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Naglreiter

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(54) **USE OF PERIPHERAL EMBOLIZATION DEVICE FOR SECONDARY TREATMENT**

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(60) Provisional application No. 62/944,953, filed on Dec. 6, 2019.

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A61M 25/00 (2006.01)

(52) **U.S. Cl.**

CPC ... *A61B 17/12109* (2013.01); *A61M 25/0082* (2013.01); *A61B 2017/1205* (2013.01); *A61B 17/1214* (2013.01); *A61M 2205/05* (2013.01)

(57) **ABSTRACT**

Methods of using a common delivery system to deliver an embolization device and provide a secondary treatment. The secondary treatment may include delivering a therapeutic agent or providing a treatment using a treatment instrument. The secondary treatment may be provided downstream of the embolization device. The secondary treatment may be provided using the inner body of the delivery system, while the inner body extends through the opening of the occlusion device.

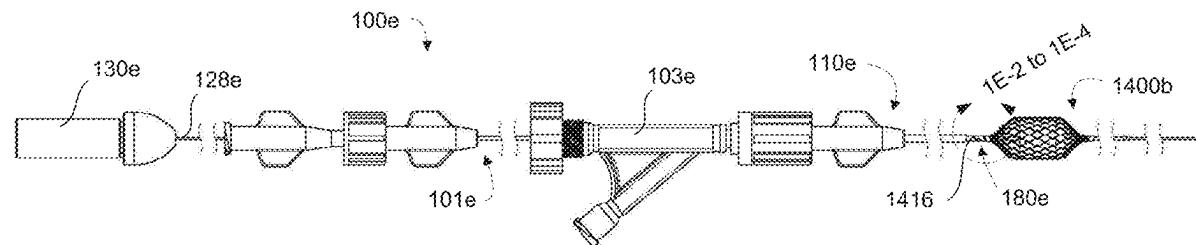


Fig. 1A-1

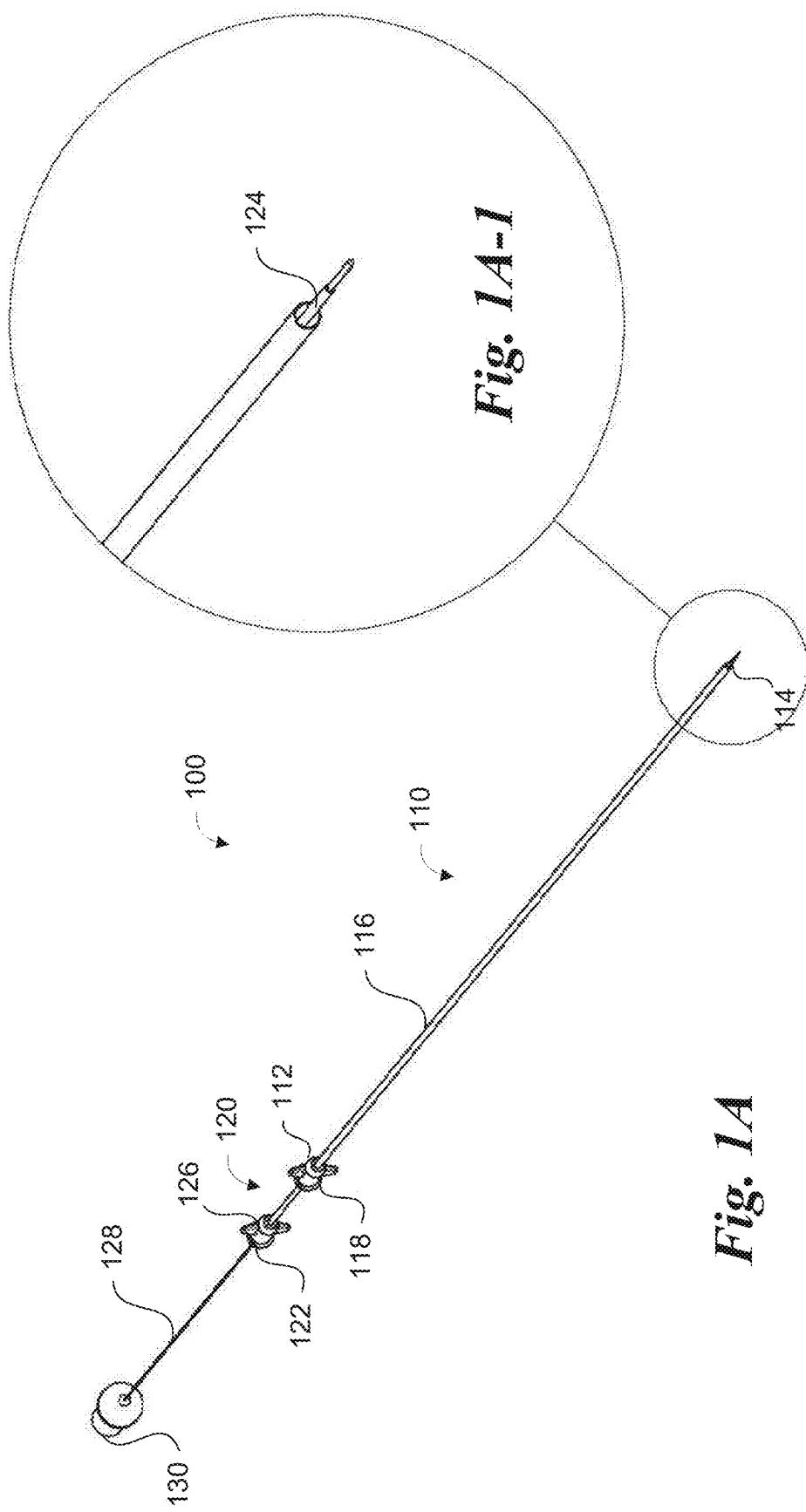


Fig. 1A

Fig. 1B-1

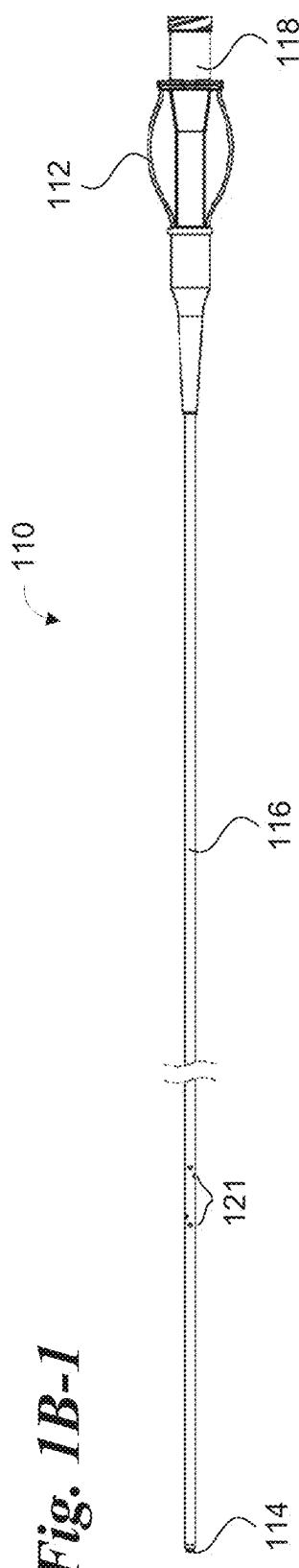


Fig. 1B-2

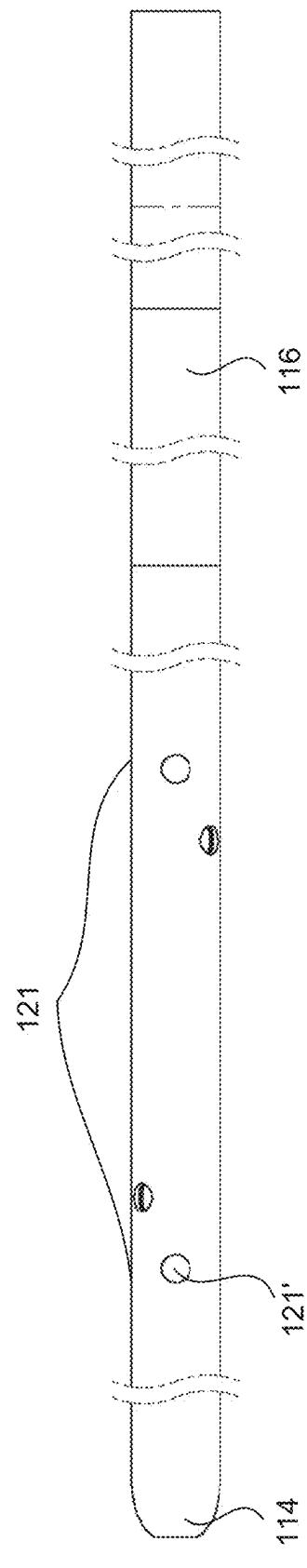


Fig. 1B-3

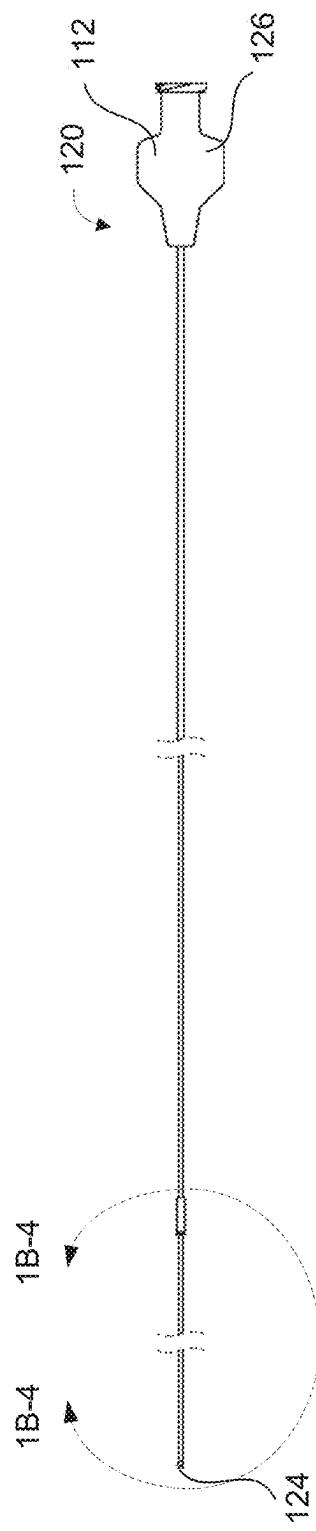


Fig. 1B-4

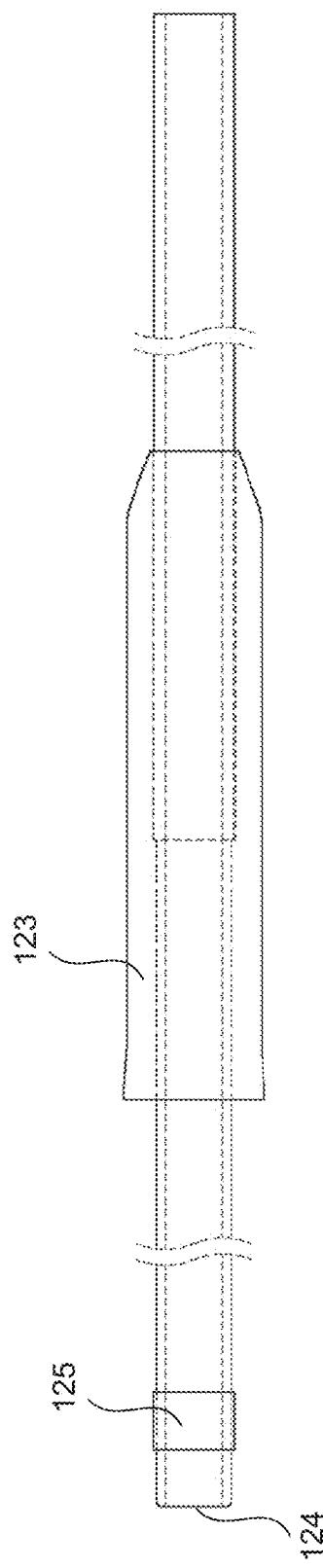


Fig. 1C-1

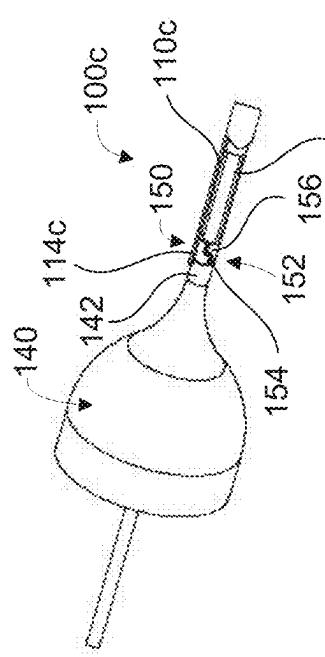


Fig. 1C-2

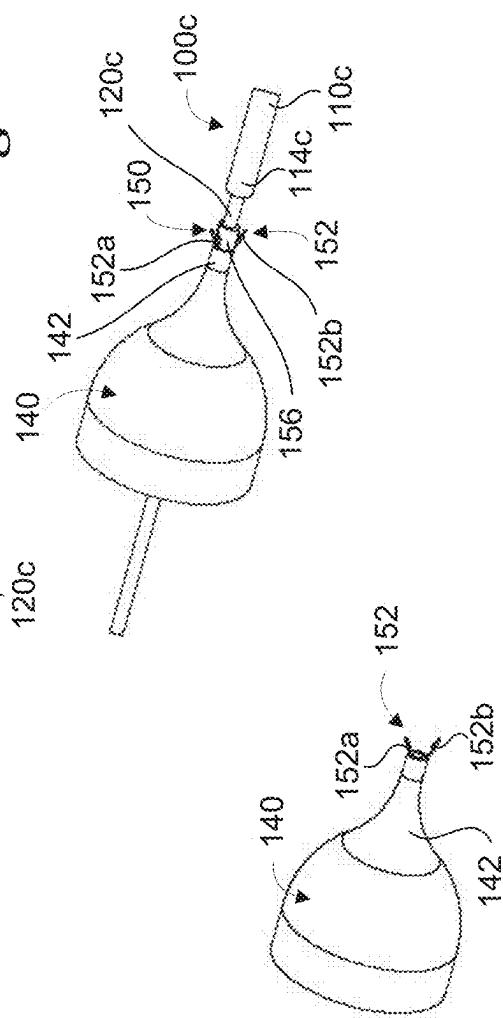


Fig. 1C-3

Fig. 1D-1

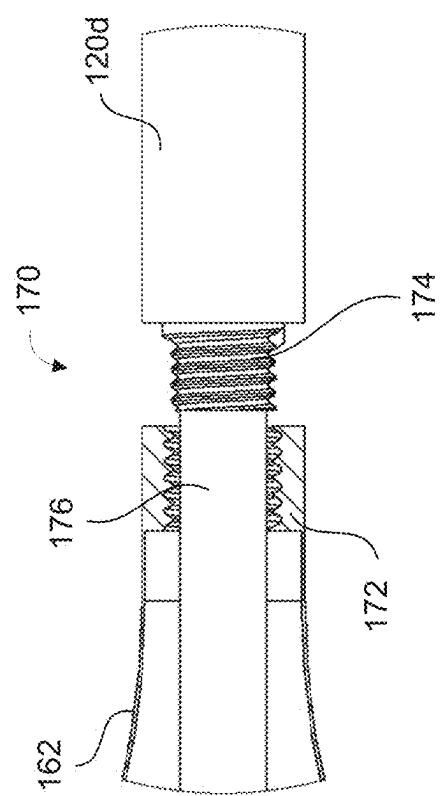
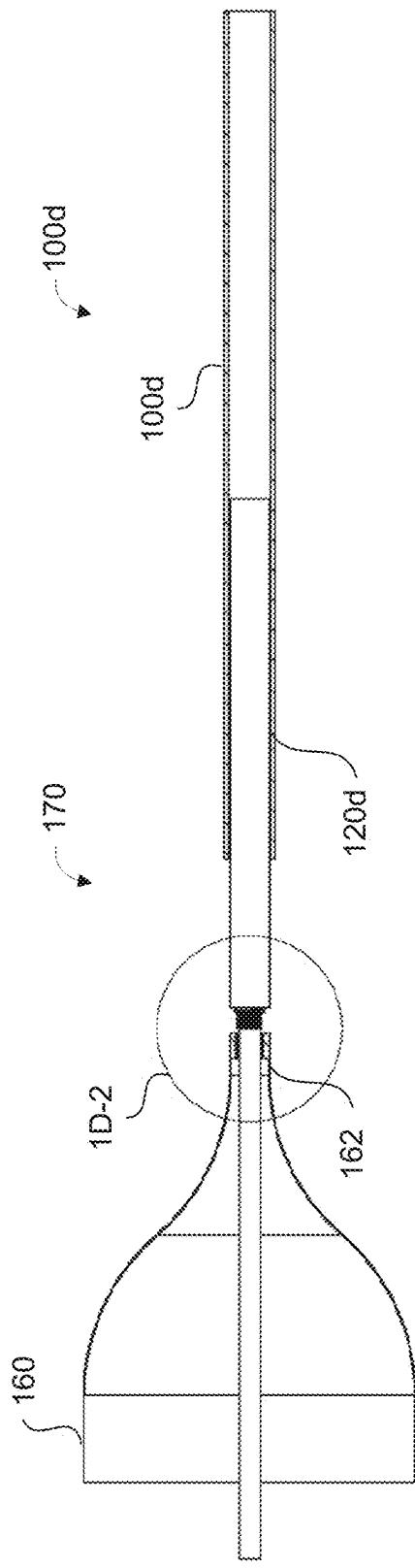


