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(54) **Title:** COMBINED STENT REPERFUSION SYSTEM

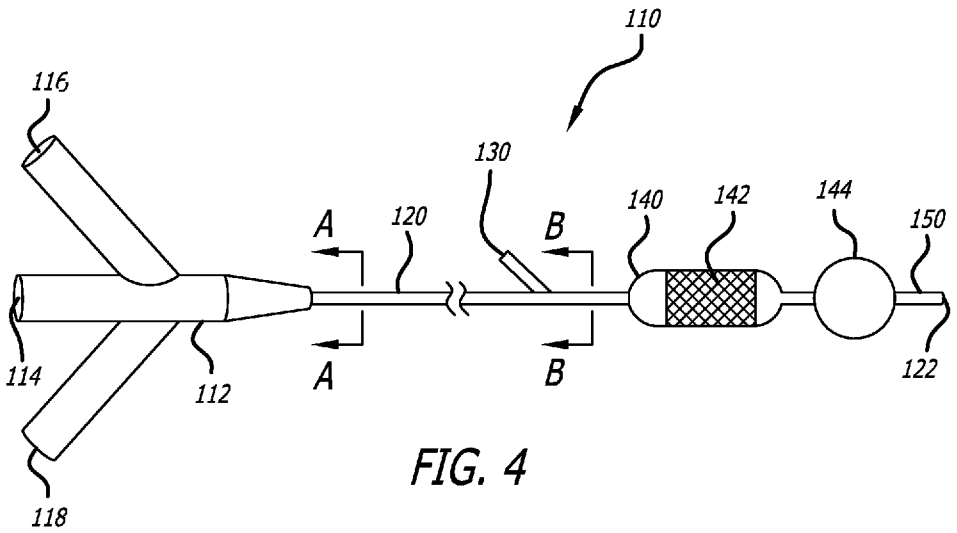

FIG. 4

(57) **Abstract:** Devices and methods for preventing reperfusion injuries when an occlusion balloon is deflated. A catheter having an infusion lumen exiting the catheter distal of a stent balloon and/or occlusion balloon allows a therapeutic agent to be introduced to a target location to establish desired temperatures and pressures prior to deflation of the balloon such that negative effects of reperfusion are minimized.

[Continued on next page]

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

COMBINED STENT REPERFUSION SYSTEM

RELATED APPLICATIONS

[0001] This application claims priority to Provisional Patent Application Serial No. 62/473,740, filed March 20, 2017, entitled *Combined Stent Reperfusion System*, which is hereby incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] The coronary microcirculation is critical for normal cardiac function, and myocardial infarction (MI) with subsequent ischemic cardiomyopathy are the most common causes of cardiac morbidity and mortality. Microvascular obstruction and no reflow are the principal causes of post-MI heart failure, adverse LV remodelling, scar/aneurysm formation and arrhythmias.

[0003] Recent publications by Hervas and Bulluck, incorporated by reference herein, have documented that the fundamental trigger for MVO is the reperfusion itself. I.e., it is the reopening of the coronary artery which triggers formation of MVO and MVO in itself is an independent predictor for patient outcomes in acute heart attack patients. Thus, there is a need for a method and device that targets the reduction of reperfusion injury, thus potentially reducing the formation of MVO.

[0004] Technologies have been recently developed to diagnose and treat MVO and are described in U.S. Patent Application Ser. No. 15/3984,470 and PCT Application Ser. No. PCT/US2017/012181, both to Schwartz et al. and entitled *System and Method for Treating MVO*. The entireties of these references are incorporated by reference herein. These references describe an easy-to-use, reliable technology that simultaneously measures and treates coronary MVO (STEMI, NSTEMI UA, Stable Angina etc.) in the catheterization lab. The technology, if desired, can be used independently for coronary and microvascular diagnosis, separately for treatment if desired.

ASPECTS AND SUMMARY OF THE INVENTION

[0005] The present invention provides a technology that combines the delivery of a coronary stent with a system for treating microvascular obstructions while avoiding reperfusion injuries.

[0006] One aspect of the invention pertains to the placement of a stent using an occlusion and perfusion catheter to diagnose and treat microvascular obstruction/ no reflow, and to avoid reperfusion injury. According to this aspect, a catheter is provided with a stent placed over a balloon delivery system and is used for revascularizing the heart and/or other organs including, but not limited to, the brain, lungs, kidneys, muscles, intestines etc.

