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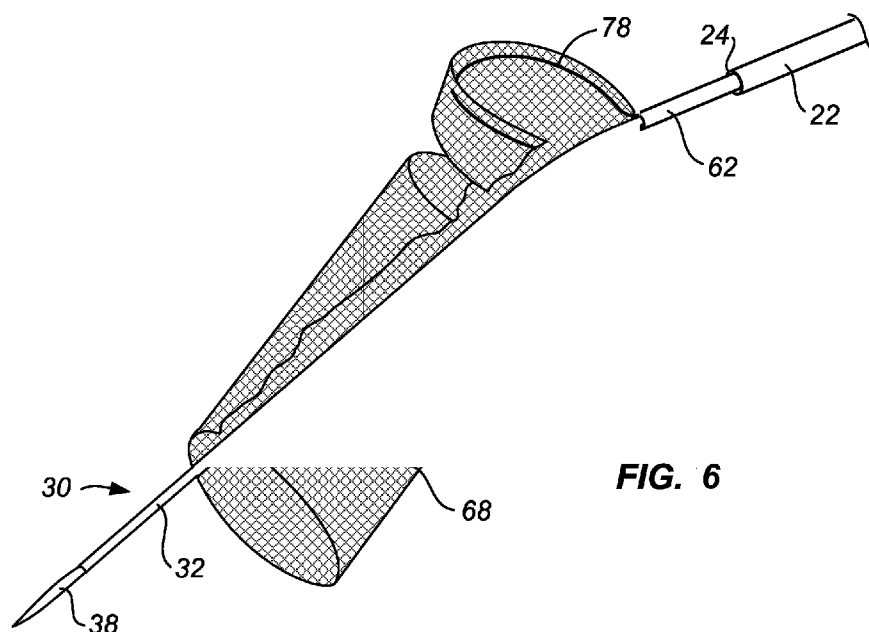


FIG. 6

(57) Abstract: An embolic filter positioning system includes a vascular delivery sheath, a filter catheter, a self-expanding embolic filter attached to a distal end of the filter catheter, and an elongate dilator having a tapered dilator tip. The elongate dilator is slidably received in a central lumen of the filter catheter, and the filter catheter is slidably received in the open lumen of the vascular delivery sheath. The tapered dilator tip is positioned distally of the distal end of the vascular delivery sheath, and the self-expanding embolic filter is radially constrained in a proximal portion of the open lumen of the vascular delivery sheath. The tapered dilator tip has an expanded configuration where it covers the open distal end of the vascular delivery sheath and facilitates entry through an arteriotomy and a contracted configuration where it can be retracted through the central lumen of the filter catheter..

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METHODS AND SYSTEMS FOR PLACING EMBOLIC FILTERS IN AN AORTIC ARCH

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of provisional patent application Serial No. 63/151,508 (Attorney Docket No 41959-715.101), filed on February 19, 2021, the full disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention. The present invention relates generally to medical apparatus and methods and more particularly to methods and systems for placing embolic filters in a patient's aortic arch prior to transcatheter aortic valve replacement (TAVR) and other aortic valve procedures.

[0003] Transcatheter aortic valve replacement (TAVR) has become a preferred alternative to open heart surgery for many patients needing aortic valve replacement. The most common approach is "transfemoral" where the femoral artery is accessed via a small incision in the groin, and the replacement valve is advanced from the femoral artery into the descending aorta and over the aortic arch using a specialized delivery catheter.

[0004] While highly successful, transfemoral and other TAVR procedures can release emboli and present a significant risk of cerebral embolism. Embolic particles, such as thrombus, atheroma and lipids, may become dislodged by advancement and manipulation of the delivery catheter and enter the bloodstream, embolizing in the brain or other vital organs downstream. Cerebral embolism can lead to neuropsychological deficits, stroke and even death. Other organs downstream can also be damaged by embolism, resulting in diminished function or organ failure.

[0005] For these reasons, the use of an embolic protection system during TAVR and other catheter-based procedures has been proposed. For example, commonly owned US10,617,509, describes a cylindrical embolic filter and a system for placing the filter into a patient's aortic arch for reducing the risk of cerebral aneurysm and other negative outcomes caused by the release of emboli during TAVR. The embolic filter is placed by introducing a convention dilator and access sheath assembly 10, as shown in FIG. 1, though the femoral artery. The sheath assembly 10 comprises a tubular access sheath 12 and a dilator 14 having a tapered distal tip 16. The dilator tip 16 is solid, and the dilator 14 has a guidewire lumen (not shown) extending axially therethrough to receive a guidewire 18. As the dilator 14 and tip 16 are solid and one piece, the entire dilator must be removed from the access sheath 12 to free the access sheath lumen to introduce a filter delivery catheter. As described in US10,617,509, the separate filter delivery

catheter is introduced into the access sheath lumen using a peel-away sheath after removing the dilator. While fully workable, the time needed to remove the dilator, place the peel-away sheath, and introduce the filter delivery catheter is significant and adds to the overall procedure time.

[0006] For those reasons, it would be advantageous to provide improved methods and systems for introducing embolic filters into a patient's aortic arch for embolic protection during TAVR and other cardiac and vascular procedures. In particular, it would be advantageous to reduce the number of steps need to deploy such embolic filters and/or to reduce an overall procedure time. At least some of these objectives will be met by the inventions described and claimed herein.

[0007] 2. Description of the Background Art. US10,617,509, has been described above.

WO2017/116828 and US2020/0197151 are related to US10,617,509. Other devices for inhibiting cerebral embolism are described in the following commonly patents and patent applications, which are hereby incorporated by reference: U.S. Pat. No. 10,166,094, for Catheter with integrated embolic protection device; U.S. Pat. No. US 9,877,821 for Introducer sheath with embolic protection; U.S. Pat. No. 6,254,563 for Perfusion shunt apparatus and method; U.S. Pat. App. 2010/0312268 for Embolic protection device; U.S. Pat. App. 2004/0215167 for Embolic protection device; PCT App. WO2004/019817 for Embolic protection device; U.S. Pat. No. 6,371,935 for Aortic catheter with flow divider and methods for preventing cerebral embolization; U.S. Pat. No. 6,361,545 for Perfusion filter catheter; U.S. Pat. No. 6,254,563 for Perfusion shunt apparatus and method; U.S. Pat. No. 6,139,517 for Perfusion shunt apparatus and method; U.S. Pat. No. 6,537,297 for Methods of protecting a patient from embolization during surgery; U.S. Pat. No. 6,499,487 for Implantable cerebral protection device and methods of use; U.S. Pat. No. 5,769,816 for Cannula with associated filter; and U.S. Pat. App. 2003/0100940 for Implantable intraluminal protector device and method of using same for stabilizing atheroma. See also US8,419,677 and US2012/0109056.

SUMMARY OF THE INVENTION

[0008] In a first aspect, the present invention provides a method for positioning an embolic filter in a patient's aortic arch. The method comprises providing an embolic filter positioning assembly including a dilator component that facilitates introduction into the patient's vasculature and reduces the steps and time need to place the embolic filter in the aortic arch. The embolic filter positioning assembly includes (1) a vascular delivery sheath, (2) a filter catheter slidably received in an open lumen of said vascular delivery sheath, (3) an elongate dilator having a guidewire lumen slidably received in a central lumen of the filter catheter, (4) a tapered dilator tip attached at a distal end of the elongate dilator, and (5) an embolic filter carried on a distal portion of the filter catheter. The tapered dilator tip is expanded and positioned to extend distally beyond and

cover an open distal end of the vascular delivery sheath, and the expanded tapered dilator tip of the embolic filter positioning assembly is introduced through an arteriotomy, over a first guidewire received in the guidewire lumen of the elongate dilator, and into the patient's arterial vasculature. A distal end of the embolic filter positioning assembly is advanced to position the embolic filter carried on the distal portion of the filter catheter in the patient's aortic arch, and a distal portion of the vascular delivery sheath is retracted from over the embolic filter, and the embolic filter is expanded within the patient's aortic arch. The tapered dilator tip may then be contracted, and the tip retracted proximally into or through the central lumen of the filter catheter.

