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ORGAN PERFUSION DEVICE

Abstract

Disclosed is a device for the perfusion of an organ, including: a container of fluid, containing an organ bathed in the perfusion fluid; a first path including an inlet, an outlet and a pump; and a second path including an inlet, an outlet and a pump. The “arterial” outlet of the first path has a diameter smaller than a diameter of the “portal” outlet of the second path. The device additionally includes, between the pump and the outlet of the first path and/or between the pump and the outlet of the second path, an oxygenation unit arranged to oxygenate the fluid emerging from the “arterial” outlet of the first path more than the fluid emerging from the “portal” outlet of the second path. The device can include a communication path between the first path and the second path in order to oxygenate the second path. Use in liver transplantation.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 18/410,112, filed Jan. 11, 2024, which is a continuation of U.S. patent application Ser. No. 18/095,943, filed Jan. 11, 2023, which is a continuation of U.S. patent application Ser. No. 16/622,066, filed Dec. 12, 2019, which is a 371 National Stage of International Application No. PCT/EP2018/065559, filed Jun. 12, 2018, which claims priority to French Application 1755321, filed Jun. 13, 2017, the entirety of which are incorporated herein by reference.

Technical Field
[0002] The present invention relates to a device for perfusing an organ.
[0003] Such a device makes it possible for example to preserve an organ before a transplant. The field of the invention is more particularly, but non-limitatively, that of liver transplantation.
State of the Prior Art
[0004] Liver transplantation makes it possible to cure certain primary liver cancers developed from cirrhosis and terminal liver diseases. Indications continue to increase. In order to increase the number of grafts available, it is necessary to turn to grafts having an extra risk, and that are therefore not commonly used because there is a risk of failure which is potentially fatal for the recipient. In order to reduce this risk of failure, the conventional method is to make the period between the removal and the graft as short as possible. A novel method consists of maintaining the organ to be grafted in circulation ex vivo in a perfusion medium so as to limit the harmful effects of ischemia-reperfusion. Also, in the latter case, increasing the preservation period can make it possible to increase the number of viability tests or even to “repair” certain livers.
[0005] The purpose of the present invention is to propose a device for perfusing an organ making it possible to: [0006] optimize the perfusion conditions of the organ and/or increase the preservation time of the organ, this time being able to be used for example to produce an accurate histological and biological evaluation; and/or [0007] develop functionality tests and consequently predict the risk of primary graft failure, and/or correct metabolic anomalies, macrovesicular steatosis in particular, by a perfusion medium and temperature, flow rate and pressure conditions that are specifically adapted.
DISCLOSURE OF THE INVENTION
[0008] This objective is achieved with a device for perfusing an organ, said device comprising:
[0009] a fluid container, arranged in order to contain an organ immersed in a perfusion fluid,

[0010] a first channel comprising an inlet arranged in order to be submerged in the container, an outlet arranged in order to be submerged in the container, and at least one pump arranged in order to circulate the fluid from the inlet to the outlet of the first channel, [0011] a second channel comprising an inlet arranged in order to be submerged in the container, an outlet arranged in order to be submerged in the container, and at least one pump arranged in order to circulate the fluid from the inlet to the outlet of the second channel, [0012] the outlet of the first channel being separate from the outlet of the second channel.
[0013] Preferably, the outlet of the first channel can have a diameter smaller than a diameter of the outlet of the second channel.
[0014] The device according to the invention can also comprise, between the pump of the first channel and the outlet of the first channel and/or between the pump of the second channel and the outlet of the second channel, means for oxygenating the fluid, preferably arranged in order to create a difference in the oxygenation of the fluid between the outlet of the first channel and the outlet of the second channel.
[0015] The oxygenation means can be arranged in order to give more oxygen to the fluid leaving the outlet of the first channel than the fluid leaving the outlet of the second channel.
[0016] The device according to the invention preferably comprises oxygenation means between the pump of the first channel and the outlet of the first channel.
[0017] The device according to the invention may not comprise means for oxygenating the fluid on the second channel.
[0018] The pump of the first channel and/or the pump of the second channel can be a peristaltic pump.
[0019] The device according to the invention can comprise means for regulating the temperature of the fluid between the pump of the second channel and the outlet of the second channel.
[0020] The device according to the invention may not comprise means for regulating the temperature of the fluid on the first channel.
[0021] The inlet of the first channel and the inlet of the second channel can be separate or one and the same common inlet.
[0022] The inlet of the first channel and the inlet of the second channel are preferably one and the same common inlet.
[0023] The device according to the invention can comprise a separator between the first channel and the second channel: [0024] between the common inlet and the pump of the first channel, and [0025] between the common inlet and the pump of the second channel.
[0026] The device according to the invention can comprise, between the common inlet and the separator, a pump common to the first channel and the second channel.
[0027] The device according to the invention can comprise, between the common inlet and the separator, a reservoir common to the first channel and the second channel.
[0028] The common reservoir is preferably placed between the common pump and the separator.
[0029] The common reservoir can be equipped with dialysis means, preferably arranged on a circuit parallel to the first channel and parallel to the second channel, the dialysis means comprising an inlet starting from the common reservoir and an outlet arriving in the common reservoir.
[0030] The common reservoir can be equipped with a bubble trap.
[0031] The inner diameter of the outlet of the first channel is preferably less than or equal to 12 mm and/or greater than or equal to 5 mm.
[0032] The inner diameter of the outlet of the second channel is preferably less than or equal to 12 mm and/or greater than or equal to 5 mm.
[0033] The pump of the first channel and the pump of the second channel can be arranged and/or programmed so that the fluid has a flow rate at the outlet of the second channel that is greater than a flow rate at the outlet of the first channel.
[0034] The inlet of the first channel and/or the inlet of the second channel may not have a cannula.