[0007] The catheter may be placed over a pressure/temperature-sensing guidewire to allow for real-time measurement of distal vessel pressure and temperatures, i.e. distal to the balloon delivery system. Alternatively, the measurement technology may be mounted directly to the delivery catheter.

[0008] In one aspect, the catheter has an infusion lumen, which can infuse cardioprotective or therapeutic agents into the coronary circulation.

[0009] Another aspect of the invention is a system that can infuse cardio-protective and/or therapeutic agents into the microcirculation before a stent delivery balloon is collapsed. In this way the stent balloon, while inflated, acts as an occlusion balloon. Furthermore, the catheter lumen is available to deliver a cardio-protective agent to reduce the potential negative effect of the reintroduction of blood flow when the balloon is deflated. After deflation, the stent remains in place to promote continued epicardial perfusion of the coronary tree.

[0010] Yet another aspect of the invention provides a stent delivery balloon with an occlusion balloon. These two balloons may have different properties.

[0011] In one embodiment the stent delivery balloon and the occlusion balloon may be mounted on a catheter shaft. They may be fixed longitudinally to the shaft or may be mounted such that the longitudinal position is adjustable to offer more accurate placement.

[0012] Another aspect of the invention is a method of reperfusing using a catheter having a stent delivery balloon and an occlusion balloon. The method begins by placing a catheter into the artery, preferably over a rapid exchange wire with pressure and temperature-sensing capabilities at a distal end of the guide wire. The occlusion balloon is then inflated to avoid reperfusion. The stent is then delivered by inflating the stent delivery balloon. Once the stent is in place, the stent delivery balloon is deflated. The occlusion balloon remains inflated to prevent reperfusion from occurring. A cardio-protective agent is then infused through the infusion lumen of the catheter. During this time, the effect of the cardio-protective agent is measured with the pressure/temperature sensor. Once the cardio-protective effect is achieved, the occlusion balloon is deflated. After the blood reperfuses, the degree of microvascular damage can be measured and potentially treated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] These and other aspects, features and advantages of which embodiments of the invention are capable of will be apparent and elucidated from the following description of embodiments of the present invention, reference being made to the accompanying drawings, in which

[0014] Fig. 1 is a perspective view of an embodiment of a single balloon inflation system of the invention;

[0015] Fig. 2 is a section view taken along lines A-A of Fig. 1;

[0016] Fig. 3 is a section view taken along lines B-B of Fig. 1;

[0017] Fig. 4 is a perspective view of an embodiment of a single balloon inflation system of the invention;

[0018] Fig. 5 is a section view taken along lines A-A of Fig. 1; and,

[0019] Fig. 6 is a section view taken along lines B-B of Fig. 1.

DESCRIPTION OF EMBODIMENTS

[0020] Specific embodiments of the invention will now be described with reference to the accompanying drawings. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. The terminology used in the detailed description of the embodiments illustrated in the accompanying drawings is not intended to be limiting of the invention. In the drawings, like numbers refer to like elements.

[0021] Figure 1 shows a single balloon embodiment 10 of a delivery system of the invention. The delivery system 10 includes a manifold 12 at a proximal end that includes an infusion port 14 and a stent balloon inflation port 16. The manifold tapers to a flexible catheter 20 that proximally contains two lumens – an infusion lumen 22 that is in fluid communication with the infusion port 14 and an inflation lumen 24 that is in fluid communication with the balloon inflation port 16.

[0022] Figure 2 is a cross section of the catheter 20 taken along section lines A-A of Figure 1. Figure 2 shows the infusion lumen 22 and the inflation lumen 24.

[0023] Proceeding distally in Figure 1, there is shown a therapeutic agent or Rx port 30 that leads to an Rx lumen 32 in the catheter 20. Figure 3 shows a cross section of the catheter 20 taken along section lines B-B of Figure 1. It can thus be seen that distal of the Rx port, the catheter has three lumens, an infusion lumen 22, an inflation lumen 24 and an Rx lumen 32.

[0024] Distal of the Rx port 30 is a balloon 40 with a stent 42. The balloon 40 is in fluid communication with the inflation lumen 24 such that fluid passing distally through the inflation lumen 24 terminates in the balloon 40.

[0025] A stent 42 surrounds the balloon 40 and is expanded thereby when the balloon 40 in inflated. The stent 42, due to its memory properties, remains expanded after the balloon 40 deflates. Thus, deflating balloon 40 results in separation of the stent 42.

[0026] Distal of the balloon 40 is the distal end 50 of the catheter 20. The distal end 50 includes an open end of the infusion lumen 22.

