Patent “Front Page” - since 1971
Selected Bibliographic Patent Information

(1) Patent Number (10) a unique identifying number given to each invention receiving patent protection. First number one assigned 13 July 1836. Prior patent were retroactively assigned numbers. They are called the “X” patents.

(2) Date of Issuance (45) USPTO date of grant for patent protection. Pre-1993, protection is granted for 17 years after this date.

(3) Title (54) a merely descriptive, and sometimes arbitrary, name given to an invention. The title cannot be a trademark name.

(4) Applicant(s) (71) a person to whom the inventor has assigned or is under an obligation to assign an invention to file and prosecute an application for patent as the applicant, and to permit a person who otherwise shows sufficient proprietary interest in the matter to file and prosecute an application for patent as the applicant on behalf of the inventor.

(5) Inventors (72) person(s) credited with the conception of the invention. U.S. patent law requires that the applicant in a patent application must be the inventor(s). Not all countries require the inventor listing.

(6) Assignee (73) the owner of the patent grant. If no assignor is given, then the inventor is the owner. There is no law that requires companies to inform the USPTO of the selling of their rights (assignment) to other companies or individuals.

(7) Application number (21) on the filing date of an application a serial number is assigned to the application. This serial number, along with the date filed is known as the priority number. A priority number will follow an application throughout the examination process and with any international filings.

(8) Date Filed (22) the day the USPTO received the application. The ability to exclude from the marketplace begins with this date, once a patent grant is achieved. The exclusion lasts for 20 years from this date unless there is an abandonment of the application or patent grant.

(9) Prior Publication (65) the publication number assigned to an application when published. Usually, this occurs at the 18 months publication date but there can be earlier publication dates is requested by applicant.

(10) CPC and IPC Classes (52) Cooperative Patent Classification (CPC) and international classifications (IPC) are used to identify the technology encompassing the invention. At the USPTO, these numbers are assigned by Classifiers and the examiners.

(11) Reference Cited (56) applicants are required by law to disclose to the examiner all prior art (Technology) relevant to their invention. The examiner lists the prior art up to the time of the examination of the patent application.

(12) Abstract (57) a short technical summary of the invention. Abstracts do not appear on patents prior to 1971. Abstracts are very limited in their disclosure of the technologies behind an invention.

(13) Drawings representative mechanical drawings, diagrams, graphical data, flow diagrams, charts, or other visual information of the invention. Drawings are models and are viewed “artistically” rather than “concretely.” Chemical and pharmaceutical patents do not contain drawings of formulas or chemical structures. Formulas/structures are usually found in the description/specification of the application or patent.
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Yellow: Drawing

These sheets are an illustration of the invention. The drawing is merely representative of the invention. It is not a disclosure of what is being invented. Chemical patents do not contain drawings of chemical structures.

Red: Field in which the Invention Lies

This is a brief paragraph, typically one to two sentences long, describing the field in which the invention pertains.

Black: Statement of the Problem

This section briefly summarizes the invention. It describes the invention in broad terms and how it overcomes the disadvantages of the prior art.

Purple: Definition

The definition describes the solution to the problem and is the heart of the patent. This is where the purpose of the patent is found. Many United States patents highlight the definition by titling this section Summary of the Invention. If this heading is not used, the reader can look for key phrases such as “the invention comprises,” “in accordance with present invention,” or “my invention is characterized....” In this patent example, the phrase is “...the present invention....”

Green: Objects of the Invention

This section may also include the title Summary of the Invention. The objects of the invention are the benefits it provides.

Orange: Definition in Detail

This section gives the detailed elaboration of the drawings, terms and limits summarized in the definition. Unlike a scientific paper, a patent generally avoids detailed discussions about mechanisms or why the invention is not effective. This is done so that interpretation does not limit the scope of the claims or make it seem obvious from theory. It is sometimes titled Description of the Preferred Embodiments.