[0035] The device according to the invention can comprise means for regulating the temperature of the container.
[0036] The device according to the invention can comprise a first pressure sensor arranged in order to measure the pressure of the fluid in the first channel (preferably at less than 10 cm from the outlet of the first channel), between the pump of the first channel and the outlet of the first channel.
[0037] The device according to the invention can comprise means for controlling the pump of the first channel so as to regulate the flow rate of the pump of the first channel as a function of pressure measurement data provided by the first pressure sensor.
[0038] The device according to the invention can comprise a second pressure sensor arranged in order to measure the pressure of the fluid in the second channel (preferably at less than 10 cm from the outlet of the second channel), between the pump and the second channel and the outlet of the second channel.
[0039] The device according to the invention can comprise means for controlling the pump of the second channel so as to regulate the flow rate of the pump of the second channel as a function of pressure measurement data provided by the second pressure sensor.
[0040] The device according to the invention can comprise a communication channel between the first channel and the second channel, the communication channel preferably starting from the first channel between the oxygenation means and the outlet of the first channel. The communication channel can comprise a flowmeter arranged in order to measure the flow rate of fluid passing through the communication channel and/or means for regulating this flow rate.
[0041] According to another aspect of the invention, a method for perfusing an organ is proposed, implemented in a device comprising: [0042] a fluid container, containing an organ immersed in a perfusion fluid, [0043] a first channel comprising an inlet submerged in the container, an outlet submerged in the container, and at least one pump circulating the fluid from the inlet to the outlet of the first channel, [0044] a second channel comprising an inlet submerged in the container, an outlet submerged in the container, and at least one pump circulating the fluid from the inlet to the outlet of the second channel, [0045] the outlet of the first channel being separate from the outlet of the second channel.
[0046] The outlet of the first channel preferably has a diameter smaller than a diameter of the outlet of the second channel.
[0047] The method according to the invention can comprise, between the pump of the first channel and the outlet of the first channel and/or between the pump of the second channel and the outlet of the second channel, creating, by oxygenation means, a difference in the oxygenation of the fluid between the outlet of the first channel and the outlet of the second channel.
[0048] Creating the difference in the oxygenation can give more oxygen to the fluid leaving the outlet of the first channel than to the fluid leaving the outlet of the second channel.
[0049] The method according to the invention can comprise oxygenation of the fluid between the pump of the first channel and the outlet of the first channel.
[0050] The method according to the invention may not comprise oxygenation of the fluid on the second channel.
[0051] The pump of the first channel and/or the pump of the second channel is preferably a peristaltic pump.
[0052] The method according to the invention can comprise regulating the temperature of the fluid between the pump of the second channel and the outlet of the second channel.
[0053] The method according to the invention may not comprise regulating the temperature of the fluid on the first channel.
[0054] The inlet of the first channel and the inlet of the second channel are preferably one and the same common inlet.
[0055] The device for implementing the method according to the invention can comprise a separator between the first channel and the second channel: [0056] between the common inlet and

the pump of the first channel, and [0057] between the common inlet and the pump of the second channel.
[0058] The device for implementing the method according to the invention can comprise, between the common inlet and the separator, a pump common to the first channel and the second channel.
[0059] The device for implementing the method according to the invention can comprise, between the common inlet and the separator, a reservoir common to the first channel and the second channel.
[0060] The common reservoir can be placed between the common pump and the separator.
[0061] The method according to the invention can comprise dialysis, by dialysis means, of the fluid on a circuit parallel to the first channel and parallel to the second channel, the dialysis means comprising an inlet starting from the common reservoir and an outlet arriving in the common reservoir.
[0062] The common reservoir can be equipped with a bubble trap.
[0063] The inner diameter of the outlet of the first channel can be less than or equal to 12 mm and/or greater than or equal to 5 mm.
[0064] The inner diameter of the outlet of the second channel can be less than or equal to 12 mm and/or greater than or equal to 5 mm.
[0065] The fluid can have a flow rate at the outlet of the second channel that is greater than a flow rate at the outlet of the first channel.
[0066] The inlet of the first channel and/or the inlet of the second channel may not have a cannula.
[0067] The method according to the invention can comprise regulating the temperature of the container.
[0068] The method according to the invention can comprise measuring, by a first pressure sensor, the pressure of the fluid in the first channel (preferably at less than 10 cm from the outlet of the first channel), between the pump of the first channel and the outlet of the first channel. The method according to the invention can comprise controlling the pump of the first channel so as to regulate the flow rate of the pump of the first channel as a function of pressure measurement data provided by the first pressure sensor.
[0069] The method according to the invention can comprise measuring, by a second pressure sensor, the pressure of the fluid in the second channel (preferably at less than 10 cm from the outlet of the second channel), between the pump of the second channel and the outlet of the second channel. The method according to the invention can comprise controlling the pump of the second channel so as to regulate the flow rate of the pump of the second channel as a function of pressure measurement data provided by the second pressure sensor.
[0070] In the method according to the invention, the organ can be perfused by the fluid which is initially at a minimum temperature comprised between 0 and 10° C., before being reheated gradually by the fluid, this fluid gradually reaching a maximum temperature comprised between 33 and 43° C.