Fig. 1D-2

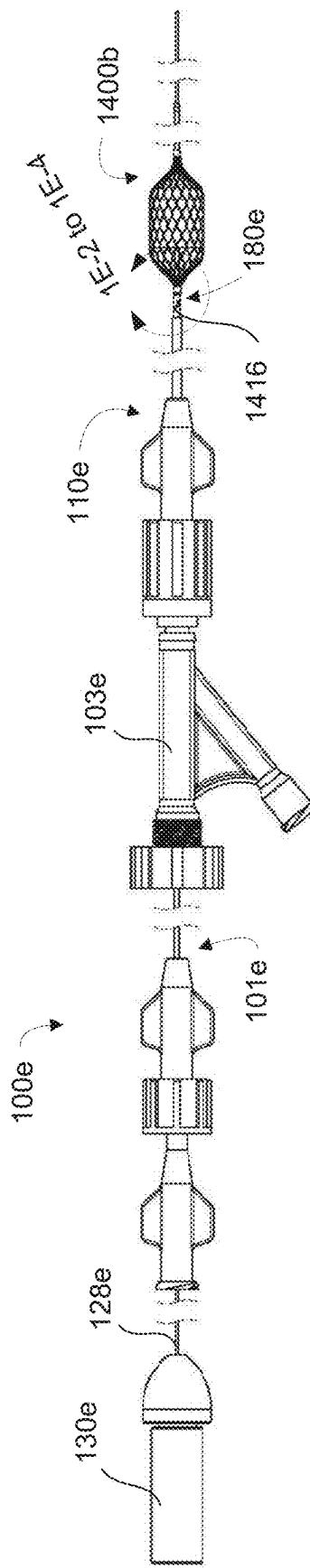


Fig. 1E-1

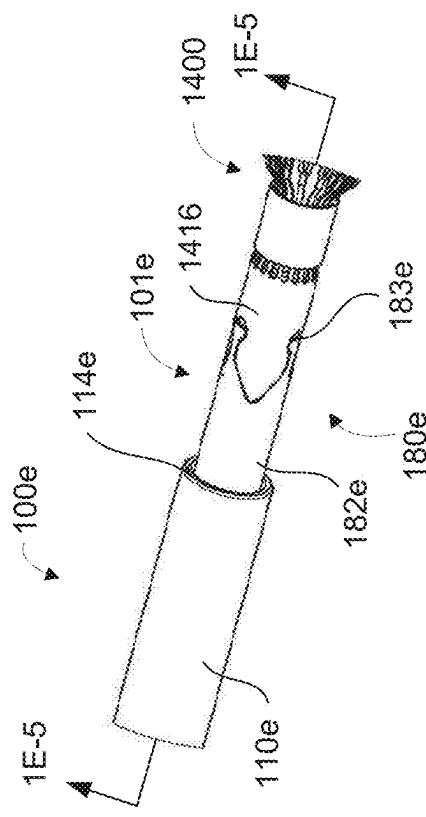


Fig. 1E-2

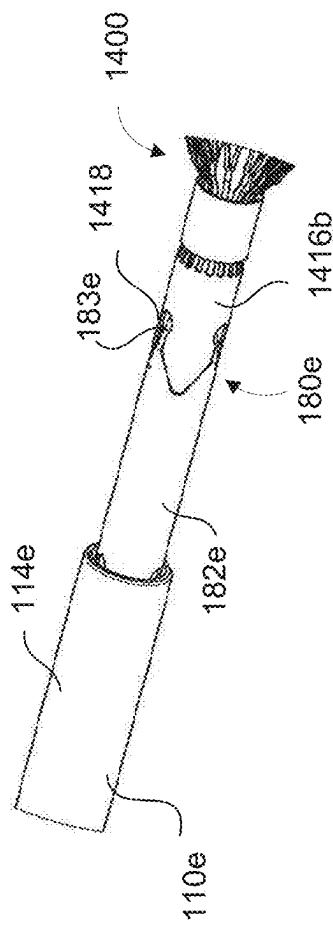


Fig. 1E-3

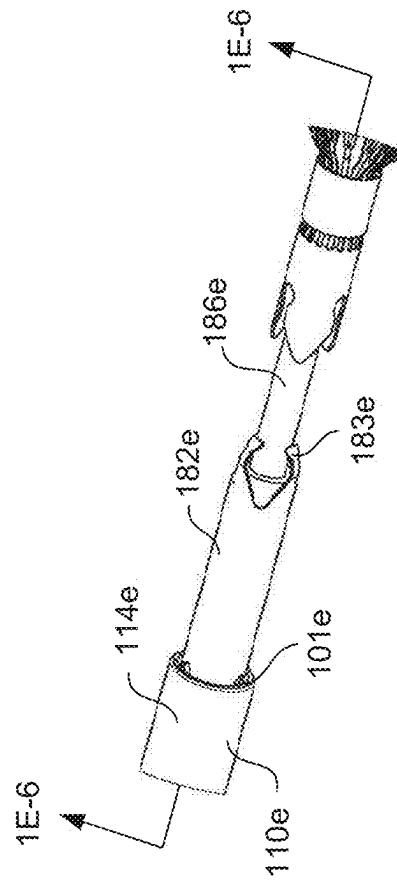


Fig. 1E-4

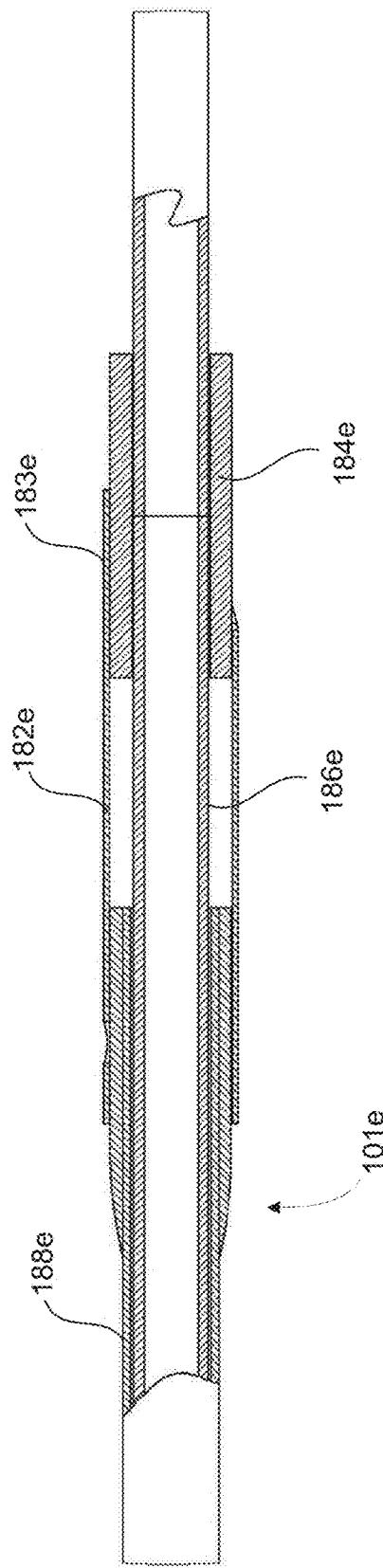


Fig. 1E-5

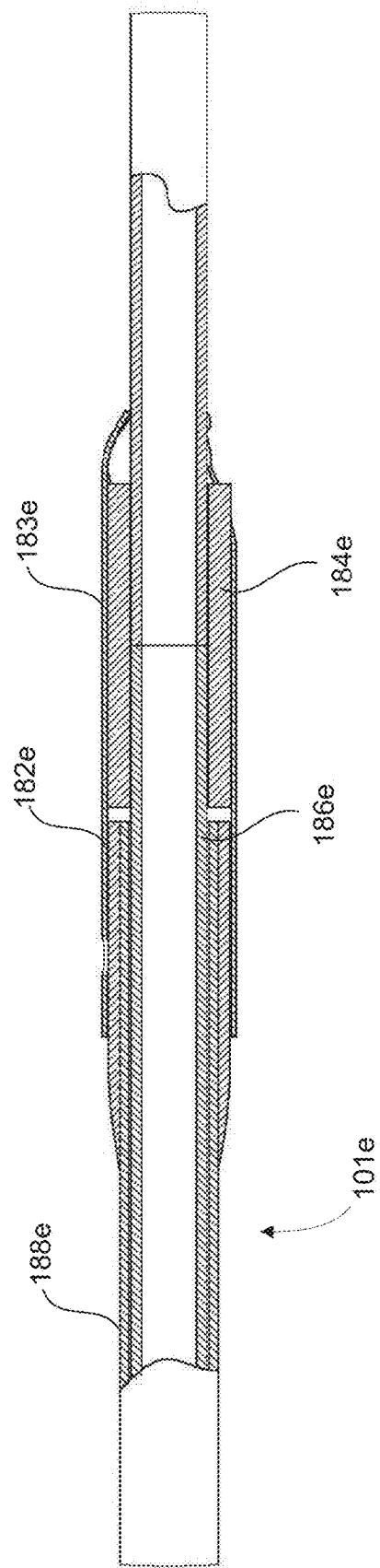


Fig. 1E-6

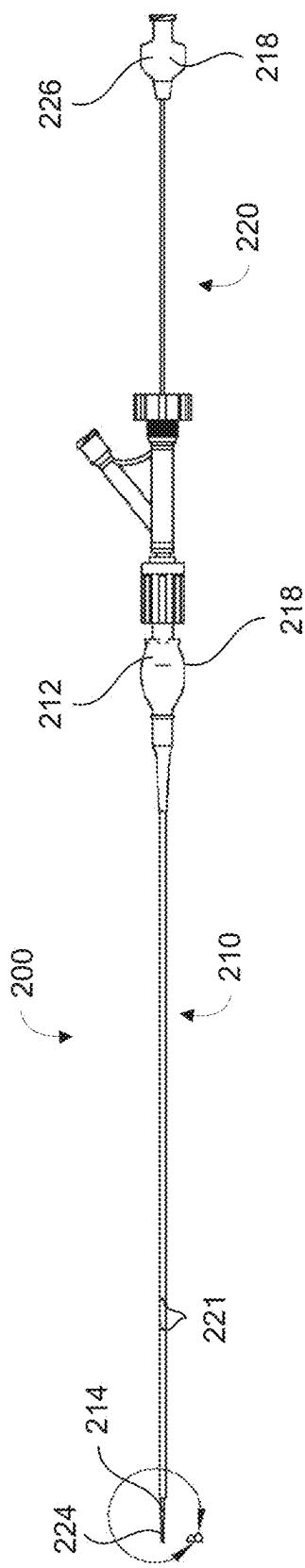


Fig. 2A

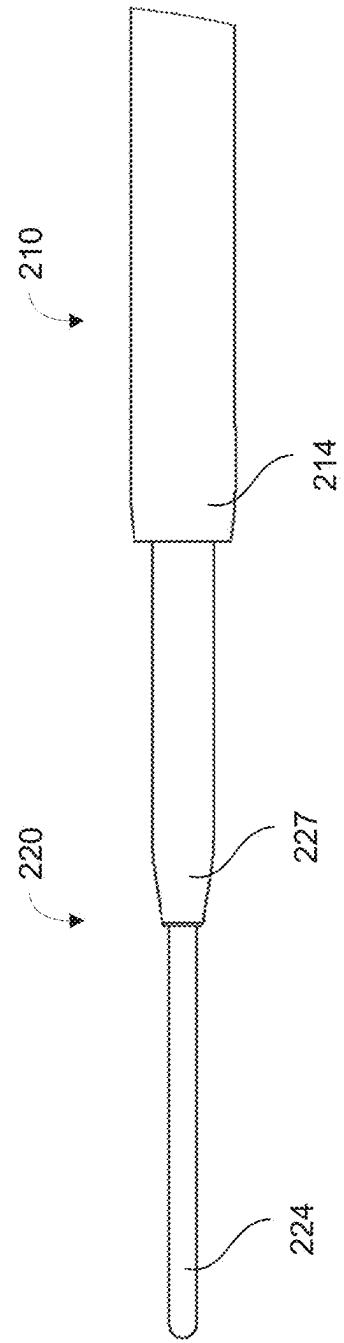


Fig. 2B

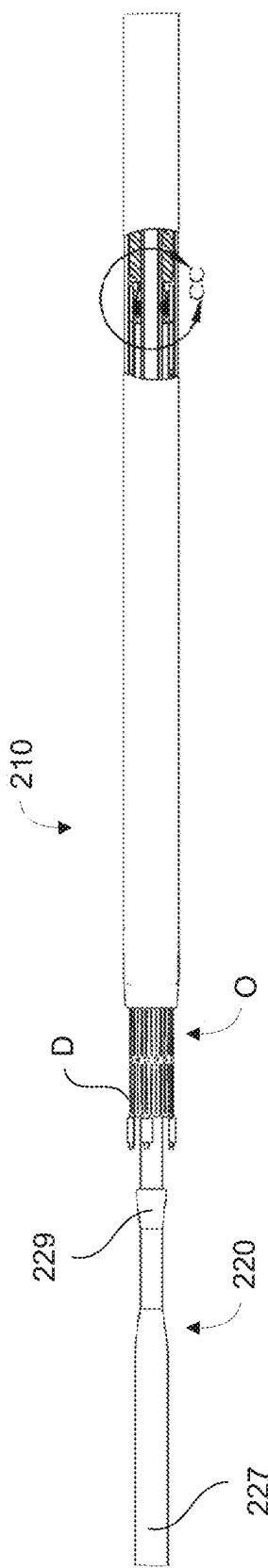


Fig. 2C

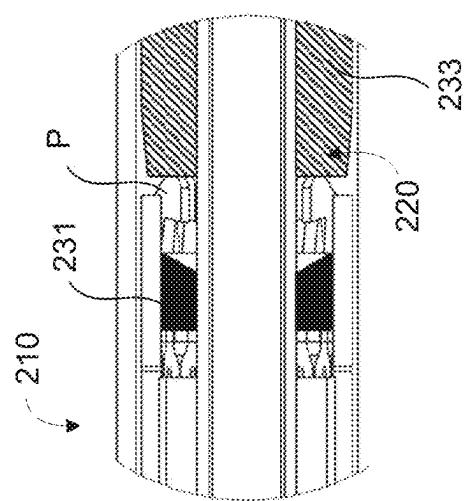


Fig. 2CC

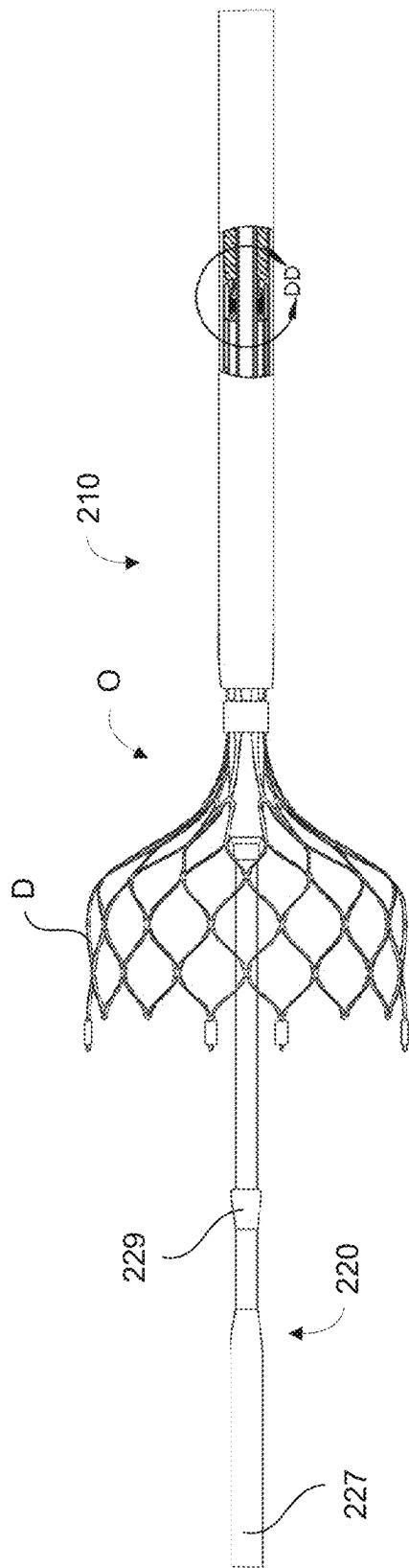


Fig. 2D

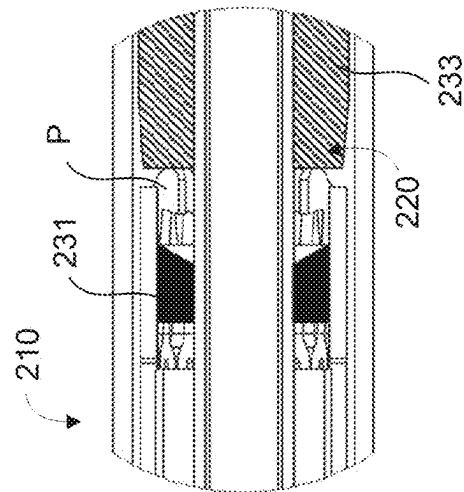


Fig. 2DD

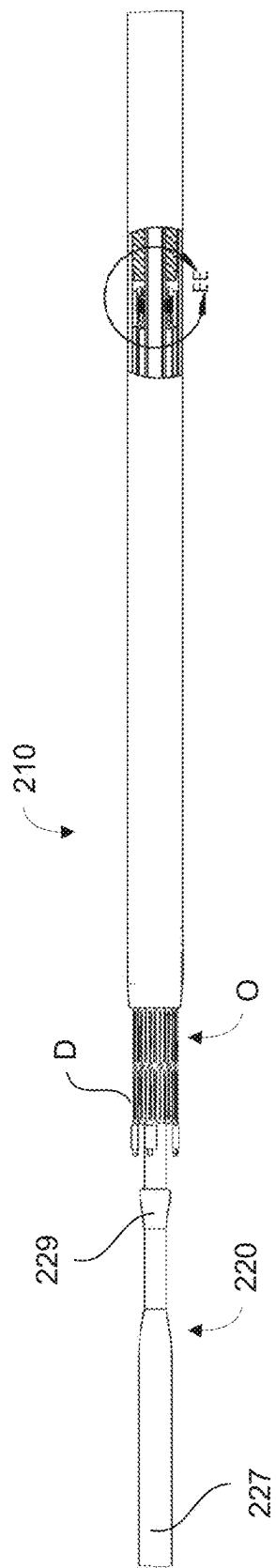


Fig. 2E

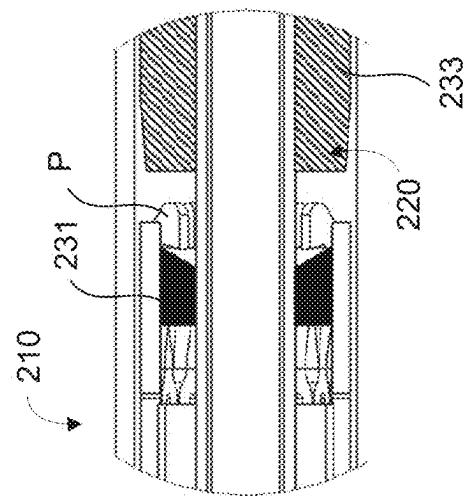


Fig. 2EE

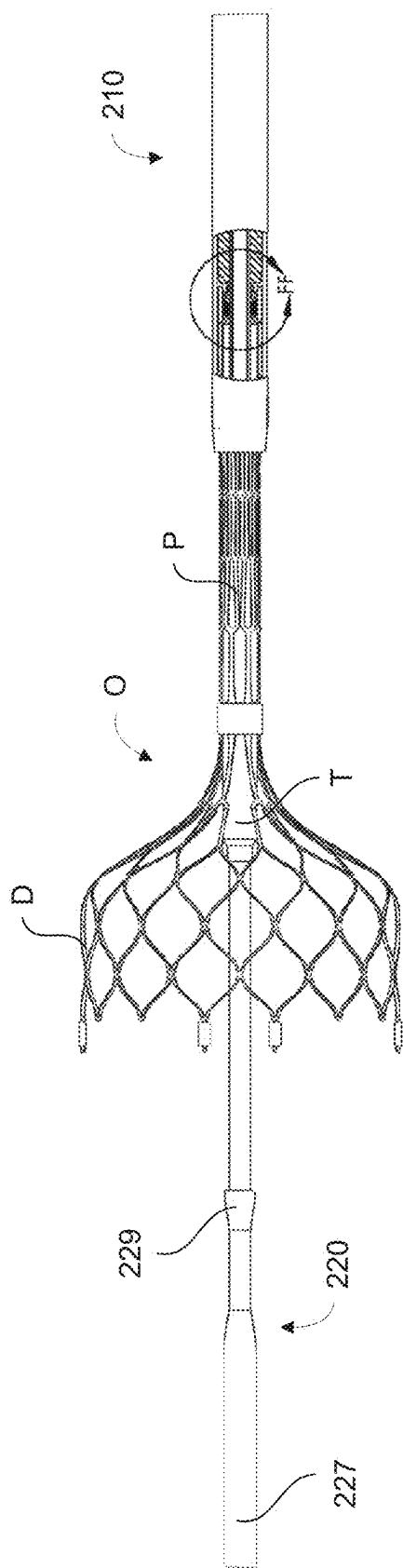


