MULTI-POLE SYNCHRONOUS PULMONARY ARTERY RADIOFREQUENCY ABLATION CATHETER

BACKGROUND OF THE INVENTIONS

Field of the Inventions

[0001] The present inventions relate to medical devices for treatment of pulmonary hypertension in the pulmonary artery by de-sympathetic methods, for example, with multi-pole synchronous pulmonary artery radiofrequency ablation catheters, as well as methods for diagnosis and method of treating pulmonary hypertension.

Description of the Related Art

[0002] Pulmonary hypertension (PH) is understood to be an intractable disease in the cardiovascular, respiratory, connective tissue, immune and rheumatic systems. Currently available clinical treatments of pulmonary hypertension are limited and therapy efficacy thereof is poor. Incidence of primary pulmonary hypertension is low, but those secondary to pulmonary interstitial fibrosis, connective tissue disease, portal hypertension, chronic pulmonary artery embolism and left heart system disorder are common, with five-year mortality rate up to 30%. Therefore, prevention and treatment for pulmonary hypertension is of great significance.

[0003] In recent years, new targeted drugs have emerged based on the research into the pathogenesis of pulmonary hypertension. However, some of those drugs have serious limitations including many side effects, inappropriate dosage form, expensive cost and unreliable efficacy, and thus many have not been widely applied in clinical treatment.

SUMMARY

[0004] An example of at least one of the disclosures disclosed herein includes the realization, supported by experimental data which demonstrates, that pulmonary hypertension is associated with hyper sympathetic activity in pulmonary artery and hyperactive baroreceptor. Blocking the sympathetic nerves in the pulmonary artery or permanently

damaging the baroreceptor structure and function thereof can decrease the pulmonary artery pressure, which can provide more successful treatments of pulmonary hypertension.

[0004a] The present disclosure refers to a device for ablating a target tissue at a main pulmonary artery of a patient, the device comprising: a catheter body comprising a proximal end and a terminal distal end; an annular ring coupled to the terminal distal end of the catheter body; and a plurality of electrodes supported by the annular ring, wherein the plurality of electrodes comprises a first electrode arranged and sized to contact a left lateral apex of the main pulmonary artery, a second electrode arranged and sized to contact an anterior side of the left lateral apex, and a third electrode arranged and sized to contact a posterior side of the left lateral apex when the annular ring is deployed in the main pulmonary artery.

[0005] Some examples disclosed herein provide a multi-pole synchronous pulmonary artery radiofrequency ablation catheter for treatment of pulmonary hypertension in the pulmonary artery by a de-sympathetic method. In some examples, the catheter only heats the adherent tissue rather than the blood. Additionally, in some examples, the catheter can be configured to provide cold saline perfusion at or near the ablation site to protect the vascular intima. Some examples can also provide advantages of simple operation, short operation time and controllable, precise ablation.

[0006] In some examples, a multi-pole synchronous pulmonary artery radiofrequency ablation catheter can comprise a control handle, a catheter body and an annular ring. The control handle can be provided with an adjustment apparatus. The catheter body can be hollow and can include a cavity. One or a plurality of lead wires, one or more temperature sensing wires and one or more pull wires can be arranged in the cavity. One end of the catheter body can be flexible. The flexible end can be connected to an annular ring and the other end of the catheter body can be connected to the control handle. One end of the pull wire can be connected to the flexible end and the other end of the pull wire can be connected to the adjustment apparatus. Tension in the pull wire can be adjusted through the adjustment apparatus to achieve shape control, such as curvature control, of the flexible end. A shape memory wire can be arranged in the annular ring. One end of the shape memory wire can extend to the end of the annular ring and the other end of the shape memory wire can pass through the root of the annular ring and can be fixed on the flexible end of the catheter body. The annular ring can be provided with an electrode group with each electrode connected to the one or more lead wires and the one or more temperature sensing wires. The lead wire(s) and the temperature sensing wire(s) extend through the catheter body and are electrically connected to the control handle.

[0007] An infusion tube can be arranged in the cavity of the catheter body and a through hole can be arranged on one or more of the electrodes. The infusion tube can be connected to the electrodes through the annular ring. The transfused fluid flows out from the

through hole and thus can be used for cooling purposes during ablation as part of the percutaneous pulmonary denervation (PADN) procedure.

