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(54) **TEMPERATURE MANAGEMENT SYSTEM
AND METHOD FOR BURN PATIENTS**

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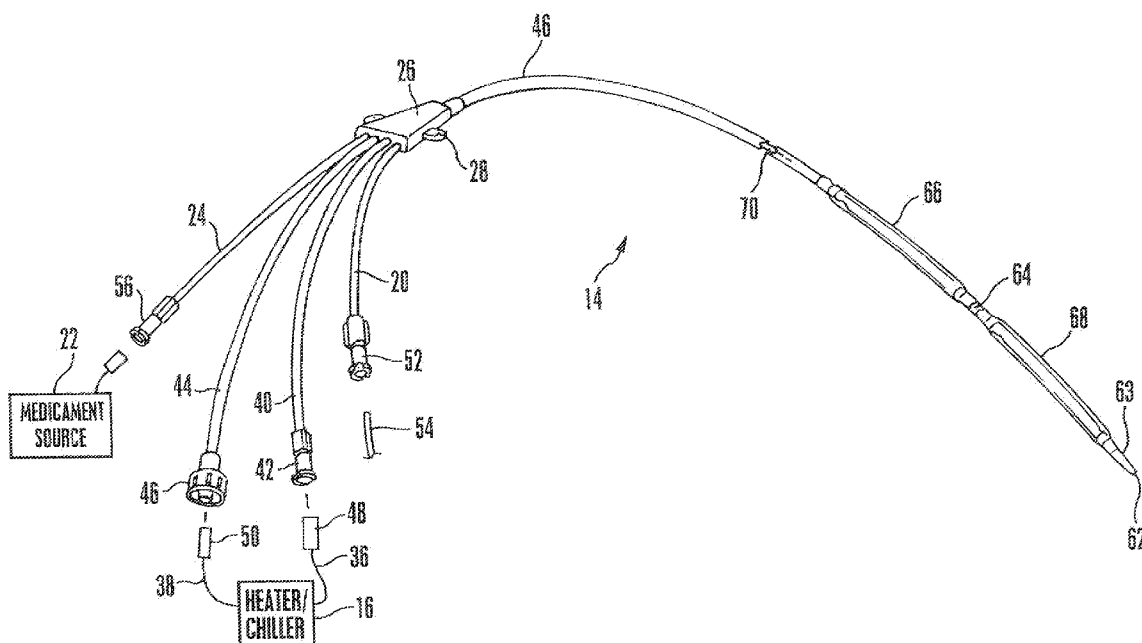
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(63) Continuation of application No. 11/602,738, filed on
Nov. 21, 2006, now Pat. No. 7,892,270.

(57) **ABSTRACT**

Intravascular closed loop heat exchange catheters are used to
manage temperature in burn patients.