Fig. 2F

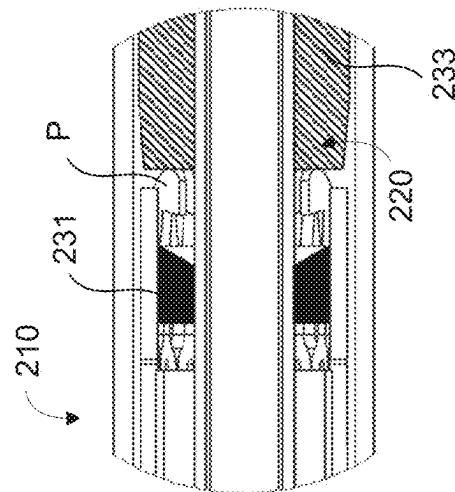


Fig. 2FF

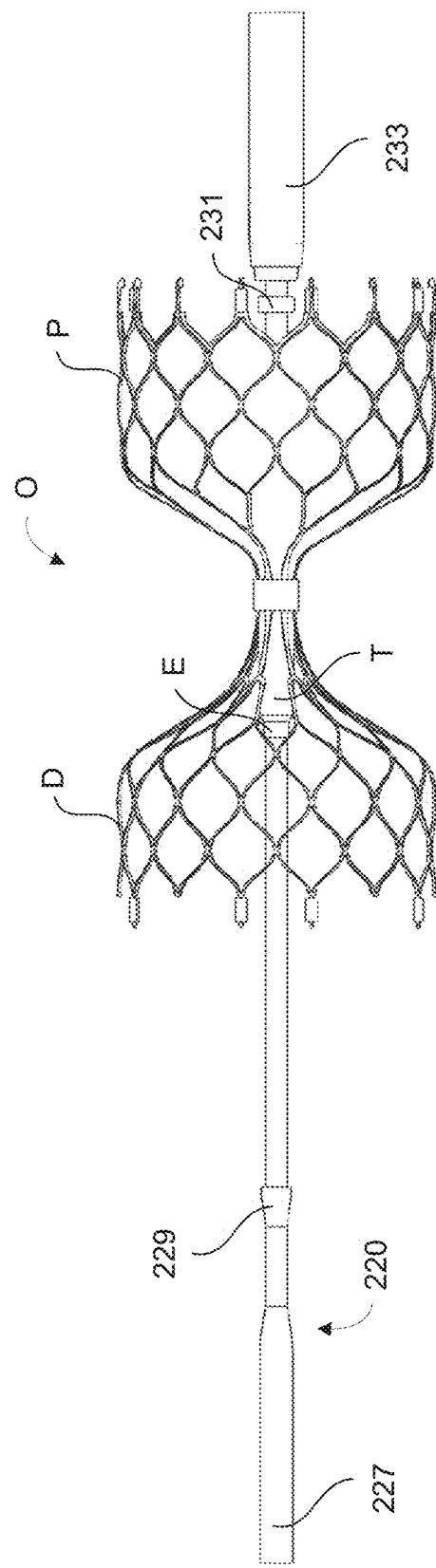


Fig. 2G

Fig. 2H

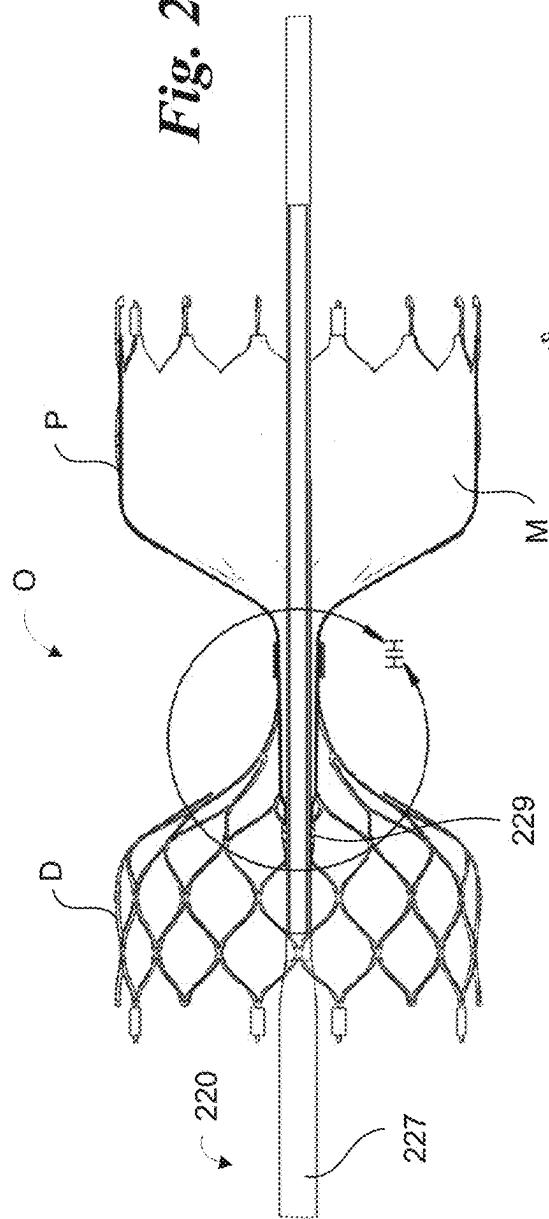


Fig. 2HH

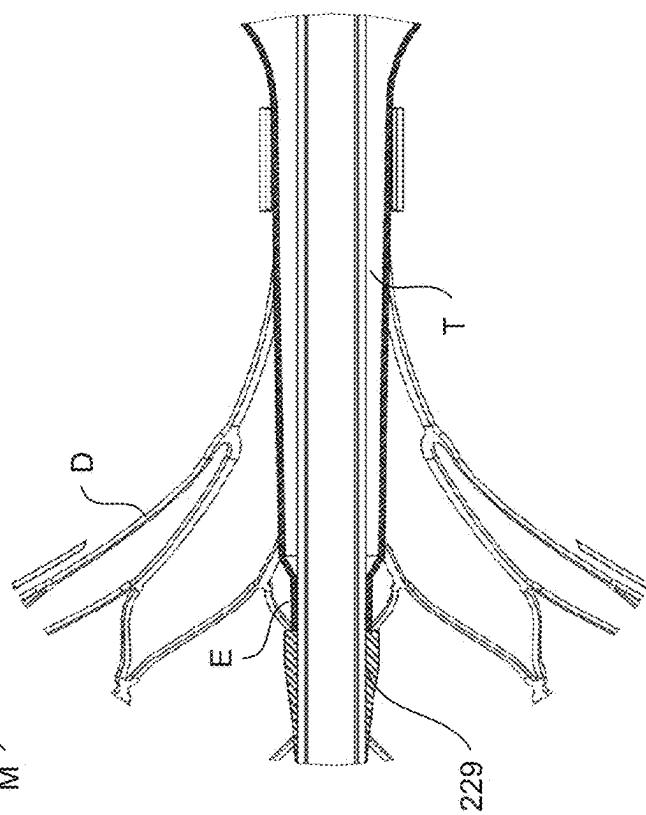


Fig. 2I

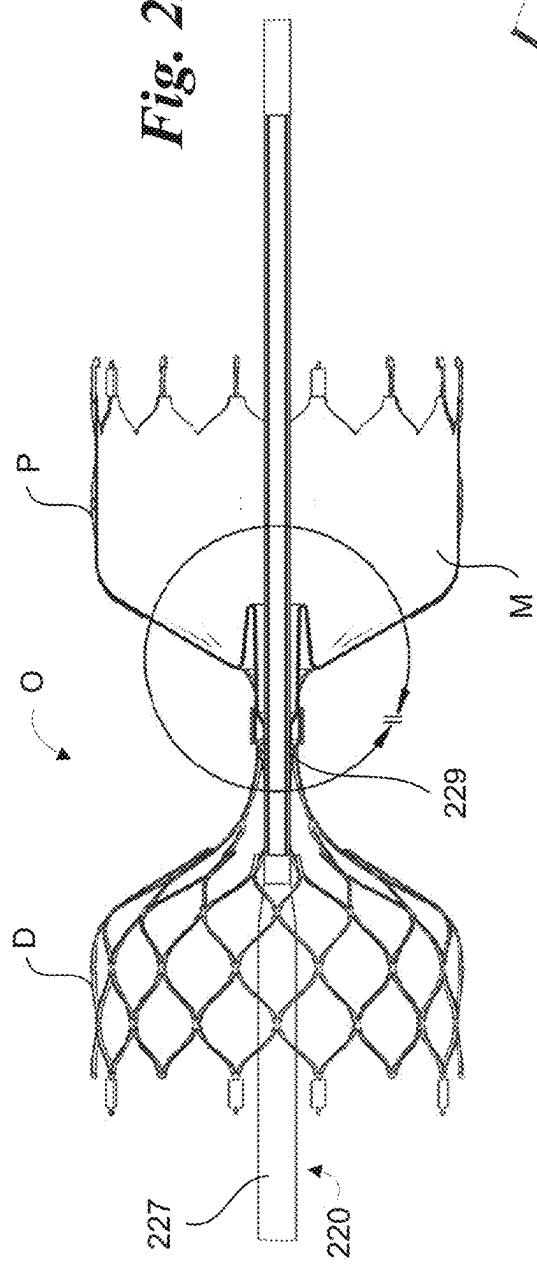


Fig. 2II

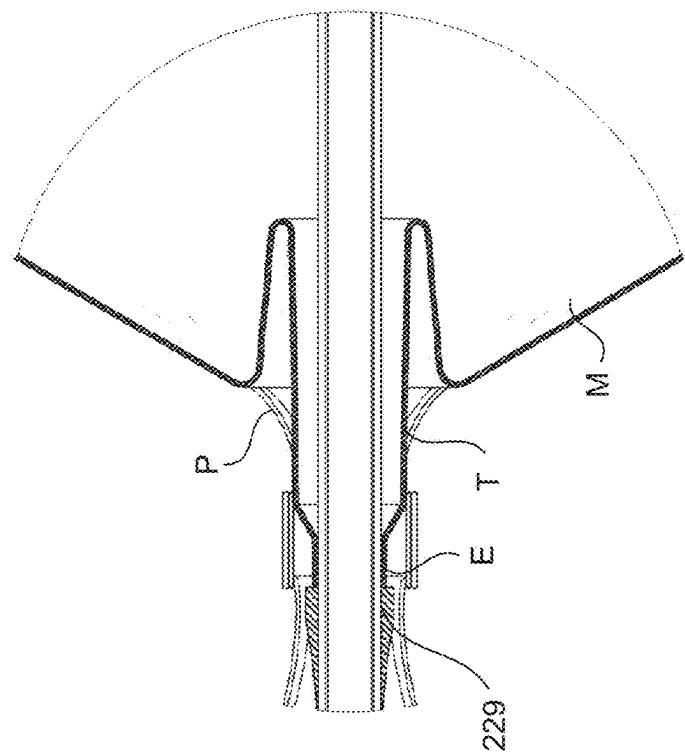


Fig. 2J

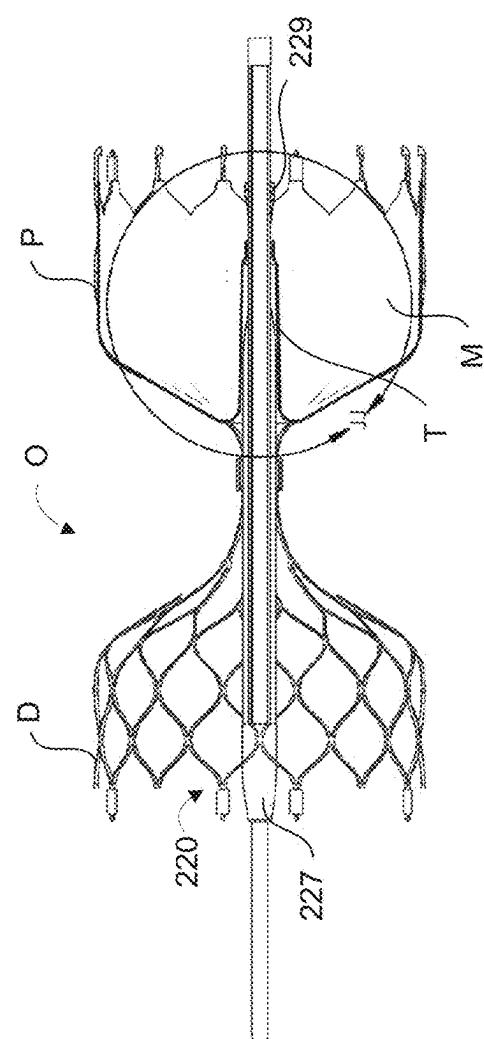
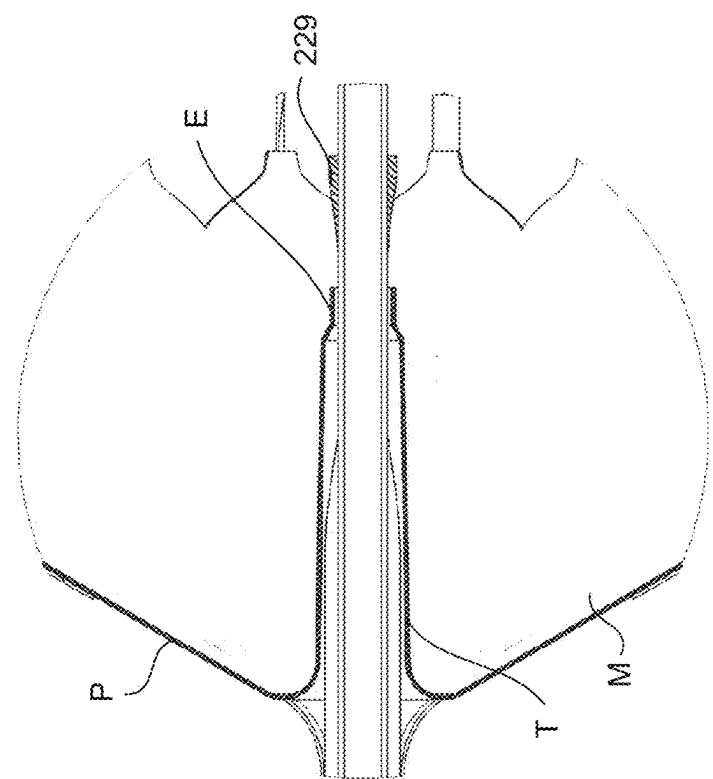


Fig. 2JJ



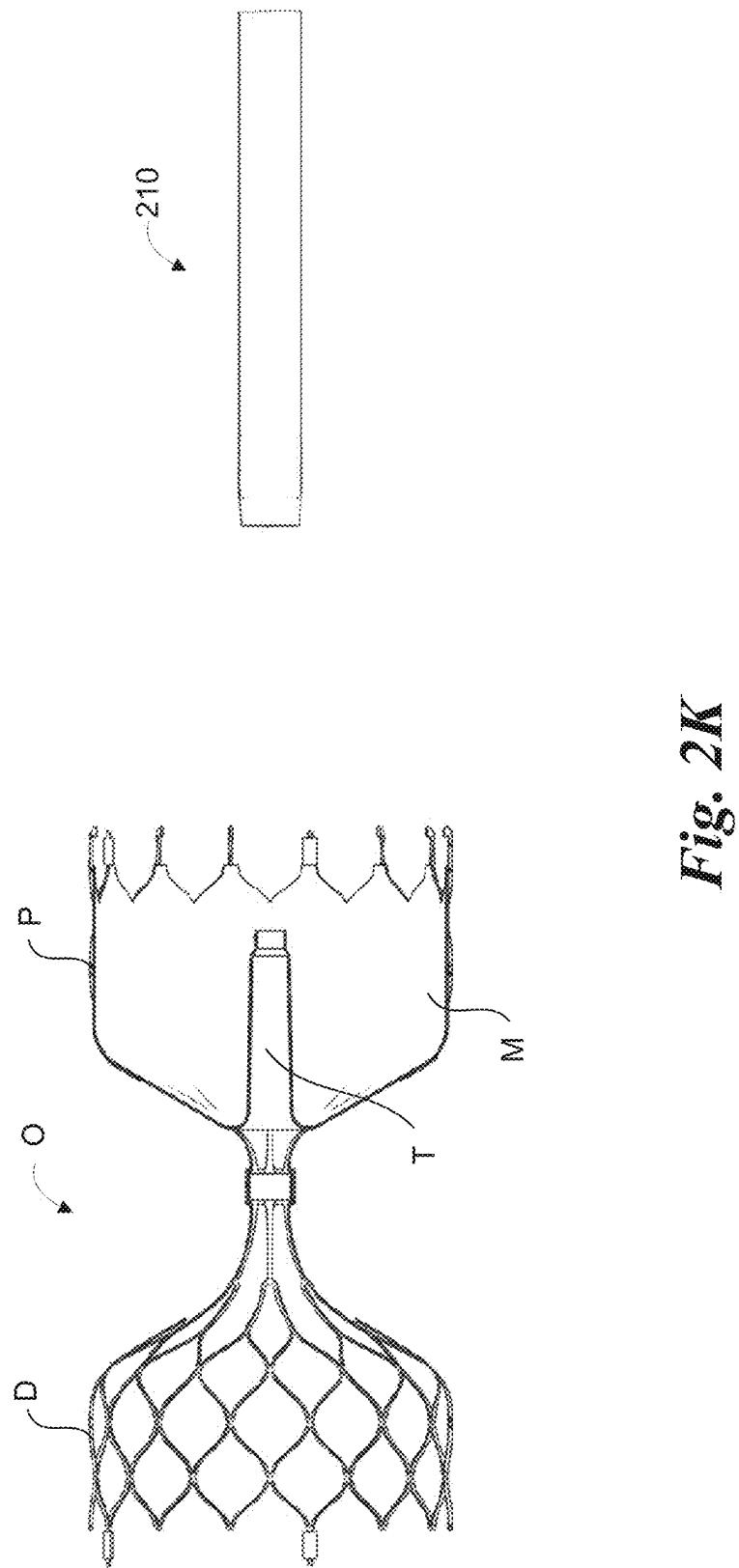


Fig. 2K

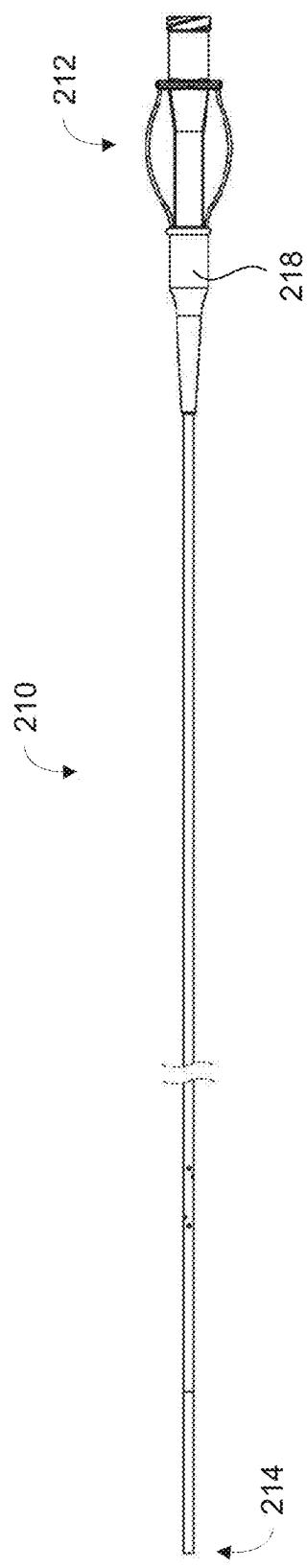


Fig. 2L

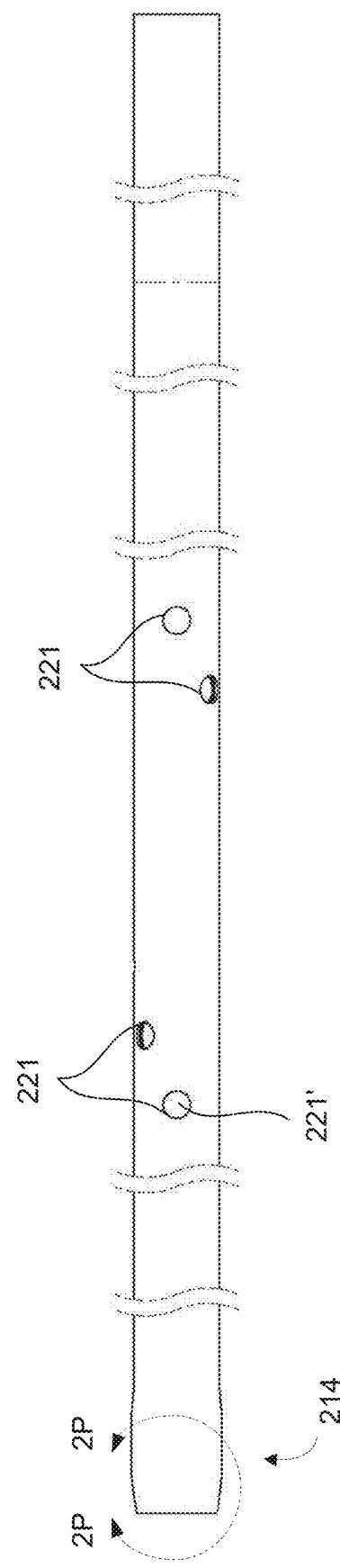


Fig. 2M

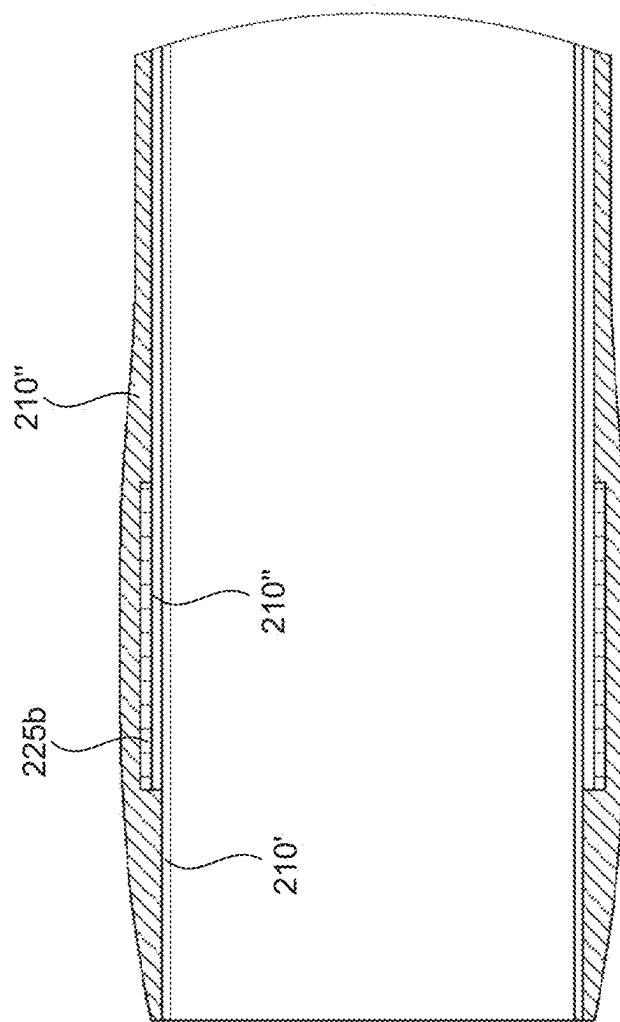


Fig. 2N

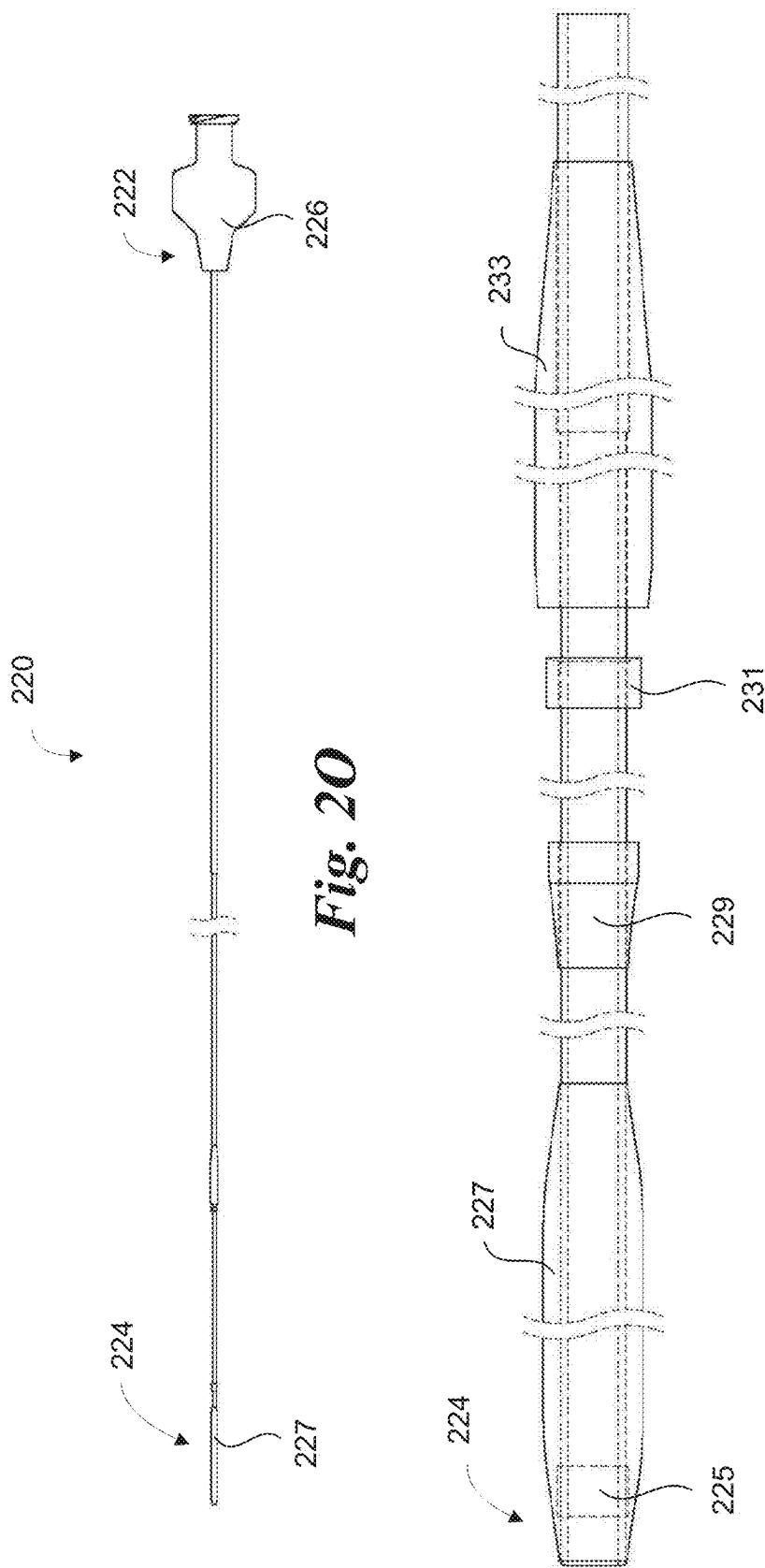


Fig. 2Q

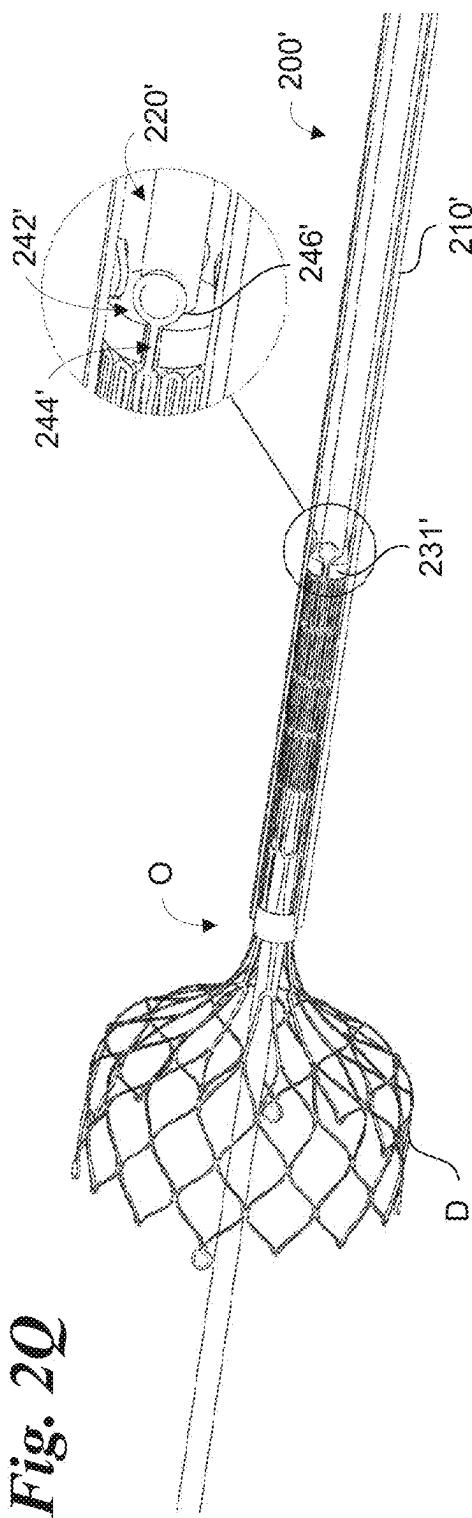
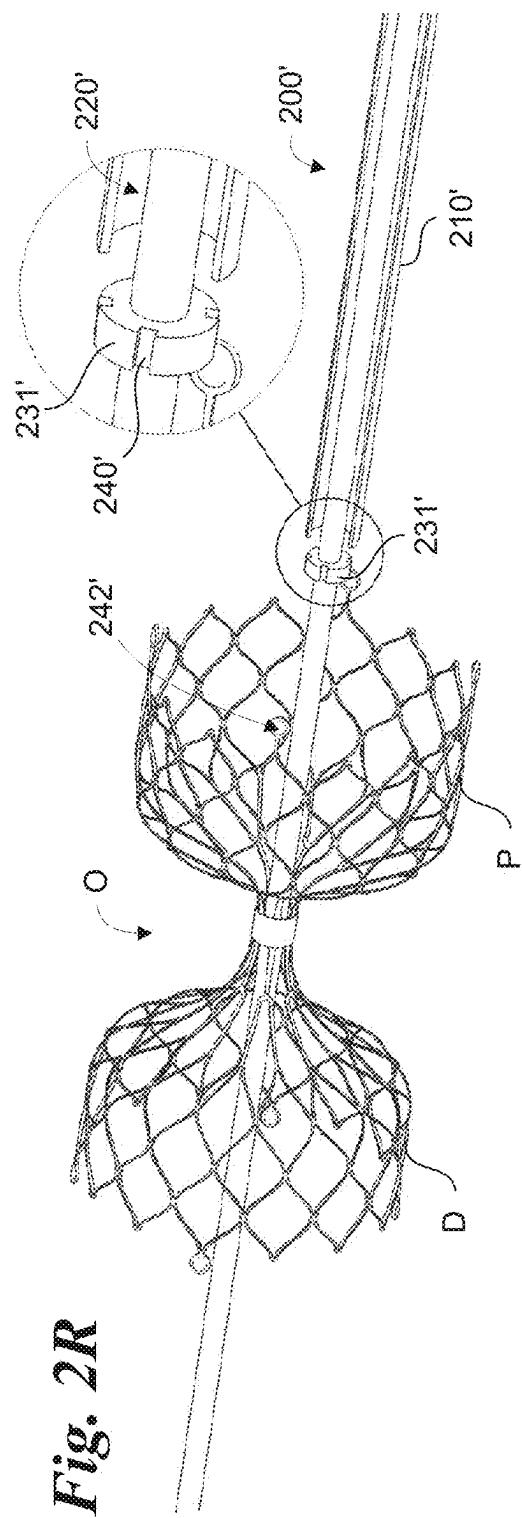