[0009] In some examples of these methods, expanding the tapered dilator tip may comprise inflating the tapered dilator tip and contracting the tapered dilator tip comprises deflating the tapered dilator tip.

[0010] In some examples of these methods, the tapered dilator tip may have a conical geometry with a base and positioning the tapered dilator tip to extend distally beyond and cover an open distal end of the vascular delivery sheath comprises detachably mating the base with the open distal end of the vascular delivery sheath. In some instances, the base of the tapered dilator tip may be cylindrical and configured to fit inside the open distal end of the vascular delivery sheath.

[0011] In some examples of these methods, a proximal end of the embolic filter may be closed and the filter may be retracted back into the vascular delivery sheath. In specific instances, closing the proximal end of the embolic filter may comprise ratcheting a lasso on the proximal end of the embolic filter.

[0012] In some examples of these methods, the embolic filter self-expands within the patient's aortic arch after the distal portion of the vascular sheath is retracted from over the embolic filter.

[0013] In a second aspect, the present invention provides method for implanting a prosthetic aortic valve in a patient's aortic arch. The method comprises placing an embolic filter in the patient's aortic arch by any of the methods described above and elsewhere herein. The prosthetic aortic valve is advanced through the embolic filter, and the prosthetic aortic valve is deployed in the patient's aortic annulus while the embolic filter remains in place in the aortic arch.

[0014] In some examples of such valve implantation methods, advancing the prosthetic aortic valve through the embolic filter comprises removing the elongate dilator from the central lumen of the filter catheter leaving the first guidewire in place in the central lumen of the filter catheter. The first guidewire is then exchanged for an angiography pigtail catheter, and one or more valve placement guidewires are advanced through the embolic filter and over the aortic arch in parallel to the embolic filter positioning assembly. A valve placement catheter carrying the prosthetic

valve is then advanced over the one or more valve placement guidewires to the aortic annulus or other target location.

[0015] In a third aspect, the present invention provides an embolic filter positioning system which comprises (1) a vascular delivery sheath having a proximal hemostasis valve, an open distal end, and an open lumen extending from the open distal end to the hemostasis valve, (2) a filter catheter having a proximal end, a distal end, and a central lumen therethrough, (3) a self-expanding embolic filter attached to the distal end of the filter catheter, (4) an elongate dilator having a proximal end, a distal end, and a guidewire lumen therethrough, and (5) a tapered dilator tip attached at the distal end of the elongate dilator. The elongate dilator is configured to be slidably received in the central lumen of the filter catheter, and the filter catheter is configured to be slidably received in the open lumen of the vascular delivery sheath. The tapered dilator tip is positionable distally of the distal end of the vascular delivery sheath, and the self-expanding embolic filter is configured to be radially constrained in a proximal portion of the open lumen of the vascular delivery sheath. The tapered dilator tip has an expanded configuration where it covers the open distal end of the vascular delivery sheath and facilitates entry through an arteriotomy and a contracted configuration where it can be retracted through the central lumen of the filter catheter.

[0016] In some examples of the embolic filter positioning systems of the present invention, the tapered dilator tip may have a conical geometry with a base configured to detachably mate with the open distal end of the vascular delivery sheath. In particular instances, the base of the tapered dilator tip may be cylindrical and configured to fit inside the open distal end of the vascular delivery sheath.

[0017] In other examples, the embolic filter positioning systems of the present invention may further comprise a handle attached to the proximal end of the filter catheter. In particular instances, the handle may comprise a mechanism for closing a proximal end of the embolic filter prior to retraction of the filter back into the vascular delivery sheath, for example the mechanism for closing a proximal end of the embolic filter may comprise a ratcheting retractor coupled to a lasso on the proximal end of the embolic filter.

[0018] In some examples of the embolic filter positioning systems of the present invention, the embolic filter may comprise a cylindrical body configured to self-expand in and conform to the inner wall of the patient's aortic arch. In particular instances, the embolic filter may further comprise a port extending across a central passage of cylindrical body, wherein the port is expandable and configured to seal against the outer surfaces of catheters and guidewires advanced therethrough. In other instances, the cylindrical body of the embolic filter may

comprise comprises a porous material comprising a fabric of knitted, woven, or nonwoven fibers, filaments, or wires. For example, the porous material is made of a resilient metal, polymer material, a malleable material, a plastically deformable material, a shape-memory material, or combinations thereof. In other examples, the porous material may have a pore size chosen to prevent emboli over a predetermined size from passing through.

INCORPORATION BY REFERENCE

[0019] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0021] FIG. 1 shows a prior art endovascular sheath having a conventional solid dilator with a guidewire extending distally from a lumen of the dilator.

[0022] FIGS. 2A-2C show a distal portion of a vascular delivery sheath according to the present invention with the balloon dilator uninflated in FIG. 2A, the balloon dilator inflated in FIG. 2B, and the inflated balloon dilator drawn proximally into the distal tip of the sheath in FIG. 2C.

[0023] FIG. 3 shows the full-length sheath of FIGS. 2A-2C including a hemostatic valve at its proximal end and without the dilator.

[0024] FIG. 4 shows the full-length dilator of the vascular delivery sheath of FIGS. 2A-2C including a proximal hub.

[0025] FIG. 5 shows a filter catheter according to the present invention having an embolic filter at its distal end and a handle at its proximal end.

[0026] FIG. 6 is a detailed view with portions broken away showing the embolic filter attached at a distal end of a filter catheter shaft and having the vascular delivery sheath assembly positioned therethrough with an inflatable tip in its deflated configuration.

[0027] FIG. 7 is a detailed view showing the inflatable tip of the dilator of the vascular delivery sheath assembly in its inflated configuration extending from the distal end of the vascular delivery sheath.

[0028] FIG. 8 is a detailed view similar to that of FIG. 7 where the inflated tip of the dilator has been drawn proximally into an open end of the vascular delivery sheath to a patient's femoral artery.

[0029] FIGS. 9A-9F illustrate use of the vascular delivery sheath assembly of the present invention for placing an embolic filter in a patient's aortic arch and thereafter implanting a prosthetic valve in the patient's aortic valve annulus.

[0030] FIGS. 10A and 10B illustrate use of a ratcheting mechanism for closing an end of the embolic filter prior to drawing the filter back into the delivery sheath.

DETAILED DESCRIPTION OF THE INVENTION

[0031] For purposes of this patent application, the term "distal" refers to the end of the device that is farthest away from the operator, and closest to the heart. This is also the "upstream" direction of blood flow. The term "proximal" refers to the end of the device nearer to the operator, toward the direction of the access site where the device has been introduced into the body, and farthest away from the heart. This is also the "downstream" direction of blood flow.

[0032] In the present invention, a conventional dilator is replaced with an "expandable tip catheter," typically a "balloon dilator," having a distal taper of similar profile to the tapered tip of a conventional dilator, attached to a smaller diameter shaft having a guidewire lumen to accommodate a guidewire with additional lumen(s) to enable inflation and deflation of the balloon. The construction may similar to a non-distensible balloon catheter used for angioplasty, where the shape of the balloon optimized to facilitate its use as a dilator, typically being a tapered cone with the narrow end facing in a distal direction.

[0033] A principal benefit of the balloon or other expandable dilator of the present invention is that the associated interventional or diagnostic catheter can be placed through a sheath and over the shaft of the balloon dilator (that is in turn over a guidewire), without the need for removal of the balloon dilator. In preferred embodiments, the interventional or diagnostic device can be preloaded over the balloon dilator in the sheath to save procedural time and enhance the ease of use of devices, which no longer require an initially introducing step through the proximal end of the sheath.