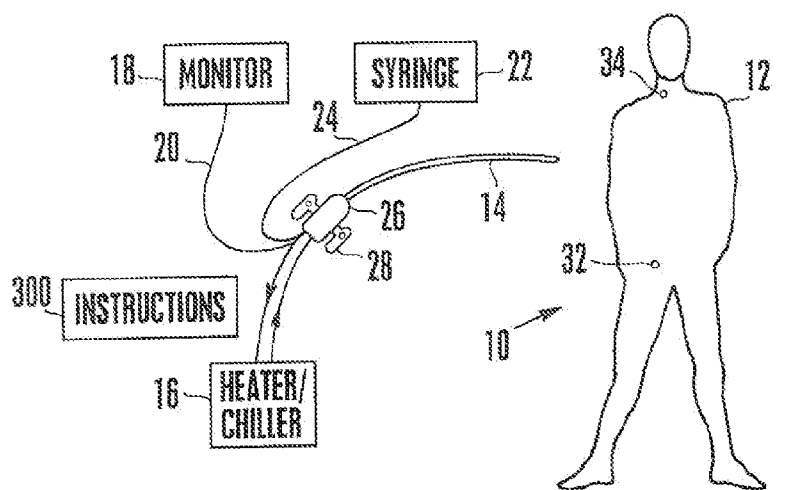


Figure 1

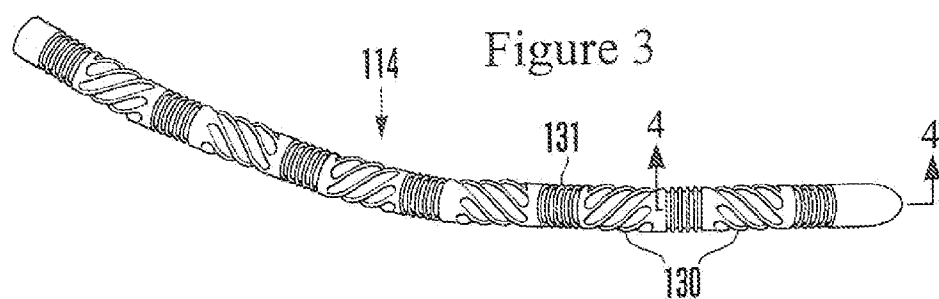


Figure 3

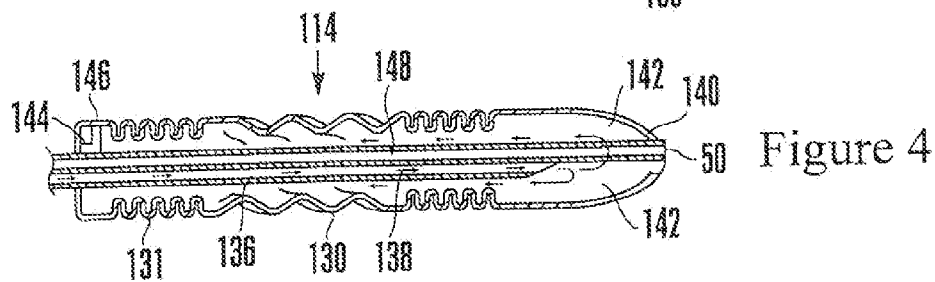


Figure 4

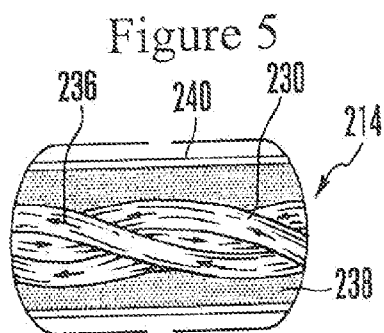


Figure 5

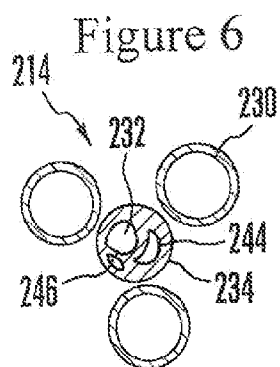
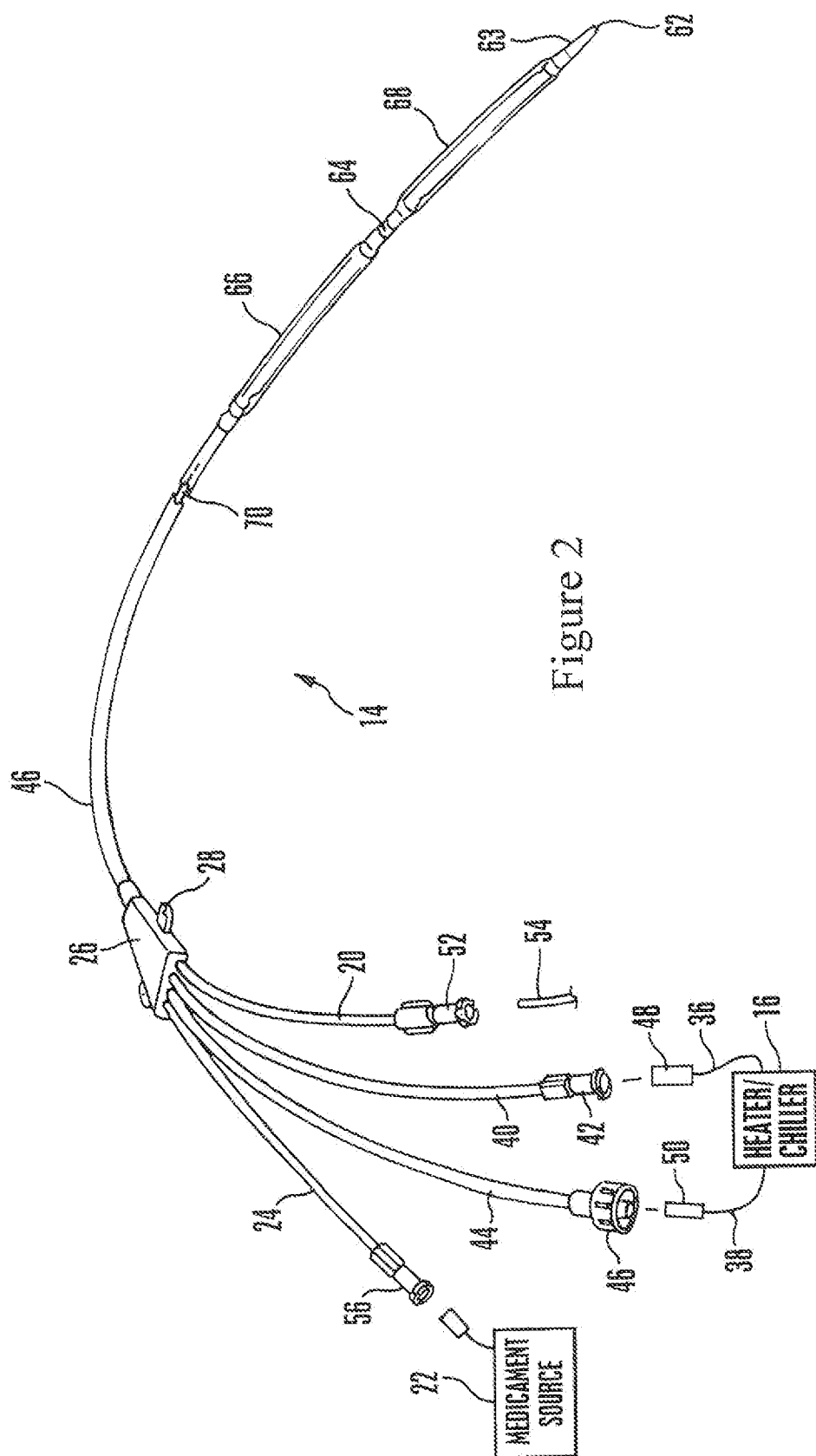


Figure 6



TEMPERATURE MANAGEMENT SYSTEM AND METHOD FOR BURN PATIENTS

FIELD OF THE INVENTION

[0001] The present invention relates generally to patient temperature control systems.

BACKGROUND OF THE INVENTION

[0002] It has been discovered that the medical outcome for a patient suffering from severe brain trauma or from ischemia caused by stroke or heart attack or cardiac arrest is improved if the patient is cooled below normal body temperature (37° C.). Furthermore, it is also accepted that for such patients, it is important to prevent hyperthermia (fever) even if it is decided not to induce hypothermia. Moreover, in certain applications such as post-CABG surgery, it might be desirable to rewarm a hypothermic patient.