Description

DESCRIPTION OF THE FIGURES AND EMBODIMENTS
[0071] Other advantages and features of the invention will become apparent on reading the detailed description of embodiments which are in no way limitative, and from the following attached drawings:
[0072] FIG. **1** is a diagrammatic view of a first embodiment of the invention, which is the preferred embodiment of the invention, and
[0073] FIG. **2** illustrates different variants or modifications, each of which can be implemented in the first embodiment of the invention independently or in combination with other variants.

[0074] As this embodiment is in no way limitative, variants of the invention can in particular be considered comprising only a selection of the characteristics described or illustrated hereinafter, in isolation from the other characteristics described or illustrated (even if this selection is isolated within a phrase containing these other characteristics), if this selection of characteristics is sufficient to confer a technical advantage or to differentiate the invention with respect to the state of the prior art. This selection comprises at least one, preferably functional, characteristic without structural details, and/or with only a part of the structural details if this part alone is sufficient to confer a technical advantage or to differentiate the invention with respect to the state of the prior art.
[0075] Firstly, with reference to FIG. **1** a first embodiment of the device **1** according to the invention will be described.
[0076] The device **1** is a device for perfusing an organ **2**.
[0077] This organ **2**, which does not form part of the device **1**, is for example a liver (preferably human) intended for transplantation.
[0078] The device **1** comprises a fluid container **3**, arranged in order to contain the organ (**2**) immersed in a perfusion fluid **4**.
[0079] The fluid **4** does not form part of the device **1**, but is a consumable of the device **1**.
[0080] The container **3** is for example an open tank made from stainless steel.
[0081] The container **3** is preferably equipped with grips which make it possible to fasten one or more additional tubes (not shown) of suitable gauge(s), each additional tube (not shown) being connected to a natural channel (example: the bile duct for the liver, the ureter for a kidney) and the collection being carried out by gravity in a receptacle placed outside and below the container **3**.
[0082] The container **3** is for example a BackTherm container, Connectorate AG, Bernstrasse 390 CH-8953 Dietkon/Switzerland.
[0083] The perfusion fluid **4** is preferably an acellular organ preservation liquid or a buffered physiological liquid, with or without added molecules or cells for transporting oxygen or for a pharmacological effect.
[0084] The device **1** comprises a first channel **5** comprising: [0085] an inlet **51** arranged in order to be submerged in the container **3**, [0086] an outlet **52** (called arterial outlet) arranged in order to be submerged in the container **3**, and [0087] at least one pump **53** arranged in order to circulate the fluid **4** from the inlet **51** to the outlet **52** of the first channel **5**.
[0088] The inner diameter of the outlet **52** of the first channel **5** is less than or equal to 12 mm (or ⅜ inch) and/or greater than or equal to 5 mm (or ⅛ inch).
[0089] The different elements **51**, **10**, **11**, **9**, **53**, **55**, **7** of the first channel **5** are preferably connected by tubes made from silicone and/or polyvinyl chloride (PVC).
[0090] The inner diameter of these tubes of the first channel **5** from its inlet **51** to its outlet **52** is less than or equal to 12 mm (or ⅜ inch) and/or greater than or equal to 5 mm (or ⅛ inch).
[0091] The device **1** comprises a second channel **6** comprising: [0092] an inlet **61** arranged in order to be submerged in the container **3**, [0093] an outlet **62** (called portal outlet) arranged in order to be submerged in the container **3**, and [0094] at least one pump **63** arranged in order to circulate the fluid **4** from the inlet **61** to the outlet **62** of the second channel **6**.
[0095] The inner diameter of the outlet **62** of the second channel **6** is less than or equal to 12 mm (or ⅜ inch) and/or greater than or equal to 5 mm (or ⅛ inch).
[0096] The different elements **61**, **10**, **11**, **9**, **63**, **65**, **8** of the second channel **6** are preferably connected by tubes made from silicone and/or polyvinyl chloride (PVC).
[0097] The inner diameter of these tubes of the second channel **6** from its inlet **61** to its outlet **62** is less than or equal to 12 mm (or ⅜ inch) and/or greater than or equal to 5 mm (or ⅛ inch).
[0098] The outlet **52** of the first channel is separate from the outlet **62** of the second channel.
[0099] The inlet **51** of the first channel **5** does not have a cannula. It is a simple tube end with or without a connector suitable for the diameter of the tube on at least one of its ends.