Blue: Claims

The full-disclosure of what is being invented. The claims are analyzed to determine the scope of protection of a patent. This is important when deciding if you are infringing on the patent. The claims are also useful in figuring out how to “design around” a patent so that you do not infringe upon it. Experienced patent readers will read claims and examples first to get a feel for the breadth of the inventor’s thinking. Usually the claims will follow the declarations We claim, I claim, or What is claimed.
**ABSTRACT**

Compositions, methods, systems/devices and media are provided for maintaining a harvested organ in a functioning and viable state prior to implantation. The organ perfusion apparatus includes a preservation chamber for storing the organ during the preservation period. A perfusion circuit is provided having a first line for providing an oxygenated fluid to the organ, and a second line for carrying depleted fluid away from the organ. The perfusion apparatus also includes a device operably associated with the perfusion circuit for maintaining the organ at a substantially normothermic temperature.

17 Claims, 11 Drawing Sheets
Related U.S. Application Data
No. 13/849,295, filed on Mar. 22, 2013, now abandoned, which is a division of application No. 11/006,968, filed on Feb. 17, 2005, now Pat. No. 8,409,846, which is a continuation of application No. 09/534,092, filed on Mar. 23, 2000, now Pat. No. 6,593,655, which is a continuation of application No. PCT/ US98/19912, filed on Sep. 23, 1998, which is a continuation-in-part of application No. 09/054,698, filed Apr. 3, 1998, now Pat. No. 6,046,046, which is a continuation-in-part of application No. 08/936,062, filed on Sep. 23, 1997, now Pat. No. 6,100,082.

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RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 14/671,771 filed on Mar. 27, 2015, which is a continuation of U.S. application Ser. No. 13/845,295, filed on Mar. 22, 2013, which is a divisional of U.S. application Ser. No. 11/060,006, filed on Feb. 17, 2005, now U.S. Pat. No. 8,409,846, which is a continuation of U.S. application Ser. No. 09/234,092, filed on Mar. 23, 2000, now U.S. Pat. No. 6,553,655, which is a continuation of PCT/US98/09912, filed on Oct. 23, 1998, which is a continuation-in-part of U.S. application Ser. No. 09/364,698 filed on Apr. 3, 1998, now U.S. Pat. No. 6,046,046, which is a continuation-in-part of U.S. application Ser. No. 08/936,062 filed on Sep. 23, 1997, now U.S. Pat. No. 6,100,862. The specifications of each of the above applications are incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates to compositions, methods, systems/devices and media for maintaining a harvested (extracorporeal) animal organ in a functioning and viable state prior to transplantation or reimplantation. In particular, the present invention relates to compositions, methods, systems/devices and media for maintaining a harvested human organ in a functioning and viable state. The organ may also be assessed in such a state or reimplanted after death.

The present invention also relates to an organ perfusion apparatus, and more particularly, to a perfusion apparatus and method and chemical compositions for extending the preservation period of an organ which has been harvested.

2. Discussion

While having many embodiments, the present invention is directed to systems, devices (apparatuses), methods and media for preserving organs in near ideal conditions and physiological states. This allows the organs to be stored for longer periods of time, reduces organ deterioration, and allows for a more predictable and reliable supply of organs which can allow for a more predictable and reliable supply of organs. The increase in storage periods in a normal or near normal functioning state also provides certain advantages, for example, organs can be transported greater distances and there is an increased time for testing and evaluation of the organs.

It is estimated that one of every four patients listed for cardiac transplantation dies awaiting the availability of a suitable donated organ. While some progress has been made in increasing the number of donors available, the development of successful techniques for donor heart preservation has not kept pace with the demand for cardiac transplantation. With improvements in patient survival and the development of new immunosuppressive agents, heart transplantation has become more feasible, making the problem of organ supply even more critical. Despite the acceptable clinical results obtained with the current donor organ and donor heart preservation techniques, one of the major challenges that remains is the current inability to safely preserve the donor heart for more than four hours. Extending the preservation period beyond four hours using current preservation techniques significantly increases the risk of organ failure during or after transplantation; this failure correlates with the period and technique of storage. This four hour limitation also restricts the geographic area from which donor hearts can be transported for successful transplantation. Moreover, current methods of storing or preserving the heart or other organs make it impossible to fully or meaningfully test or evaluate the stored organ due to the storage of the organ in a non-functioning and/or hypothermic state.