Fig. 2R



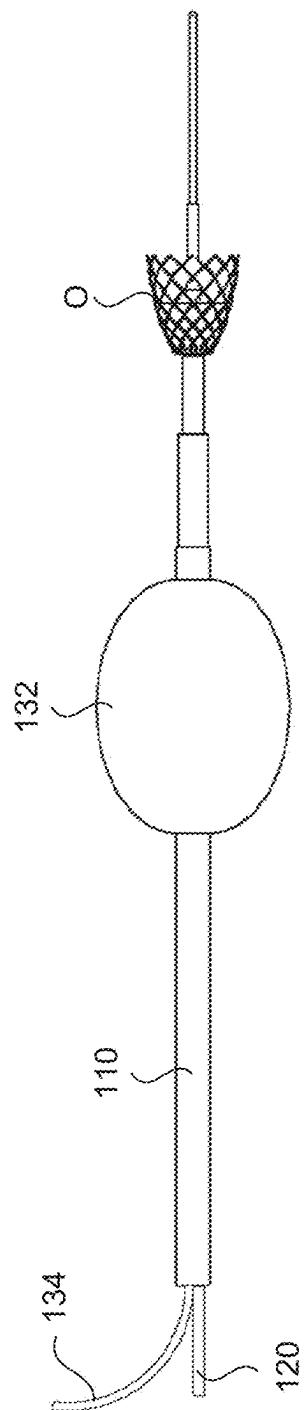
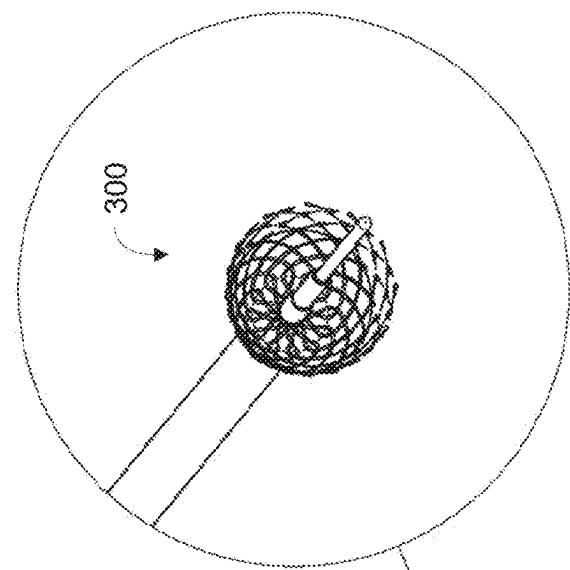
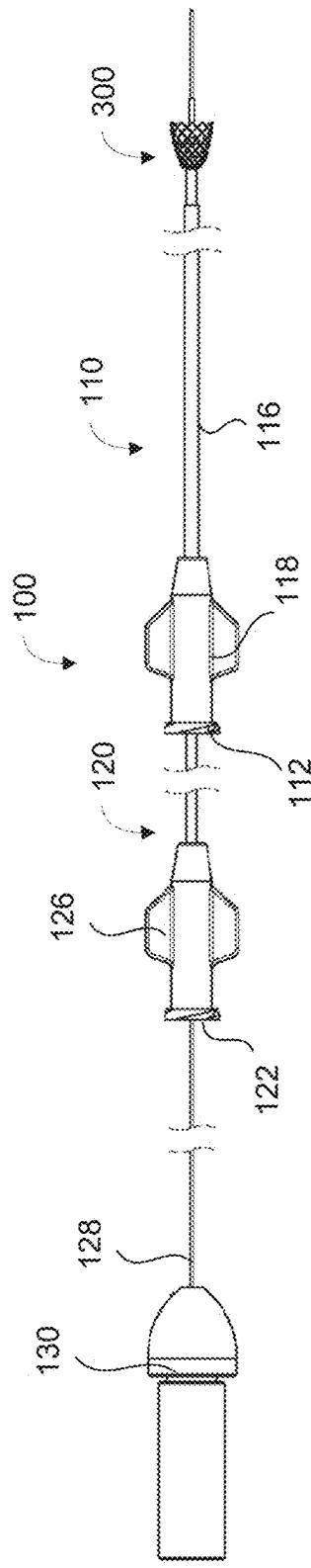


Fig. 2S



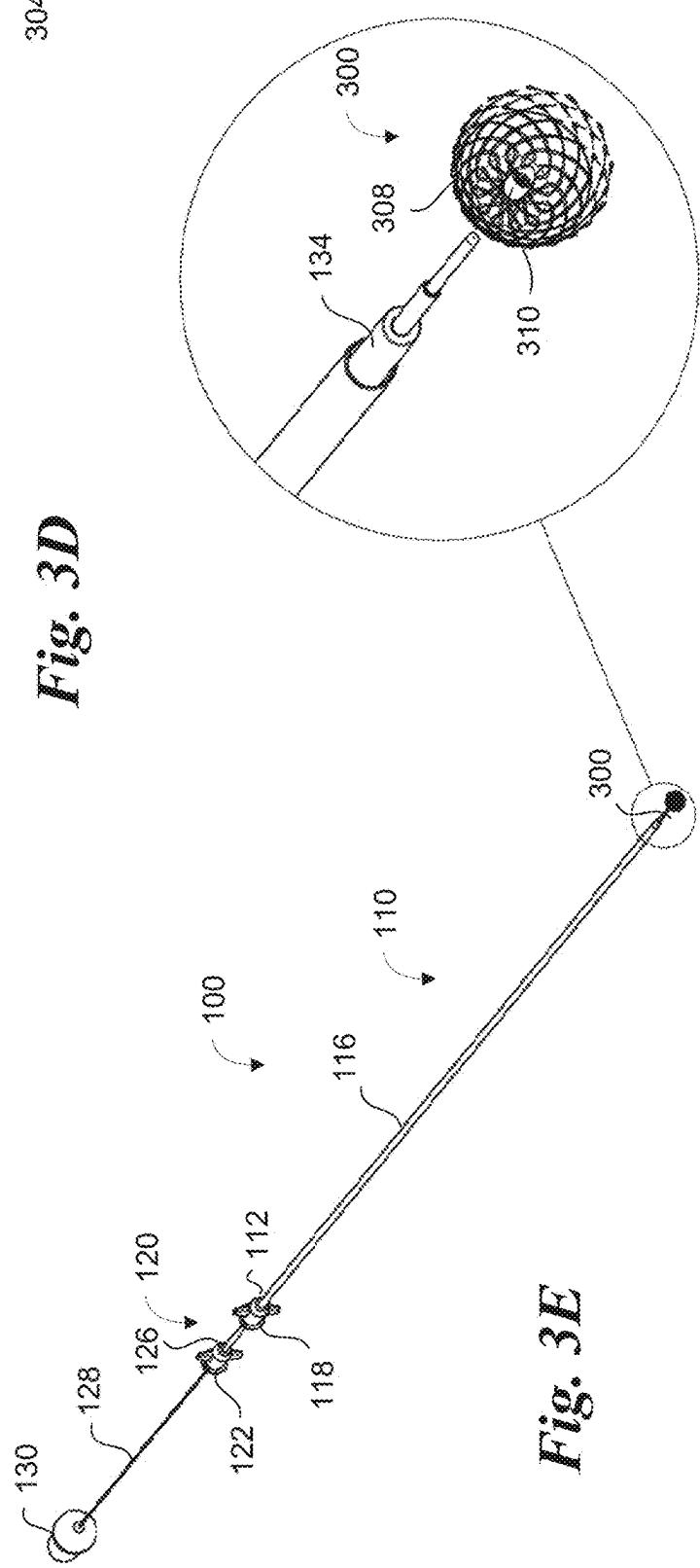
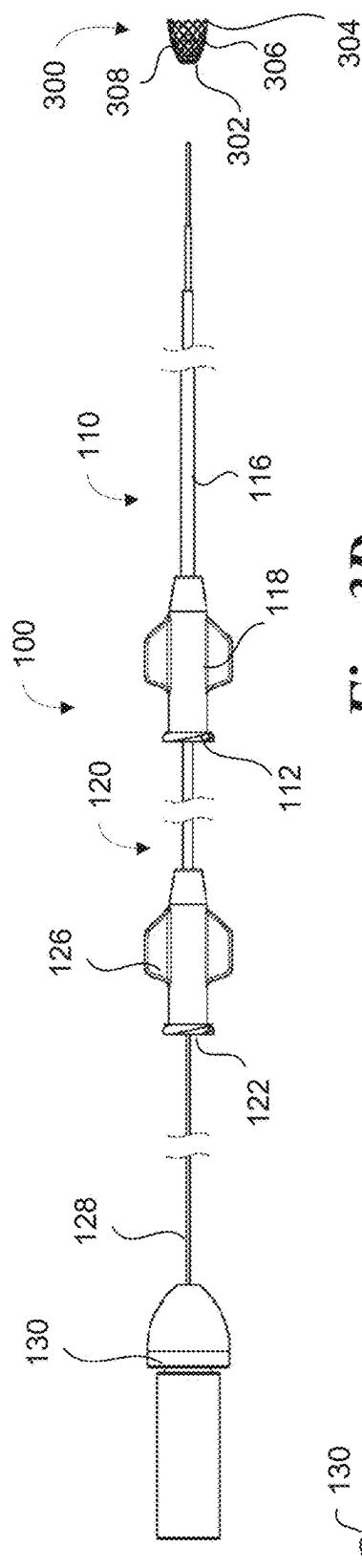


Fig. 3F

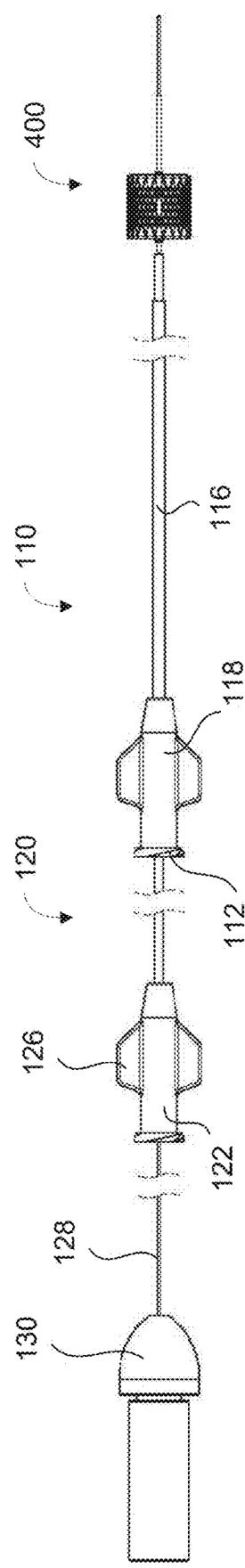


Fig. 4A

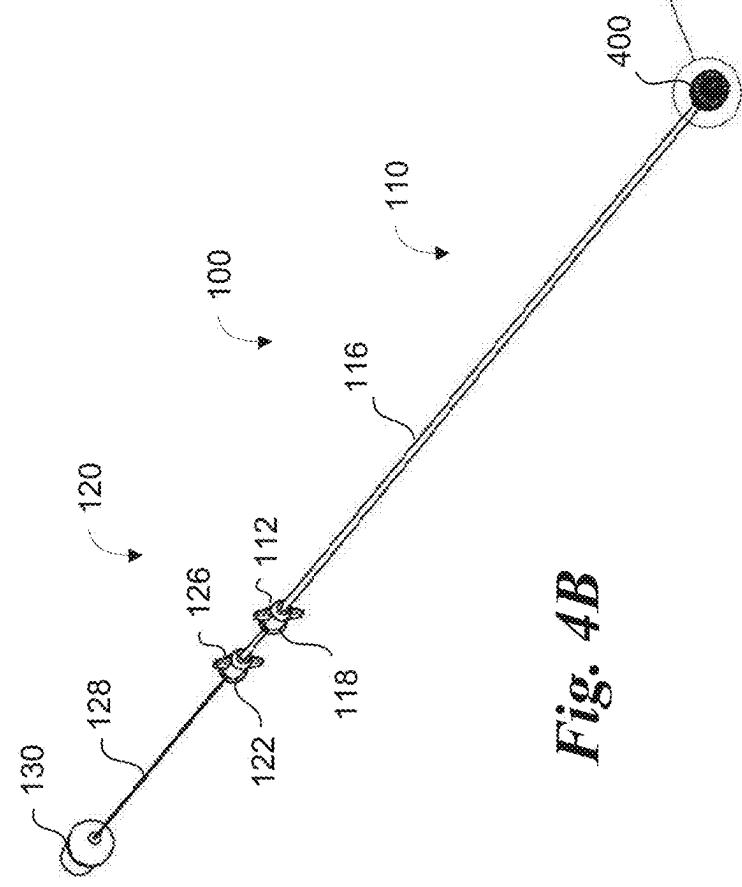


Fig. 4B

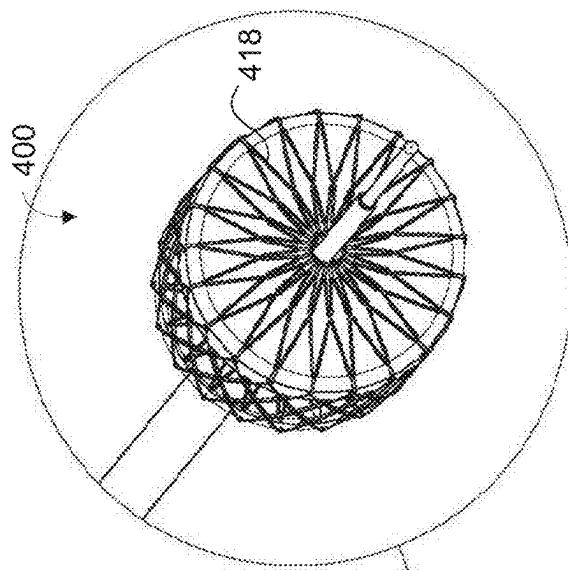


Fig. 4C

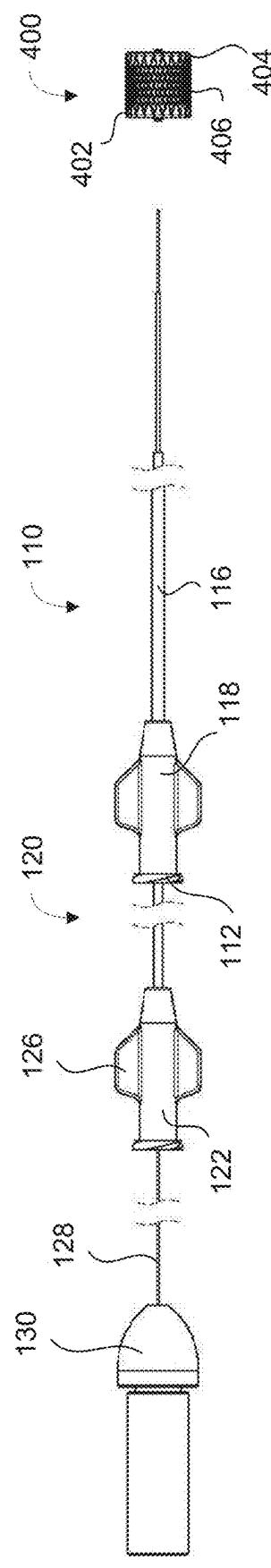


Fig. 4D

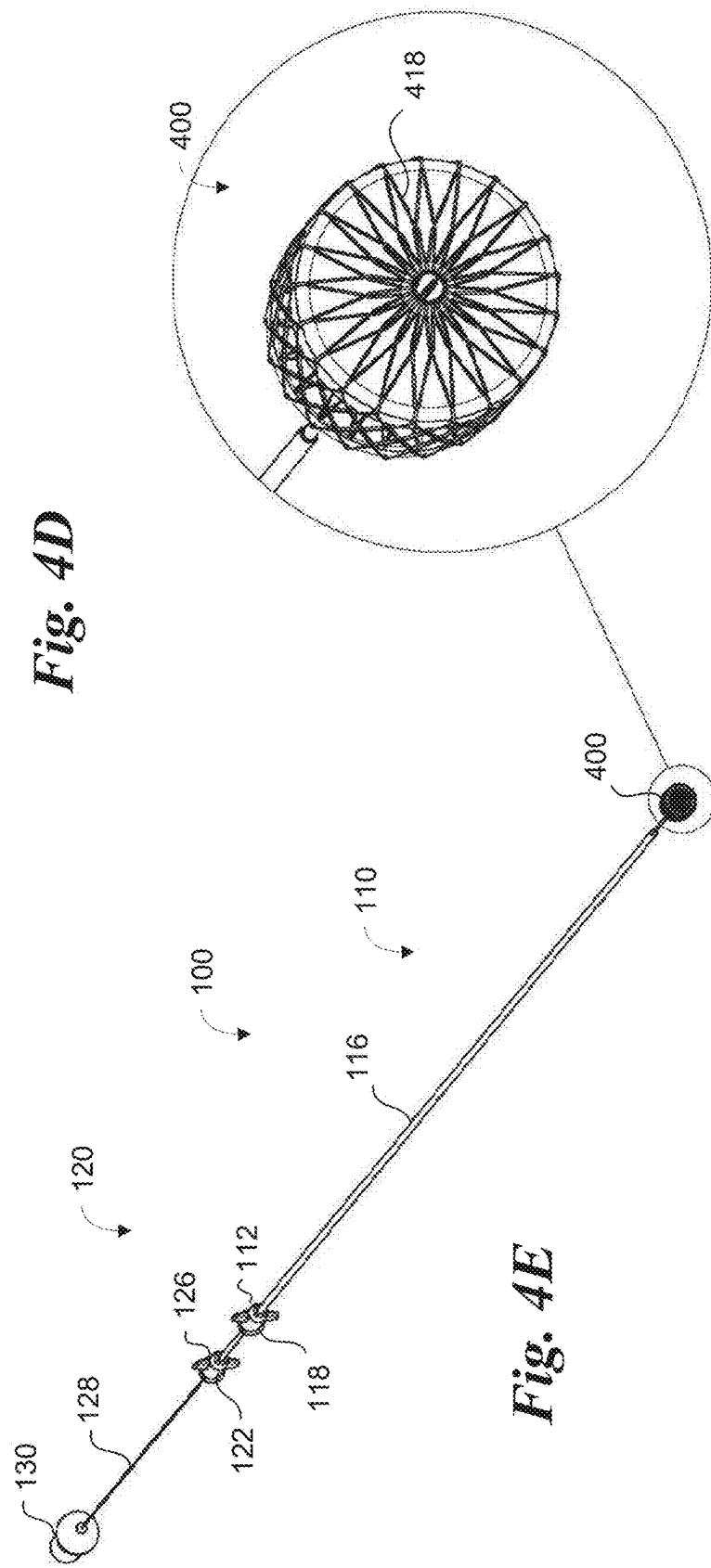


Fig. 4E

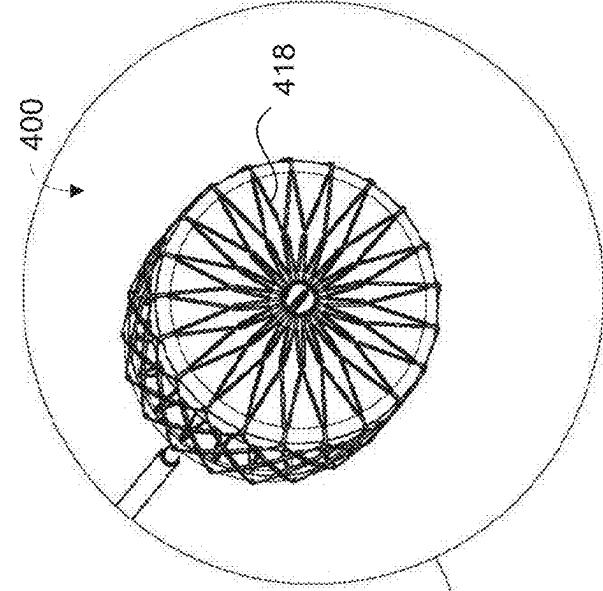


Fig. 4F

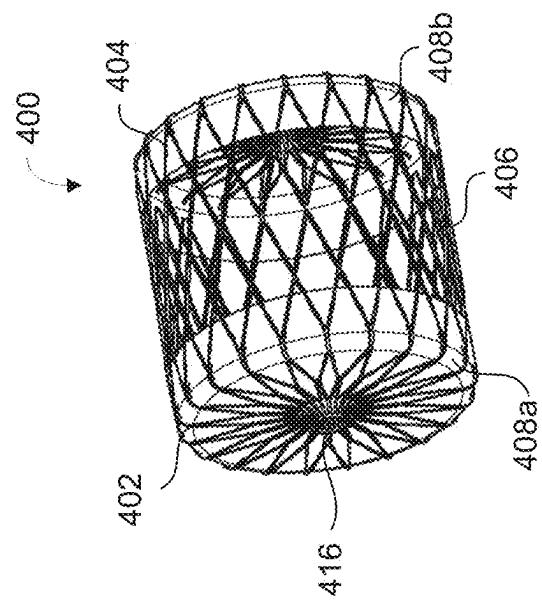
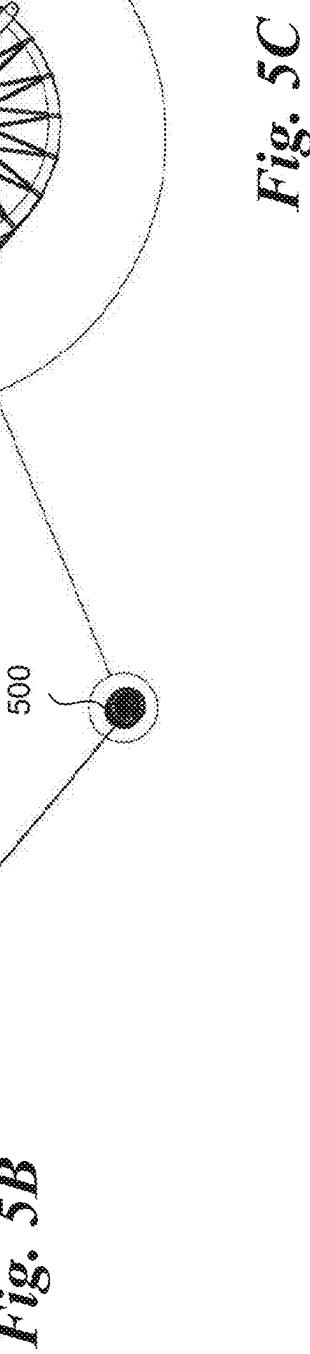
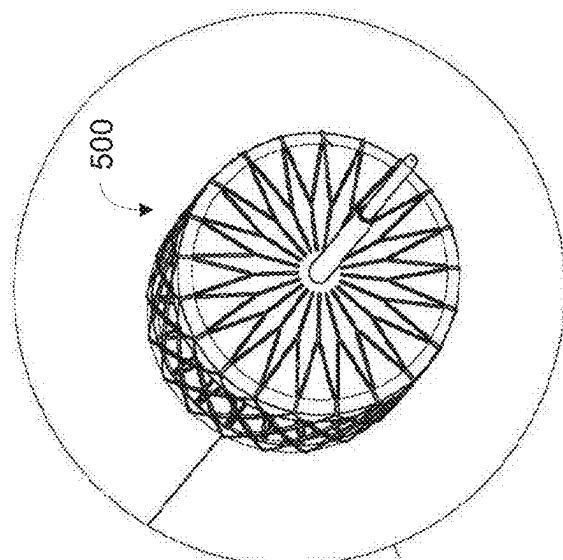
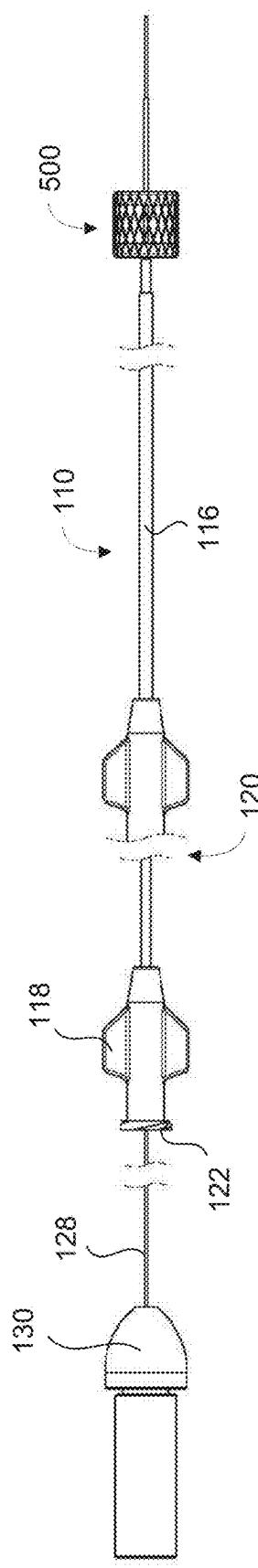