[0100] By cannula is meant a tube that is specifically adapted to be inserted into an organic natural vessel or an organic natural duct.
[0101] The inlet **61** of the second channel **6** does not have a cannula. It is a simple tube end.
[0102] The outlet **52** of the first channel **5** does not have a cannula.
[0103] The outlet **62** of the second channel **6** does not have a cannula.
[0104] The arterial outlet **52** of the first channel **5** has a diameter D1 that is smaller than a diameter D2 of the portal outlet **62** of the second channel **6**, preferably by at least 25% i.e. $(D2-D1)/D2>25\%$.
[0105] The device **1** also comprises means **7** for oxygenating the fluid **4** arranged and/or programmed and/or adjusted in order to increase the oxygen level in the fluid **4** passing through the means **7**.
[0106] The oxygenation means **7** are arranged and/or programmed and/or adjusted in order to create a difference in the oxygenation of
the fluid **4** between the outlet **52** of the first channel **5** and the outlet **62** of the second channel **6**.
[0107] More specifically, the oxygenation means **7** are arranged and/or programmed and/or adjusted in order to give more oxygen to the fluid **4** leaving the outlet **52** of the first channel **5** than to the fluid **4** leaving the outlet **62** of the second channel **6**. In other words, the oxygenation means **7** are arranged and/or programmed and/or adjusted so that the final total concentration C1 of oxygen dissolved in the fluid **4** leaving the outlet **52** of the first channel **5** is greater than the final total concentration C2 of oxygen dissolved in the fluid **4** leaving the outlet **62** of the second channel **6**, preferably by at least 25% or even 50% i.e. $(C1-C2)/C1>25\%$ or even 50%.
[0108] Thus, due to the means **7**, promoting oxygenation of the arterial channel **5** in comparison with the portal channel **6**, the organ perfusion conditions are improved under natural physiological conditions.
The organ preservation time is improved.
The oxygenation means **7** are situated in the first channel **5**.
[0109] The oxygenation means **7** are situated in the first channel **5** between the pump **53** of the first channel **5** and the outlet **52** of the first channel **5**.
[0110] The oxygenation means **7** are for example an oxygenator referenced Dideco D902 ECMO Phisio ND Lilliput (Mirandola, Italy). The device **1** does not comprise oxygenation means on the second channel **6**. In other words, the device **1** does not comprise on the second channel **6** means arranged in order to increase, on the second channel **6**, the concentration of oxygen dissolved in the fluid **4**.
[0111] The pump **53** of the first channel **5** is a peristaltic pump, for example a cardioplegia pump of a Stokert SIII or S5 or SC (Sorin Group LivaNova) extracorporeal circulation (ECC) console or subsequent model.
[0112] Similarly, the pump **63** of the second channel **6** is a peristaltic pump, for example a cardioplegia pump of a Stokert SIII or S5 or SC (Sorin Group/LivaNova) extracorporeal circulation (ECC) console or subsequent model.
[0113] The device **1** comprises, in the second channel **6**, means **8** for regulating the temperature of the fluid situated between the pump **63** of the second channel **6** and the outlet **62** of the second channel **6**, over a range of temperatures from at least −10° C. to +40° C., or preferably at least between 4° C. and 37° C.
[0114] The temperature regulation means **8** comprise for example a heat exchanger referenced “CSC **14** cardioplegia heat exchanger” (Sorin Group/LivaNova).
[0115] On the other hand, the device **1** does not comprise means for regulating the temperature of the fluid **4** on the first channel **5**.
[0116] In a particularly astute manner, the structure of the device **1** is thus rationalized, manufacturing is simplified, and costs are reduced: [0117] by only providing oxygenation means **7** on the first channel **5** in order to create an imbalance close to natural conditions, and/or [0118] by