Generally, current donor organ preservation protocols do not attempt to recreate an in vivo-like physiologic state for harvested organs. Instead, they utilize hypothermic (below 20°C and typically at about 4°C) arrest and storage in a chemical perfusate for maintaining the heart (non-beating) or other organ (non-functioning) for up to four hours. These protocols utilize a variety of crystalloid-based cardioplegic solutions that do not completely protect the donor coronary vascular endothelial and smooth muscle injury leading to coronary vasomotor dysfunction, which is believed to be the leading cause of late organ failure. (Ischemia is generally defined as an insufficient blood supply to the heart muscle.)

Techniques have also been developed for perfusing the heart with the storage solution in the hypothermic state. Other organs (liver, kidney, lungs, etc.) have been maintained in a similar, non-functioning, hypothermic state. The heart or the other organs so preserved are then transported in this hypothermic state for only up to four hours until implantation.

As is well known in the art, for optimal donor heart or other organ preservation, the following principles apply and are thought to assist in the minimization of ischemic and/or reperfusion injuries: a) minimization of cell swelling and edema; b) prevention of intracellular acidosis; c) minimization of ischemia and/or reperfusion injury, and overall improve outcome. The current methods of hypothermic arrest and storage preservation have been shown to result in cell swelling, intracellular acidosis, and degradation of protein and cellular components. Moreover, studies in humans have clearly demonstrated significant endothelial dysfunction following donor heart preservation when utilizing hypothermic arrest and storage protocols. In some instances, an organ which has undergone hypothermic arrest is transplanted into the recipient and cannot be restored or resuscitated after transplantation. In addition, many times inadequate preservation results in acute graft failure and the inability of the transplanted organ to resume normal function and sustain the recipient's circulation. The problem of acute graft failure then requires constant support of the recipient's circulatory system by ventricular assist devices and/or cardiopulmonary bypass until another donor heart can be located. In some instances, a suitable organ cannot be located in time which results in the death of the recipient.

There is also increasing evidence from a number of recent clinical studies that the preservation of metabolic, contrac- tile and vasomotor function is not optimized with current preservation protocols. See, e.g., Pearl et al., “Loss of Endothelium-Dependent Vasodilation and Nitric Oxide Release After Myocardial Protection With University of Wisconsin Solution”, Journal of Thoracic and Cardiovascular Surgery, Vol. 107, No. 1, January 1994.

Because the art has not been able to store harvested organs at near optimal endogenous conditions, and has not recog-
nized such storage as feasible or desirable, it has attempted to use the above combination of hypothermic conditions and/or crystalloid-based cardioplegic solutions for protection against organ condition deterioration.

Another approach attempted in the art has been to simulate near normal physiologic conditions by harvesting almost all the donor's organs together. For example, Chien et al., "Canine Lung Transplantation After More Than Twenty-Four Hours of Normothermic Preservation," The Journal of Heart and Lung Transplantation, Vol. 16, No. 3, March 1997, developed an autoperfusion set-up in which a swine heart was preserved in a beating, working state for up to 24 hours by being continuously perfused with non-compatible blood. While this system demonstrated the feasibility of safely extending the preservation time of the donor heart, this method is too cumbersome and impractical for widespread use as it requires the removal and preservation of the lungs, liver, pancreas, and kidneys (en bloc) in combination with the heart, all in functioning condition, and all still interacting and interdependent.

There is a need in the art to achieve prolonged ex vivo or ex corporel preservation of the donor heart or other organ that has been harvested from a donor by providing continuous sanguineous perfusion, while maintaining the donor heart or other organ in the normal (beating or functioning) state. Such a technique would eliminate the need to arrest the heart for storage in a hypothermic environment, reduce reperfusion injuries, and overcome many of the problems associated with hypothermic arrest and storage, many of which are clearly time dependent.