Fig. 4G



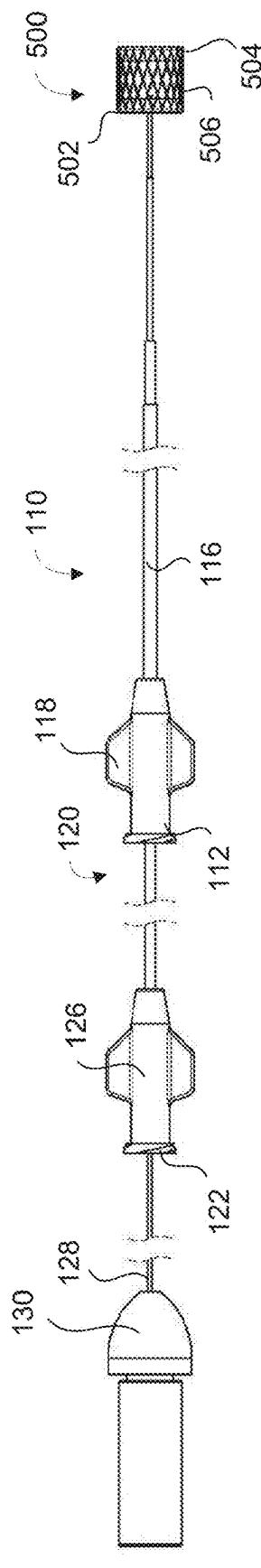


Fig. 5D

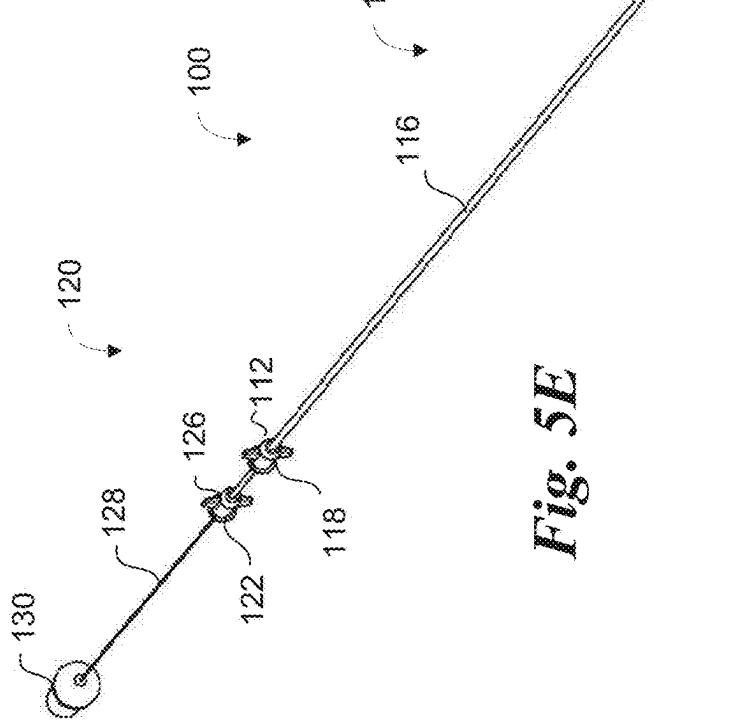


Fig. 5E

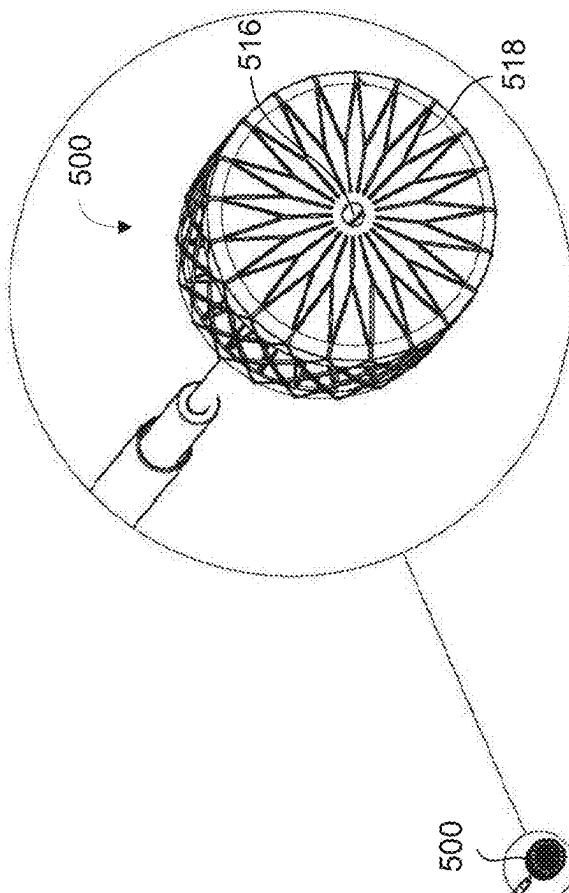


Fig. 5F

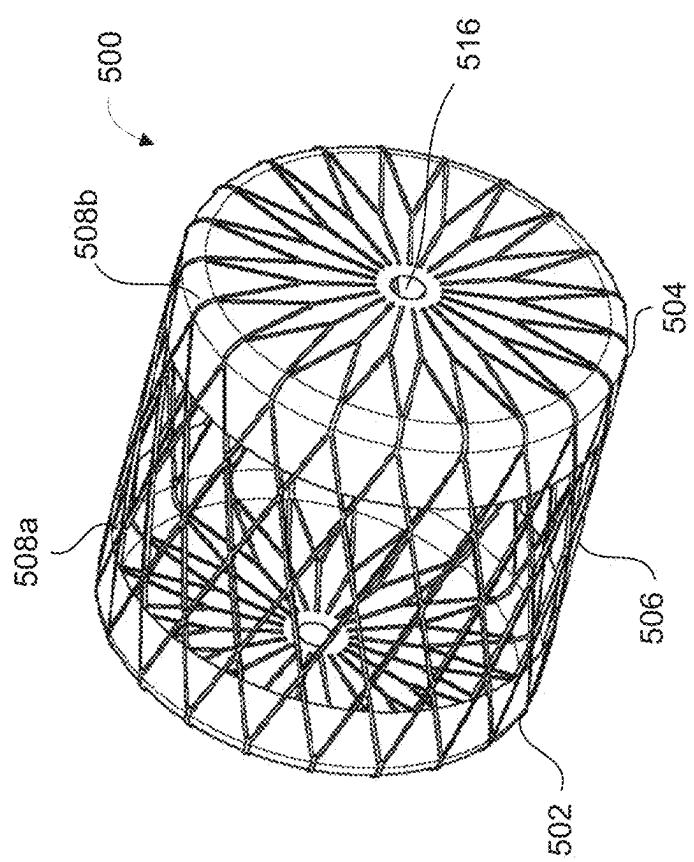


Fig. 5G

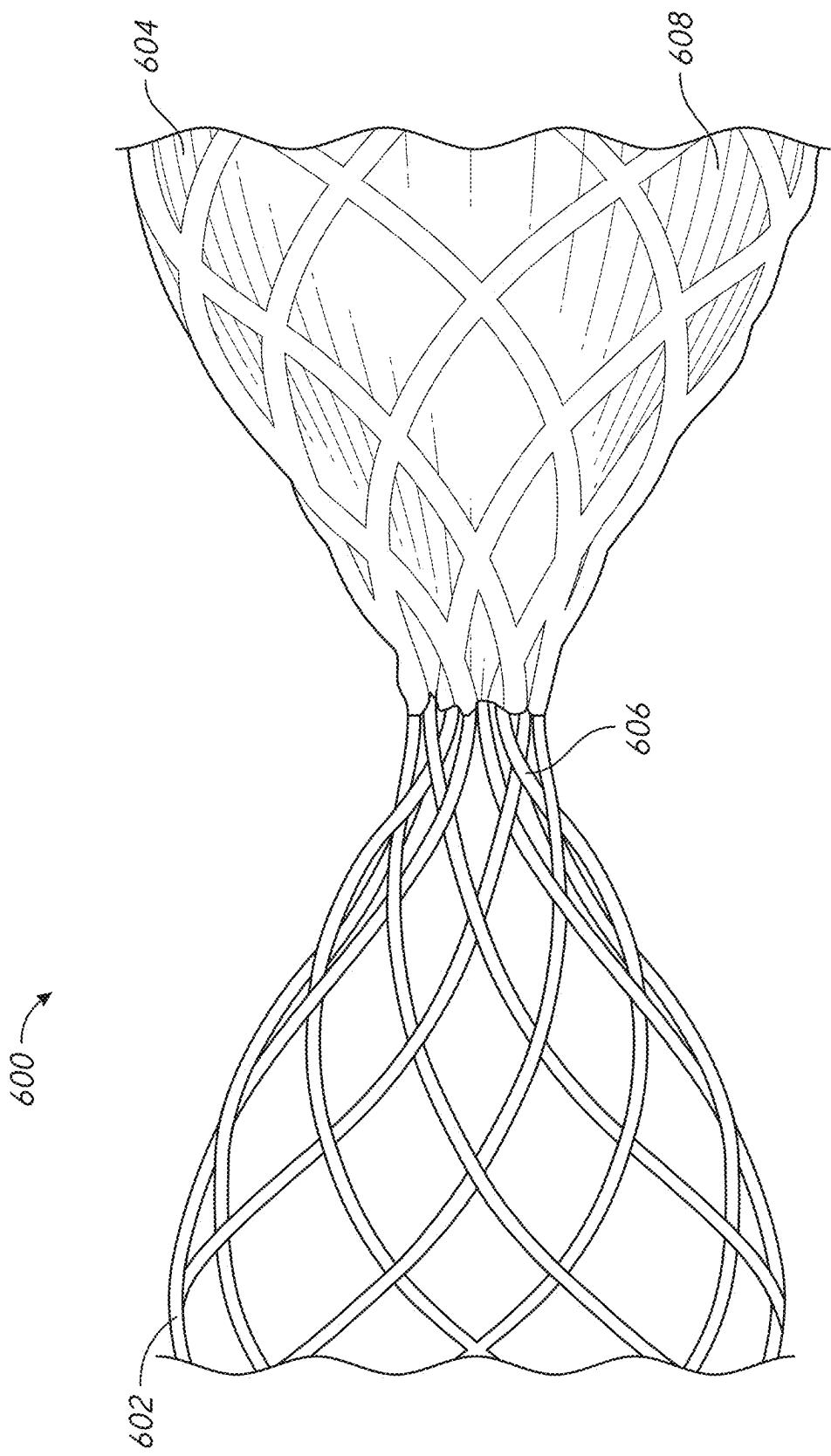
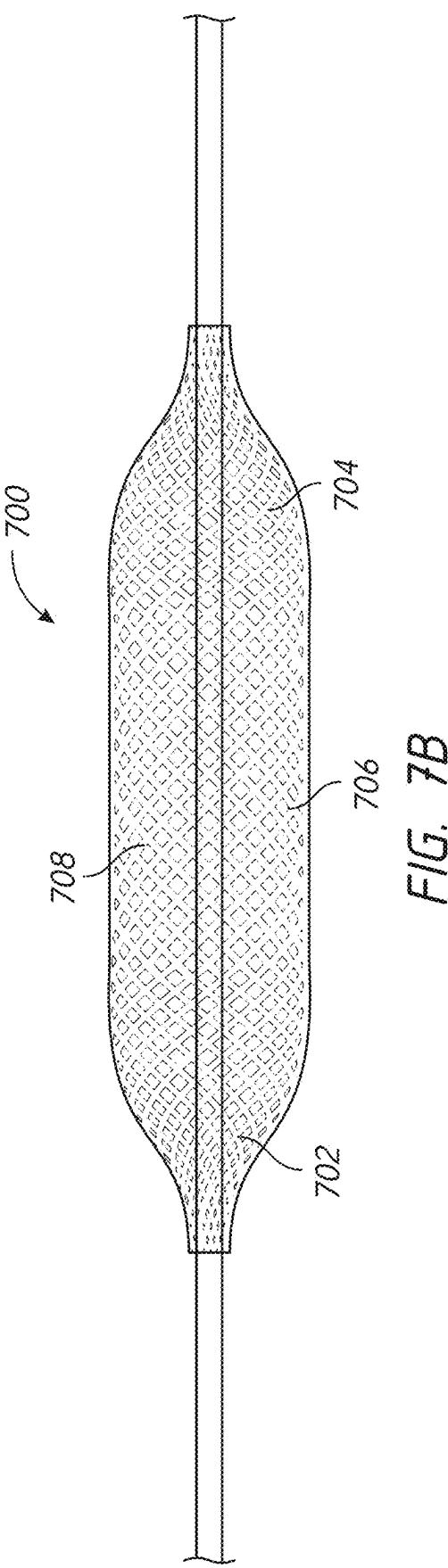
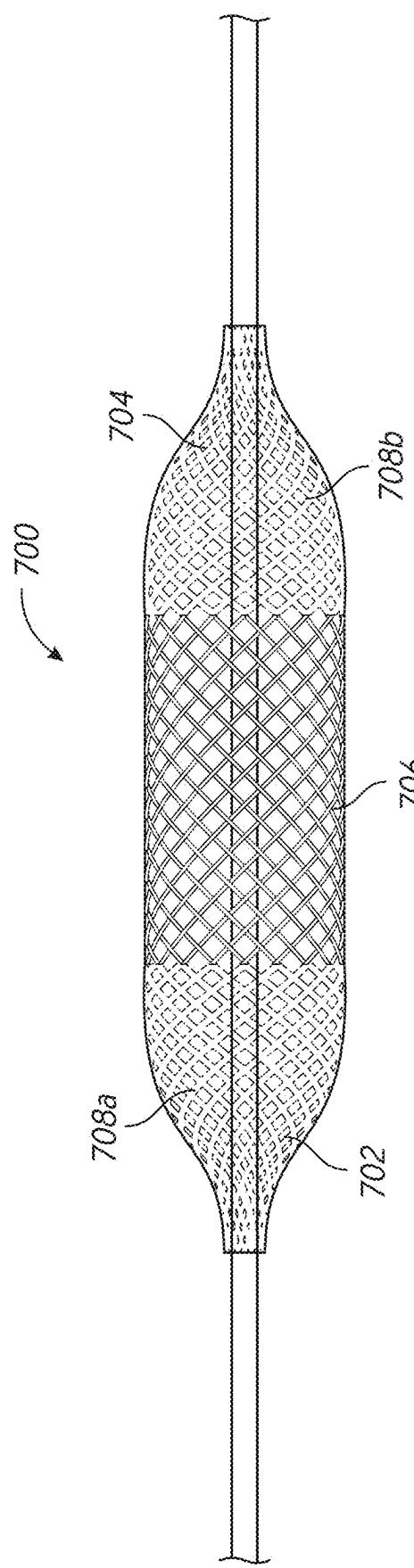


FIG. 6



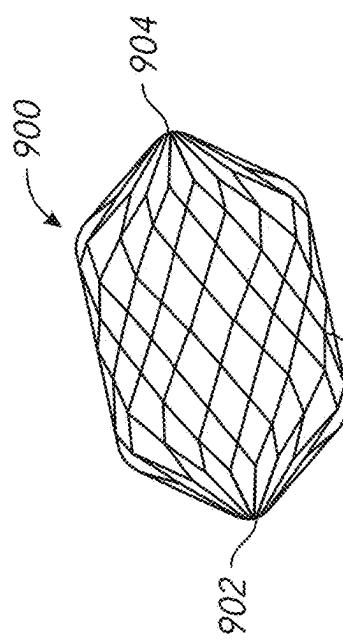


FIG. 9A

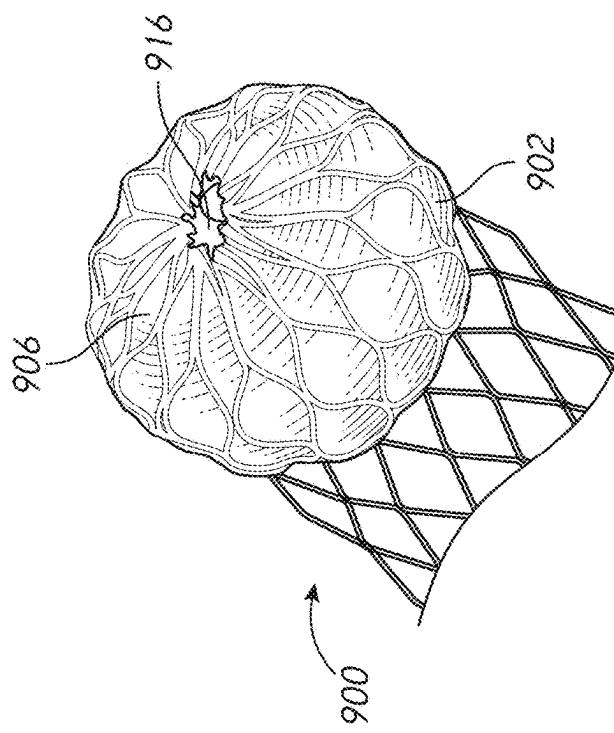


FIG. 9C

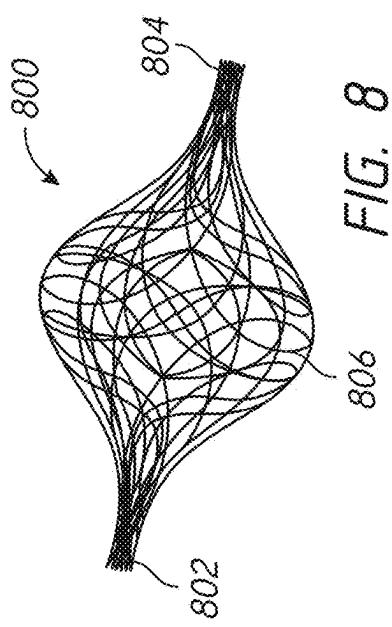


FIG. 8

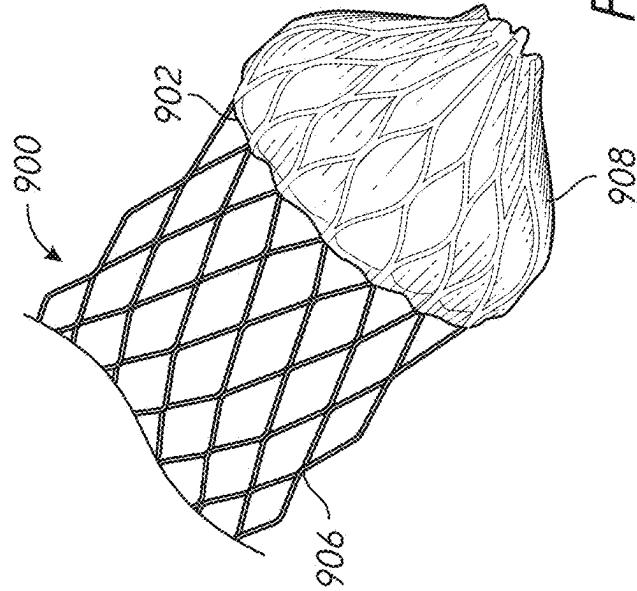
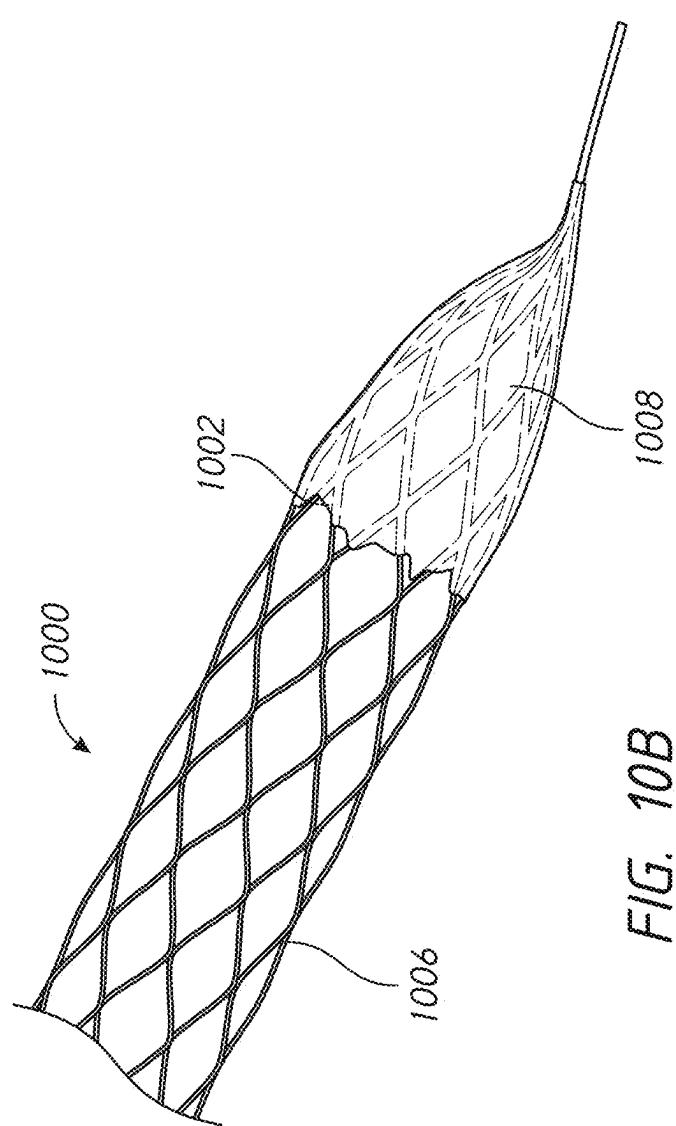
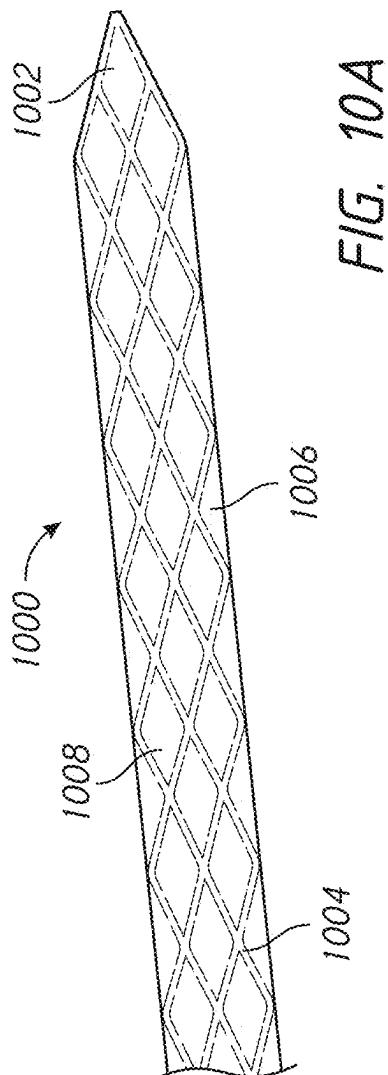
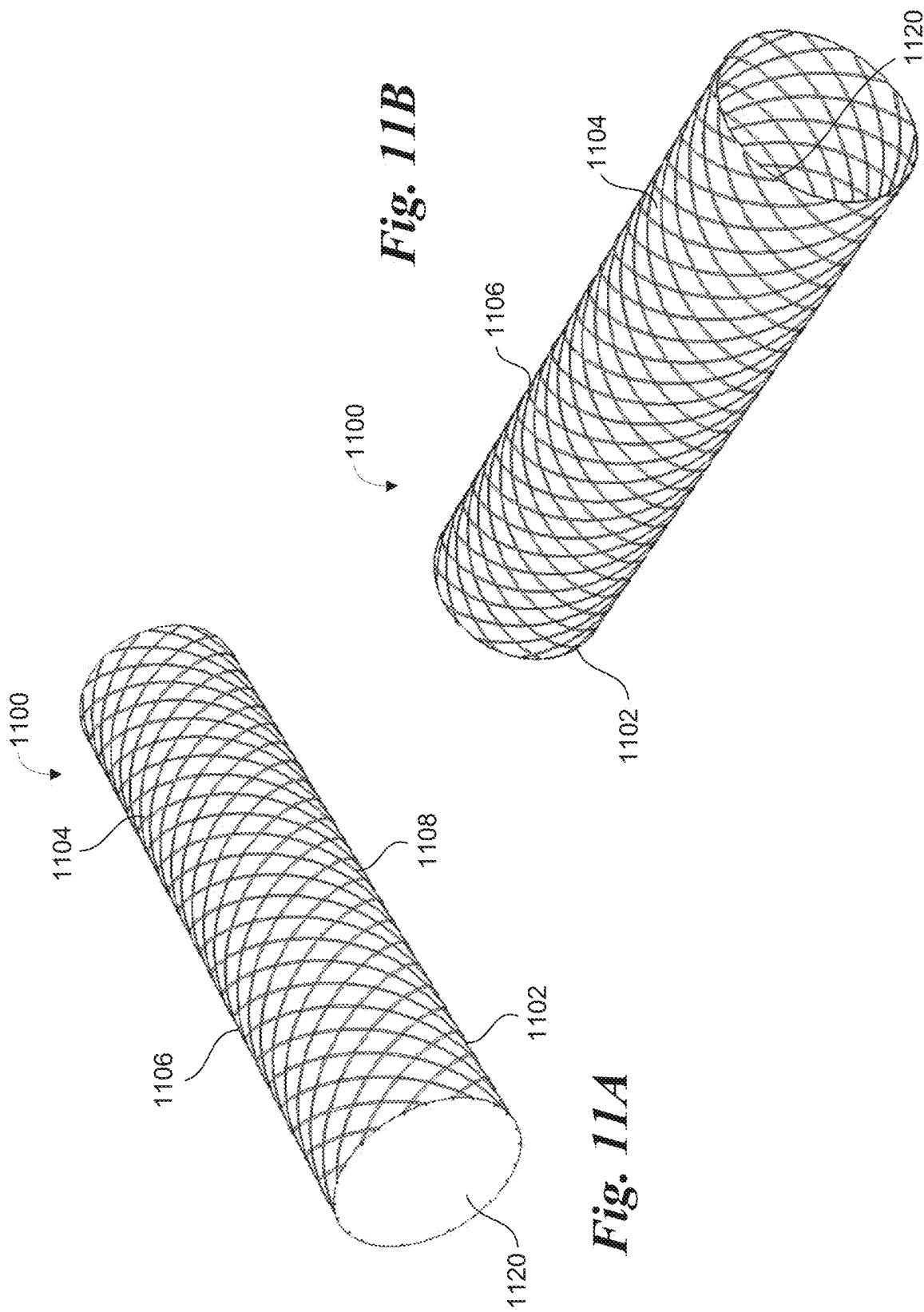