only providing temperature regulation means **8** on the second channel **6** which has the higher flow rate.
[0119] It is noted in FIG. **1** that the inlet **51** of the first channel **5** and the inlet **61** of the second channel **6** are one and the same common inlet.
The device **1** comprises: [0120] between the common inlet **51**, **61** and the pump **53** of the first channel **5**, and [0121] between the common inlet **51**, **61** and the pump **63** of the second channel **6**, [0122] a separator **9** between the first channel **5** and the second channel **6**.
[0123] In other words, the first channel **5** and the second channel **6** are not totally common and merged, but only over a portion starting from the common inlet **51**, **61** and up to the separator **9**. The pumps **53** and **63** are separate.
[0124] The pump **53** is situated on the first channel **5** after the separator **9**, but not on the second channel **6**.
[0125] The pump **63** is situated on the second channel **6** after the separator **9**, but not on the first channel **5**.
[0126] The device **1** comprises, between the common inlet **51**, **61** and the separator **9**, a pump **10** common to the first channel **5** and the second channel **6**.
[0127] The common pump **10** is a peristaltic pump, for example a main pump of a Stokert SIII or S5 or SC (Sorin Group/LivaNova) extracorporeal circulation (ECC) console or subsequent model.
[0128] The device **1** comprises, between the common inlet **51**, **61** and the separator **9**, a reservoir **11** common to the first channel **5** and the second channel **6**.
[0129] The reservoir **11** is for example a reservoir **11** referenced D 754 PH ND (Sorin Group).
[0130] The common reservoir **11** is placed between the common pump **10** and the separator **9**.
[0131] The common reservoir **11** is equipped with dialysis means **12** placed on a circuit parallel to the first channel **5** and parallel to the second channel **6**.
[0132] The dialysis means **12** comprise an inlet starting from the common reservoir **11** and an outlet arriving in the common reservoir **11**.
[0133] The dialysis means comprise for example a Polyflux 2H artificial kidney dialyzer (Gambro/Baxter) as well as a dialysis system of the Artis type.
[0134] The common reservoir **11** is equipped with a bubble trap (not shown) arranged in order to remove bubbles of gas from the fluid **4** passing through the reservoir **11**. The device **1** does not comprise another bubble trap on the channels **5**, **6** between the reservoir **11** and the outlets **52**, **62**.
[0135] The pump **53** of the first channel and the pump **63** of the second channel are arranged and/or programmed (via the control means **13** described below) so that the fluid **4** has a flow rate Q**65** at the outlet **62** of the second channel that is greater than the flow rate Q**55** at the outlet **52** of the first channel, preferably by at least 25% i.e. (Q**65**−Q**55**)/Q**65**>25%.
[0136] The device **1** is arranged and/or programmed in order to adjust (via the means **13** described below) the flow rate of each of the pumps from the pump **53** of the first channel and the pump **63** of the second channel independently of one another. This makes it possible to be able to act separately on the arterial **5** and portal **6** channels in particular for functionality tests and/or in order to optimize the perfusion conditions to which the organ **2** is subjected.
[0137] More specifically, the device **1** is arranged and/or programmed in order to adjust (via the means **13** described below) the flow rate of each of the pumps from the pump **10**, the pump **53** of the first channel and the pump **63** of the second channel independently of one another.
[0138] The device **1** comprises means **14** for regulating the temperature of the container **3** (and thus regulating the temperature of the fluid **4** and/or of the organ **2** contained in the container **3**), over a range of temperatures from at least −10° C. to +40° C., or preferably of at least between 4° C. and 37° C.
[0139] The means **14** typically comprise a regulator included in the electronics system of the BackTherm (BackTherm, Connectorate AG, Bernstrasse 390 CH-8953 Dietkon/Switzerland) which bears the container **3**.

[0140] The device **1** comprises a first pressure sensor **54** arranged in order to measure the pressure of the fluid **4** in the first channel **5** at less than 10 cm from the outlet **52** of the first channel, between the pump **53** of the first channel **5** and the outlet **52** of the first channel **5**.
[0141] The sensor **54** is for example a sensor referenced Edwards Lifesciences TruWave™ (EdisonStr. 6 85716 Unterschleissheim, Germany).
[0142] The device **1** comprises means **13** arranged and/or programmed to control the pump **53** of the first channel **5** so as to regulate the flow rate of the pump **53** of the first channel **5** as a function of pressure measurement data provided by the first pressure sensor **54**.
[0143] The device **1** comprises a second pressure sensor **64** arranged in order to measure the pressure of the fluid **4** in the second channel **6** at less than 10 cm from the outlet **62** of the second channel, between the pump **63** of the second channel **6** and the outlet **62** of the second channel **6**.
[0144] The sensor **64** is for example a sensor referenced Edwards Lifesciences TruWave™ (EdisonStr. 6 85716 Unterschleissheim, Germany).
[0145] The device **1** comprises means **13** arranged and/or programmed to control the pump **63** of the second channel **6** so as to regulate the flow rate of the pump **63** of the second channel **6** as a function of pressure measurement data provided by the second pressure sensor **64**.
The means **13** only comprise technical means.
[0146] The means **13** comprise at least one computer, a central or calculation unit, an analogue electronic circuit (preferably dedicated),
a digital electronic circuit (preferably dedicated), a microprocessor (preferably dedicated) and/or software means.
[0147] In this non-limitative embodiment example of the device **1**, the means **13** can for example comprise or be adapted from a control system of a Stokert SIII or S5 or SC (Sorin Group/LivaNova) extracorporeal circulation (ECC) console or subsequent model.
[0148] The control means **13** are arranged and/or programmed in order to: [0149] send a command to the pump **53**, as a function of the pressure measurement data provided by the pressure sensor **54**, until the pressure measured by the sensor **54** corresponds to or is less than a first pressure setting (called "arterial setting"), and/or [0150] send a command to the pump **63**, as a function of pressure measurement data provided by the second pressure sensor **64**, until the pressure measured by the sensor **64** corresponds to or is less than a second pressure setting (called "portal setting").
[0151] The control means comprise means for storing the first pressure setting (called "arterial setting") and the second pressure setting (called "portal setting"), and/or means (buttons, touch screen, etc.) for input by a user of the first pressure setting (called "arterial setting") and the second pressure setting (called "portal setting").
[0152] The reservoir **11** comprises control means (not shown, but able for example to comprise the control means **13**) arranged and/or programmed in order to: [0153] trigger an alarm (acoustic, visual, or other) and/or stop the pump **10** if the level of fluid **4** in the reservoir **11** exceeds a maximum threshold, and/or [0154] trigger an alarm (acoustic, visual, or other) and/or stop the pumps **53** and **63** if the level of fluid **4** in the reservoir **11** is less than a minimum threshold.
[0155] The device **1** also comprises a flow rate sensor **55** situated on the first channel **5** downstream of the pump **53** (more specifically between the pump **53** and the outlet **52**, more specifically between the pump **53** and the means **7**) and arranged in order to measure the flow rate Q**55** of the fluid **4** on the first channel **5** downstream of the pump **53** (more specifically between the pump **53** and the outlet **52**, more specifically between the pump **53** and the means **7**).
[0156] The device **1** also comprises a flow rate sensor **65** situated on the second channel **6** downstream of the pump **63** (more specifically between the pump **63** and the outlet **62**, more specifically between the pump **63** and the means **8**) and arranged in order to measure the flow rate Q**65** of the fluid **4** on the second channel **6** downstream of the pump **63** (more specifically between the pump **63** and the outlet **62**, more specifically between the pump **63** and the means **8**).
[0157] The device **1** also comprises a flow rate sensor **20** situated on the common part of the first