[0008] The electrodes on the annular ring can be made of material selected from a group consisting of platinum-iridium alloy, gold, stainless steel and nickel alloy, with the number in the range of 3-30 electrodes, a diameter in the range of 1.3-2.0 mm, a length in the range of 1.2-4 mm and an edge space between adjacent electrodes in the range of 0.5-10 mm.

[0009] The flexible end of the catheter body can be provided with a counterbore, an inner diameter of the counterbore can be sized to fit an outer diameter of the root of the annular ring, and thus the root of the annular ring can be inserted and fixed into the counterbore.

[0010] The flexible end of the catheter body is provided with a groove in which a connector is arranged, one end of the connector is connected to the pull wire and the other end of the connector is connected to the shape memory wire.

[0011] The material of the shape memory wire in the annular ring can be a shape memory alloy selected from a group consisted of nickel-titanium alloy, stainless steel or titanium, with a diameter of 0.25-0.5 mm. The diameter of the annular ring can be 12-40 mm. For example, the annular ring can be configured so as to be biased toward a circumferential shape, having a desired diameter (e.g., in the range of 12-40 mm), for example, with the use of a memory shape material. Preferably, 10 electrodes are arranged on the annular ring. The width of naked section of the electrode is 0.75 mm, and the space therebetween is 5 mm.

[0012] The flexible end can be made of medical polymer materials with a length in the range of 30-80 mm. The connection can be achieved by a UV-curing adhesive. The joint between the flexible end and the annular ring can be sealed.

[0013] The pull wire is made of stainless steel or nickel-titanium alloy. The outside of pull wire is provided with a spring coil, and the outside of the spring coil is provided with a spring sleeve made of polyimide material.

[0014] In some examples, the catheter can be packaged into a kit including a plurality of different annular rings that are biased to different diameters. In some examples, where the annular rings, flexible bodies, and handles are permanently

connected together, a kit can include a plurality of different catheters, each having handles and flexible bodies, but differently sized annular rings.

[0015] In some examples and/or methods of use, the catheter can heat, with radiofrequency energy, the tissue in direct contact with the electrode and avoid heating blood. Additionally, the catheter can provide advantages of simple operation, short operation time and controllable precise ablation. The catheter body can preferably be made of a polymer material, which is a poor heat conductor, so that it can avoid transmitting the heat when heating the electrodes to the flowing blood contacting the catheter body, thereby effectively avoid heating the blood.

[0016] Furthermore, the shape or curvature of the flexible end can be adjusted by operating the adjustment apparatus, which allows the operator to control the handle with one hand, so as to easily adjust the curvature of the flexible end for purposes of placement of the annular ring and the electrodes. As such, after achieving the desired placement, the electrodes on the annular ring can be pressed against the pulmonary artery and achieve ablation of pulmonary artery intima. During application of the radiofrequency current, the electrodes can produce high local temperature and cause severe damage on the vascular intima.

[0017] Thus, in some examples, the catheter can be configured to provide cold saline perfusion to cool down the local temperature. When the electrodes receive current, the saline is automatically and uniformly diffused through the through holes, which can provide beneficial cooling, for example, decreasing the local temperature to be below 60 °C, thereby protecting the vascular intima.

[0018] In some examples, a multi-pole synchronous pulmonary artery radiofrequency ablation catheter may comprise a control handle, a catheter body and an annular ring. The control handle may include an adjustment apparatus. The catheter body may be hollow and comprise a cavity arranged in the catheter body. A lead wire, a temperature sensing wire and a pull wire may be arranged in the cavity. One end of the catheter body may be flexible, and the flexible end of the catheter body may be connected to the annular ring. The other end of the catheter body may be connected to the control handle. One end of the pull wire may be connected to the flexible end. The other end of the pull wire

may be connected to the adjustment apparatus on the control handle. The adjustment apparatus may adjust the tension of the pull wire to change a curvature of the flexible end. A shape memory wire may be arranged in the annular ring. One end of the shape memory wire may extend to an end of the annular ring and the other end of the shape memory wire may pass through a root of the annular ring and be fixed on the flexible end of the catheter body. The annular ring may be provided with an electrode group. The electrode group may comprise a first electrode of a first length, a second electrode of a second length different than the first length, and a third electrode. Each electrode of the electrode group may be connected to the lead wire and temperature sensing wire. The lead wire and the temperature sensing wire may go through the catheter body and be electrically connected to the control handle.

[0019] The annular ring may extend from the root of the annular ring to the end of the annular ring and comprise a curve of less than 360 degrees. The annular ring may extend from the root of the annular ring to the end of the annular ring and comprise a curve of more than 270 degrees. The annular ring may comprise a first diameter and a second diameter different than the first diameter. The first diameter may be at least 25 mm and the second diameter may be at least 20 mm.