[0003] As recognized by the present invention, the above-mentioned advantages in regulating temperature can be realized by cooling or heating the patient's entire body. Moreover, the present invention understands that since many patients already are intubated with central venous catheters for other clinically approved purposes anyway such as drug delivery and blood monitoring, providing a central venous catheter that can also cool or heat the blood requires no additional surgical procedures for those patients. The following U.S. patents, all of which are incorporated herein by reference, disclose various intravascular catheters/systems/methods: U.S. Pat. Nos. 6,749,625, 6,786,916, 6,581,403, 6,454,792, 6,436,130, 6,146,411, 6,109,783, 6,419,643, 6,416,533, 6,409,747, 6,405,080, 6,393,320, 6,368,304, 6,338,727, 6,299,599, 6,290,717, 6,287,326, 6,165,207, 6,149,670, 6,146,411, 6,126,684, 6,306,161, 6,264,679, 6,231,594, 6,149,676, 6,149,673, 6,110,168, 5,989,238, 5,879,329, 5,837,003, 6,383,210, 6,379,378, 6,364,899, 6,325,818, 6,312,452, 6,261,312, 6,254,626, 6,251,130, 6,251,129, 6,245,095, 6,238,428, 6,235,048, 6,231,595, 6,224,624, 6,149,677, 6,096,068, 6,610,083, 6,042,559, and U.S. patent application Ser. No. 10/355,776.