[0034] By way of example, an embolic protection filter may be made from a self-expanding material (e.g., a shape memory alloy) can be compressed and preloaded into the distal end of the sheath over the shaft of a balloon dilator. The balloon dilator can then be withdrawn until the balloon itself is located at the distal end of the sheath. The balloon can then be inflated to create a somewhat rigid distal taper that mates with the end of the sheath. This whole system can then be introduced over a guidewire, through a Seldinger puncture and advanced to the treatment

location. The sheath is then withdrawn from around the filter, allowing the filter to expand into position. After filter deployment, the balloon is deflated and the entire balloon dilator system is withdrawn through the filter and attachment catheter lumen and removed, leaving the sheath, filter and guidewire behind.

[0035] The tapered balloon of the present invention could also be replaced with a mechanically expandable frame with a polymer covering, or any other expandable and contractable system that acts as a temporary dilator tip during insertion of the sheath through the Seldinger puncture.

[0036] Some delivery systems use a nose cone, or olive at the distal end replacing the traditional dilator and allowing for devices to be loaded over a smaller shaft at the distal end. In these cases, the olive can be either closely mated to the ID of the sheath, in which case, it is possible to remove it through the sheath, or matched to the OD of the sheath which prohibits its removal from the sheath. In the balloon dilator of the present invention, the diameter of the inflated balloon can be matched to the diameter of the sheath and still be removed because the balloon is collapsible, providing more flexibility for delivery or passage of other interventional devices.

[0037] In addition, as interventional procedures and devices increase in complexity, multi-catheter systems may be required for their delivery into the body. One example is a system comprised of four catheters in which each catheter has a separate function, while being able to be introduced through a singular arteriotomy. The first (outermost) catheter acts as a vehicle for access and removal within the vasculature of two additional devices. A second catheter is attached to, or carries, either a therapeutic, or a prophylactic device. A third balloon dilator catheter passes through the second catheter to allow for insertion through the arteriotomy. Finally, a diagnostic catheter replaces the balloon dilator catheter leaving three catheters with separate functions in a single arteriotomy. Any fixed diameter dilator, nose cone, or olive (as opposed to the collapsible balloon dilator) matched to the diameter of the outer catheter for use in crossing the arteriotomy, would therefore be too large to be removed through the second catheter, and therefore would require a second puncture/access site for placement of the diagnostic catheter.

[0038] Referring now to FIGS. 2A-2C, 3, and 4, a vascular delivery sheath assembly 20 according to the present invention comprises a vascular delivery sheath 22 having an open distal end 24, a proximal end 26 (FIG. 3), and a lumen 28 therethrough. A dilator 30 comprises a shaft 32 having a distal end 34, a proximal end (not shown), and an inflatable tip 38 at its distal end. The inflatable tip 38 is shown in its uninflated condition in FIG. 2A. The tip 38 is shaped to be inflated into a tapered profile, typically a conical profile, as shown in FIG 2B. The conical configuration includes a narrow or pointed distal end 40 and a cylindrical base 42 at its proximal

end. As shown in FIG. 2C, the dilator shaft 32 may be pulled proximally in order to draw the base 42 into the distal opening 24 of the vascular delivery sheath 22. Once the inflated distal tip 38 is fully proximally retracted, as shown in FIG. 2C, the vascular delivery sheath assembly 20 is ready to be introduced over a guidewire 44 and used in the vascular procedures of the present invention as described more fully below. The sheath 22 typically includes a hemostatic valve 46 which may include a side port 48 for introducing contrast or other purposes. The dilator 30 has a guidewire lumen (not shown) and typically includes a hub 50 with a hemostatic port 52 for receiving the guidewire 44 and an inflation port 54 for inflating the inflatable tip 38.

[0039] Referring now to FIG. 5, a filter catheter 60 comprises a shaft 62 having a distal end 64 and a proximal end 66. The shaft 62 will be dimensioned to fit within the lumen of the vascular delivery sheath 22, as will be described in more detail below. The shaft 62 will typically itself include a lumen or central passage for connecting a purse string loop 78 at the distal end 64 to a handle 70 at the proximal end 66. An embolic filter 68, typically a self-expanding cylindrical mesh filter of the type described in commonly owned US Patent Publication No. 2020/0253709, the full disclosure of which is incorporated herein by reference, is secured to the distal end 64 of the shaft 62, typically by the purse string loop 78. The handle 70 includes a side port 72, typically configured to receive the dilator 30 and/or associated guidewires, and a ratchet pull 76. The ratchet pull is configured to be “ratcheted,” as shown in FIGS. 10A and 10B, to apply a proximal tension on the purse string 78 in order to close a proximal end of the embolic filter, as shown in FIG. 10B.

[0040] Referring now to FIG. 6, to prepare the vascular delivery sheath assembly 20 for introduction to a patient, the dilator 30 is first introduced through the lumen of shaft 62 so that it extends through the interior of the embolic filter 68. A subassembly of the dilator 30 and the filter catheter 60 is then advanced into the vascular delivery sheath 22 so that they together extend beyond the distal opening 24 of sheath 22.

[0041] Referring now to FIGS. 7 and 8, the vascular delivery sheath assembly 24 is further prepared by retracting the embolic filter 68 through opening 24 of the sheath 22 so that it elongates and is radially constrained. The inflatable tip 38 of the dilator 30 is then inflated to assume its tapered configuration. The inflatable tip 38 is typically formed from a non-distensible material such as polyethylene terephthalate (PET), a nylon, or other material of a type used in fabricating angioplasty balloons. The inflatable tip will be inflated with a non-compressible fluid, typically saline, to a pressure sufficient to form a rigid body suitable for advancement into the femoral artery and through the patient’s vasculature. In this way, during use, the inflatable tip will perform in a manner similar to a conventional solid-tip dilator.

[0042] After the inflatable tip 38 has been inflated, it can be retracted into the open end 24 of the vascular delivery sheath 22. When inflated, the inflatable tip 38 will typically have a generally conical shape with a pointed tip 40 and a cylindrical base 42, where the cylindrical base is sized and configured to mate with the open end 24 of the sheath and the dilator is retracted proximally within the sheath, as shown in FIG. 8.

[0043] Referring now to FIGS. 9A-9F, use of the vascular delivery sheath assembly 20 for placing the embolic filter 68 in a patient's aortic arch AA will be described. With the distal region of the vascular delivery sheath assembly 20 in the configuration shown in FIGS. 2C and 8, the inflatable tip 38 is introduced over guidewire 44 through a femoral access site FAS. The inflated tip 38 acts in a manner identical to a conventional solid dilator at this stage of the intervention. The inflated tip 38 and vascular delivery sheath 22 are then advanced over the patient's aortic arch AA, as shown in FIG. 9B.

[0044] After the distal portion of the vascular delivery sheath assembly 20 reaches a target location over the aortic arch AA, the delivery sheath 22 will be retracted to deploy the embolic filter 68, as shown in FIG. 9C. Reflection may be achieved by pulling proximally on the hemostatic valve 46 at the proximal end of the sheath 22 to pull the sheath back over shaft 62 of the filter catheter 60, allowing the filter to self-expand. After the embolic filter has been employed, the inflatable tip 38 may be deflated and drawn proximally back into the lumen 28 of sheath 22. Typically, the entire dilator 30 will be removed from the sheath 22 at this point.

[0045] With the embolic filter 68 probably deployed, a separate guidewire GW can be introduced over the aortic arch AA and through the filter, and a delivery catheter 92 advanced over the guidewire GW, as shown in FIG. 9E. The delivery catheter 92 may be used to deliver any conventional prosthetic aortic valve, typically a balloon-expandable aortic valve, such as an Edwards Sapien® valve or a Medtronic CoreValve® heart. Details of how the valve can be introduced through embolic filter 68 are provided in commonly owned US Patent Publication No. 2020/0253709, the full disclosure which has been previously incorporated herein by reference.