[0020] The electrodes of the electrode group may be substantially coplanar. The first length of the first electrode may be least 4 mm. The second length of the second electrode may be least 3 mm. The third electrode may comprise a third length different than the first length and different than the second length. The third length may be at least 2 mm.

[0021] In some examples, a catheter may comprise a catheter body and an annular ring. One end of the catheter body may be flexible and connected to the annular ring. The curve of the annular ring may be less than 360 degrees and greater than 270 degrees.

[0022] The annular ring may be provided with an electrode group comprising a first electrode of a first length, a second electrode of a second length different than the first length, and a third electrode of a third length different than the first length and different than the second length. The electrodes of the electrode group may be substantially coplanar and arranged along a curve of the annular ring that extends from a root of the annular ring to an end of the annular ring. The first length may be least 4 mm. The second length may be least

3 mm and may be less than the first length. The third length may be least 2 mm and may be less than the second length. The first length may be 4 mm. The electrode group may comprise less than four electrodes.

[0023] The first electrode may be separated from the second electrode and the third electrode by an equal distance. The equal distance may be 1 mm. The first electrode may be farther in distance from a root of the annular ring than the second electrode and the third electrode.

[0024] In some examples, a controller may comprise a housing, an electronic display, a battery, an electronic data store, and a computing device. The housing may comprise a catheter connection port disposed along a surface of the housing. The connection port may be configured to interface with a catheter. The catheter may comprise a first electrode of a first length, and a second electrode of a second length different than the first length. The housing may comprise an electronic display disposed along the surface of the housing. The housing may envelop a battery, an electronic data store and a computing device. The electronic display may be configured to present a user interface. The battery may be configured to store power at a level sufficient for ablation using the first electrode, or the second electrode. The electronic data store may comprise stored patient profiles characterizing a plurality of patients. The computing device may comprise one or more processors. The computing device may be in communication with the electronic data store, the electronic display and the battery. The computing device may be configured to at least: receive a selection of a first patient profile of the stored patient profiles from the user interface, display information characterizing the first patient profile on the user interface, receive a selection of the first electrode from the user interface, direct power from the battery at the level sufficient for ablation using the first electrode to the first electrode, receive a selection of the second electrode from the user interface, and direct power from the battery at the level sufficient for ablation using the second electrode to the second electrode.

[0025] The computing device may be configured to direct power from the battery to the first electrode and direct power from the battery to the second electrode at a same time. The computing device may be configured to direct power from the battery to the first electrode and direct power from the battery to the second electrode at different times. The

computing device may be configured to interrupt power directed from the battery to the first electrode and direct power from the battery to the second electrode after the power directed from the battery to the first electrode is interrupted. The computing device may be configured to direct power from the battery to the first electrode after the battery has finished charging. The computing device may be configured to display on the user interface first electrode ablation information captured by the first sensor while the first electrode receives power from the battery. The computing device may be configured to store the first electrode ablation information with the first patient profile. The computing device may be configured to display on the user interface first electrode ablation information captured by the first sensor while the first electrode receives power from the battery and second electrode ablation information captured by the second sensor while the second electrode receives power from the battery. The second electrode ablation information may be displayed on the user interface after the first electrode stops receiving power from the battery.

[0026] The housing may comprise a power connection port configured to receive power at a level sufficient to charge the battery.

[0027] The catheter may comprise a first sensor connected with the first electrode. The catheter may comprise a first sensor connected with the first electrode and a second sensor connected with the second electrode.

[0028] In some examples, a computer-implemented method, under control of one more computing devices executing specific computer executable instructions, may comprise receiving a selection of a first patient profile of a plurality of stored patient profiles from a user interface presented on an electronic display disposed across a surface of a housing. The method may comprise displaying information characterizing the first patient profile on the user interface. The method may comprise receiving a selection of the first electrode from the user interface. The method may comprise directing power from a battery at the level sufficient for ablation using the first electrode to the first electrode, the battery configured to store power at a level sufficient for ablation using the first electrode. The method may comprise receiving a selection of the second electrode from the user interface. The method may comprise directing power from the battery at the level sufficient for ablation using the second electrode to the second electrode. The battery may be configured to store

power at a level sufficient for ablation using the second electrode. The housing may comprise a catheter connection port disposed along a surface of the housing. The connection port may be configured to interface with a catheter comprising a first electrode of a first length, and a second electrode of a second length different than the first length. The housing may envelop the battery, an electronic data store and the one or more computing devices executing specific computer executable instructions. The electronic data store may comprise the plurality of stored patient profiles characterizing a plurality of patients.