[0004] As understood herein the control of body temperature for burn patients is also important, e.g., it would be advantageous to prevent fever in burn patients and/or to prevent accidental therapeutic hypothermia in burn patients. For example, heat loss is a common finding in burned victims. Severe hypothermia during operation of debridement of burn wound, especially when patients are sedated and mechanically ventilated, is associated with increased mortality and morbidity. Studies showed almost 100% mortality in severely burned patients who presented with core temperature less than 32° C. The present invention recognizes that current therapeutic approaches such as warm blanket are limited.

SUMMARY OF THE INVENTION

[0005] A method includes advancing a closed loop intravascular heat exchange catheter into the vasculature of a burn patient, and establishing a desired patient temperature using the catheter. The catheter may be used to warm the patient during skin graft surgery, as well as to establish normothermia in the patient should the patient become febrile.

[0006] In non-limiting implementations the catheter has plural heat exchange elements. In one-non-limiting embodiment the heat exchange elements are balloons. In another embodiment the heat exchange elements are metal. In yet

another embodiment they are established by plural heat exchange fluid return tubes communicating with a central supply lumen at a distal end of the catheter for carrying heat, exchange fluid. In this last embodiment each return, tube is formed spirally around the supply lumen such that a body fluid flowing past the return tube exchanges heat with the heat exchange fluid flowing therein.

[0007] In another aspect, a system for treating a burn patient includes a heater/chiller and an intravascular catheter configured for receiving working fluid from the heater/chiller and returning working fluid thereto in a closed loop. A substrate is provided bearing instructions for using the catheter to establish a desired patient temperature in the patient.

[0008] In yet another aspect, a method for treating a burn patient includes conducting skin graft surgery on the patient, and during surgery, countering hypothermia in the patient using a catheter.

[0009] The details of the present invention, both as to its structure and operation, can best be understood in reference to the accompanying drawings, in which like reference numerals refer to like parts, and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a schematic diagram of a system according to present principles;

[0011] FIG. 2 is a perspective view of a first non-limiting catheter, schematically showing a medicament source and coolant source in an exploded relationship with the catheter;

[0012] FIG. 3 is a perspective view of a second non-limiting catheter;

[0013] FIG. 4 is a cross-section as seen along the line 4-4 in FIG. 3;

[0014] FIG. 5 is a side view of a portion of a third non-limiting catheter; and

[0015] FIG. 6 is a cross-section of the catheter shown in FIG. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0016] Referring initially to FIG. 1, a system, generally designated 10, is shown for managing and otherwise controlling whole body temperature of a burn patient 12. The system 10 may be used to establish normothermia in the burn patient 12, i.e., to prevent undesired hypothermia during, e.g., surgery or to prevent hyperthermia in the patient, and/or the system 10 may be used to therapeutically cool the patient 12 to a hypothermic state, e.g., moderate hypothermia around thirty four degrees Celsius. In some implementations discussed below, the system 10 may also be used to provide central venous access to the burn patient 12. In non-limiting implementations the burn patient 12 may be treated with the system upon a predetermined burn threshold, e.g., the body temperature of the burn patient 12 may be managed using the system 10 in the event that the burn patient 12 has suffered third degree burns over thirty percent or more of the patient's body, it being understood that this percentage is not limiting on present principles.