[0046] After the prosthetic aortic valve 90 has been properly implanted, the valve delivery catheter 90 can be removed followed by removal of the embolic filter 68, as shown in FIG. 9F. Typically, the ratchet pull 76 on the filter catheter handle 70 is used to drawdown the purse string loop 78 on the filter prior to drawing proximally on the filter catheter to pull the filter 68 into the open end 24 of the sheath 22, as shown in FIGS. 10A and 10B.

[0047] While preferred embodiments of the present invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in

the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

WHAT IS CLAIMED IS:

1. A method of positioning an embolic filter in a patient's aortic arch, said method comprising:

providing an embolic filter positioning assembly including (1) a vascular delivery sheath, (2) a filter catheter slidably received in an open lumen of said vascular delivery sheath, (3) an elongate dilator having a guidewire lumen slidably received in a central lumen of the filter catheter, (4) a tapered dilator tip attached at a distal end of the elongate dilator, and (5) an embolic filter carried on a distal portion of the filter catheter;

expanding and positioning the tapered dilator tip to extend distally beyond and cover an open distal end of the vascular delivery sheath;

introducing the expanded tapered dilator tip of the embolic filter positioning assembly through an arteriotomy, over a first guidewire received in the guidewire lumen of the elongate dilator, and into the patient's arterial vasculature;

advancing a distal end of the embolic filter positioning assembly to position the embolic filter carried on the distal portion of the filter catheter in the patient's aortic arch;

retracting a distal portion of the vascular delivery sheath from over the embolic filter and expanding the embolic filter within the patient's aortic arch; and

contracting the tapered dilator tip and retracting said tip proximally into or through the central lumen of the filter catheter.

2. The method of claim 1, wherein expanding the tapered dilator tip comprises inflating the tapered dilator tip and contracting the tapered dilator tip comprises deflating the tapered dilator tip.

3. The method of claim 1 or 2, wherein the tapered dilator tip has a conical geometry with a base and positioning the tapered dilator tip to extend distally beyond and cover an open distal end of the vascular delivery sheath comprises detachably mating the base with the open distal end of the vascular delivery sheath.

4. The method of claim 3, wherein the base of the tapered dilator tip is cylindrical and configured to fit inside the open distal end of the vascular delivery sheath.

5. The method of claim 1 to 4, further comprising closing a proximal end of the embolic filter and retracting the filter back into the vascular delivery sheath.

6. The method of claim 5, wherein closing the proximal end of the embolic filter comprises a ratcheting a lasso on the proximal end of the embolic filter.

7. The method of claim 1 to 6, wherein the embolic filter self-expands within the patient's aortic arch after the distal portion of the vascular sheath is retracted from over the embolic filter.

8. A method for implanting a prosthetic aortic valve in a patient, said method comprising:
placing an embolic filter in the patient's aortic arch as in any one of claims 1 to 7;
advancing the prosthetic aortic valve through the embolic filter; and
deploying the prosthetic aortic valve in the patient's aortic annulus while the embolic filter remains in place in the aortic arch.

9. The method of claim 8, wherein advancing the prosthetic aortic valve through the embolic filter comprises:

removing the elongate dilator from the central lumen of the filter catheter leaving the first guidewire in place in the central lumen of the filter catheter;

exchanging the first guidewire for an angiography pigtail catheter;

advancing one or more valve placement guidewires through the embolic filter and over the aortic arch in parallel to the embolic filter positioning assembly; and

advancing a valve placement catheter carrying the prosthetic valve over the one or more valve placement guidewires.

10. An embolic filter positioning system comprising:

a vascular delivery sheath having a proximal hemostasis valve, an open distal end, and an open lumen extending from the open distal end to the hemostasis valve;

a filter catheter having a proximal end, a distal end, and a central lumen therethrough;

a self-expanding embolic filter attached to the distal end of the filter catheter;

an elongate dilator having a proximal end, a distal end, and a guidewire lumen therethrough;

a tapered dilator tip attached at the distal end of the elongate dilator;

wherein the elongate dilator is configured to be slidably received in the central lumen of the filter catheter, the filter catheter is configured to be slidably received in the open lumen of the vascular delivery sheath, the tapered dilator tip is positionable distally of the distal end of the vascular delivery sheath, and the self-expanding embolic filter is configured to be radially constrained in a proximal portion of the open lumen of the vascular delivery sheath; and

wherein the tapered dilator tip has an expanded configuration where it covers the open distal end of the vascular delivery sheath and facilitates entry through an arteriotomy and a contracted configuration where it can be retracted through the central lumen of the filter catheter.

11. The embolic filter positioning system of claim 10, wherein the tapered dilator tip has a conical geometry with a base configured to detachably mate with the open distal end of the vascular delivery sheath.

12. The embolic filter positioning system of claim 11, wherein the base of the tapered dilator tip is cylindrical and configured to fit inside the open distal end of the vascular delivery sheath.

13. The embolic filter positioning system of claim 10 to 12, further comprising a handle attached to the proximal end of the filter catheter.

14. The embolic filter positioning system of claim 13, wherein the handle comprises a mechanism for closing a proximal end of the embolic filter prior to retraction of the filter back into the vascular delivery sheath.

15. The embolic filter positioning system of claim 14, wherein the mechanism for closing a proximal end of the embolic filter comprises a ratcheting retractor coupled to a lasso on the proximal end of the embolic filter.

16. The embolic filter positioning system of claim 10 to 15, wherein the embolic filter comprises a cylindrical body configured to self-expand in and conform to the inner wall of the patient's aortic arch.

17. The embolic filter positioning system of claim 16, wherein the embolic filter further comprises a port extending across a central passage of cylindrical body, wherein the port is expandable and configured to seal against the outer surfaces of catheters and guidewires advanced therethrough.

18. The embolic filter positioning system of claims 16 or 17, wherein the cylindrical body comprises a porous material comprising a fabric of knitted, woven, or nonwoven fibers, filaments, or wires.

19. The embolic filter positioning system of claim 18, wherein the porous material is made of a resilient metal, polymer material, a malleable material, a plastically deformable material, a shape-memory material, or combinations thereof.

20. The embolic filter positioning system of claim 18 or 19, wherein the porous material has a pore size chosen to prevent emboli over a predetermined size from passing through.

1 / 8

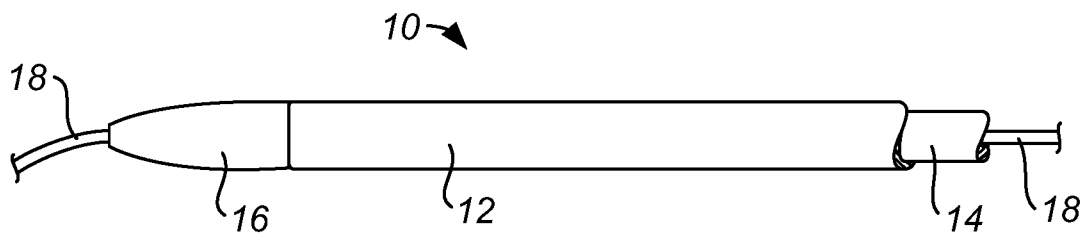


FIG. 1
(PRIOR ART)