[0029] The first electrode and the second electrode may be configured to convert the power from the battery to radiofrequency (RF) energy for ablation of sympathetic nerve fibers. The first electrode and the second electrode may be configured to convert the power from the battery to ultrasonic energy for ablation of sympathetic nerve fibers. The first electrode and the second electrode is configured to convert the power from the battery to electroporation energy for ablation of sympathetic nerve fibers. The first electrode and the second electrode may be configured to convert the power from the battery to ionizing energy for ablation of sympathetic nerve fibers.

[0030] In some examples, a computer-readable, non-transitory storage medium storing computer executable instructions that, when executed by one or more computer systems, configure the one or more computer systems to perform operations comprising receiving a selection of a first patient profile of a plurality of stored patient profiles from a user interface presented on an electronic display disposed across a surface of a housing. The operations may comprise displaying information characterizing the first patient profile on the user interface. The operations may comprise receiving a selection of the first electrode from the user interface. The operations may comprise directing power from a battery at the level sufficient for ablation using the first electrode to the first electrode. The battery may be configured to store power at a level sufficient for ablation using the first electrode. The operations may comprise receiving a selection of the second electrode from the user interface. The operations may comprise directing power from the battery at the level sufficient for ablation using the second electrode to the second electrode. The battery may be configured to store power at a level sufficient for ablation using the second electrode.

[0031] The housing may comprise a catheter connection port disposed along a surface of the housing. The connection port may be configured to interface with a catheter comprising a first electrode of a first length, and a second electrode of a second length different than the first length. The housing may envelop the battery, an electronic data store and the one or more computer systems. The electronic data store may comprise the plurality of stored patient profiles characterizing a plurality of patients.

[0032] The directing power from the battery to the second electrode may be performed by switching power directed from the battery from the first electrode to the second electrode. The directing power from the battery to the second electrode may direct an amount of power greater than an amount of power directed from the battery to the first electrode.

[0033] In some examples, a multi-pole synchronous pulmonary artery radiofrequency ablation catheter comprises a control handle, a catheter body and an annular ring. The control handle may comprise an adjustment apparatus. The catheter body may be hollow and comprising a cavity arranged in the catheter body. One end of the catheter body may be flexible. The flexible end may be connected to the annular ring. The other end of the catheter body may be connected to the control handle. One end of the pull wire may be connected to the flexible end, and the other end of the pull wire may be connected to the adjustment apparatus on the control handle. The adjustment apparatus may adjust the tension of the pull wire to change a curvature of the flexible end. A shape memory wire may be arranged in the annular ring. One end of the shape memory wire may extend to an end of the annular ring and the other end of the shape memory wire may pass through a root of the annular ring and be fixed on the flexible end of the catheter body. The annular ring may be shaped with an oval comprising a major axis and a minor axis. The major axis may comprise a first diameter along the major axis longer than a second diameter along the minor axis. The annular ring, extending from the root of the annular ring to the end of the annular ring, may comprise a curve of less than 360 degrees. The annular ring may an electrode that straddles the apex of the major axis.

[0034] In some examples, a catheter comprises a catheter body and an annular ring. One end of the catheter body may be flexible and connected to the annular ring. The annular ring may be oval shaped.

[0035] The annular ring may comprise a major axis and a minor axis, the major axis comprising a first diameter along the major axis longer than a second diameter along the minor axis. The first diameter may be 5 mm longer than the second diameter. The major axis may be along a first axis of symmetry and the minor axis may be along a second axis of symmetry. The annular ring may comprise an electrode that straddles the apex of the major axis. The annular ring may be orthogonal to the end of the catheter body that is flexible. The annular ring may be planar. The annular ring may comprise a curve of less than 360 degrees. The annular ring may comprise a curve of less than 360 degrees and greater than 270 degrees.

[0036] The annular ring may comprise an electrode group comprising a first electrode of a first length, a second electrode of a second length different than the first length, and a third electrode of a third length different than the first length and different than the second length. The electrodes of the electrode group may be substantially coplanar. The first length may be least 4 mm. The second length may be least 3 mm and may be less than the first length. The third length may be least 2 mm and may be less than the second length. The first length may be 4 mm. The first electrode may be separated from the second electrode and the third electrode by an equal distance.