[0017] As shown, the system 10 includes an intravascular closed loop heat exchange catheter 14 that receives a heat exchange fluid (also referred to herein as "coolant") from a heater/chiller 16, with the fluid circulating in a closed loop. The fluid can be saline or other fluid such as refrigerant. Either the fluid flow rate and/or the temperature of the fluid is con-

trolled by a controller associated with the heater/chiller **16** based on a patient temperature feedback signal to control the amount and if desired the rate at which heat is added or subtracted from the patient. The controller can be implemented by a software-executing processor or by discrete logic circuits or other electronic circuitry device to establish a desired patient temperature by appropriately controlling the flow rate and/or heat exchanger in response to a temperature signal derived from a sensor in the patient **12**. Non-limiting examples of heater/chillers that can be used are disclosed in U.S. Pat. Nos. 7,101,388; 6,878,156; 6,786,916; 6,454,792; 6,454,792; 6,146,411; and 6,019,783, all of which are incorporated herein by reference. Further examples of non-limiting heater/chillers are shown in U.S. Pat. Nos. 6,581,403, 6,436,130, and 6,109,783, incorporated herein by reference.

[0018] As also shown in FIG. 1, in some non-limiting implementations at least two central venous (CV) components can be in communication with the catheter **16** for undertaking central venous functions in addition to controlling the temperature of the patient. These functions include and are not limited to drug infusion and blood extraction for blood monitoring, as well as blood pressure monitoring. For instance, a blood monitor **18** can communicate with the catheter **14** via a line **20** to monitor blood pressure or withdraw blood from the central venous system of the patient **12**. Also, a syringe **22** can engage the catheter **14** via a connector line **24** for infusing drugs or other medicament such as epinephrine into the patient **12**. The components **16**, **18**, **22** can all be connected to the catheter **14** via a proximal connector hub **26** of the catheter **14**. The hub **26** can be formed with a suture anchor **28** or other anchor structure such as tape for providing a means to fasten the catheter **14** to the skin of the patient **14** for long-term use.

[0019] The catheter **14** may be any suitable closed loop intravascular temperature control catheter including without limitation in addition to the specific structures disclosed herein, the catheters disclosed in the following U.S. patents, all incorporated herein by reference: U.S. Pat. Nos. 5,486,208, 5,837,003, 6,110,168, 6,149,673, 6,149,676, 6,231,594, 6,264,679, 6,306,161, 6,235,048, 6,238,428, 6,245,095, 6,251,129, 6,251,130, 6,254,626, 6,261,312, 6,312,452, 6,325,818, 6,409,747, 6,368,304, 6,338,727, 6,299,599, 6,287,326, 6,126,684.

[0020] In any case, once the patient **12** has been diagnosed as suffering skin burns sufficient to warrant management of the temperature of the patient **12**, the catheter **12** may be placed in the venous system, e.g., in the superior or inferior vena cava without blocking the vessel so that blood can flow around the catheter to effect, heat exchange. In non-limiting embodiments the catheter **14** may be advanced (possibly through an introducer sheath) into the vena cava of the patient **12** through a groin entry point **32** or through a neck entry point **34** to the central venous system of the patient **12**. When advanced through the groin the catheter is advanced either through the saphenous vein or femoral vein to the inferior vena cava, and when advanced through the neck through the jugular or subclavian vein to the superior vena cava or inferior vena cava. Less desirably, the catheter **14** may be advanced into the arterial system of the patient **12**.

[0021] Once disposed in the bloodstream of the patient **12**, a target patient temperature is input to the heater/chiller **16**. The target temperature can be, e.g., normothermia (i.e., approximately thirty eight degrees Celsius), in which case the heater/chiller **16** controls the temperature and/or flow rate of

the coolant circulating through the catheter **14** in response to a patient temperature signal as appropriate to heat or cool the patient to achieve and maintain target temperature. It is to be understood that the patient temperature signal may be generated by a sensor on the catheter **14** and sent to the heater/chiller **16**. Or the sensor may be on another device that can be electrically connected to the heater/chiller **16** for sending a patient temperature signal thereto. For example, the sensor may be on a Foley catheter, a rectal temperature probe, an esophageal probe, a tympanic temperature device, or other suitable patient temperature generating device.

[0022] Or, target temperature may be below normothermia for the purpose of therapeutically establishing mild or moderate (or even deeper) hypothermia in the patient, in which case the heater/chiller **16** removes heat from the coolant as necessary to achieve and maintain hypothermia for a therapeutic amount of time.