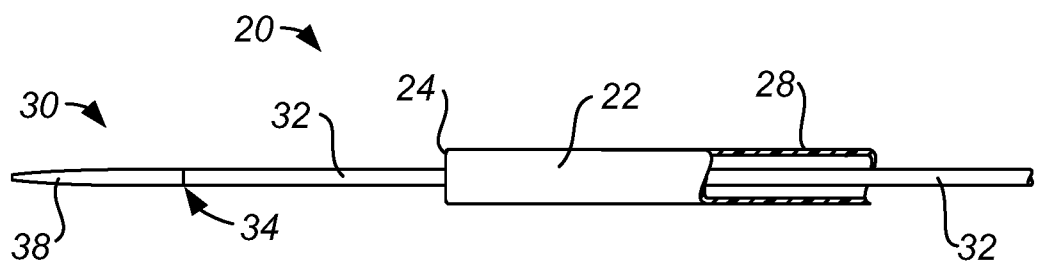


FIG. 2A

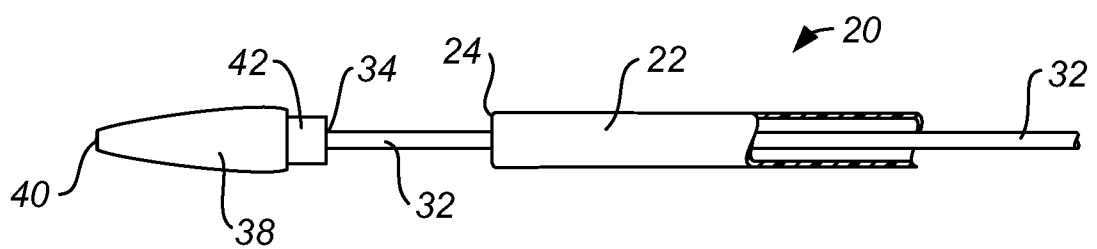


FIG. 2B

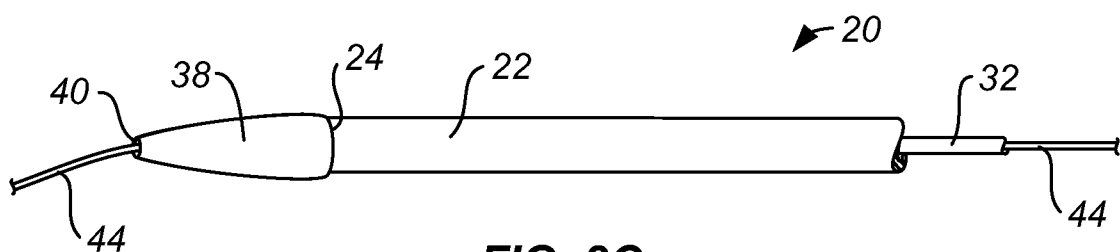


FIG. 2C

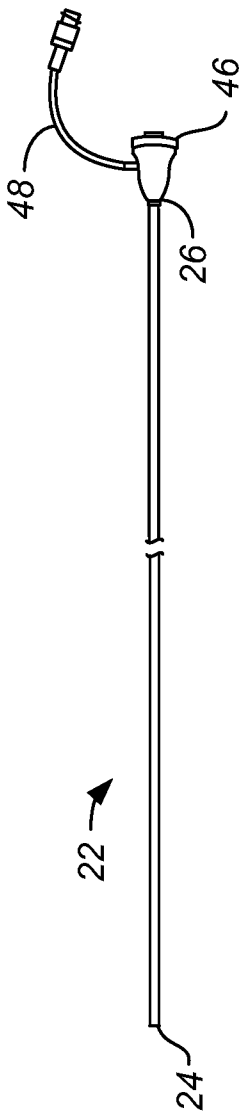


FIG. 3

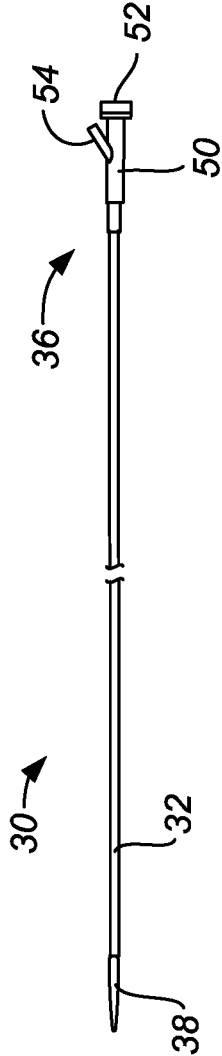


FIG. 4

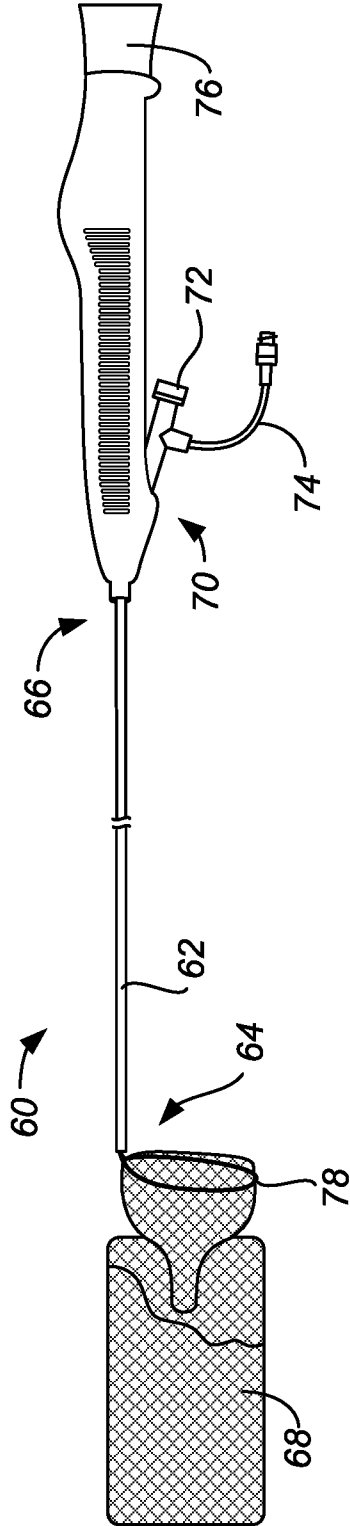
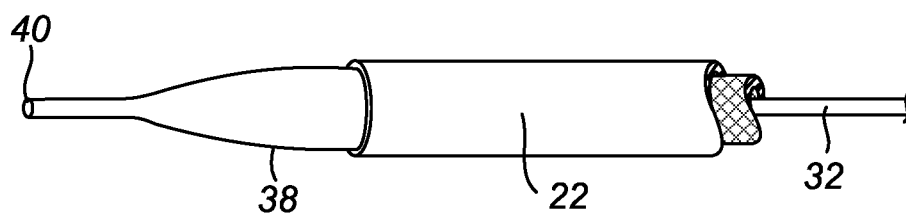
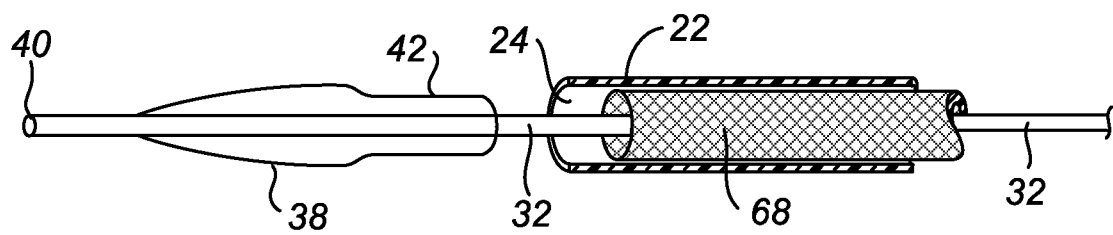
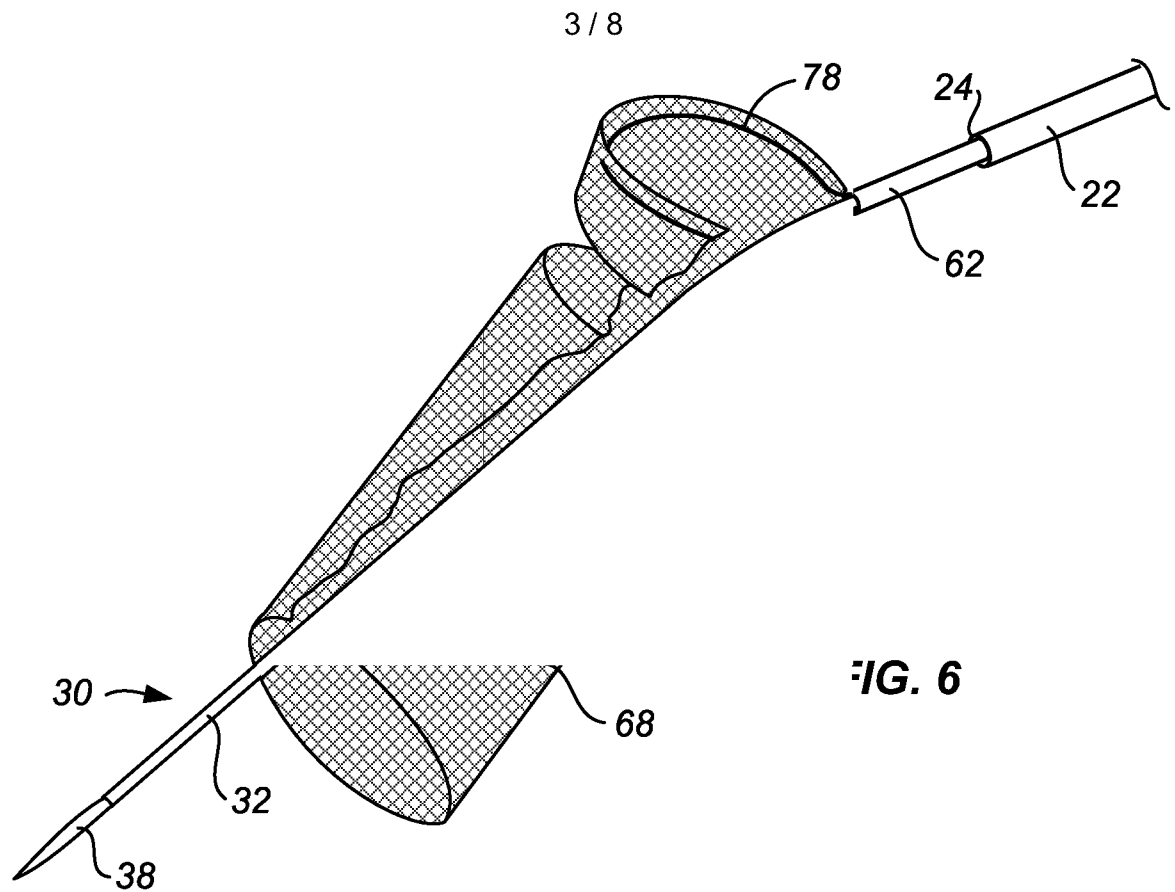