[0037] In some examples, a method of performing pulmonary denervation may comprise positioning an ablation device in a pulmonary artery trunk of a live animal. The pulmonary artery trunk may include a distal portion of a main pulmonary artery, a proximal portion of a left pulmonary artery, and a proximal portion of a right pulmonary artery. The method may comprise deploying an annular ring from the ablation device. The annular ring may comprise a major axis and a minor axis. The major axis may comprise a first diameter along the major axis longer than a second diameter along the minor axis. The method may comprise ablating at least one of the distal portion of the main pulmonary artery, the proximal portion of the left pulmonary artery and the proximal portion of the right pulmonary artery.

[0038] In some examples, a controller may comprise a housing, an electronic display, an electronic data store, and a computing device. The housing may comprise a connection port disposed along a surface of the housing. The connection port may be configured to interface with a catheter comprising a first electrode of a first length, and a

power from the battery. The computing device may be further configured to store the first electrode ablation information with the first patient profile. The first electrode ablation information may comprise a temperature. The catheter may comprise an annular ring shaped with an oval comprising a major axis and a minor axis. The major axis may comprise a first diameter along the major axis longer than a second diameter along the minor axis. The first electrode may straddle the apex of the major axis.

[0042] In some examples, a computer-implemented method may be under control of one more computing devices executing specific computer executable instructions. The method may comprise receiving a selection of a first patient profile, displaying information characterizing the first patient profile on a user interface, receiving a selection of the first patient profile from the user interface, determining, from the first patient profile, a first power level sufficient for ablation using a first electrode, and directing power at the first power level to the first electrode.

[0043] The first patient profile may be part of a plurality of stored patient profiles from the user interface presented on an electronic display disposed across a surface of a housing. The housing may comprise a catheter connection port disposed along a surface of the housing. The connection port may be configured to interface with a catheter comprising the first electrode. The housing may envelop an electronic data store and the one or more computing devices executing specific computer executable instructions. The electronic data store may comprise the plurality of stored patient profiles characterizing a plurality of patients.

[0044] The first electrode may be configured to convert the power to radiofrequency (RF) energy for ablation of sympathetic nerve fibers. The first electrode may be configured to convert the power to ultrasonic energy for ablation of sympathetic nerve fibers. The first electrode may be configured to convert the power to electroporation energy for ablation of sympathetic nerve fibers. The first electrode may be configured to convert the power to ionizing energy for ablation of sympathetic nerve fibers.

[0045] In some examples, a computer-readable, non-transitory storage medium storing computer executable instructions that, when executed by one or more computer systems, configure the one or more computer systems to perform operations

comprising receiving a selection of a first patient profile of a plurality of stored patient profiles from a user interface presented on an electronic display disposed across a surface of a housing, displaying information characterizing the first patient profile on the user interface, receiving a selection of the first patient profile from the user interface, determining, from the first patient profile, a first power level sufficient for ablation using the first electrode, determining, from the first patient profile, a second power level sufficient for ablation using the second electrode, directing power at the first power level to the first electrode, and directing power at the second power level to the second electrode.

[0046] The housing may comprise a catheter connection port disposed along a surface of the housing. The connection port may be configured to interface with a catheter comprising a first electrode of a first length, and a second electrode of a second length different than the first length. The housing may envelop an electronic data store and the one or more computer systems. The electronic data store may comprise the plurality of stored patient profiles characterizing a plurality of patients. The directing power to the second electrode may direct an amount of power greater than an amount of power directed to the first electrode.

[0047] In some examples, a controller may comprise a housing, a user interface, an electronic data store, and a computing device including one or more processors, the computing device in communication with the electronic data store, and the user interface. The housing may comprise a connection port disposed along the surface of the housing, a user interface disposed along the surface of the housing. The housing may envelop the electronic data store and the computing device. The connection port may be configured to interface with a catheter comprising a first electrode of a first length, and a second electrode of a second length different than the first length. The computing device may be configured to at least receive a selection of the first electrode from the user interface, direct power at a first power level sufficient for ablation using the first electrode to the first electrode, receive a selection of the second electrode from the user interface, and direct power at a second power level sufficient for ablation using the second electrode to the second electrode.