[0027] In use, the delivery device 10 involves routing the catheter 20 over a guide wire (not shown) to the target site. The infusion lumen 22 is used as a guidewire lumen while the device 10 is being advanced to the target site. The guidewire preferably includes a pressure and temperature sensor to provide real-time measurement of distal vessel pressures and temperatures at a location distal of the balloon delivery system.

[0028] Once the device 10 has reached its target location, the balloon 40 is inflated causing the stent 42 to expand against the native tissue. The inflation of the balloon 40 also results in an occlusion of the vessel.

[0029] While the balloon 40 remains inflated and the vessel occluded, a cardio-protective agent is infused via the infusion port 30 and through the infusion lumen 32, exiting the lumen 32 at the distal end 50 of the catheter, downstream of the occlusion balloon 40. The cardio-protective agent reduces the potential negative effects of reintroducing blood flow when the balloon 40 is deflated.

[0030] Once the desired cardio-protective effect has been achieved, as measured by the pressure/temperature sensor on the guidewire, the balloon 40 is deflated, allowing normal blood reperfusion of the coronary circulation. The stent 42 remains in place and secures continued epicardial perfusion of the coronary tree. After blood reperfusion is complete, the degree of microvascular damage can be measured and potentially treated as described in the incorporated references.

[0031] Figure 4 shows a dual balloon embodiment 110 of a delivery system of the invention. The delivery system 110 includes a manifold 112 at a proximal end that

includes an infusion port 114, a stent balloon inflation port 116, and an occlusion balloon inflation port 118. The manifold tapers to a flexible catheter 120 that proximally contains three lumens – an infusion lumen 122 that is in fluid communication with the infusion port 114, a stent balloon inflation lumen 124 that is in fluid communication with the stent balloon inflation port 116, and an occlusion balloon inflation lumen 126 that is in fluid communication with the occlusion balloon inflation port 118.

[0032] Figure 5 is a cross section of the catheter 120 taken along section lines A-A of Figure 4. Figure 5 shows the infusion lumen 122 and the inflation lumen 124.

[0033] Proceeding distally in Figure 6, there is shown a therapeutic agent or Rx port 130 that leads to an Rx lumen 132 in the catheter 20. Figure 6 shows a cross section of the catheter 20 taken along section lines B-B of Figure 4. It can thus be seen that distal of the Rx port, the catheter has four lumens, the infusion lumen 122, the inflation lumen 124, the occlusion lumen 126, and an Rx lumen 132.

[0034] Distal of the Rx port 130 is a balloon 140 with a stent 142. The balloon 140 is in fluid communication with the inflation lumen 124 such that fluid passing distally through the inflation lumen 124 terminates in the balloon 140.

[0035] A stent 142 surrounds the balloon 140 and is expanded thereby when the balloon 140 in inflated. The stent 142, due to its memory properties, remains expanded after the balloon 140 deflates. Thus, deflating balloon 140 results in separation of the stent 142.

[0036] Distal of the balloon 140 is an occlusion balloon 144. The occlusion balloon 144 is in fluid communication with the occlusion lumen 126 such that fluid passing distally through the occlusion lumen 126 terminates in the balloon 144.

[0037] Distal of the balloon 144 is the distal end 150 of the catheter 120. The distal end 150 includes an open end of the infusion lumen 122.

[0038] In use, the delivery device 110 involves routing the catheter 120 over a guide wire (not shown) to the target site. The infusion lumen 122 is used as a guidewire

lumen while the device 110 is being advanced to the target site. The guidewire preferably includes a pressure and temperature sensor to provide real-time measurement of distal vessel pressures and temperatures at a location distal of the balloon delivery system.

[0039] Once the device 110 has reached its target location, the occlusion balloon 144 is inflated to occlude the vessel and prevent reperfusion.

[0040] Next the stent balloon 140 is inflated causing the stent 142 to expand against the native tissue. The stent balloon 140 is then deflated, separating the stent 142 from the device.

[0041] While the occlusion balloon 144 remains inflated and the vessel occluded, a cardio-protective agent is infused via the infusion port 130 and through the infusion lumen 132, exiting the lumen 132 at the distal end 150 of the catheter, downstream of the occlusion balloon 144. The cardio-protective agent reduces the potential negative effects of reintroducing blood flow when the balloon 144 is deflated.