FIG. 9B





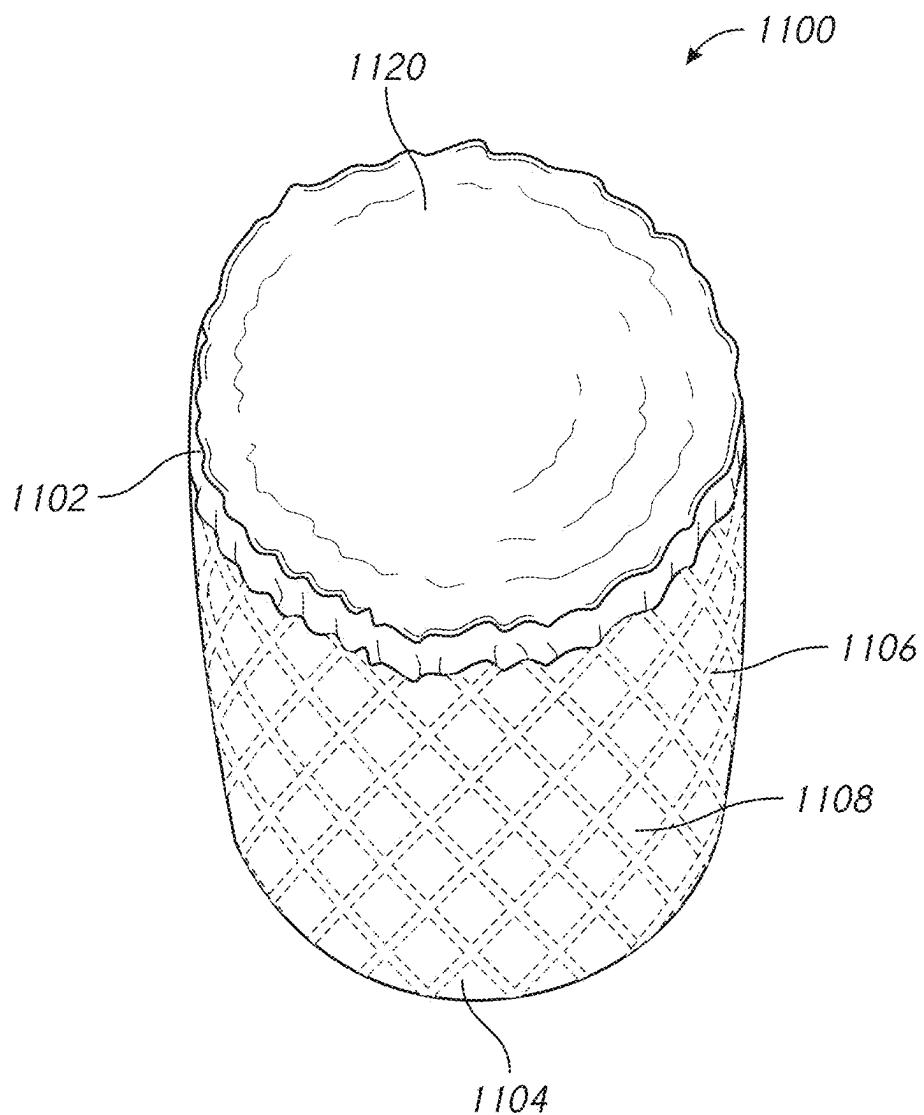


FIG. 11C

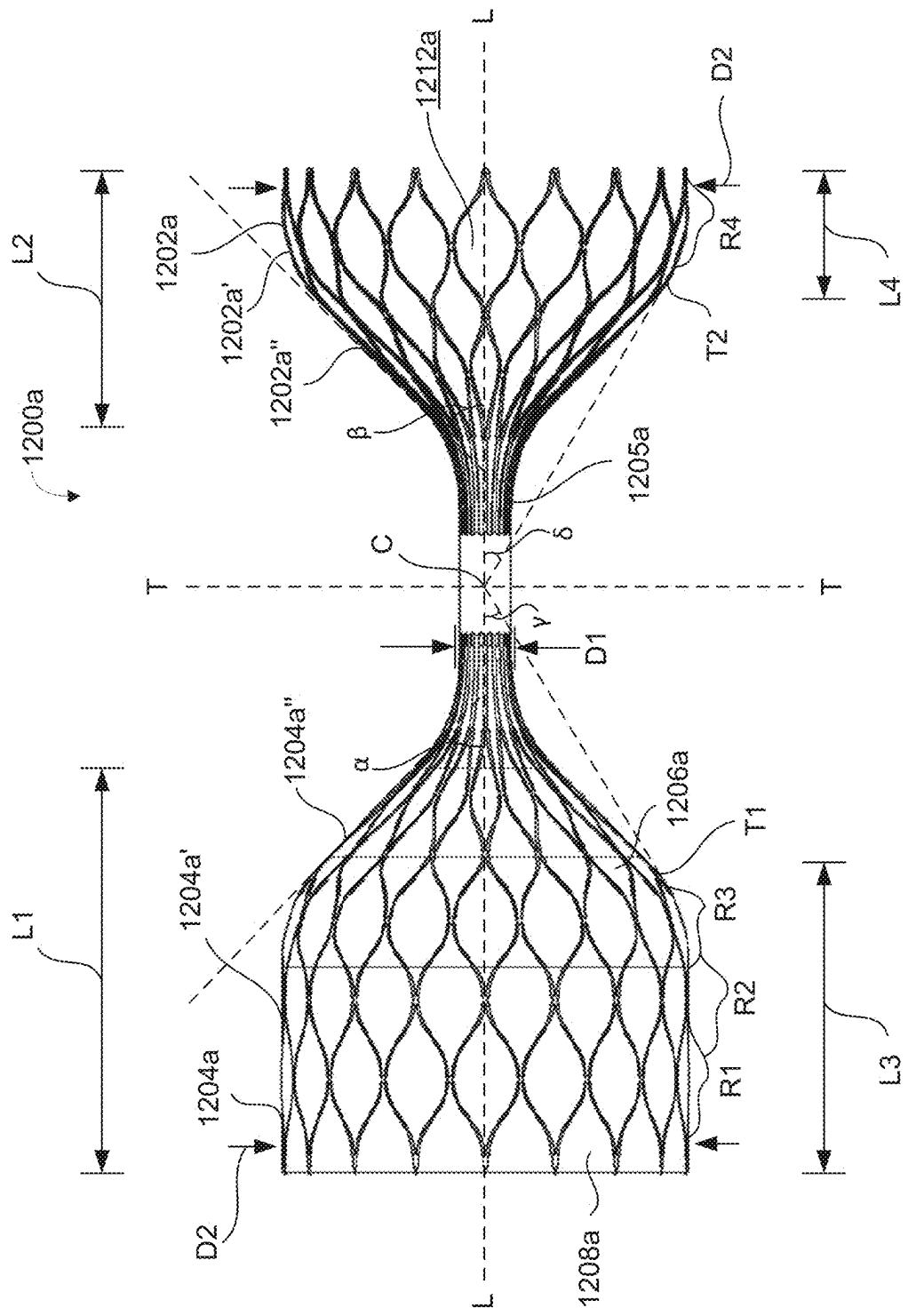


Fig. 12A

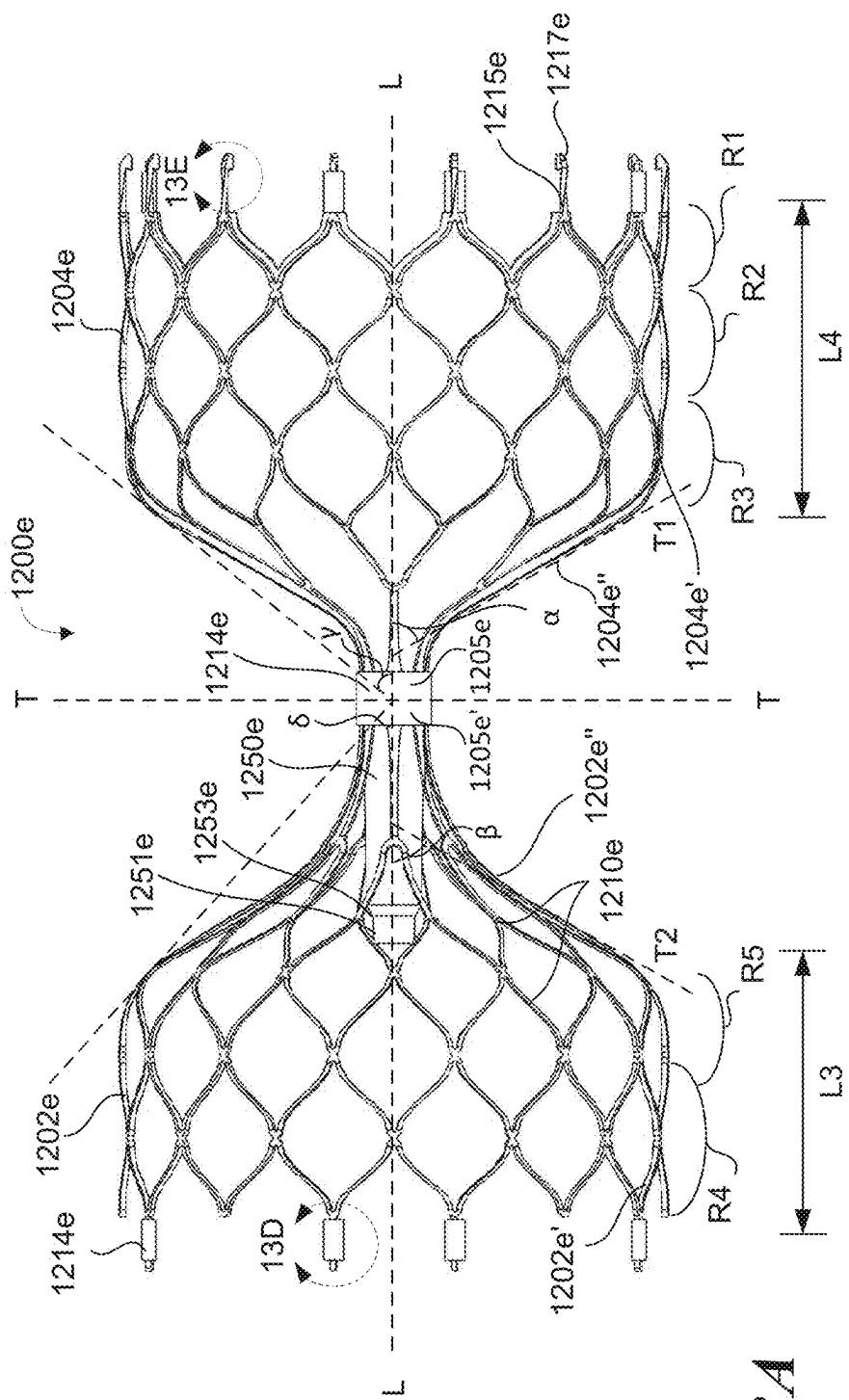


Fig. 13A

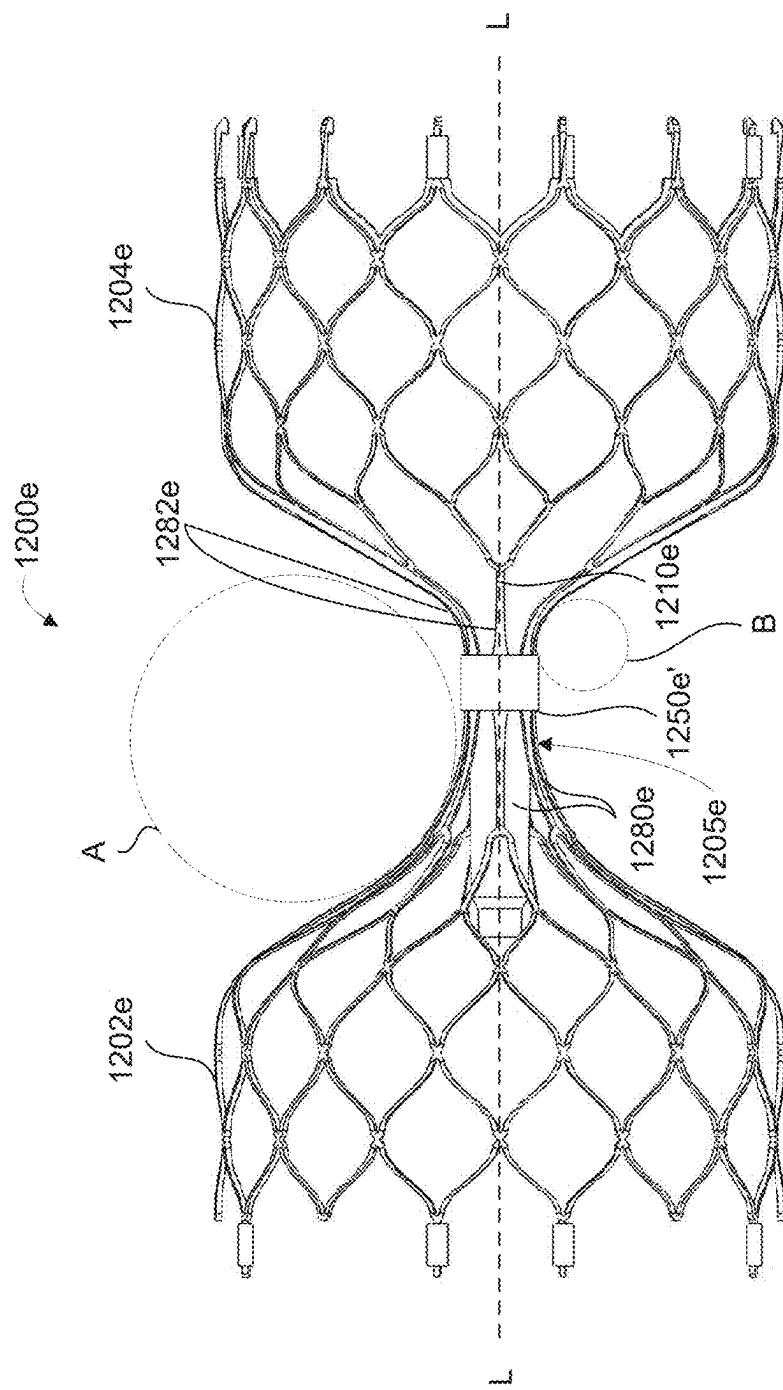


Fig. 13B

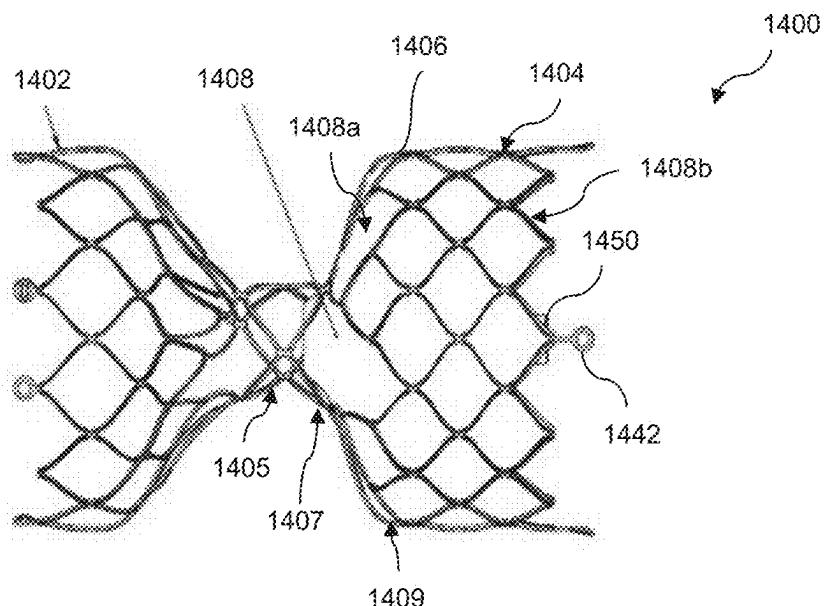


FIGURE 14A

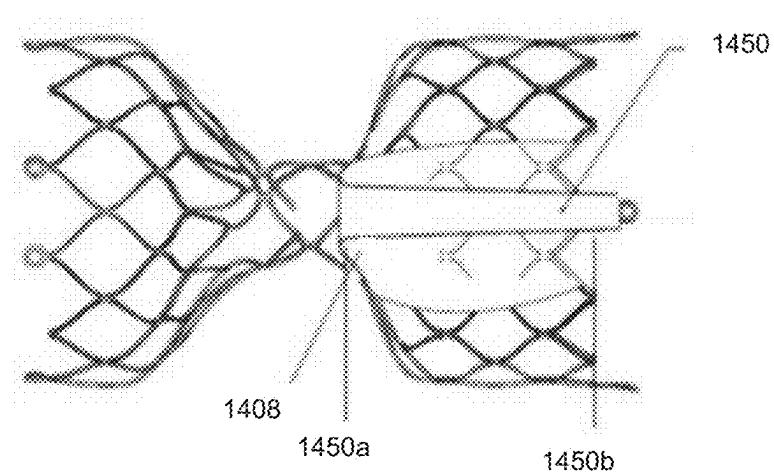


FIGURE 14B

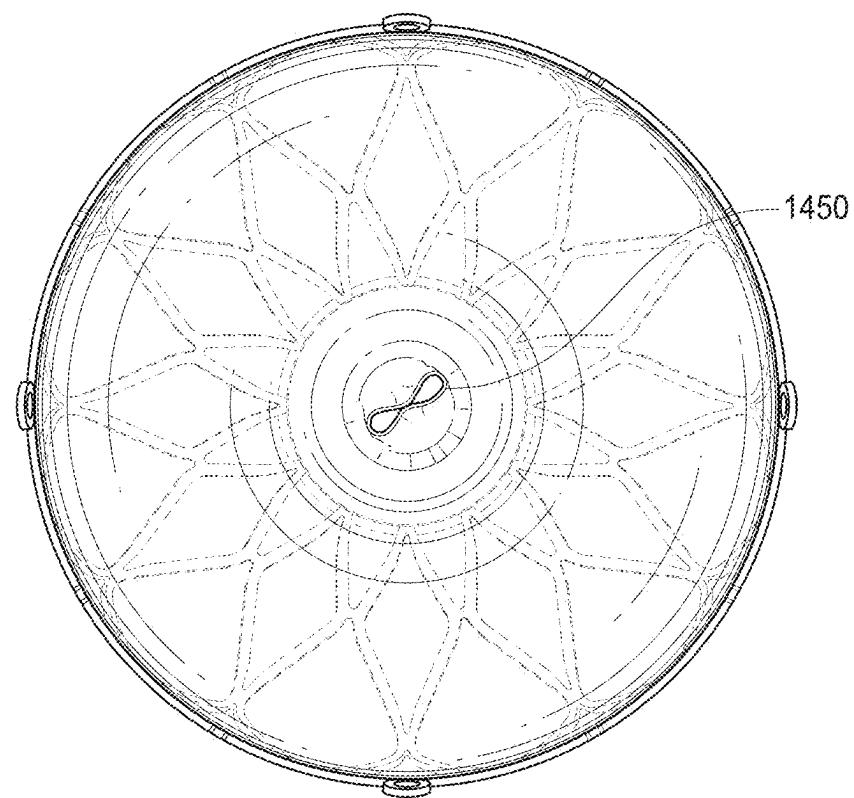


FIGURE 14C

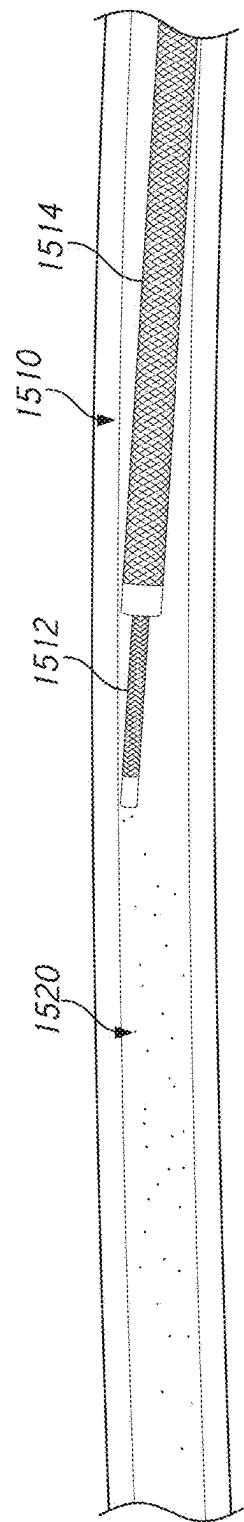


FIG. 15A

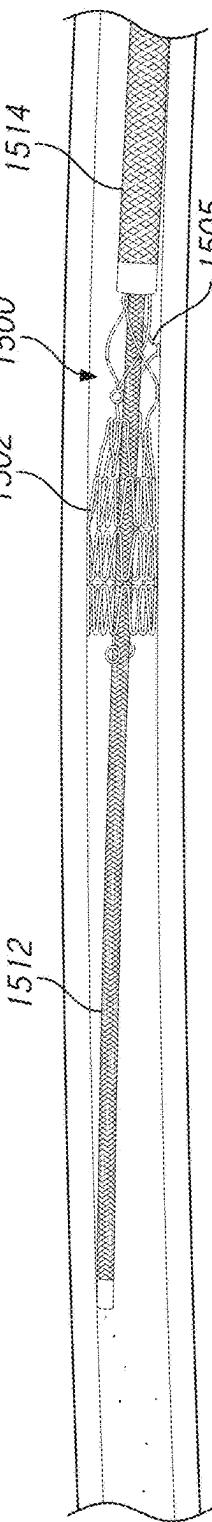


FIG. 15B

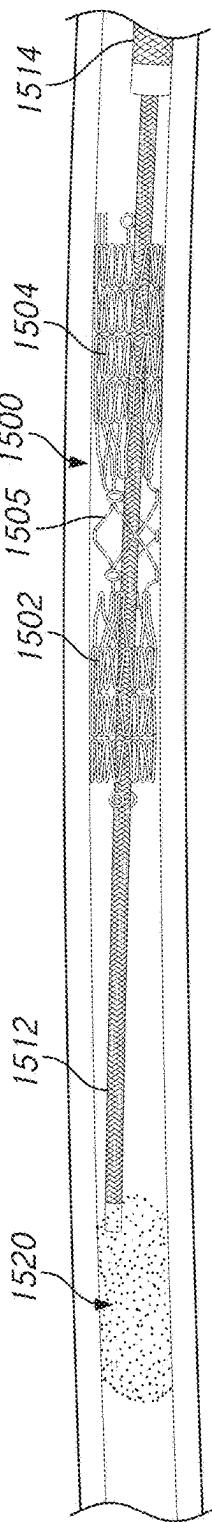


FIG. 15C

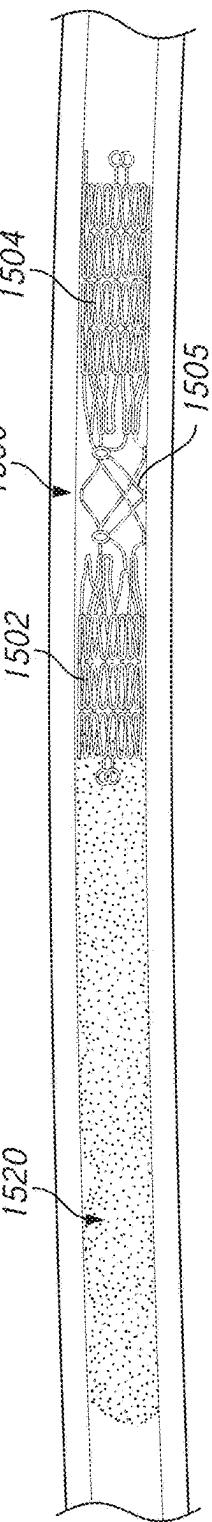
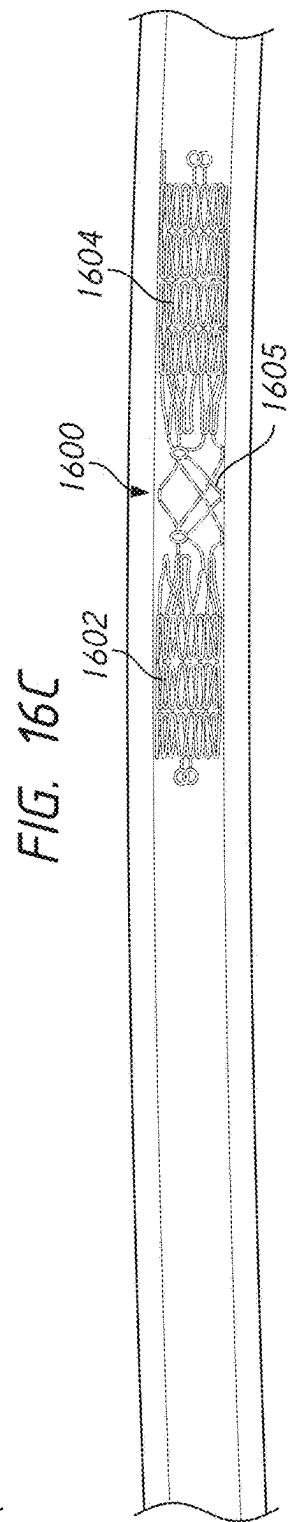
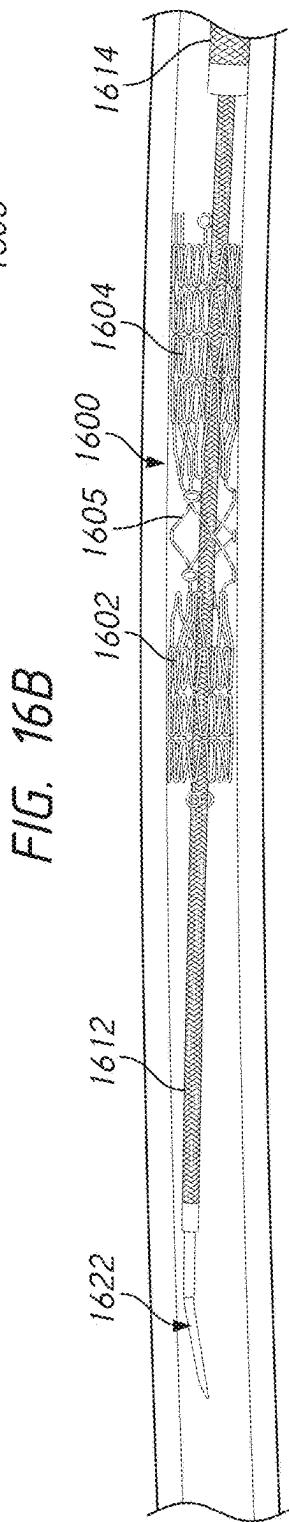
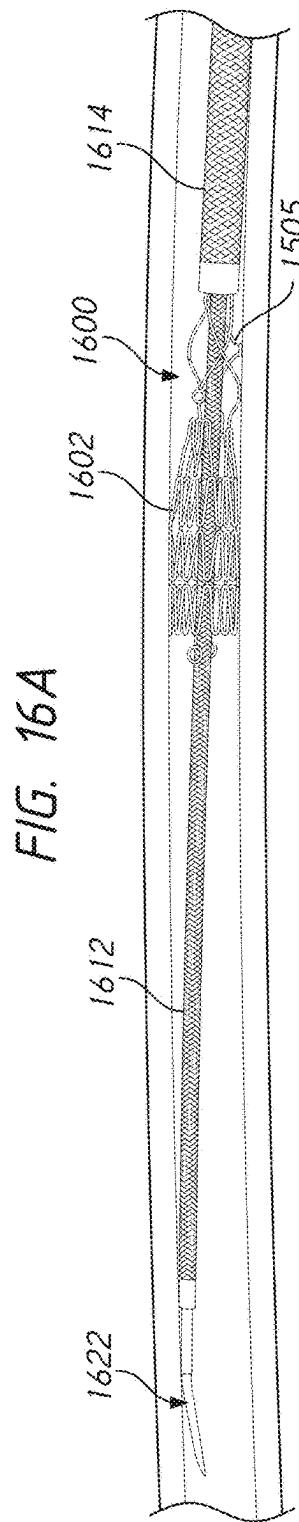
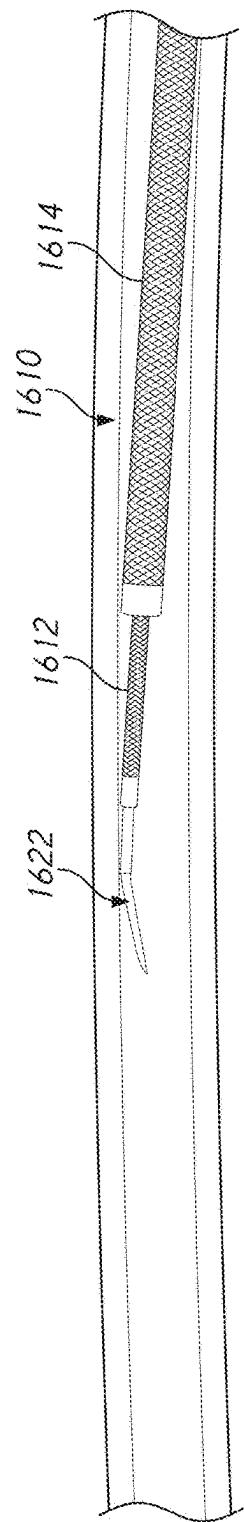


FIG. 15D



USE OF PERIPHERAL EMBOLIZATION DEVICE FOR SECONDARY TREATMENT

INCORPORATION BY REFERENCE TO ANY PRIORITY APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 17/107,732, filed Nov. 30, 2020, titled "USE OF PERIPHERAL EMBOLIZATION DEVICE FOR SECONDARY TREATMENT," which claims priority benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application No. 62/944,953, filed Dec. 6, 2019, titled "USE OF A PERIPHERAL EMBOLIZATION DEVICE FOR THE DELIVERY OF AGENTS," which is hereby incorporated by reference in its entirety.

BACKGROUND

Field

[0002] The present disclosure generally relates to apparatuses and methods for delivering therapeutic agents or advancing a treatment instrument through an embolization device.

Description of the Related Art

[0003] When a therapeutic agent is delivered to the body, the therapeutic agent is systemically distributed through the body by blood circulation. As a result, suboptimal concentrations of the therapeutic agent may reach the target site. A majority of the therapeutic agent will accumulate in healthy tissue, which may have detrimental effects. There remains a need for solutions to targeted drug delivery.

SUMMARY

[0004] Peripheral occlusion devices delivered over-the-wire, as described herein, provide physicians with accurate, stent-like delivery of the occlusion device in the vessel. Such occlusion devices take advantage of natural hemodynamic forces to provide immediate, focal, and stable occlusions. A single delivery system may be used to deliver both the peripheral occlusion device and a therapeutic agent. In addition to the delivering therapeutic agents, the inner body of the delivery system can serve as a working channel for complimentary medical devices such as steerable ablation needles.

[0005] Certain aspects of the disclosure are directed toward improved methods of providing targeted drug delivery. The improved methods increase the amount of therapeutic agent that reaches the target site. The improved methods also prevent reflux during infusion, thereby preventing the therapeutic agent from accumulating in healthy tissue.

[0006] Certain methods of delivering a therapeutic agent may include advancing a delivery system to a vessel, for example over a guidewire or through an access catheter. The delivery system may include an outer body and an inner body disposed within the outer body. The delivery system may carry an implantable occlusion device between the inner body and the outer body. For example, the occlusion device may be carried by the inner body and/or radially restrained between the inner body and the outer body. The method may include at least partially deploying, which may be less than fully deploying, the implantable occlusion device from the outer body of the delivery system. At least

partially deploying the implantable occlusion device may include moving the inner body relative to the outer body, which may include retracting the outer body or advancing the inner body. The method may include delivering therapeutic agent from the inner body of the delivery system. For example, the therapeutic agent may be released from the opening at the distal most end of the inner body. The therapeutic agent may be delivered from the guidewire lumen of the inner body or a lumen separate from the guidewire lumen. Delivery of the therapeutic agent may occur prior to deploying any portion of the occlusion device from the outer body, prior to fully deploying the occlusion device from the outer body, and/or after fully deploying the occlusion device from the outer body. The therapeutic agent may be delivered in a single dose or in multiple doses at different time points during the procedure. The therapeutic agent may be delivered from the inner body of the delivery system, while the inner body carries or extends through an opening of the implantable occlusion device, for example extending through a guidewire opening in the neck portion of the implantable occlusion device. The therapeutic agent may be delivered upstream or downstream, with respect to blood flow, of the implantable occlusion device. Prior to delivering the therapeutic agent, the guidewire may be withdrawn from the delivery system. The method may include releasing the implantable occlusion device from the delivery system, for example by releasing the implantable occlusion device from the outer body and/or withdrawing the inner body from the implantable occlusion device.

[0007] Certain methods are directed toward providing a secondary treatment near an implantable occlusion device. The method may include using a common delivery system to deliver the occlusion device and provide the secondary treatment near the occlusion device. The secondary treatment may be provided downstream or upstream, with respect to blood flow, of the implantable occlusion device. The method may include advancing a delivery system to the vessel, for example over a guidewire or through an access catheter. The delivery system may include an outer body and an inner body disposed within the outer body. The inner body may include a working lumen extending therethrough. The working lumen may be the same lumen as the guidewire lumen or separate from the guidewire lumen. The delivery system may carry the implantable occlusion device between the inner body and the outer body. For example, the occlusion device may be carried by the inner body and/or radially restrained between the inner body and the outer body. The method may include at least partially deploying the implantable occlusion device from the outer body of the delivery system. The method may include advancing a treatment instrument through the working lumen of the inner body. The treatment instrument may be an ablation device, for example a steerable ablation needle. The treatment instrument may be advanced through the working lumen, while the inner body extends through an opening of the implantable occlusion device, for example a guidewire opening in the neck portion. The treatment instrument may be advanced relative to the inner body prior to deploying any portion of the implantable occlusion device, after at least partially deploying the implantable occlusion device, or after fully deploying the implantable occlusion device. The method may include providing the secondary treatment, for example ablation therapy, at the target site using the treatment instrument. The secondary treatment may be provided prior to

deploying any portion of the implantable occlusion device, after at least partially deploying the implantable occlusion device, or after fully deploying the implantable occlusion device. The treatment instrument may provide the treatment upstream or downstream, with respect to blood flow, of the implantable occlusion device. In some methods, the secondary treatment may be ablation therapy. The method may include releasing the implantable occlusion device from the delivery system, for example by releasing the implantable occlusion device from the outer body and/or withdrawing the inner body from the implantable occlusion device. For purposes of summarizing the disclosure, certain aspects, advantages, and features of the inventions have been described herein. It is to be understood that not necessarily any or all such advantages are achieved in accordance with any particular embodiment of the inventions disclosed herein. No aspects of this disclosure are essential or indispensable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Various embodiments are depicted in the accompanying drawings for illustrative purposes, and should in no way be interpreted as limiting the scope of the embodiments. Furthermore, various features of different disclosed embodiments can be combined to form additional embodiments, which are part of this disclosure.

[0009] FIG. 1A illustrates a delivery system for delivering an occlusion device.

[0010] FIG. 1A-1 illustrates an enlarged view of a distal portion of the delivery system shown in FIG. 1A.

[0011] FIG. 1B-1 illustrates an embodiment of an outer catheter that can be used with the delivery system shown in FIG. 1A.

[0012] FIG. 1B-2 illustrates an enlarged view of the working length of the outer catheter shown in FIG. 1B-1.

[0013] FIG. 1B-3 illustrates an embodiment of an inner catheter that can be used with the delivery system shown in FIG. 1A.

[0014] FIG. 1B-4 illustrates an enlarged view of a distal portion of the inner catheter shown in FIG. 1B-3 through line 1B-3-1B-3.

[0015] FIG. 1C-1 illustrates an embodiment of a delivery system having a pusher interlock assembly in a locked configuration.

