storage and reperfusion of organs for implantation comprising:
 - (a) a balanced isotonic solution comprising sodium, potassium, calcium, magnesium and bicarbonate ions in a physiologically acceptable amount;
 - (b) a safe and effective amount of a mutein of the C5a anaphylatoxin which is a C5a receptor antagonist, wherein the amino acid residue naturally occurring at sequence position 69 is mutated; and
 - (c) water.
2. The preservation solution according to claim 1 which contains from about 0.1 μ M to about 10 μ M per liter of the C5a mutein.
3. The preservation solution according to claim 2 wherein, in the mutein, the amino acid residue at sequence position 69 is replaced by leucine or a positively charged amino acid residue.
4. The preservation solution according to claim 2 wherein, in the mutein, the amino acid residue naturally occurring at sequence position 67 is mutated.
5. The preservation solution according to claim 2 wherein, in the mutein, at least one of the amino acid residues at sequence positions 70 to 74 of the natural amino sequence is mutated and/or wherein at least one of the amino acid residues at said sequence positions 70 to 74 is deleted.
6. The preservation solution according to claim 3 wherein, in the mutein, the positively charged amino acid residue at sequence position 69 is Arg or Lys.
7. The preservation solution according to claim 4 wherein the mutein comprises at sequence position 67 an aromatic amino acid selected from the group consisting of Phe, Trp and Tyr.
8. The preservation solution according to claim 5 wherein the mutein comprises a hydrophobic amino acid residue at sequence position 70.

9. The preservation solution according to claim 8 wherein the mutein comprises Leu or Ala at sequence position 70.
10. The preservation solution according to claim 5 wherein the mutein comprises Ser at sequence position 70.
11. The preservation solution according to claim 4 wherein the mutein comprises a hydrophobic amino acid residue at sequence position 71 or 72.
12. The preservation solution according to claim 11 wherein the mutein comprises Leu at sequence position 71.
13. The preservation solution according to claim 5 wherein the mutein comprises Leu at sequence position 72.
14. The preservation solution according to claim 2 wherein the mutein comprises a terminal sequence selected from group consisting of 67-FKRSLLR-73, 67-FKRLLLLR-73, 67-FKRSC-71, 67-FKRSLLC-73, 67-FKRLLLY-73, 67-FKKALLR-73, 67-FKRS-70, and 67-FKLLLLLR-73.
15. The preservation solution according to claim 2 wherein the mutein further comprises Arg at sequence position 27.
16. The preservation solution according to claim 2 wherein the mutein has an amino acid sequence selected from
SEQ ID NO: 14 (C5a-(1-66, Cys27Ala)-A8B);
SEQ ID NO: 15 (C5a-(1-66, Cys27Ala)-A8B-Leu 70);
SEQ ID NO: 16 (C5a-(1-66, Cys27Ala)-Ab8-Cys71);
SEQ ID NO: 17 (C5a-(1-66, Cys27Ala)-A8B-Cys73);
SEQ ID NO: 18 (C5a-(1-66, Cys27Ala)-A8B-Leu70-Tyr73);
SEQ ID NO: 19 (C5a-(1-66, Cys27Ala)-A8B-Lys69-Ala70);
SEQ ID NO: 20 (C5a-(1-66, Cys27Arg)-A8B);
SEQ ID NO: 21 (C5a-(1-66, Cys27Ala)-A8B-De1,71-73);
SEQ ID NO: 22 (C5a-(1-66, Cys-3, Gly-2, -1,Cys27Ala)-A8B); and
SEQ ID NO: 39 (C5a-(1-66, Cys27Ala)A5a).