[0042] Once the desired cardio-protective effect has been achieved, as measured by the pressure/temperature sensor on the guidewire, the occlusion balloon 144 is deflated, allowing normal blood reperfusion of the coronary circulation. The stent 142 remains in place and secures continued epicardial perfusion of the coronary tree. After blood reperfusion is complete, the degree of microvascular damage can be measured and potentially treated as described in the incorporated references.

[0043] Although the invention has been described in terms of particular embodiments and applications, one of ordinary skill in the art, in light of this teaching, can generate additional embodiments and modifications without departing from the spirit of or exceeding the scope of the claimed invention. Accordingly, it is to be understood that the drawings and descriptions herein are proffered by way of example to facilitate comprehension of the invention and should not be construed to limit the scope thereof.

What is claimed is:

1. A combined stent delivery and occlusion device comprising:

a proximal manifold including:

an infusion port;

a stent balloon inflation port;

a catheter extending distally from the manifold and defining an infusion lumen in fluid communication with the infusion port, and an inflation lumen in fluid communication with the stent balloon inflation port;

a therapeutic agent port in fluid communication with a therapeutic agent lumen further defined by the catheter and leading to a distal end thereof;

a stent balloon near a distal end of the catheter and surrounding the catheter, the stent balloon in fluid communication with the inflation lumen;

a stent surrounding the stent balloon.

2. The combined stent delivery and occlusion device of claim 1 wherein said stent balloon, when inflated, serves as an occlusion balloon, blocking blood flow through a vessel in which the stent balloon is inflated.

3. The combined stent delivery and occlusion device of claim 1 wherein said therapeutic agent port is located distal of said manifold.

4. The combined stent delivery and occlusion device of claim 1 further comprising an occlusion balloon.

5. The combined stent delivery and occlusion device of claim 4 wherein said occlusion balloon is located distal of the stent delivery balloon.

6. The combined stent delivery and occlusion device of claim 4 wherein said proximal manifold further includes an occlusion balloon inflation port.

7. The combined stent delivery and occlusion device of claim 6 wherein said catheter further defines an occlusion balloon inflation lumen.

8. A method of delivery a stent while preventing injury due to reperfusion comprising:

navigating a catheter including a stent to a target location within a vessel;

monitoring a pressure and temperature of the target location;

inflating a balloon disposed within the stent, thereby expanding the stent against a vessel wall of the target location and occluding the vessel;

infusing an infusate into the vessel downstream of the balloon;

monitoring an effect of the infusion of the infusate;

deflating the balloon once a desired effect of the infusion of the infusate has been reached.

9. The method of claim 8 wherein navigating a catheter comprises navigating a guidewire to the target location and then advancing the catheter over the guidewire.

10. The method of claim 9 wherein navigating a guidewire comprises navigating a guidewire having pressure and temperature sensors near a distal end thereof.

11. The method of claim 8 wherein monitoring an effect of the infusion of the cardio-protective agent comprises monitoring a temperature and pressure at said target location distal of said balloon.

12. The method of claim 8 wherein said infusate comprises a cardio-protective agent.

13. A method of delivery a stent while preventing injury due to reperfusion comprising:

navigating a catheter including a stent to a target location within a vessel;

monitoring a pressure and temperature of the target location;

inflating an occlusion balloon, thereby stopping blood flow through the vessel;

inflating a stent balloon disposed within the stent, thereby expanding the stent against a vessel wall of the target location;

deflating the stent balloon;

infusing a cardio-protective agent into the vessel downstream of the balloon;

monitoring an effect of the infusion of the cardio-protective agent;

deflating the balloon once a desired effect of the infusion of the cardio-protective agent has been reached.

14. The method of claim 12 wherein navigating a catheter comprises navigating a guidewire to the target location and then advancing the catheter over the guidewire.

15. The method of claim 13 wherein navigating a guidewire comprises navigating a guidewire having pressure and temperature sensors near a distal end thereof.

16. The method of claim 12 wherein monitoring an effect of the infusion of the cardio-protective agent comprises monitoring a temperature and pressure at said target location distal of said balloon.