[0016] FIG. 1C-2 illustrates the pusher interlock assembly shown in FIG. 1C-1 in an unlocked configuration.

[0017] FIG. 1C-3 illustrates an embodiment of an occlusion device having a portion of the pusher interlock assembly shown in FIG. 1C-1 and detached from the delivery system.

[0018] FIG. 1D-1 illustrates another embodiment of a delivery system having a threaded interlock assembly.

[0019] FIG. 1D-2 illustrates an enlarged view of the threaded interlock assembly through line 1D-2 shown in FIG. 1D-1.

[0020] FIG. 1E-1 illustrates another embodiment of a delivery system having an interlock catheter.

[0021] FIG. 1E-2 illustrates an enlarged view of a portion of the delivery system shown in FIG. 1E-1 taken through line 1E-2 to 1E-4 with the interlock assembly in a locked configuration.

[0022] FIG. 1E-3 illustrates an enlarged view of a portion of the delivery system shown in FIG. 1E-1 taken through line 1E-2 to 1E-4 with the interlock assembly in an unlocked configuration.

[0023] FIG. 1E-4 illustrates an enlarged view of a portion of the delivery system shown in FIG. 1E-1 taken through line 1E-2 to 1E-4 with the occlusion device detached.

[0024] FIG. 1E-5 illustrates a cross-section of FIG. 1E-2 taken through line 1E-5 to 1E-5 without the occlusion device.

[0025] FIG. 1E-6 illustrates a cross-section of FIG. 1E-4 taken through line 1E-6 to 1E-6.

[0026] FIG. 2A illustrates another embodiment of a delivery system.

[0027] FIG. 2B illustrates an enlarged view of a distal portion of the delivery system shown in FIG. 2A through line B prior to deployment.

[0028] FIG. 2C illustrates the distal portion of the delivery system shown in FIG. 2A with the distal lobe of the occlusion device partially deployed.

[0029] FIG. 2CC illustrates an enlarged cross-section of the distal portion shown in FIG. 2C taken through line CC.

[0030] FIG. 2D illustrates the distal portion of the delivery system shown in FIG. 2A with the distal lobe of the occlusion device fully deployed.

[0031] FIG. 2DD illustrates an enlarged cross-section of the distal portion shown in FIG. 2D taken through line DD.

[0032] FIG. 2E illustrates the distal portion of the delivery system shown in FIG. 2A with the distal lobe of the occlusion device partially retracted.

[0033] FIG. 2EE illustrates a cross-section of the distal portion shown in FIG. 2E taken through line EE.

[0034] FIG. 2F illustrates the distal portion of the delivery system shown in FIG. 2A with a majority of the occlusion device deployed.

[0035] FIG. 2FF illustrates a cross-section of the distal portion shown in FIG. 2F taken through line FF.

[0036] FIG. 2G illustrates the distal portion of the delivery system shown in FIG. 2A with the occlusion device fully deployed.

[0037] FIG. 2H illustrates a cross-section of the occlusion device shown in FIG. 2G with the inner catheter partially retracted.

[0038] FIG. 2HH illustrates an enlarged view of a tubular membrane portion of the occlusion device shown in FIG. 2H taken through line HH.

[0039] FIG. 2I illustrates a cross-section of the occlusion device shown in FIG. 2H with the inner catheter further retracted.

[0040] FIG. 2II illustrates an enlarged view of the tubular membrane portion of the occlusion device shown in FIG. 2I taken through line II.

[0041] FIG. 2J illustrates a cross-section of the occlusion device shown in FIG. 2I with the inner catheter further retracted.

[0042] FIG. 2JJ illustrates an enlarged view of the tubular membrane portion of the occlusion device shown in FIG. 2J taken through line JJ.

[0043] FIG. 2K illustrates a cross-section of the occlusion device shown in FIG. 2J with the delivery system fully withdrawn from the occlusion device.

[0044] FIG. 2L illustrates the inner catheter of the delivery system shown in FIG. 2A.

[0045] FIG. 2M illustrates an enlarged view of a distal portion of the inner catheter shown in FIG. 2L.

[0046] FIG. 2N illustrates a cross-section of a distal portion through line 2N of the outer catheter shown in FIG. 2M.

[0047] FIG. 2O illustrates the outer catheter of the delivery system shown in FIG. 2A for contrast dye injection.

[0048] FIG. 2P illustrates an enlarged view of a working length of the outer catheter shown in FIG. 2O.

[0049] FIG. 2Q illustrates another deployment system having an interlock attachment member interfacing with an occlusion device.

[0050] FIG. 2R illustrates another deployment system having an interlock attachment member released from the occlusion device.

[0051] FIG. 2S illustrates an embodiment of a delivery system for delivering an occlusion device having a test balloon.

[0052] FIGS. 3A-3F illustrate another delivery system and an occlusion device having a tapered proximal end.

[0053] FIGS. 4A-4F illustrate yet another delivery system and a generally cylindrical occlusion device.

[0054] FIG. 4G illustrates an enlarged view of the occlusion device shown in FIGS. 4A-4F.

[0055] FIGS. 5A-5F illustrate a delivery system and another generally cylindrical occlusion device.

[0056] FIG. 5G illustrates an enlarged view of the occlusion device shown in FIGS. 5A-5F.

[0057] FIG. 6 illustrates a partially covered, hourglass-shaped occlusion device.

[0058] FIG. 7A illustrates a partially covered occlusion device having tapered ends.

[0059] FIG. 7B illustrates a fully covered occlusion device having tapered ends.

[0060] FIG. 8 illustrates an expandable structure having a non-uniform diameter.

[0061] FIG. 9A illustrates another expandable structure having tapered ends.

[0062] FIGS. 9B-9C illustrate the expandable structure in FIG. 9A partially covered with a cover.

[0063] FIG. 10A illustrates a fully covered occlusion device having a first, closed end portion and a second, opened end portion.

[0064] FIG. 10B illustrates a partially covered occlusion device having a first, closed end portion and a second, opened end portion.

[0065] FIGS. 11A-11C illustrate different views of an occlusion device having a drumhead and a cover.

[0066] FIG. 12A illustrates an embodiment of an occlusion device having an asymmetrical hourglass shape.

[0067] FIG. 13A illustrates another embodiment of an hourglass-shaped occlusion device in an expanded configuration with a portion of the membrane removed to show the tubular portion of the membrane.

[0068] FIG. 13B illustrates the occlusion device shown in FIG. 13A in an unexpanded configuration.

[0069] FIG. 14A illustrates yet another embodiment of an occlusion device.

[0070] FIG. 14B illustrates a cross-section of the occlusion device shown in FIG. 14A.

[0071] FIG. 14C is an image of a proximal end view of the occlusion device shown in FIG. 14A in a closed configuration.

[0072] FIGS. 15A to 15D illustrate a method of delivering a therapeutic agent downstream of the occlusion device.

[0073] FIGS. 16A to 16D illustrate a method of providing a secondary treatment downstream of the occlusion device.

DETAILED DESCRIPTION

[0074] The following discussion is presented to enable a person skilled in the art to make and use one or more embodiments of the invention. The general principles described herein may be applied to embodiments and applications other than those detailed below without departing from the spirit and scope of the invention. Therefore the present invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed or suggested herein.

[0075] FIGS. 1A and 1A-1 illustrate an exemplary delivery system 100 for delivering any of the occlusion devices illustrated herein. The delivery system 100 can include an outer catheter 110 and an inner catheter 120 extending through the outer catheter 110. Although primarily described in the context of an intravascular embolic deployment catheter with a single central lumen, catheters of the present invention can readily be modified to incorporate additional structures, such as permanent or removable column strength enhancing mandrels, two or more lumens such as to permit drug or irrigant infusion or aspiration or radiation delivery or to supply inflation media to an inflatable balloon, or combinations of these features, as will be readily apparent to one of skill in the art in view of the disclosure herein.

[0076] The catheters and occlusion devices disclosed herein may readily be adapted for use throughout the body wherever it may be desirable to introduce an occluder. For example, occlusion devices may be deployed throughout the coronary and peripheral vasculature, neurovasculature, the gastrointestinal tract, the urethra, ureters, Fallopian tubes, and other lumens and potential lumens, as well.

[0077] Generally, the occlusion devices described herein can be delivered via a low profile outer catheter 110 (e.g., having an outer diameter from about 2.8 F (0.93 mm) to about 6 F (2.0 mm), typically from about 3 F (1.0 mm) to about 5F (1.67 mm), preferably less than about 5F (1.67 mm), such as about 4.7F (1.57 mm)). Further, the occlusion devices described herein can be delivered over a guide wire having a diameter of at least about 0.010 inches and/or less than or equal to about 0.02 inches to facilitate trackability of the delivery catheter, while still utilizing a low profile delivery catheter. For example, the guide wire can have a diameter of about 0.01 inches, 0.014 inches, or about 0.018 inches.