There is a further need in the art to provide an apparatus, method and physiologic media for creating an extracorporeal circuit for sanguineously perfusing the harvested organ at normothermic temperatures (about 20° C. to about 37° C.) for prolonged preservation of the harvested organ for up to twenty-four hours or longer. Such an apparatus, method and media would optimally maintain the heart or other harvested organ in the beating or functioning state during the preservation period to insure pulsatile coronary flow and homogenous distribution of the substrate. Such an apparatus, system, method and media would provide the ability to extend the preservation period of the harvested organ beyond the current four hour limit, while avoiding time dependent ischemic injury and prolonged ischemia, thereby preserving coronary endothelial vasomotor function, and preventing the metabolic degradation of high-energy phosphates.

Additionally, such an apparatus, method and media would allow for expanding the organ donor pool, increasing the histocompatibility matching time, and potentially reducing the incidents of cardiac allotransplant vasculopathy. It will be appreciated that prolonging the preservation period of the donor heart would have a dramatic impact on the practice of heart transplantation; a worldwide retrieval of organs would be made possible, thus increasing the pool of available organs. Organs would not go unused because of lack of suitable nearby recipients. Moreover, additional time in combination with storage in the functional state would allow evaluation and testing of the organ to determine, e.g., the immunologic and functional characteristics of each organ, thereby allowing a more complete assessment of the organ, reducing the risk of graft failure.

In summary, the prior art has failed to appreciate the feasibility and/or desirability of employing a near ideal physiologic state ex vivo for harvested organs.

This state is provided for by the compositions, methods and systems/devices of the present invention. A fluid or fluid media is provided comprising (1) donor-compatible whole blood (or leukocyte-depleted whole blood) and (2) a storage solution which includes a carbohydrate source, insulin and other hormones including epinephrine, electrolytes and a buffer such as a source of bicarbonate ions. This fluid or fluid media is delivered to at least one major vessel and optimally to the "exterior" portions of the organ substantially surrounding or bathing the organ. The compositions, methods, systems/devices and media of the present invention can thus be employed to provide ideal storage conditions at normothermic or substantially normothermic temperatures, allowing the organ to remain functioning.

SUMMARY OF THE INVENTION

The present invention provides a system for preserving a human or human-compatible harvested organ in need of preservation or resuscitation during a preservation or evaluation period prior to implantation, including transplantation or reimplantation. The system of the invention also allows the organ to be transported to alternate geographic locations during the preservation period. This system includes:

(a) containment means for containing said organ in communication with a physiologic media or fluid comprising (i) whole blood (or leukocyte-depleted whole blood) compatible with said organ and (ii) a preservation solution;

(b) delivery means for delivering said fluid to at least one major vessel of said organ;

(c) means for carrying said fluid away from said organ;

(d) temperature control means for maintaining the temperature of the perfusate and said organ at a normothermic temperature of about 20° C. to about 37° C.;

(e) pressure control means for controlling the pressure of said fluid;

(f) oxygenation means for oxygenating at least a part of said fluid;

(g) filtering means for removing unwanted filtrate from said fluid, said filtering means preferably positioned between said oxygenation means and said organ; and

(h) flow control means for controlling the flow of at least a part of said fluid.

The system optionally includes means for delivering said fluid to said containment means so that the exterior of said organ is substantially completely bathed in or surrounded by said fluid.

The present invention also provides an organ preservation solution for the preservation of a human or human-compatible harvested organ in a functioning state at a normothermic temperature of about 20° C. to about 37° C. that is particularly useful in combination with the systems and methods of the present invention. These solutions include:

(1) a carbohydrate or other energy source;

(2) sodium chloride;

(3) potassium;

(4) calcium;

(5) magnesium;

(6) bicarbonate ion;

(7) epinephrine; and

(8) adenosine.