channel **5** and the second channel **6** downstream of the pump **10** (more specifically between the pump **10** and the separator **9**, more specifically between the pump **10** and the reservoir **11**) and arranged in order to measure the flow rate Q**20** of the fluid **4** on the common part of the first channel **5** and the second channel **6** downstream of the pump **10** (more specifically between the pump **10** and the separator **9**, more specifically between the pump **10** and the reservoir **11**).
[0158] Each of the flow rate sensors **20**, **55**, **65** is for example an external electromagnetic flowmeter or means of the Stokert SIII or S5 or SC (Sorin Group/LivaNova) (ECC) Console which calculates the flow rate as a function of the rotational speed of each pump respectively **10**, **53**, **63** and the diameter of the tubes.
[0159] The device **1** also comprises means (not shown, but able for example to comprise the control means **13**) arranged and/or programmed in order to trigger an alarm (acoustic, visual or other) and/or modify flow rate controls of the pumps **10**, **55** and/or **65** as a function of the sign and/or of the value of:

$$(Q55-Q65)-Q10.$$

[0160] This makes it possible to avoid the container **3** overflowing or emptying.
[0161] Also, the device **1** makes it possible to correct metabolic anomalies of the organ **2**, macrovesicular steatosis in particular, by a specifically adapted perfusion medium and temperature (via the means **8**, **14**), flow rate (via the sensors **55** and **65** and the means **13**) and pressure (via the sensors **54** and **64** and the means **13**) conditions.
[0162] A method according to the invention for perfusing the organ **2**, implemented in the device **1**, will now be described. For this method: [0163] the container **3** contains the organ **2** which is immersed in the perfusion fluid **4**, [0164] the inlet **51** is submerged in the container **3**, the outlet **52** is submerged in the container **3**, and the pump **53** circulates the fluid from the inlet **51** to the outlet **52** of the first channel **5**, [0165] the inlet **61** is submerged in the container **3**, the outlet **62** is submerged in the container **3**, and the pump **63** circulates the fluid from the inlet **61** to the outlet **62** of the second channel **6**.
[0166] The method comprises creating, by oxygenation means **7**, a difference in the oxygenation of the fluid **4** between the outlet **52** of the first channel **5** and the outlet **62** of the second channel **6**.
[0167] In other words, the difference in the oxygenation is such that the final total concentration C1 of oxygen dissolved in the fluid **4**
leaving the outlet **52** of the first channel **5** is greater than the final total concentration C2 of oxygen dissolved in the fluid **4** leaving the outlet **62** of the second channel **6**, preferably by at least 25% or even 50% i.e. $(C1-C2)/C1>25\%$ or even 50%.
[0168] This creating a difference in the oxygenation is carried out by injecting and dissolving oxygen in the fluid **4** (preferably only) between the pump **53** of the first channel **5** and the outlet **52** of the first channel **5**.
[0169] Creating the difference in the oxygenation gives more oxygen to the fluid **4** leaving the outlet **52** of the first channel **5** than to the fluid **4** leaving the outlet **62** of the second channel **6**.
[0170] The method comprises oxygenating, by the means **7**, the fluid **4** between the pump **53** of the first channel **5** and the outlet **52** of the first channel **5**.
[0171] The method does not comprise oxygenating the fluid **4** on the second channel **6**.
[0172] The method comprises regulating, by the means **8**, the temperature of the fluid **4** between the pump **63** of the second channel **6** and the outlet **62** of the second channel **6**.
[0173] The method does not comprise regulating the temperature of the fluid **4** over the first channel **5**.
[0174] The method comprises dialysis, by dialysis means **12**, of the fluid **4** on the circuit parallel to the first channel **5** and parallel to the second channel **6**.
[0175] The method comprises regulating, by the means **14**, the temperature of the container **3** and thus of the liquid **4** and the organ **2** contained in the container **3**.