17. The preservation solution according to claim 2 wherein the mutein further comprises an N-terminal linker sequence which is capable of dimerizing the C5a mutein.
18. The preservation solution according to claim 17 wherein, in the mutein, the N-terminal linker sequence comprises the sequence Cys-Gly-Gly or Cys-(Gly-Gly-Gly-Gly-Ser)₂.
19. The preservation solution according to claim 2 wherein the mutein is fused to a protein or a peptide tag with the proviso that the fusion proteins of the mutein A8B with Jun/Fos alone or with Jun/Fos and the minor coat protein (pIII) of the filamentous M13 phage mutein A8B, wherein the Jun/Fos moiety is fused to the N-terminus of the mutein A8B, as well as the mutein A8B having a hexahistidine tag directly fused to the N-terminus are excluded.
20. The preservation solution according to claim 2 wherein the mutein is conjugated to a moiety which enhances the *in vivo* half-life of the mutein.
21. A method of preservation, storage and reperfusion of an organ intended for implantation, said method comprising perfusing said organ with a solution comprising:
- (a) a balanced isotonic solution comprising sodium, potassium, calcium, magnesium and bicarbonate ions in a physiologically acceptable amount;
 - (b) a safe and effective amount of a mutein of the C5a anaphylatoxin which is a C5a receptor antagonist wherein the amino acid residue naturally occurring at sequence position 69 is mutated; and
 - (c) water.
22. The method of preservation according to claim 21 wherein the C5a mutein is present at from about 0.1 to about 10 μ M/liter of the solution.
23. The method of preservation according to claim 22 wherein the C5a mutein has an amino acid sequence selected from
- SEQ ID NO: 14 (C5a-(1-66, Cys27Ala)-A8B);
- SEQ ID NO: 15 (C5a-(1-66, Cys27Ala)-A8B-Leu 70);
- SEQ ID NO: 16 (C5a-(1-66, Cys27Ala)-Ab8-Cys71);
- SEQ ID NO: 17 (C5a-(1-66, Cys27Ala)-A8B-Cys73);

SEQ ID NO: 18 (C5a-(1-66, Cys27Ala)-A8B-Leu70-Tyr73);
SEQ ID NO: 19 (C5a-(1-66, Cys27Ala)-A8B-Lys69-Ala70);
SEQ ID NO: 20 (C5a-(1-66, Cys27Arg)-A8B);
SEQ ID NO: 21 (C5a-(1-66, Cys27Ala)-A8B-De1.71-73);
SEQ ID NO: 22 (C5a-(1-66, Cys-3, Gly-2, -1, Cys27Ala)-A8B); and
SEQ ID NO: 39 (C5a-(1-66, Cys27Ala)A5a).

24. A method of preservation of organs intended for implantation, said method comprising perfusing the body of the dead organ donor, prior to removal of the organs, with a solution comprising:

- (a) a balanced isotonic solution comprising sodium, potassium, calcium, magnesium and bicarbonate ions in a physiologically acceptable amount;
- (b) a safe and effective amount of a mutein of the C5a anaphylatoxin which is a C5a receptor antagonist wherein the amino acid residue naturally occurring at sequence position 69 is mutated; and
- (c) water.

25. The method of preservation according to claim 24 wherein the C5a mutein has an amino acid sequence selected from

SEQ ID NO: 14 (C5a-(1-66, Cys27Ala)-A8B);
SEQ ID NO: 15 (C5a-(1-66, Cys27Ala)-A8B-Leu 70);
SEQ ID NO: 16 (C5a-(1-66, Cys27Ala)-A8B-Cys71);
SEQ ID NO: 17 (C5a-(1-66, Cys27Ala)-A8B-Cys73);
SEQ ID NO: 18 (C5a-(1-66, Cys27Ala)-A8B-Leu70-Tyr73);
SEQ ID NO: 19 (C5a-(1-66, Cys27Ala)-A8B-Lys69-Ala70);
SEQ ID NO: 20 (C5a-(1-66, Cys27Arg)-A8B);
SEQ ID NO: 21 (C5a-(1-66, Cys27Ala)-A8B-De1.71-73);
SEQ ID NO: 22 (C5a-(1-66, Cys-3, Gly-2, -1, Cys27Ala)-A8B); and
SEQ ID NO: 39 (C5a-(1-66, Cys27Ala)A5a).

26. The method of preservation according to claim 25 wherein the C5a mutein is present at from about 0.1 to about 10 μ M/liter of the solution.