These solutions may further include a fatty acid as well as a pharmaceutical agent selected from nitroglycerin, ACE inhibitors, beta blockers, cycloprotection agents, antioxidants, antibiotics, antimicrobial, anti-fungal, anti-viral, immunosuppressives, nonsteroidal anti-inflammatory, steroids, and mixtures thereof.
In a preferred embodiment, the organ preservation solution is substantially free of nonmetabolizable impurities; and has a pH of about 7.4 to about 8.5.

The present invention also provides a method of preserving a human or human-compatible harvested organ in a functioning state during a preservation or evaluation period prior to transplantation or reimplantation. The method includes the steps of:

(a) providing an extracorporeal organ to be preserved or tested;
(b) providing a container means for said organ;
(c) providing a preservation medium or fluid; said fluid media comprising:
(i) whole blood or leukocyte-depleted whole blood that is compatible with said organ; and
(ii) a preservation solution comprising:
(a) a metabolizable carbohydrate;
(b) sodium chloride;
(c) potassium;
(d) calcium;
(e) magnesium;
(f) bicarbonate;
(g) epinephrine; and
(h) insulin;
(d) delivering the fluid to at least one major vessel of the contained functioning organ while the organ is maintained at a normothermic temperature of about 20°C to about 37°C. In a preferred embodiment, the fluid is also delivered to the exterior of the organ.

The present invention provides systems, apparatuses, methods and media for providing optimal and prolonged ex vivo preservation of the donor organ or heart by implementing a method capable of continuous sanguineous perfusion in the normal or near-normal beating or functioning state. According to the systems, apparatuses, methods and media associated with the present invention, this preservation period can be extended for twenty-four hours or more with the heart or other organ maintained in a viable state.

Accordingly, by way of example, in one embodiment, a perfusion apparatus for maintaining a harvested organ during a preservation period is provided. The perfusion apparatus includes a preservation chamber for storing the organ during the preservation period. A perfusion circuit is provided having a first line for providing an oxygenated fluid to the organ, and a second line for carrying fluid away from the organ. The perfusion apparatus also includes a device operably associated with the perfusion circuit for maintaining the organ at a substantially normothermic temperature. Moreover, the perfusion apparatus maintains the organ in a viable state.

In another embodiment, by way of example, a method of perfusing an organ or donor heart is provided. The method comprises providing a preservation chamber for containing the organ, and a perfusion circuit operably associated with the preservation chamber. The perfusion circuit includes a first line for delivering fluid to the organ and a second line for carrying fluid away from the organ. The method also includes providing several chemical solutions to the fluid in the perfusion circuit and perfusing the organ or donor heart with the fluid.

The compositions, methods, systems/devices and media of the present invention maintain the donor heart in the beating state during the preservation period to insure homogeneous distribution of the substrate. Maintaining the heart in the beating state further serves to sustain normal metabolic, contractile and endothelial vasomotor function beyond the four hour hypothermic arrest and storage period currently employed for donor heart preservation.

BRIEF DESCRIPTION OF THE DRAWINGS

The various advantages of the present invention will become apparent to one skilled in the art by reading the following specification and appended claims, and by reference to the following drawings in which:

FIG. 1 is a schematic of the perfusion circuit and the components forming the perfusion system according to a preferred embodiment of the present invention;

FIG. 2 is a cross-sectional view of the preservation chamber for maintaining the donor heart in the beating state according to a preferred embodiment of the present invention;

FIG. 3 is a top plan view of the cover assembly utilized with the preservation chamber according to the present invention;

FIG. 4 is a perspective view of the perfusion system installed on a mobile cart for facilitating transportation of the harvested organ, also according to a preferred embodiment of the present invention;

FIG. 5 is a schematic diagram of the preservation circuit utilizing an integrated container and reservoir according to a preferred embodiment of the present invention;

FIG. 6 is a schematic diagram of the preservation circuit in an alternate configuration and is shown utilizing a pulsatile pump for maintaining a heart in the non-working beating state according to an alternate embodiment of the present invention;

FIG. 7 is a schematic diagram of the preservation system and soft shell container for maintaining a kidney according to the teachings of the present invention;