[0176] The method comprises controlling, by the means **13**, the pump **53** of the first channel **5** and the pump **63** of the second channel **6** such that the fluid **4** has a flow rate Q**65** at the outlet **62** of the second channel **6** greater than a flow rate Q**55** at the outlet **52** of the first channel **5**.
[0177] During this method the fluid has a flow rate Q**65** at the outlet **62** of the second channel that is greater than a flow rate Q**55** at the outlet **52** of the first channel **5**, preferably of at least 25% i.e. (Q**65**−Q**55**)/Q**65**>25%.
[0178] The method comprises triggering an alarm (acoustic, visual or other) and/or modifying the flow rate controls of the pumps **10**, **55** and/or **65** as a function of the sign and/or of the value of:

(Q55−Q65)−Q10
[0179] This makes it possible to avoid the container **3** overflowing or emptying.
[0180] The method comprises measuring, by the first pressure sensor **54**, the pressure of the fluid **4** in the first channel **5** (at less than 10 cm from the outlet **52** of the first channel **5**), between the pump **53** of the first channel **5** and the outlet **52** of the first channel **5**.
[0181] The method comprises controlling, by the means **13**, the pump **53** of the first channel so as to regulate the flow rate Q**55** of the pump **53** of the first channel **5** as a function of pressure measurement data provided by the first pressure sensor **54**.
[0182] The method comprises measuring, by the second pressure sensor **64**, the pressure of the fluid **4** in the second channel **6** (at less than 10 cm from the outlet **62** of the second channel **6**), between the pump **63** of the second channel **6** and the outlet **62** of the second channel **6**.
[0183] The method comprises controlling, by the means **13**, the pump **63** of the second channel so as to regulate the flow rate Q**65** of the pump of the second channel **6** as a function of pressure measurement data provided by the second pressure sensor **64**.
[0184] More specifically, with regard to regulating the flow rates Q**55** and Q**65**, the method comprises: [0185] sending, by the means **13**, a command to the pump **53**, as a function of pressure measurement data provided by the pressure sensor **54**, until the pressure measured by the sensor **54** corresponds to or is less than the first pressure setting (called “arterial setting”), and/or [0186] sending, by the means **13**, a command to the pump **63**, as a function of pressure measurement data provided by the second pressure sensor **64**, until the pressure measured by the sensor **64** corresponds to or is less than the second pressure setting (called “portal setting”).
[0187] The method comprises: [0188] triggering an alarm (acoustic, visual, or other) and/or stopping the pump **10** if the level of fluid **4** in the reservoir **11** exceeds a maximum threshold, and/or [0189] triggering an alarm (acoustic, visual, or other) and/or stopping the pumps **53** and **63** if the level of fluid **4** in the reservoir **11** is less than a minimum threshold.
[0190] In this embodiment of the method according to the invention, the means **8** for regulating the temperature of the fluid are used in order to regulate the temperature of the fluid over an entire range: [0191] starting from a minimum temperature typically comprised between 0 and 10° C., preferably between 2° C. and 8° C., preferably between 3° C. and 6° C., typically equal to 4° C., [0192] up to a maximum temperature typically comprised between 33 and 43° C., preferably between 35° C. and 41° C., preferably between 36° C. and 39° C., typically equal to 37° C.
[0193] In this embodiment of the method according to the invention, the organ **2** is perfused by the fluid which is initially at the level of the means **8** at the minimum temperature (typically 4° C.; in order to allow the organ **2** to rebuild stores of oxygen), before being gradually reheated by the fluid, this fluid gradually reaching the maximum temperature (typically 37° C.) at the level of the means **8**.
[0194] This distinguishes the invention with respect to normothermic use as can be the case for the devices of the prior art.
[0195] Of course, the invention is not limited to the examples which have just been described and numerous adjustments can be made to these examples without exceeding the scope of the invention.

[0196] For example, non-limitatively, in variants of the device **1** which can be combined with one another and/or the method previously illustrated: [0197] the device **1** can also comprise, in the second channel **6**, between the pump **63** of the second channel **6** and the outlet **62** of the second channel **6**, means **7** for oxygenating the fluid **4**, arranged in order to increase the level of oxygen in the fluid **4** passing through the means **7** and/or for creating the difference in the oxygenation of the fluid between the outlet **52** of the first channel and the outlet **62** of the second channel, and/or [0198] the device **1** can also comprise in the first channel **5**, between the pump **53** of the first channel **5** and the outlet **52** of the first channel **5**, means for regulating the temperature of the fluid **4**, and/or [0199] the dialysis means **12** can be removed, and/or [0200] with reference to FIG. **2**, the device **1** can also comprise, a communication channel **72** between the first channel **5** and the second channel **6**, after the oxygenator **7** (i.e. the channel **72** starting from the first channel **5** between the oxygenation means **7** and the outlet **52** and arriving in the second channel **6** preferably between the pump **63** of the second channel **6** and the outlet **62** of the second channel **6**). Even more preferably, the channel **72** arrives in the second channel **6** between the means **8** for regulating the temperature of the fluid and the outlet **62** of the second channel **6**. This channel **72** is arranged in order to guide (and guides, in the embodiment of the method according to the invention of this variant) fluid from the first channel **5** to the second channel **6**. This channel **72** is arranged in order to oxygenate the second channel **6**, so as to reduce or better control or refine the difference in the oxygenation between the two channels **5**, **6** and thus approach the physiological conditions of the organ **2** with even closer accuracy. A flowmeter **73** can be connected to the channel **72**, this flowmeter **73** being arranged in order to measure the flow rate of fluid passing through the channel **72**. In addition to this flowmeter, means **74** for regulating this flow rate (comprising for example a valve) can be added in order to control or modify the flow rate of this communication channel **72**. The flowmeter **73** and the means **74** for controlling the flow rate are optional, and/or—the pump **10** can be removed, and replaced by a gravity system, the container **3** being placed in a raised position with respect to the reservoir **11**. Of course, the various characteristics, forms, variants and embodiments of the invention can be combined with one another in various combinations, provided that they are not incompatible or mutually exclusive. In particular, all the variants and embodiments described previously can be combined with each other.