[0048] The computing device may be configured to direct power to the first electrode and direct power to the second electrode at a same time. The computing device

[0052] In some examples, a computer-implemented method may, under control of one more computing devices executing specific computer-executable instructions, comprise receiving a selection of a first electrode on a user interface disposed across a surface of a housing, directing power at a first power level sufficient for ablation using the first electrode to the first electrode, receiving a selection of the second electrode from the user interface, and switching from directing power to the first electrode to directing power at a second power level sufficient for ablation using the second electrode to the second electrode. The housing may comprise a connection port disposed along a surface of the housing, the connection port configured to interface with a catheter comprising the first electrode (which may be of a first length), and the second electrode (which may be of a second length different than the first length). The housing may envelop an electronic data store and the one or more computing devices executing specific computer-executable instructions.

[0053] The switching may be performed using a mechanical switch that comprises at least one moving part. The user interface may be a rotatable knob. The switching may be performed using a switching system comprising a mechanical switch that comprises at least one moving part, and a solid state switch that comprises no moving parts.

[0054] In some examples, a computer-readable, non-transitory storage medium storing computer executable instructions that, when executed by one or more computer systems, may configure the one or more computer systems to perform operations. The operations may comprise receiving a selection of a first electrode from a user interface presented on an electronic display disposed across a surface of a housing, directing power at a first power level sufficient for ablation using the first electrode to the first electrode, receiving a selection of the second electrode from the user interface, and switching from directing power to the first electrode to directing power at a second power level sufficient for ablation using the second electrode to the second electrode. The housing may comprise a connection port disposed along the surface of the housing. The connection port may be configured to interface with a catheter comprising the first electrode (of a first length), and the second electrode (of a second length different than the first length). The housing may envelop an electronic data store and the one or more computer systems. The switching may be performed by controlling a solid state switch that comprises no moving parts.

WHAT IS CLAIMED IS:

1. A device for ablating a target tissue at a main pulmonary artery of a patient, the device comprising:

a catheter body comprising a proximal end and a terminal distal end;

an annular ring coupled to the terminal distal end of the catheter body; and

a plurality of electrodes supported by the annular ring,

wherein the plurality of electrodes comprises a first electrode arranged and sized to contact a left lateral apex of the main pulmonary artery, a second electrode arranged and sized to contact an anterior side of the left lateral apex, and a third electrode arranged and sized to contact a posterior side of the left lateral apex when the annular ring is deployed in the main pulmonary artery.

2. The device according to claim 1, wherein the annular ring is elliptical, wherein the elliptical ring has a major axis and a minor axis, and wherein the minor axis divides the elliptical ring into a first portion and a second portion, the first portion encompassing an apex of the major axis.

3. The device according to claim 2, wherein a number of electrodes supported by the first portion of the elliptical ring exceeds a number of electrodes supported by the second portion of the elliptical ring.

4. The device according to claim 2, wherein the major axis comprises a first diameter and the minor axis comprises a second diameter.

5. The device according to claim 4,, and wherein the first diameter is 5 mm longer than the second diameter.

6. The device according to claim 4, wherein the first diameter has a length from 25 mm to 50 mm, and wherein the second diameter is shorter than the first diameter and has a length of 20 mm to 45 mm.

7. The device according to claim 4, wherein the length of the second diameter is about 10% to about 20% shorter than the length of the first diameter.

8. The device according to claim 2, wherein the first electrode of the plurality of electrodes is disposed over the apex of the major axis.

9. The device according to claim 1, wherein the second and third electrodes of the plurality of electrodes straddle both sides of the first electrode on the annular ring.

10. The device according to claim 1, wherein the distal end of the catheter body is flexible, and wherein the annular ring is orthogonal to the distal end when the annular ring is deployed in the main pulmonary artery.

11. The device according to claim 1, wherein the annular ring is planar.

12. The device according to claim 1, wherein the annular ring comprises a curve of less than 360 degrees.

13. The device according to claim 1, wherein the first electrode has a first length, the second electrode has a second length different than the first length, and the third electrode has a third length different than the first length and different than the second length.

14. The device according to claim 1, wherein the first, second, and third electrodes are substantially coplanar.

15. The device according to claim 1, wherein the annular ring comprises a curve of less than 360 degrees and greater than 270 degrees.

16. The device according to claim 15, wherein the first length is about 4 mm.

17. The device according to claim 15, wherein the second length is at least 3 mm and is less than the first length.

18. The device according to claim 15, wherein the third length is at least 2 mm and is less than the second length.

19. The device according to claim 1, wherein the first electrode is separated from the second electrode and the third electrode by an equal distance.