FIG. 8 is a schematic diagram of the preservation system and soft shell container for maintaining a liver according to the teachings of the present invention;

FIG. 9 is a schematic diagram of the preservation system and soft shell container for maintaining a pancreas according to the teachings of the present invention;

FIG. 10 is a schematic diagram of the preservation system and soft shell container for maintaining one or two lungs according to the teachings of the present invention;

FIG. 11 is a perspective view of the portable preservation system for maintaining any number of organs according to the teachings of the present invention;

FIG. 12 is a flow diagram according to the method of the present invention.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to a perfusion apparatus and method for extending the preservation time of at least one human or human-compatible organ, such as a human heart, which has been harvested for transplantation or reimplantation.

Referring now to FIG. 1, the perfusion system 10 is shown in accordance with the present invention. While FIG. 1
illustrates a schematic of perfusion system 10, it will be appreciated that various modifications to this schematic are within the scope of the present invention. The present invention allows the donor heart to be optimally harvested in the beating state and connected to perfusion system 10 where the organ is maintained in the beating state and provided with a pulsatile, physiologic coronary flow. Accordingly, the donor heart does not have to be arrested prior to its connection with perfusion system 10. Moreover, since the donor heart is not stored in the arrested hypothermic state during the preservation period, time-dependent ischemic injury is eliminated. Another advantage of the present invention is that the perfusate used to extend the preservation period is comprised primarily of autologous (preferably) or some homologous blood which is circulated through the perfusion system 10. Thus, the donor heart is provided with oxygen and essential nutrients during the preservation period which maintains the organ in a viable state. Moreover, cellular waste in carried away from the organ and filtered out of perfusion system 10.

Perfusion system 10 is designed to simulate the human cardiovascular system for maintaining the donor heart 12 in the beating state for periods up to or exceeding 24 hours. As with the human cardiovascular system, perfusion system 10 comprises a closed perfusion circuit 14 for circulating a fluid, comprised of autologous blood and other chemical compositions, to the donor heart 12. Accordingly, perfusion circuit 14 includes one or more arterial lines 16 for providing oxygenated perfusion fluid to donor heart 12, one or more venous lines 18 for carrying depleted perfusion fluid away from donor heart 12. As part of the method of the present invention, the arterial lines 16 are used for perfusing donor organ 12 in the both the non-working and working states. This method of antegrade perfusion will be discussed in more detail below.

With continued reference to FIG. 1, donor heart 12 is shown as being connected to perfusion circuit 14. The donor heart 12 is enclosed within preservation chamber 20 which is preferably made of a hard, clear plastic to allow for visualization of the preserved organ. While it is preferred that preservation chamber 20 is formed from a plastic material such as LI-SPANO plastic, the preservation chamber 20 may also be made of plastic in the form of a zipper bag (not shown) to accommodate the contour and shape of donor heart 12. When preservation chamber 20 is a hard plastic container, a plastic cover assembly 22 is used to seal the preservation chamber 20 and to maintain the sterility and humidity of donor organ 12. When a soft plastic preservation chamber (not shown) is employed, a zipper is used to seal the preservation chamber 20 and to protect the organ. A suitable drain 24 is provided at the lowest portion of preservation chamber 20. The drain 24 is connected to a reservoir 30 via drain line 26 to allow for the return of any blood escaping from the organ 12 during the instrumentation period, or from any leakage occurring during the preservation and transport period.

As disclosed, reservoir 30 is designed to contain approximately 500-3000 ml of fluid. Initially, reservoir 30 is primed with 500-2500 ml of autologous or crossmatched blood which is then pumped throughout perfusion circuit 14. Alternatively, compatible blood or blood substitute is within the scope of the present invention. The reservoir output line 32 is connected to the input of a centrifugal pump 34 (preferred) which circulates the perfusion fluid through the arterial lines 16 of perfusion circuit 14. The preferred pump for this application is the Bioaerodisc 550, manufactured by Medtronic, which propels the blood via magnetic field driven cones. While a conventional roller pump may also be used, the magnetic propulsion generated by centrifugal pump 34 is preferable to minimize hemolysis of the blood.