[0023] Now referring to FIG. 2 for a description of a first non-limiting catheter **14**, commencing at the proximal end the heater/chiller **16** provides coolant such as saline through a coolant supply line **36**, and coolant is returned from the catheter **14** via a coolant return line **38**. The non-limiting catheter **14** includes a source tube **40** terminating in a fitting such as a female luer fitting **42**. Also, the catheter **14** has a return tube **44** terminating in a fitting such as a male luer fitting **46**. The fittings **42**, **46** can be selectively engaged with complementary fittings **48**, **50** of the lines **36**, **38** to establish a closed circuit coolant path between the catheter **14** and heater/chiller **16**.

[0024] Additionally, the non-limiting catheter **14** shown in FIG. 2 may include the primary infusion tube **20** as mentioned above that can also be used as a guidewire tube. The tube **20** terminates in a fitting such as a female luer **52**. A guide wire **54** or the syringe **22** shown in FIG. 1 can be advanced through the tube **20** in accordance with central venous catheter placement principles, or the monitor **18** shown in FIG. 1 may be engaged with the tube **20**.

[0025] Moreover, the connector line **24**, which can establish a secondary infusion tube, can end in a female luer fitting **56** that can be selectively engaged with, e.g., the syringe **22** for infusing fluid from the syringe or other source such as an IV bag into the patient.

[0026] The tubes **20**, **24**, **40**, **44** are held in the hub **26**, which may be distally tapered as shown. As set forth in U.S. Pat. No. 6,368,304, incorporated herein by reference, the hub **26** establishes respective pathways for fluid communication between the tubes **20**, **24**, **40**, **44** and respective lumens in the body **46** of the catheter **14**. The suture anchor **28** advantageously may be formed on the hub **26** for suturing the catheter **14** to a patient in accordance with central venous catheter operating principles.

[0027] The non-limiting the catheter body **46** may include at least two lumens, and in a preferred embodiment the catheter body **46** includes at least four lumens and, more preferably has five lumens. Two of the lumens are coolant supply and return lumens through which coolant is circulated to and from one more distally-located, axially-spaced thin-walled heat exchange membranes **66**, **68** (two shown) that are arranged along the last fifteen or so centimeters of the catheter body **46** and are bonded to the outer surface of the catheter body **46**, with an infusion port **64** being located between the heat exchange membranes **66**, **68**. Essentially, the heat exchange membranes **66**, **68** extend along most or all of that portion of the catheter **46** that is intubated within the patient.

The heat exchange membranes can be established by a medical balloon material. When coolant is circulated through them the heat exchange membranes may define a diameter of about ten French, and preferably no more than twelve French in non-limiting embodiments. Thus, the heat exchange membranes **66**, **68** are relatively long and comparatively thin, to advantageously avoid excessively blocking blood flow through the vena cava while nevertheless effecting patient cooling. If desired, a temperature sensor **70** such as a thermistor or other suitable device can be attached to the catheter **14** as shown by solvent bonding at a point that is proximal to the membranes **66**, **68**. The sensor **70** provides patient temperature feedback to the heater/chiller **16** through a wire disposed in the catheter **14**. Or, the sensor **70** can be disposed in a lumen of the catheter **14**, or attached to a wire that is disposed in a lumen of the catheter **14**, with the sensor hanging outside the catheter **14**. Alternatively, a separate temperature probe can be used, such as an esophageal probe, a rectal probe or tympanic temperature sensor.

[0028] FIGS. **3** and **4** show another non-limiting intravascular closed loop heat exchange catheter that can be used, generally designated **114**. As shown in FIG. **3**, the catheter **114** can include plural heat exchange elements **130**. The heat exchange elements **130** can be established by one or more metal, preferably gold, hollow elongated segments that have external surfaces which have turbulence-inducing irregular exterior surfaces that are shaped to induce gentle turbulence in blood flowing past the elements. Separating adjacent heat exchange elements **130** can be a flexible articulating joint **131**, it being understood that the heat exchange elements **130** and joints **131** can be formed from a single piece of material such as plastic or metal, e.g., gold. The details of the heat exchange elements **130** and their configuration are set forth in U.S. Pat. Nos. 6,554,797 and 6,096,068, incorporated herein by reference. In any case, coolant is circulated in a closed fluid communication loop between the heat exchange elements **130** and heater/chiller **16** to remove heat from the patient **12** or to add heat to the patient to rewarm the patient.