Claims

1. A device for perfusing an organ, said device comprising: a fluid container containing perfusion fluid; a common channel having a common inlet fluidly connected to the fluid container, and a separator splitting the common channel into a first channel with a first outlet fluidly connected to the fluid container, and a second channel with a second outlet fluidly connected to the fluid container, wherein the first outlet has a first diameter that is at least 25% smaller than a second diameter of the second outlet; a first pump configured to circulate fluid in the fluid container from the common inlet to the first outlet; a second pump configured to circulate the fluid in the fluid container from the common inlet to the second outlet; and an oxygenation means configured to increase a concentration of oxygen dissolved in the perfusion fluid.
2. The device of claim 1, wherein the oxygenation means is configured to create a difference in oxygenation of the fluid between the first outlet and the second outlet.
3. The device of claim 1, wherein the oxygenation means is configured to give more oxygen to the fluid leaving the first outlet than to the fluid leaving the second outlet.
4. The device of claim 1, wherein the oxygenation means is disposed on the first channel between the first pump and the first outlet.
5. The device of claim 1, wherein the oxygenation means is only disposed on the first channel.
6. The device of claim 1, further comprising a temperature regulation means disposed on the second channel.

7. The device of claim 1, wherein the concentration of oxygen dissolved in the fluid leaving the first outlet is at least 25% greater than the concentration of oxygen dissolved in the fluid leaving the second outlet.
8. The device of claim 1, further comprising a third pump connected to the common channel.
9. The device of claim 8, further comprising a reservoir disposed between the third pump and the separator.
10. The device of claim 1, wherein the fluid has a first flow rate at the first outlet and a second flow rate at the second outlet, the second flow rate being greater than the first flow rate.
11. The device of claim 10, wherein the second flow rate at the second outlet is at least 25% greater than the first flow rate at the first outlet.
12. A device for perfusing an organ, said device comprising: a fluid container; a common fluid channel having a common inlet fluidly connected to the fluid container; a separator configured to separate the common fluid channel into a first fluid channel leading to a first outlet fluidly connected to the fluid container, and a second fluid channel leading to a second outlet fluidly connected to the fluid container, wherein the first outlet is separate from the second outlet; a means for oxygenating fluid positioned on only one of the first or second fluid channel; and a temperature regulation means positioned on only one of the first or second fluid channel, such that each of the first and second fluid channel has either the means for oxygenating fluid or the temperature regulation means.
13. The device of claim 12, further comprising a fluid communication channel connecting the first fluid channel and the second fluid channel, positioned downstream of the means for oxygenating fluid and the temperature regulation means.
14. The device of claim 13, wherein the fluid communication channel includes a flowmeter configured to measure a flow rate of fluid passing through the fluid communication channel.
15. The device of claim 13, wherein the means for oxygenating fluid is positioned on the first fluid channel and the fluid communication channel includes a valve configured to control fluid flow from the first fluid channel into the second fluid channel.
16. The device of claim 12, wherein the first outlet has a first diameter smaller than a second diameter of the second outlet.
17. The device of claim 12, further comprising a first pump on the first fluid channel, a second pump on the second fluid channel, and a third pump on the common fluid channel, wherein the first, second, and third pumps are configured to be adjusted independently of one another.
18. The device of claim 12, wherein a fluid flowing through the first and second fluid channels has a first flow rate at the first outlet and a second flow rate at the second outlet, the second flow rate being at least 25% greater than the first flow rate at the first outlet.
19. The device of claim 12, further comprising a first pressure sensor disposed in the first fluid channel adjacent the first outlet and a second pressure sensor disposed in the second fluid channel adjacent the second outlet.
20. A method for perfusing an organ submerged in a fluid container in a perfusion fluid having a concentration of oxygen dissolved therein, the method comprising: submerging a first outlet of a first fluid channel in the fluid container, the first fluid channel coupled to a common channel with a common inlet submerged in the fluid container, the first fluid channel having at least a first pump circulating the perfusion fluid from the common inlet to the first outlet; submerging a second outlet of a second fluid channel in the fluid container, the second fluid channel coupled to the common channel, the second fluid channel having at least a second pump circulating the perfusion fluid from the common inlet to the second outlet; and oxygenating the perfusion fluid such that a difference in oxygenation of the perfusion fluid between the first outlet and the second outlet is created.