When pulsatile flow is desired, a pulsatile pump such as the HEARTMATE® electric assist pump manufactured by Thermo Cardiovascular Inc. or the NOVACOR left ventricular assist pump manufactured by Baxter Healthcare Corporation, may be employed. An exemplary pulsatile pump is that disclosed in U.S. Pat. No. 5,505,173 to Chen et al.

The centrifugal pump 34 propels the blood via pump output line 36 into a hollow fiber membrane oxygenator 38. The blood is oxygenated using a preferred mixture of 95% O2 and 5% CO2 at a rate of 1-2 L/min. The preferred oxygenator is a hollow fiber membrane oxygenator, such as the Monolith manufactured by Sorin Biomedica or the MINIMAX PLUS™ manufactured by Medtronic. While not specifically shown in FIG. 1, waste in carried away from the organ and filtered out of perfusion system 10.

The oxygenator output line 42 connects to the pressure of blood 40 which allows pressurized perfusion fluid to be directed to other devices. A water heater 40 provides warmed water through a water circuit 42 which maintains the fluid within perfusion circuit 14 at about 37°C (normothermia). The warmed perfusion fluid then maintains donor heart 12 at a normothermic temperature. Alternatively, water heater 40 can also remove heat from the water circulating through water circuit 42 for cooling the preservation fluid within perfusion circuit 14. Heat can be removed for a variety of reasons. For example, if the apparatus system 10 is preserving organ 12 in an excessively warm environment (i.e., exceeding normothermia), heat can be removed from the fluid to prevent the temperature from exceeding 37°C, or another predetermined temperature. Heat can also be removed from the fluid in order to cool the fluid below 37°C which is desirable when inducing the preserved organ 12 into a low normothermic or mild hypothermic state. This is also desirable prior to arresting the organ 12. Enough heat may be removed for lowering the temperature of the fluid and organ down to about 20°C. The oxygenator output line 44 carries the oxygenated and rewarmed fluid to a filter 46. Preferably, the fluid is filtered with a leukocyte filter, such as the Pall leukocyte-depleting filter manufactured by Pall Filters.

The output of filter 46 is connected to a selector valve 50 via filter output line 48. Selector valve 50 may be placed in one of several positions for directing fluid flow to either the initial perfusion line 52 (for antegrade perfusion via the aorta), the left atrium supply line 54 (for antegrade perfusion via the left atrium), or both lines simultaneously (for priming purposes). Additionally, selector valve 50 may be turned off completely. As will be appreciated, lines 48, 54, and at times lines 52 and 58 form the arterial side 16 of perfusion circuit 14. The opposite end of the initial perfusion line 52 is connected into a tee 56 which then branches to aorta line 58 and the atrial line 50. A straight connector 60 is used for connecting line 60 with the aorta return line 62. A Luer port 63 having a one-way anti-siphoning valve secured thereon is secured to connector 61 which acts as a one-way valve for allowing fluid pumped across connector 61 to flow through aorta return line 62 without siphoning additional fluid from aorta line 60. Luer port 63 operates by allowing air into aorta return line 62 for breaking the siphoning effect of the fluid. Accordingly, the peak of the perfusion line 60 is formed by connector 61 and Luer port 63.
in a functioning and viable state comprising:

- a container for holding said organ and keeping said organ in communication with a fluid media, wherein the fluid media comprises a (i) preservation solution and (ii) a component of whole blood;
- a first fluid line in fluid communication with the organ configured to deliver said fluid media to at least one major vessel of said organ when the organ is held in the container;
- a second fluid line in fluid communication with the organ configured to carry said fluid media away from said organ;
- a heater, a cooler, or both, configured to maintain the temperature of said organ at a temperature of greater than 25°C to about 37°C;
- an oxygenator for oxygenating at least a part of said fluid media; and
- a pump configured to control the flow rate of at least a portion of said fluid media;

wherein said preservation solution comprises:

- (a) a metabolizable carbohydrate;
- (b) sodium chloride;
- (c) a potassium ion; and
- (d) a magnesium ion;

wherein said first fluid line, said second fluid line, said heater and/or cooler, said oxygenator and said pump simulate the donor physiological system for maintaining said organ in a functioning and viable state.