[0029] Now referring to FIG. **4**, it can be seen that in non-limiting implementations the catheter **114** if desired may establish a tubular conduit that is disposed substantially coaxially within the heat exchange elements **130**, with the conduit having a supply lumen **136** for supplying a pressurized working fluid (represented by arrows **138**) to a distal end **140** of the catheter **114**. As the fluid exits the supply lumen **138**, it flows out and around the supply lumen **138** in a proximal direction as shown in an annular return lumen **142**. It may readily be appreciated that heat is exchanged between the fluid **138** and bloodstream into which the catheter **114** is placed across the walls of the heat exchange elements **130** to heat or cool the patient as desired.

[0030] In addition to the supply and return lumens **136**, **142**, the catheter **114** if desired may have at least two and possibly more infusion or working lumens (only two shown for clarity) for undertaking CV functions simultaneously with controlling patient temperature. Specifically, as shown in FIG. **4**, a first infusion or working lumen **144** terminates in a first outlet port **146**, and a second infusion or working lumen **148** terminates in a second outlet port **150**. Both lumens **144**, **148** are separated from the fluid **138** and both lumens **144**, **148** preferably extend to the hub **26** shown in FIG. **1**. The second infusion or working lumen **148** can be coaxial with the body of the catheter **114** as shown. The second port **150** can be located on the distal tip of the catheter **114** as shown. In any

case, to provide for mixing of infused drugs in the bloodstream if two drugs are to be administered, the ports **146**, **150** are longitudinally separated from each other as shown. With the above in mind, the monitor **18** (FIG. **1**) or other CV device such as an infusion device can communicate with one of the infusion or working lumens **144**, **148** while the syringe **22** can communicate with the other infusion or working lumen **148**, **144**.

[0031] As an alternative to the catheters **14**, **114**, a catheter **214** shown in FIGS. **5** and **6** and disclosed in U.S. Pat. Nos. 6,585,692 and 6,610,083, both of which are incorporated herein by reference, may be used. The catheter **214** can include plural heat exchange elements **230**. The heat exchange elements **230** can be established by, e.g., three coolant return tubes made of hollow plastic, with each tube establishing a respective coolant return lumen. As shown best in FIG. **6**, a central coolant supply lumen **232** that is established by a center tube **234** is also provided. It is to be understood that the supply lumen **232** conveys coolant from the heater/chiller **16** in a distal direction along the catheter **214**, whereas the heat exchange elements **230** (the coolant return tubes) convey coolant back to the heater/chiller **216** in a proximal direction as indicated by the arrows **236** in FIG. **5**. With this structure, blood **238** in a central venous system vein **240** into which the catheter **214** is advanced is cooled (or heated) by exchanging heat with the coolant across the walls of the heat exchange elements **230**. Thus, coolant is circulated in a closed fluid communication loop between the heat exchange elements **230** and heater/chiller **16** to remove heat from the patient or to add heat to the patient to rewarm the patient after surgery or after the termination of therapeutic hypothermia treatment.

[0032] The coolant return tubes are spirally formed around the center tube **234**, and can be adhered thereto or not. That is, non-limiting heat exchange elements **230** define spirals. The length "L" of the heat exchange region of the catheter **214** can be about 250 millimeters, with the pitch of the spiral heat exchange elements **230** being about **64** millimeters. In any case, the coolant supply lumen **232** terminates in a hollow distal tip, as do the lumens of the heat exchange elements **230**. Accordingly, coolant passes from the supply tube to the return tubes at the distal tip.