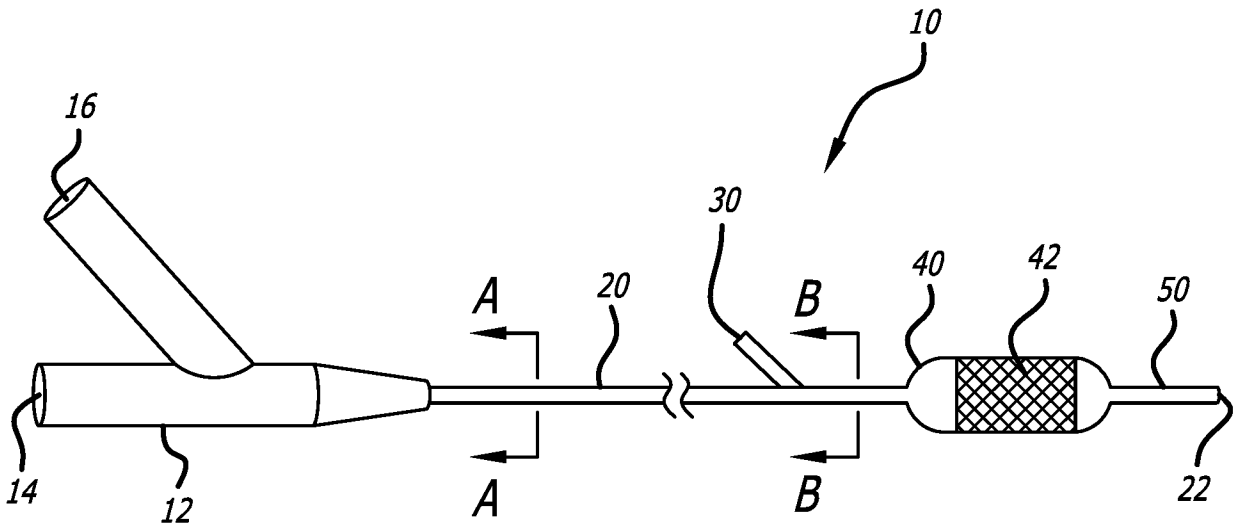

FIG. 1

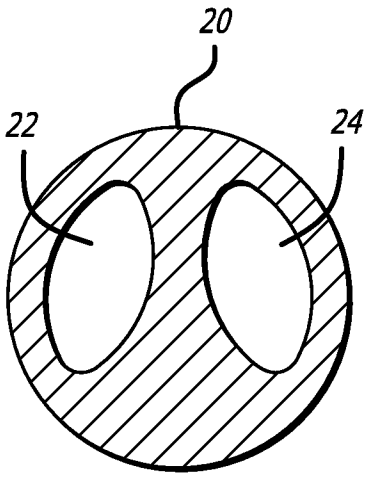

FIG. 2

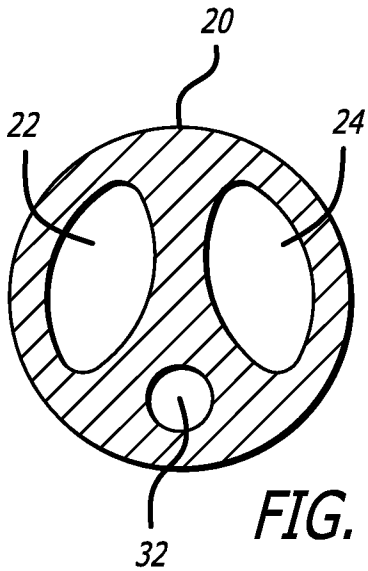

FIG. 3

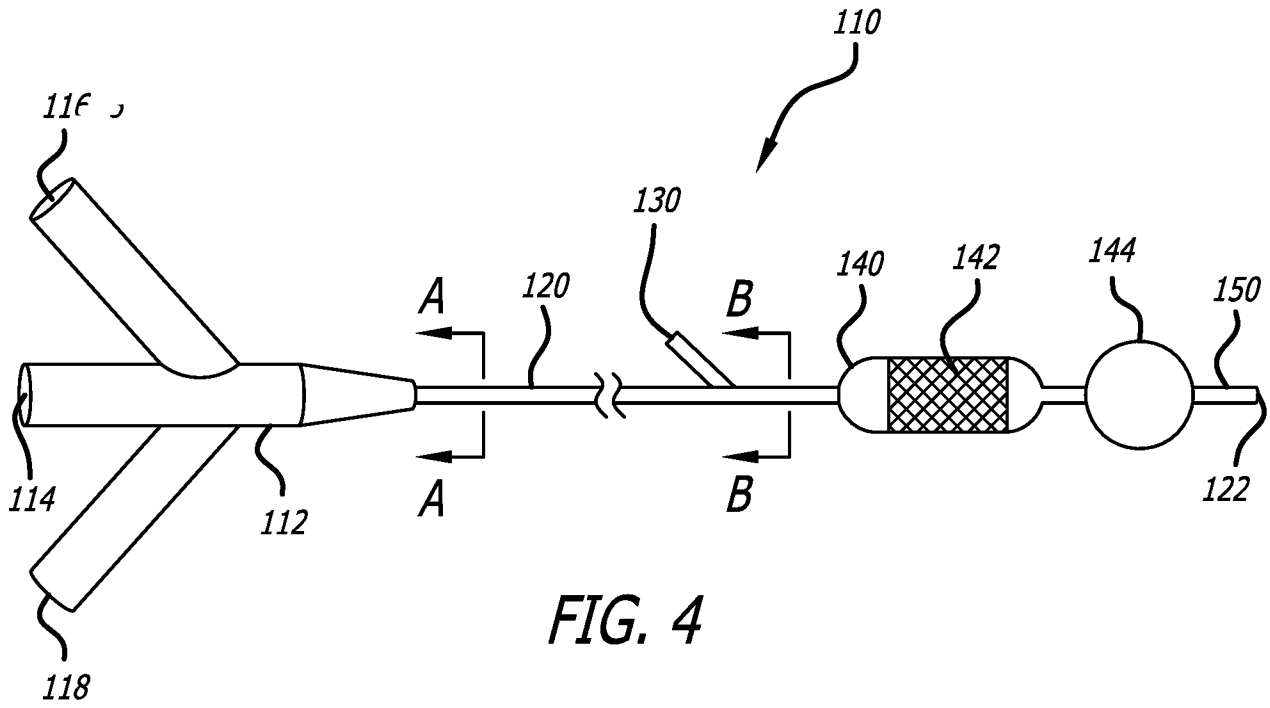

FIG. 4

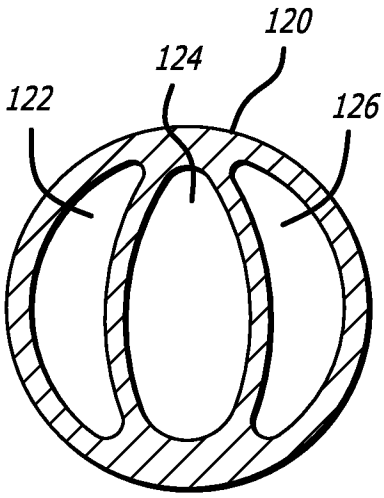

FIG. 5

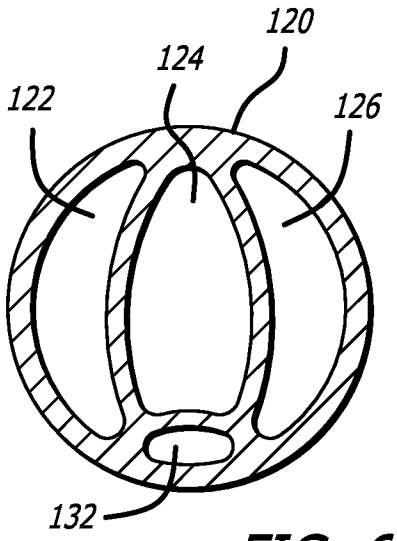

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 18/23422

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61F 2/958 (2018.01)
CPC - A61F 2/958; A61M 25/1011, 2025/0002, 2025/1052

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2012/0265283 A1 (MACK et al) 18 October 2012 (18.10.2012) see especially para [0050], [0051], [0084], [0085], [0090]-[0092], [0094]-[0097], [0176], [0177], fig 12-14	1-7 --- 8-16
Y	US 2012/0265079 A1 (HILMERSSON) 18 October 2012 (18.10.2012) see especially para [0030], [0035], fig 2	8-16
A,P	US 2017/0189654 A1 (RFFLOW THERAPEUTICS AG) 6 July 2017 (06.07.2017) see whole document	1-16
A	US 2013/0165858 A1 (ABBOTT CARDIOVASCULAR SYSTEMS INC) 27 June 2013 (27.06.2013) see whole document	1-16
A	US 2010/0280451 A1 (TEESLINK et al) 4 November 2010 (04.11.2010) see whole document	1-16
A	US 2008/0300573 A1 (CONSIGNY et al) 4 December 2008 (04.12.2008) see whole document	1-16
A	US 2005/0267561 A1 (JONES et al) 1 December 2005 (01.12.2005) see whole document	1-16
A	US 6,156,005 A (THERON) 5 December 2000 (05.12.2000) see whole document	1-16

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 May 2018	25 MAY 2018
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)