2. A system according to claim 1 further comprising a centrifugal pump.

3. A system according to claim 1 further comprising a pulsatile pump.

4. A system according to claim 1 wherein the oxygenator is a membrane oxygenator.

5. A system according to claim 1 further comprising a portable energy storage and supply unit which has electrical characteristics selected from the group consisting of:

- the reception of 110/220 VAC power at 60/50 Hz;
- the reception of DC power ranging from 12 to 24 volts;
- a bi-directional DC/AC power converter;
- the reception of power from land based vehicles and aircraft;
- a rechargeable power supply; and
- an uninterrupted power supply.

6. A system according to claim 1 wherein said container comprises:

- a continuous side wall;
- an open top;
- a bottom portion joined to said side wall, thereby enclosing said container at the bottom;
- a drain in said bottom portion; and
- a flange protruding outwardly from the open top of the side wall for providing a surface for receiving a cover assembly.

7. A system according to claim 6 further comprising a cover assembly wherein said cover assembly comprises at least one cannula selected from the group consisting of:

- an aortic cannula;
- an arterial cannula;
- a left atrial cannula;
- a pulmonary arterial cannula; and
- a venous cannula.

8. A system according to claim 1 wherein said container comprises a sterile flexible bag which has a contour formed to accommodate the contour and shape of an organ selected from the group consisting of:

- a kidney;
- at least one lung;
- a liver;
- a pancreas;
- a small intestine;
- a blood carrying vessel; and
- a myocutaneous free flap.

9. A system according to claim 8 wherein said container has a contour formed to accommodate the contour of a kidney and additionally comprises cannulas for the renal artery and renal vein of the kidney and a cannula for receiving urine from the ureter.

10. A system according to claim 8 wherein said container has a contour formed to accommodate the contour of a liver and additionally comprises cannulas for the portal vein and hepatic artery of the liver and a cannula for receiving bile from the gallbladder.

11. A system according to claim 8 wherein said container comprises a contour formed to accommodate the contour of a pancreas and additionally cannulas for at least one of the following pancreatic orifices selected from the group consisting of:

- the pancreaticoduodenal artery;
- the splenic vein;
- the portal vein; and
- the pancreatic duct for receiving pancreatic juices.

12. A system according to claim 8 wherein said container has a contour formed to accommodate the contour of at least one lung and additionally comprises cannulas for the pulmonary artery and the trachea of said at least one lung and a ventilation unit.

13. A system according to claim 1 further including a rechargeable power supply for powering the system.

14. A system according to claim 1 additionally comprising a controller for monitoring flow rate, pressure and temperature.

15. A system according to claim 14 wherein the controller adjusts flow rate and pressure.

16. A system according to claim 1 wherein said system is portable.

17. A system for preserving, resuscitating or evaluating at least one human or human-compatible harvested organ comprising:

- a container for holding said organ and keeping said organ in communication with a fluid media, wherein the fluid media comprises a (i) preservation solution and (ii) a component of whole blood;
- a preservation circuit comprising:

- at least one fluid delivery line in fluid communication with the organ configured to deliver said fluid media to at least one major vessel of said organ when said organ is held in the container; and
at least one fluid return line in fluid communication with the organ configured to carry said fluid media away from the organ; a heater, a cooler, or both, configured to maintain the temperature of said organ at a temperature of greater than 25°C to about 37°C; an oxygenation device configured to oxygenate at least a portion of said fluid media; and a pump configured to control the flow rate of at least a portion of said fluid media wherein said preservation solution comprises:
(a) a metabolizable carbohydrate;
(b) sodium chloride;
(c) a potassium ion; and
(d) a magnesium ion.