[0033] Additionally, as best shown in FIG. **6**, the center tube **234** can establish one or more working lumens (only two shown in FIG. **6** for clarity of disclosure) for undertaking CV functions simultaneously with controlling patient temperature. In the embodiment shown, the center tube **234** establishes first and second working lumens **244**, **246** that have any suitable cross-sectional shape and that can respectively communicate with the central venous components **18**, **22** discussed above. Both working lumens **244**, **246** are separated from the coolant and both working lumens preferably extend to the hub **26** shown in FIG. **1**. The working lumens **244**, **246** can terminate in respective exit ports that may be longitudinally spaced from, each other, e.g., one port can be at the distal tip of the catheter **214** and the other port can be located somewhat proximal to the tip.

[0034] Any of the catheters disclosed herein can be used to maintain normothermia in the burn patient **12**, typically by warming the patient. For example, the catheters **14**, **114**, **214** can be used during surgery to keep patient temperature above 36 C when replacing necrotic skin with grafts. Without the present invention, it is often the case that patient temperature drops so that only one limb at a time may be repaired with

grafts, but with the present invention grafts on all limbs may be completed during the same surgery.

[0035] Temperature management of the patient 12 may be maintained after surgery using the system 10 for, e.g., thirty days, with a catheter change every few days if desired, with the patient in the burn unit and/or hospital ICU.

[0036] In one non-limiting treatment protocol, the patient is older than 18 years and presents with a core temperature of under 37° C. Target temperature can be set to 36.5° C. and warming rate to maximum. A core temperature monitor is established by, e.g., placing an esophageal/Foley/rectal temperature probe in the patient, with the monitor connected to the heater/chiller 16. Warming is commenced as early as possible to prevent core temperature drop. The catheter 14 can also be used as a multi-lumen central venous catheter to deliver warm fluid such as saline, medications, to withdraw blood or conduct other monitoring acts of patient parameters. All of these steps can take place during and after skin graft surgery. Subsequently, should the patient develop fever, the catheters 14, 114, 214 can also be used to control hyperthermia. A substrate 300 (FIG. 1) may be provided that bears instructions for using the present catheter to establish a desired patient temperature in the burn patient 12 in accordance with principles set forth herein.

[0037] While the particular temperature management system and method for burn patients is herein shown and described in detail, it is to be understood that the subject matter which is encompassed by the present invention is limited only by the claims.

1. A method comprising:
advancing a closed loop intravascular heat exchange catheter into the vasculature of a burn patient; and
establishing a desired patient temperature using the catheter, wherein the catheter includes plural heat exchange elements established by one or more hollow elongated segments that have external surfaces which have turbulence-inducing exterior surfaces that are shaped to alter the flow of blood flowing past the elements.
2. The method of claim 1, wherein the catheter is used to warm the patient during skin graft surgery.

3. The method of claim 2, wherein the catheter is used to establish normothermia in the patient should the patient become febrile.

4,5. (canceled)

6. The method of claim 1, wherein the heat exchange elements are metal.

7-14. (canceled)

15. A method for treating a burn patient while skin graft surgery is being conducted on the patient, comprising:

during surgery, circulating working fluid through a catheter in the patient to counter hypothermia in the patient; and
controlling the temperature of the working fluid.

16. The method of claim 15, wherein the catheter is used to establish normothermia in the patient should the patient become febrile.

17. The method of claim 15, wherein the catheter has plural heat exchange elements.

18. The method of claim 17, wherein the heat exchange elements are balloons or are metal.

19. The method of claim 15, comprising using the catheter to undertake at least one central venous line function selected from the group consisting of: infusing medicament into the bloodstream, infusing saline into the bloodstream, and monitoring a patient parameter.

20. The method of claim 19, wherein the act of countering hypothermia is executed by circulating working fluid through the catheter such that the working fluid does not enter the bloodstream and exchanges heat therewith.

21. The catheter of claim 1, wherein the heat exchange elements are made of gold.

22. The catheter of claim 1, wherein adjacent heat exchange elements are separated by a flexible articulating joint.

23. The catheter of claim 1, wherein the heat exchange elements are made of single piece of material.

24. The catheter of claim 1, wherein the heat exchange elements are made of plastic.

25. The catheter of claim 1, wherein the heat exchange elements are spiral.

26. The catheter of claim 1, wherein the heat exchange elements are fluted.

* * * * *