FIG. 5



4 / 8

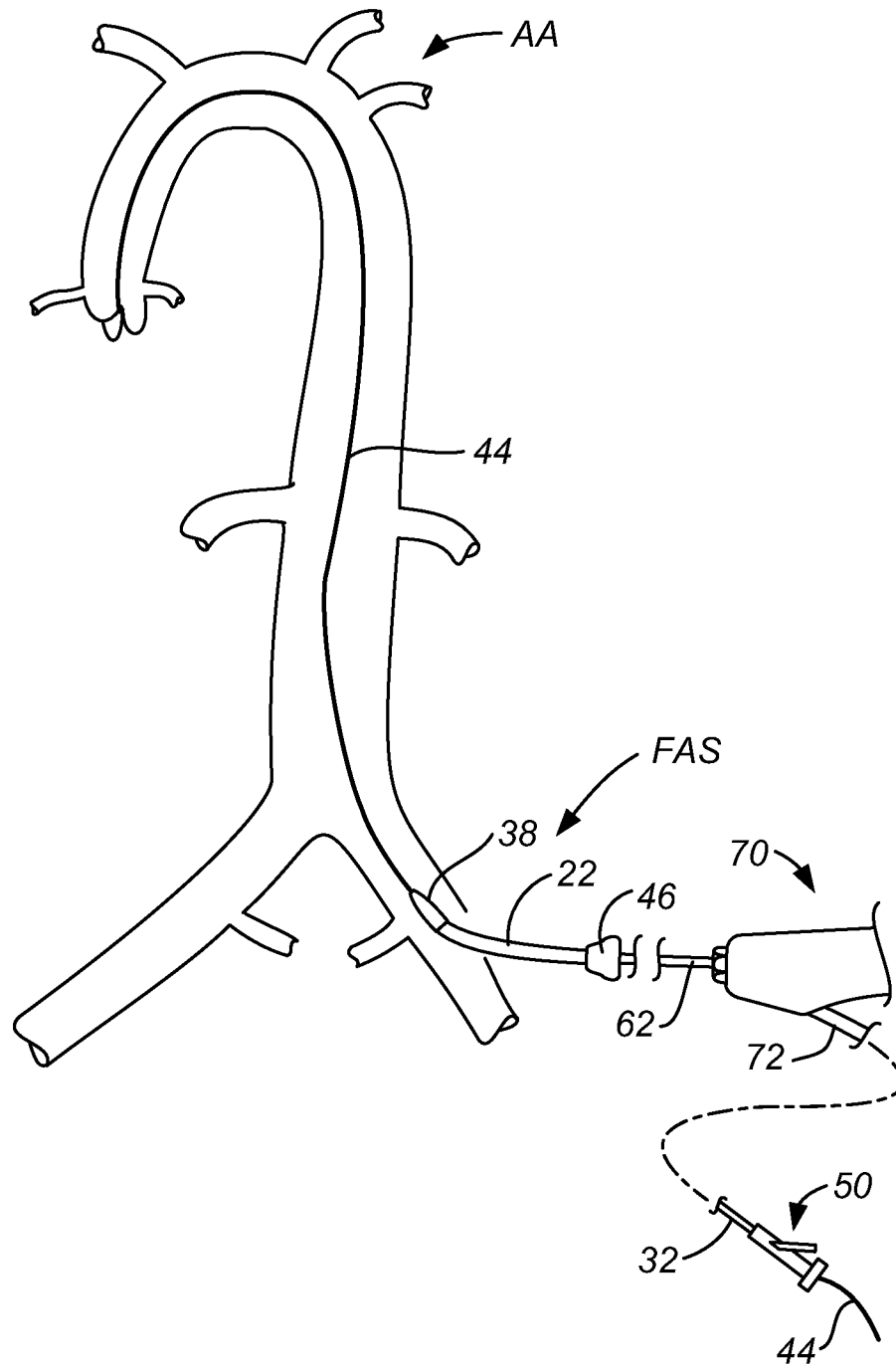


FIG. 9A

5 / 8

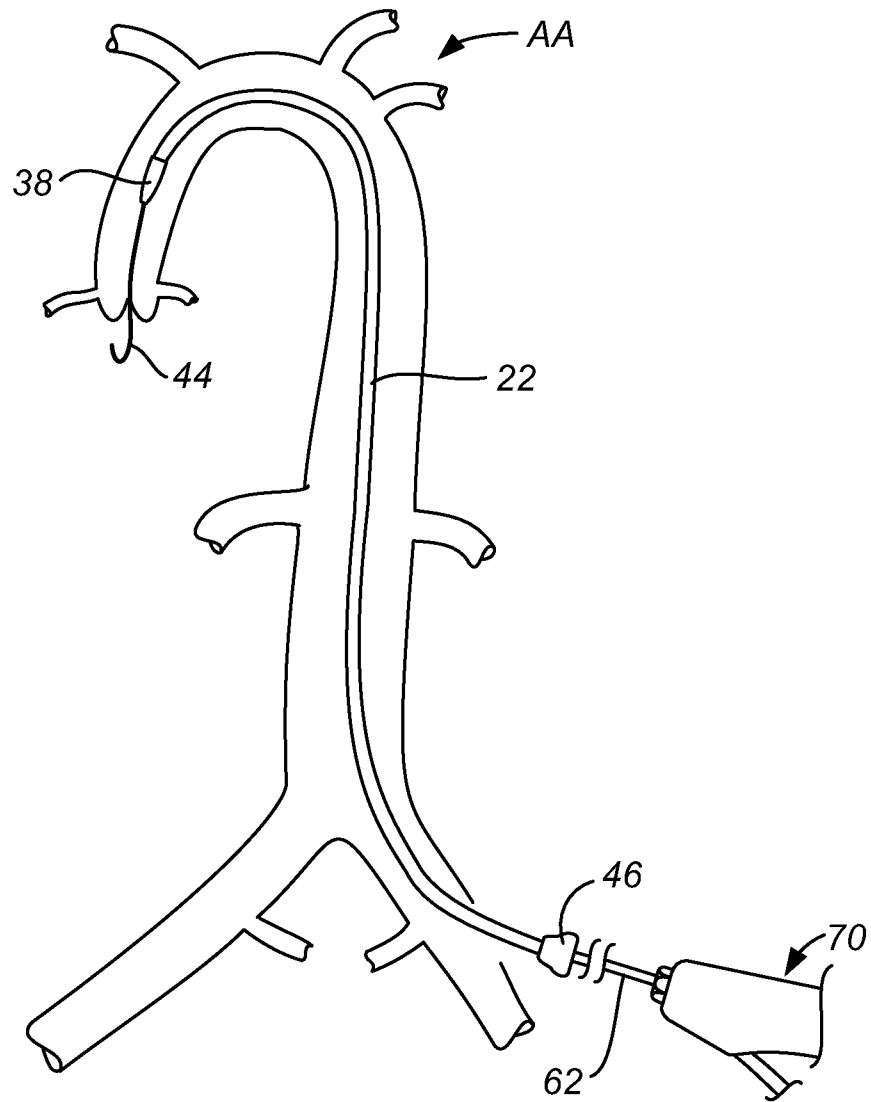


FIG. 9B

6 / 8

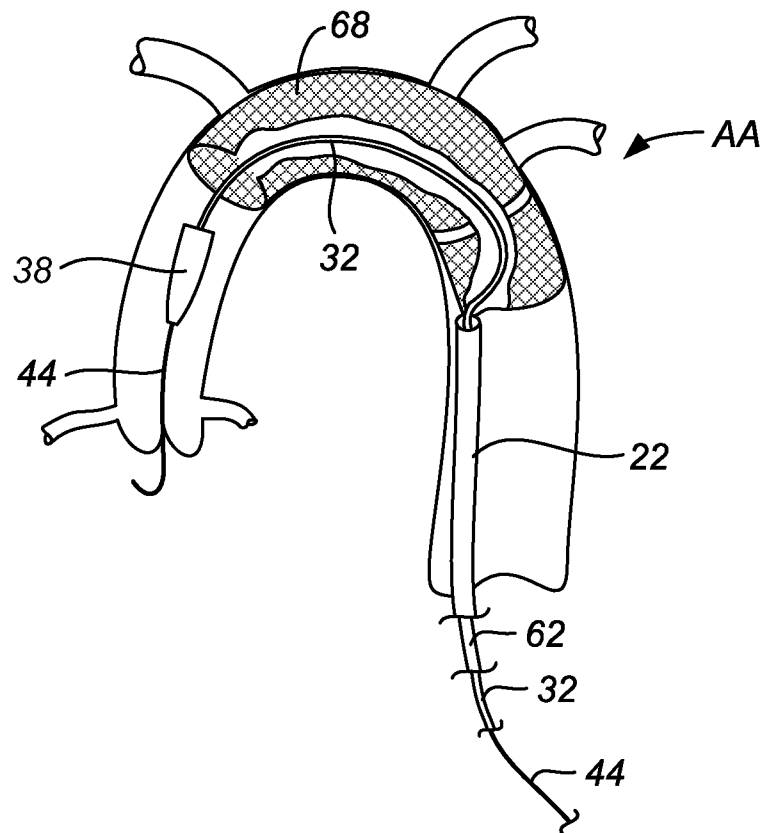


FIG. 9C

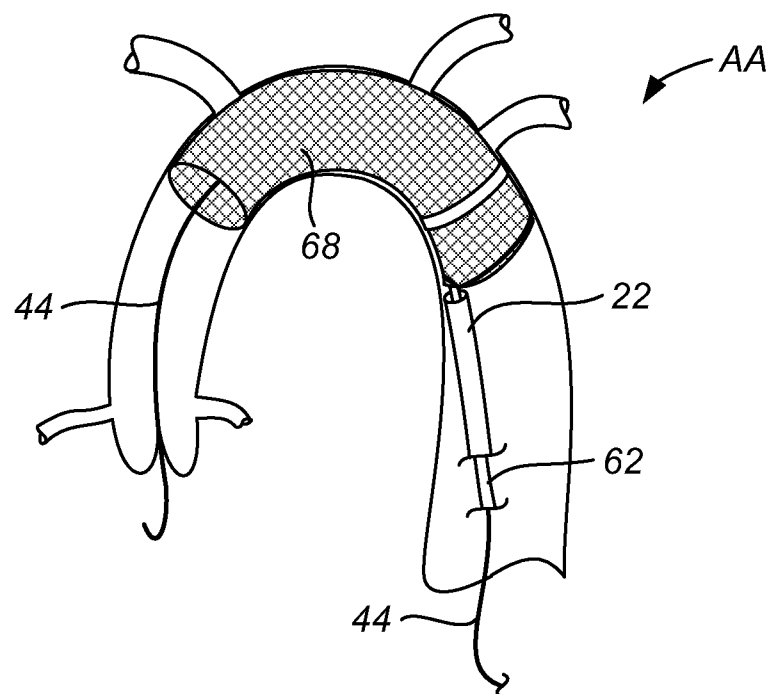


FIG. 9D

7 / 8

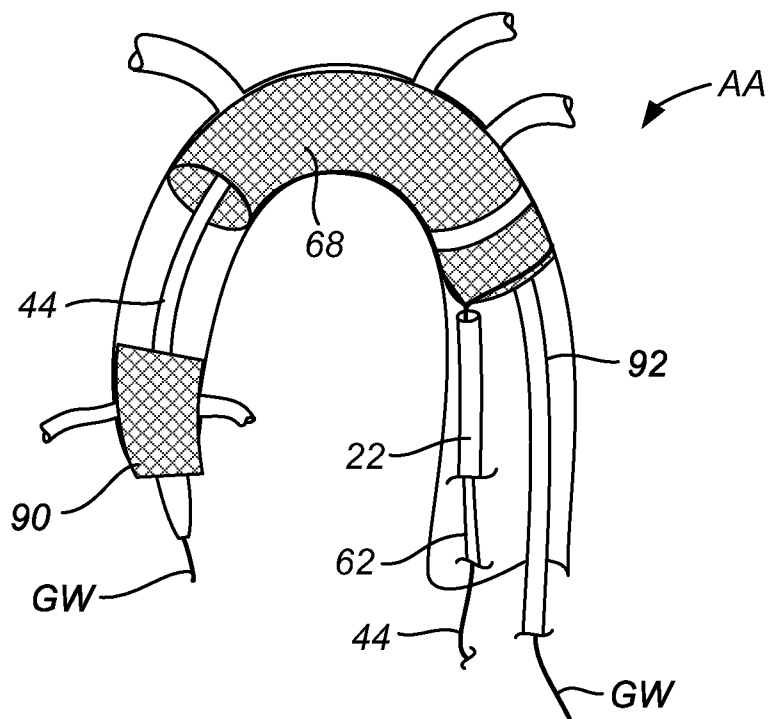


FIG. 9E

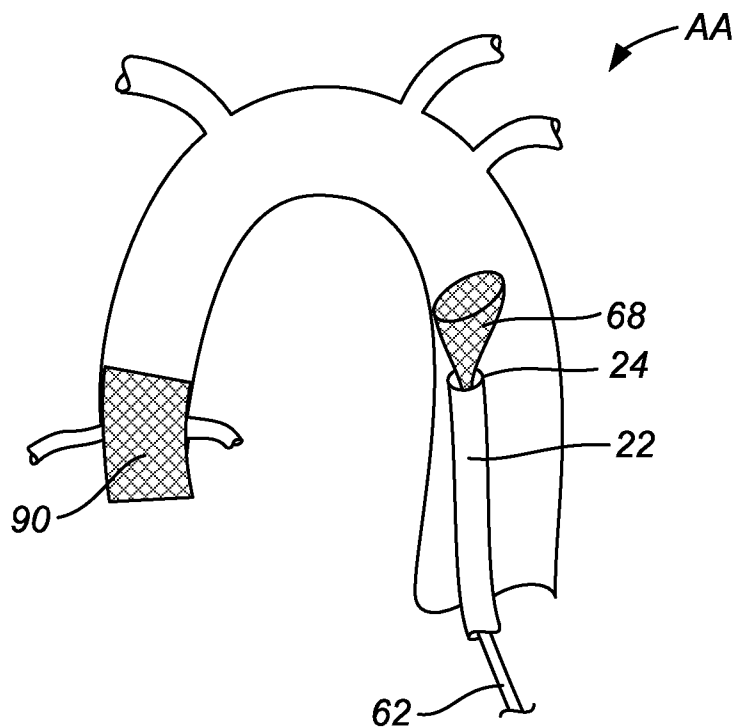


FIG. 9F

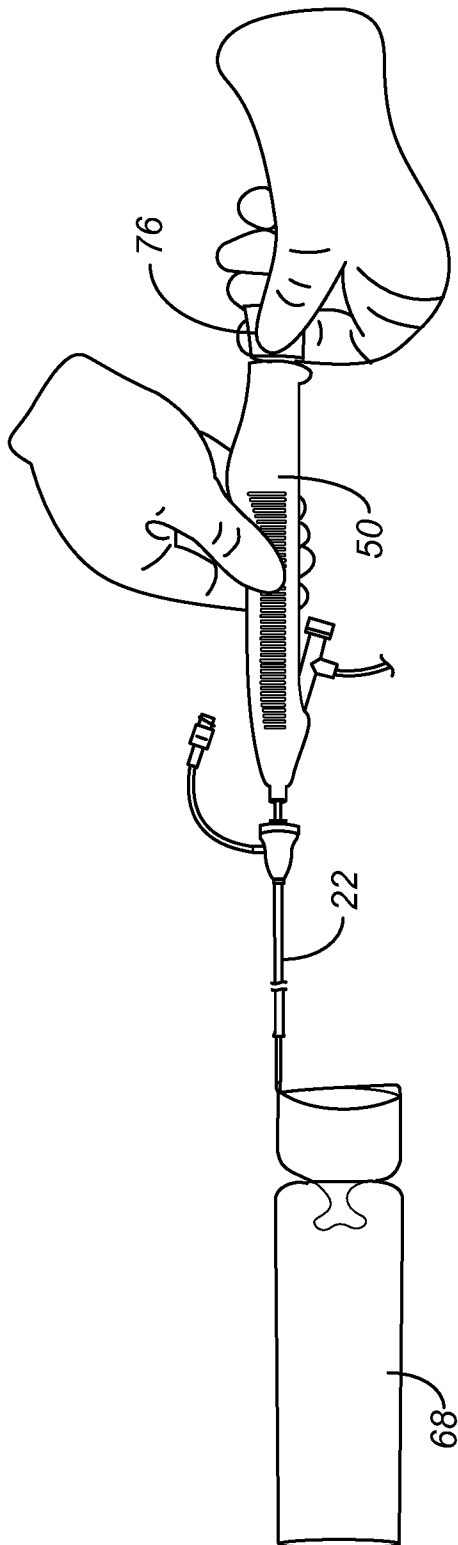


FIG. 10A

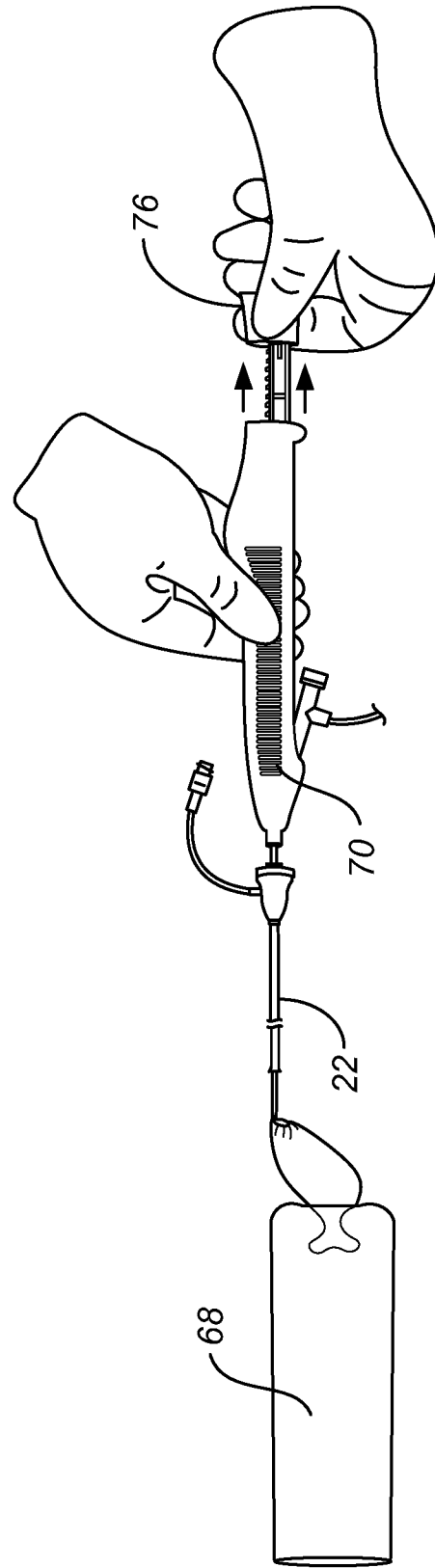


FIG. 10B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2021/060178

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61F 2/01; A61B 17/00; A61B 17/22; A61F 2/24 (2022.01)

CPC - A61F 2/013; A61F 2/014; A61F 2002/016; A61F 2230/0067 (2022.01)

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.
A	US 2020/0253709 A1 (EMBOLINE INC) 13 August 2020 (13.08.2020) entire document	1-4, 10-15
A	US 9,844,387 B2 (INARI MEDICAL INC) 19 December 2017 (19.12.2017) entire document	1-4, 10-15
A	US 9,427,252 B2 (SOS) 30 August 2016 (30.08.2016) entire document	1-4, 10-15
A	WO 2017/074530 A1 (SOS) 04 May 2017 (04.05.2017) entire document	1-4, 10-15
P, A	WO 2021/087480 A1 (SILK ROAD MEDICAL INC) 06 May 2021 (06.05.2021) entire document	1-4, 10-15

☐ 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

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"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

04 January 2022

Date of mailing of the international search report

JAN 31 2022

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Facsimile No. 571-273-8300

Authorized officer

Harry Kim

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2021/060178

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 5-9, 16-20
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.