[0078] The outer catheter 110 can generally include an elongate tubular body 116 extending between a proximal end 112 and a distal end 114. The length of the tubular body 116 depends upon the desired application. For example, lengths in the area of from about 120 cm to about 140 cm or more are typical for use in femoral access percutaneous transluminal coronary applications. Further, the outer catheter 110 should have sufficient working length to reach the target vessel. The minimum working length for these applications can be at least about 75 cm about 90 cm, or at least about 100 cm, but no more than about 175 cm. Intracranial or other applications may call for a different catheter shaft length depending upon the vascular access site, as will be understood in the art. Deployment catheters adapted for

intracranial applications generally have a total length in the range from 60 cm to 250 cm, usually from about 135 cm to about 175 cm.

[0079] In general, neurovascular devices may be deployable from catheters having a length of at least about 120 cm or 125 cm or greater, to allow access to the carotid artery bifurcation and above. Devices configured for coronary or peripheral applications may have shorter delivery catheters and other dimensional modifications as are understood in the art.

[0080] The catheters of the present invention may be composed of any of a variety of biologically compatible polymeric resins having suitable characteristics when formed into the tubular catheter body segments. Exemplary materials include polyvinyl chloride, polyethers, poly-amides, polyethylenes, polyurethanes, a polycarbonate blend, copolymers thereof, and the like. Optionally, the tubular body may be reinforced with a metal or polymeric braid or other conventional reinforcing layer.

[0081] The catheter material should be selected such that the delivery system demonstrates acceptable trackability and deployment forces to enable access to the target vessel and delivery of the implant to the target vascular. Further, the material of the outer catheter 110 should be sufficient to maintain its integrity during flushing and hemostasis. For example, the outer catheter 110 should be able to resist a pressure of at least about 45 psi/min.

[0082] Further, the outer catheter 110 must have sufficient structural integrity (e.g., column strength or "pushability") to permit the outer catheter 110 to be advanced to distal locations without buckling or undesirable bending of the tubular body 116. The ability of the outer catheter 110 to transmit torque may also be desirable, such as to avoid kinking upon rotation, to assist in steering. The outer catheter 110, and particularly the distal portion, may be provided with any of a variety of torque and/or column strength enhancing structures. For example, axially extending stiffening wires, spiral wrapped support layers, and/or braided or woven reinforcement filaments may be built into or layered on the tubular body 116.

[0083] The delivery system 100 and its variants described herein are capable of penetrating the target vessel by at least 4 cm, such as between about 4 cm and 6 cm, for example, at least 5 cm, or preferably at least about 5.5 cm as determined by the Trackability Protocol described below.

[0084] The proximal portion of the outer catheter 110 may have a shore hardness in the range from 50 D to 100 D, often being about 70 D to 80 D. Usually, the proximal portion of the outer catheter 110 will have a flexural modulus from 20,000 psi to 1,000,000 psi, preferably from 100,000 psi to 600,000 psi. The distal portion of the outer catheter 110 will be sufficiently flexible and supple so that it may navigate the patient's distal vasculature. In highly flexible embodiments, the shore hardness of the distal portion may be in the range from about 20 A to about 100 A, and the flexural modulus for the distal portion may be from about 50 psi to about 15,000 psi.

[0085] The outer catheter 110 may be produced in accordance with any of a variety of known techniques for manufacturing interventional catheter bodies, such as by extrusion of appropriate biocompatible polymeric materials. At least a proximal portion or all of the length of outer catheter 110 may comprise a polymeric or metal spring coil, solid walled

hypodermic needle tubing, or braided reinforced wall, as is known in the microcatheter arts.

[0086] The proximal end 112 of outer catheter 110 can include a manifold 118 having one or more access ports as is known in the art. Generally, the manifold 118 can include a guidewire port. Additional access ports may be provided as needed, depending upon the functional capabilities of the catheter. The manifold 118 can be compatible with luer connections from related accessories. Further, the manifold 118 may be injection molded from any of a variety of medical grade plastics, or formed in accordance with other techniques known in the art.

[0087] Manifold 118 can also include a control (not shown), for controlling deployment of the occlusion device. The control may take any of a variety of forms depending upon the mechanical structure of the support. For example, the control can include a slider switch, which can connect to the inner catheter 120. Distal axial advancement of the slider switch can produce an axial advance of the connected feature. When the occlusion device advances from the distal end of the outer catheter 110, the occlusion device can move from the reduced diameter to the enlarged diameter.

[0088] Any of a variety of controls may be utilized, including switches, levers, rotatable knobs, pull/push wires, and others that will be apparent to those of skill in the art in view of the disclosure herein.

[0089] The outer catheter 110 can define a lumen through which the inner catheter 120 can move axially. The inner catheter 120 can include a proximal end 122 and a distal end 124. Similar to the outer catheter 110, the inner catheter 120 can include a manifold 126 disposed at the proximal end 122 of the inner catheter 120. The manifold 126 can be configured to control movement of the inner catheter 120, deployment of the occlusion device, and/or fluid flow through the inner catheter 120. The inner catheter 120 should be sufficiently long to deliver the occlusion device out of the distal end 114 of the outer catheter 110. Further, the inner catheter 120 can include a material exhibiting any of the material properties described in connection with the outer catheter 110.

[0090] The inner catheter 120 can define a lumen through which a conventional guide wire can move axially. In an alternate configuration, the outer catheter 110 can include a second lumen having a guide wire axially movable therein. In either scenario, the guide wire lumen should be sufficiently large to accommodate a guide wire 128 having a diameter between about 0.25 mm and about 0.5 mm. As shown in FIG. 1A, the guide wire 128 can include a hub 130 disposed at a proximal end of the guide wire 128.

[0091] Avoiding a tight fit between the guide wire 128 and inside diameter of guidewire lumen enhances the slideability of the delivery system 100 over the guidewire. In ultra-small diameter catheter designs, it may be desirable to coat the outside surface of the guidewire 128 and/or the inside surface of the inner catheter 120 with a lubricious coating to minimize friction as the inner catheter 120 is axially moved with respect to the guidewire 128. A variety of coatings may be utilized, such as Parylene, Teflon, silicone rubber, polyimide-polytetrafluoroethylene composite materials, or others known in the art and suitable depending upon the material of the guidewire or inner tubular wall.

[0092] The delivery system 100 can include different features depending on whether the occlusion device is self-expanding or balloon expandable. For example, if the

occlusion device is balloon expandable, the inner catheter 120 can carry the occlusion device on a balloon (not shown).

[0093] For example, if the occlusion device is self-expanding, the occlusion device can be constrained by a distal portion of the outer catheter 110, and the inner catheter 120 can push the occlusion device out from the distal end 114 of the catheter 110. As another example, as shown in FIG. 3F, the delivery system 100 can include a support tube 134 axially disposed between the outer catheter 110 and the inner catheter 120. The support tube 134 can move axially to push the occlusion device off the inner catheter 120. The force necessary to push the occlusion device off the inner catheter 120 can be less than or equal to about 5 N, for example, within about 0.25 N of about 4.5 N or within about 0.25 N of about 4.0 N.

[0094] Other conventional mechanisms can be used to release the occlusion device, including, but not limited to, a ratcheting mechanism, an electrolytically erodible attachment, involuted deployment, a threaded attachment, or other torque releasing attachment.

[0095] In some situations, it may be necessary to resheath the occlusion device to deliver the occlusion device to the target vessel. The delivery system 100 can be configured to resheath and reposition the occlusion device after deployment, but before release. Prior to release, the inner catheter 120 can be retracted to pull the occlusion device back into the outer catheter 110. The retraction force necessary to retract the occlusion device should be less than or equal to about 5 N, for example, between about 3 N and about 4 N, or between about 3.5 N and about 4.5 N. The interlock interference feature can have a dimension between about 0.15 mm and about 0.25 mm, for example, within about 0.02 mm of about 0.2 mm.

[0096] The delivery system 100 may further comprise other components, such as radiopaque fillers, colorants, reinforcing materials, reinforcement layers, such as braids and helical reinforcement elements, or the like. In particular, at least the proximal portion may be reinforced in order to enhance its column strength and torqueability while preferably limiting its wall thickness and outside diameter. Further, radiopaque markers may be positioned on the inner and/or outer catheters 120, 110 to monitor the delivery system 100 during the procedure.

[0097] Fluoroscopic guidance can be used to monitor the delivery of the occlusion device. For example, the delivery system can include radiopaque features that allow for their fluoroscopic visualization during delivery, deployment, and/or retraction. Usually, the delivery system can include marker bands or coiled wires disposed along one or more of the outer catheter 110, inner catheter 120, and the guide wire 128. The bands or coils can include a minimum thickness of at least about 0.02 mm and a minimum length of about 0.5 mm. Suitable marker bands can be produced from any number of a variety of materials, including platinum, gold, tantalum, and tungsten/rhenium alloy. Preferably, the radiopaque metal band will be recessed in an annular channel formed in the tubular body.

[0098] FIGS. 1B-1 and 1B-2 illustrate a possible embodiment the outer catheter 110 of the delivery system. The outer catheter permits contrast dye to be injected through the delivery system and can be used to determine the position of the occlusion device before detaching the occlusion device from the delivery system.

[0099] The outer catheter 110 can have a working length of about 120 cm or any other suitable working length described above. An internal diameter of the outer catheter 110 can be less than or equal to about 0.10 inches, such as about 0.05 inches. The distal end 114 of the outer catheter 110 can have a reduced diameter between about 0.02 inches and about 0.04 inches. The outer catheter 110 can include a plurality of openings 121 (e.g., at least two, five, six, eight, or more openings) disposed near a distal end 114 of the outer catheter 110, such that contrast dye can be released near the proximal side of the occlusion device. The placement of the openings 121 can remove the pressure of the contrast on the occlusion device to mitigate the likelihood of damaging the occlusion device prior to deployment (see FIG. 1B-2). For instance, the distal most opening 121' can be positioned less than or equal to about 2.0 inches from the distal end 114 or at a location that is between about 1.5% and 2.5% of the working length of the catheter from the distal end 114. The plurality of openings 121 can be positioned in a helical configuration spanning less than or equal to about 0.5 inches measured in an axial direction (e.g., about 0.3 inches, about 0.35 inches, or about 0.4 inches). Further, the plurality of holes 121 can be equally, axially spaced apart (e.g., less than about 0.10 inches, such as about 0.05 inches). In some embodiments, the contrast flow rate can be at least about 2 cc/second or at least about 5 cc/second under an infusion pressure of no more than about 500 psi, preferably no more than about 250 psi as measured under the Injection Protocol described herein. For example, the contrast flow rate can be between about 2 cc/second and 5 cc/second under infusion pressures between about 100 psi and 200 psi or between about 100 psi and 150 psi, such as about 2.0 or 2.3 cc/min. Additionally, the openings 121 provide a sufficient flow rate to prevent the buildup of pressure distal to the openings 121 such that the occlusion device is not inadvertently deployed simply by injecting contrast. The flow rate through the openings 121 prevents a distal pressure higher than 50 psi when a 200 psi infusion pressure is applied or a distal pressure of no more than 10 psi.

[0100] FIGS. 1B-3 and 1B-4 illustrate a possible embodiment of the inner catheter 120. The inner catheter 120 can include a manifold 126 that provides access to a lumen of the inner catheter 120. Further, the inner catheter 120 can include a pusher member 123. When the delivery system is assembled, the occlusion device can be positioned between the distal end 124 and the pusher member 123 of the inner catheter 120. The pusher member 123 can be used to push the occlusion device out of the outer catheter 110. As shown in FIG. 1B-4, the inner catheter 120 can also include a radiopaque marker 125 disposed near the distal end 124 of the inner catheter 120, so the user can monitor placement of the occlusion device.

[0101] It can be clinically desirable to assess the performance of the occlusion device prior to releasing the occlusion device from the delivery system 100. Thus, in some embodiments, as shown in FIGS. 1C-1 to 1C-3, the delivery system 100c (including one or more features of the delivery system 100) and the occlusion device 140 can include an interlock assembly 150 that allows the occlusion device 140 to be resheathed or repositioned. The interlock assembly 150 can removably secure the inner catheter 120c to the occlusion device 140. In some examples, the occlusion device 140 can resemble 1500 any of the occlusion devices described below.

[0102] The interlock assembly 150 can include one or more resilient members 152 and a corresponding number of recesses 154 (e.g., channels or grooves). As shown in FIG. 1C-3, the interlock assembly 150 can include a first resilient member 152a and a second resilient member 152b; however, more resilient members can be utilized (e.g., three or four). The resilient members 152 can extend from one of a reduced diameter portion (e.g., a proximal end 142) of the occlusion device 140 or a distal end of the inner catheter 120c, and the recesses 154 can be disposed on the other of the reduced diameter portion (e.g., the proximal end 142) of the occlusion device 140 or the distal portion 156 of the inner catheter 120c. When the recesses 154 are disposed on the distal portion 156 of the inner catheter 120c, a diameter of the distal end portion 156 can be greater than a remaining portion of the inner catheter 120c and less than or equal to a diameter of the proximal end 142 of the occlusion device 140 (see FIG. 1C-1). For example, as shown in FIG. 1C-1, the resilient members 152 can extend proximally from a proximal end 142 of the occlusion device 140, and the recesses 154 can be disposed at the distal end portion 156 of the inner catheter 120c.

[0103] As shown in FIG. 1C-3, the resilient members 152 can be biased toward an outward extending position. Further, the resilient members 152 can each have a Z-shape, such that a first end of a resilient member 152 is axially displaced from a second end of the resilient member 152. In certain variants, the resilient members 152 can have a T-shape, a lollipop shape, a Christmas tree shape, or any other suitable shape, which provides at least a first interference surface for engaging with a second complementary interference surface to releasably retain the occlusion device on the catheter.

[0104] Additionally, the shape of the recesses 154 can generally correspond to the shape of the resilient members 152, such that when the resilient members 152 are constrained within the outer catheter 110c, the resilient members 152 can engage the corresponding recesses 154.

[0105] The interlock assembly 150 maintains the inner catheter 120c and the occlusion device 140 in a locked configuration (see FIG. 1C-1) until the resilient members 152 are pushed beyond the distal end 114c of the catheter body 110c (see FIG. 1C-2). When the resilient members 152 are pushed beyond the distal end 114c of the catheter 110c, the resilient members 152 move back to the outward extending position, thereby releasing the occlusion device 140 from the inner catheter 120c (see FIG. 1C-3). Advantageously, the interlock assembly 150 allows the occlusion device 140 to be resheathed and repositioned so long as the resilient members 152 do not extend beyond the distal end 114c of the catheter 110c. Further, the interlock assembly 150 requires no additional movable members for actuation, which has a number of benefits, including, but not limited to, a reduced profile delivery system, a more flexible delivery system, fewer components for manufacturing, and fewer steps during the procedure.

[0106] FIGS. 1D-1 and 1D-2 illustrate another embodiment of an interlock assembly 170 that can be used with delivery system 100d (including one or more features of the delivery system 100). The interlock assembly 170 can include a first threaded region 172 at a reduced diameter portion (e.g., a proximal portion 162) of an occlusion device 160 and a second, corresponding threaded region 174 at a distal portion 156 of the inner catheter 120d. For example,

as shown in FIG. 1D-2, the first threaded region 172 can be disposed around an interior surface of the proximal portion 162 of the occlusion device 160, and the second region 174 can be disposed around an exterior surface of the distal end portion 176. An outer diameter of the distal portion 176 can be less than an interior diameter of the proximal portion 162 of the occlusion device 160, such that the second threaded region 174 can threadably engage the first threaded region 172.

[0107] The interlock assembly 170 can maintain the inner catheter 120d and the occlusion device 160 in a locked configuration (see FIG. 1D-2) until the inner catheter 120d is rotated counterclockwise and unscrewed from the occlusion device 160. Advantageously, the interlock assembly 170 allows the occlusion device 160 to be resheathed and repositioned so long as the inner catheter 120d remains threadably engaged with the occlusion device 160. Further, the interlock assembly 170 requires no additional movable members for actuation, which has a number of benefits, including, but not limited to, a reduced profile delivery system, a more flexible delivery system, fewer components for manufacturing, and fewer steps during the procedure.

[0108] With reference to FIGS. 1E-1 to 1E-6, another illustrative embodiment of a delivery system is shown. Portions of the delivery system 100e resemble the delivery system 100 discussed above. Accordingly, numerals used to identify features of the delivery system 100 include an "e" to identify like features of the delivery system 100e (e.g., the outer catheter 110e can resemble the outer catheter 110).

[0109] As shown in FIG. 1E-1, the delivery system 100e can include an interlock catheter 101e extending through the outer catheter 110e. The interlock catheter 101 can include an outer pusher 188e and an inner pusher 186e (see FIGS. 1E-5 and 1E-6). Further, a hemostasis valve 103e can form a seal between the outer catheter 110e and the interlock catheter 101c. For purposes of illustration, the delivery system 100e is described in connection with the occlusion device 1500 (described in further detail below); however, the delivery system 100e can be used with other occlusion devices, such as the occlusion device 1500.

[0110] Additionally, the interlock catheter 100e and the occlusion device 1500 can include an interlock assembly 180e. The interlock assembly 180e can include a key ring 182e that can be secured to a distal portion of the outer pusher 188e. As shown in FIG. 1E-2, an inner diameter of the key ring 182e can be greater than an outer diameter of the distal portion of the outer pusher 188e, such that the key ring 182e can be secured over the distal portion of the outer pusher 188e. Further, one or more locking tabs 183e (e.g., two, three, or four) can extend from a distal end of the key ring 182e. The locking tabs 183e can be biased inward toward the inner pusher 186e. Additionally, as shown in FIG. 1E-1, the locking tabs 183e can have a generally lollipop shape. Although, in other embodiments, the locking tab 183e can have a T-shape, Z-shape, Christmas Tree shape, or any other suitable shape.

[0111] The interlock assembly 180e can also include a locking drum 184e that is coaxial with the outer pusher 188e (see FIGS. 1E-5 and 1E-6). The locking drum 184e can be secured to the inner pusher 186e, and thus advanceable relative to the outer pusher 188e. To secure the interlock catheter 101e to the occlusion device 1500, the inner pusher 186e is advanced until the locking drum 184e pushes the locking tabs 183e outward into a corresponding interlock

feature 1518 on a reduced diameter portion (e.g., a proximal collar 1516) of the occlusion device 1500 (see FIGS. 1E-2 and 1E-5). In this locked configuration, the occlusion device 1500 can be advanced through the outer catheter 110e using the interlock catheter 101c.

[0112] To release the occlusion device 1500 from the outer pusher 188e, the inner pusher 186e is advanced further until a proximal end of the locking drum 184e is distal to the locking tabs 183c (see FIG. 1E-3). In this configuration, the locking tabs 183e can return to the inward extending position such that the occlusion device 1500 can be detached from the outer pusher 188c (see FIGS. 1E-4 and 1E-6). Advantageously, the interlock assembly 180c allows the occlusion device 1500 to be resheathed and repositioned so long as the outer pusher 188 is secured to the occlusion device 1500.

[0113] FIGS. 2A to 2K illustrate a method of using another embodiment of a delivery system 200 having an interlocking attachment member 231 that interfaces with an occlusion device O. Portions of the delivery system 200 resemble the delivery system 100 discussed above. Accordingly, numerals used to identify features of the delivery system 100 are incremented by a factor of "100" to identify like features of the delivery system 200 (e.g., the outer catheter 210 can resemble the outer catheter 110).

[0114] Generally, the delivery system 200 can include an inner catheter 220 adapted to advance an occlusion device O (e.g., an hourglass-shaped occlusion device as described below) through the outer catheter 210 and into the target vessel (see FIG. 2A). The inner catheter 220 can include an interlocking attachment member 231 that enables the clinician to advance and retract the occlusion device O, so long as the proximal end of the occlusion device O remains constrained within the outer catheter 210 and interfaces within the interlocking attachment member 231 (see FIGS. 2L and 2M). When the proximal end of the occlusion device O is advanced distally of the distal end 214 of the outer catheter 210, the proximal end of the occlusion device O expands and releases from the interlocking attachment member 231 (see FIG. 2G). Advantageously, the interlocking attachment member 231 enables the clinician to assess the performance of the occlusion device O prior to releasing the occlusion device O from the delivery system 200.

[0115] FIGS. 2A and 2B illustrates a fully assembled delivery system 200 with the inner catheter 220 extending through the outer catheter 210. To begin deployment, the distal lobe of the occlusion device D can be deployed. The occlusion device O can be deployed by advancing the inner catheter 220 relative to the outer catheter 210 (see FIGS. 2C and 2D). With only the distal lobe of the occlusion device D deployed, contrast injection can be delivered to confirm the position of the occlusion device O. Since the distal lobe of the occlusion device D is uncovered (e.g., bare metal struts), the occlusion device O does not occlude flow of the dye. As shown in FIGS. 2CC and 2DD, as the inner catheter 220 is advanced, a distal face of the interlock attachment member 231 interfaces with the occlusion device O at a location distal to the proximal end of the occlusion device O, such that the interlock attachment member 231 urges the occlusion device O in a distal direction.

[0116] If the distal lobe D is improperly positioned, the inner catheter 220 can be retracted to retract the occlusion device O (see FIG. 2E). As shown in FIG. 2EE, as the inner catheter is retracted, a proximal face of the interlock attach-

ment member 231 interfaces with the occlusion device O (e.g., proximal hooks of the occlusion device O), such that the interlock attachment 231 urges the occlusion device O in a proximal direction.

[0117] Once the distal lobe 1202e of the occlusion device 1200e is properly position, the remaining portion of the occlusion device can be deployed (see FIGS. 2F and 2G). Next, the inner catheter 220 can be retracted relative to the outer catheter 210 (see Figure H). As shown in FIG. 2HH, a proximal face of the ramp 229 is larger than an end portion E of the tubular membrane portion of the occlusion device T (e.g., a larger diameter or larger surface area). Consequently, as the inner catheter 220 is further withdrawn, the ramp 229 forces the tubular portion T to invert (see FIGS. 2I and 2II), such that a proximal portion of the tubular membrane portion T that is within the proximal lobe P begins to fold over a remaining portion of the tubular membrane portion T. Viewed another way, an inner surface of the tubular portion T becomes an external surface of the tubular portion T. During the inversion process, the tubular portion T moves from being positioned within the distal lobe D (see FIGS. 2H and 2HH) to being positioned within the proximal lobe P (see FIGS. 2J and 2JJ). Viewed another way, the tubular portion T moves from being external to a membrane cover M (see FIGS. 2H and 2HH) to being positioned within the membrane cover M (see FIGS. 2J and 2JJ). When the inner catheter 220 is fully removed from the occlusion device O (see FIG. 2K), the tubular portion T closes like a valve to prevent blood from flowing through the tubular portion T. The tubular portion T has sufficiently low collapse resistance such that when the delivery system 200' (and guidewire, if present) is removed, the tubular portion T collapses (e.g., kinks, folds, buckles, flops over, or likewise) into a closed position.

[0118] FIGS. 2L to 2N illustrate the outer catheter 210 of the delivery system 200. The outer catheter 200 permits contrast dye to be injected through the delivery system 200 and can be used to determine the position of the occlusion device before detaching the occlusion device from the delivery system 200.

[0119] The outer catheter 210 can have a working length of about 120 cm or any other suitable working length described above. An internal diameter of the outer catheter 210 can be less than or equal to about 0.10 inches, such as about 0.05 inches. A distal portion of the outer catheter 210 can be bulbous shaped if a marker band 225 is embedded within the outer catheter 210 (see FIG. 2N). As shown in FIG. 2N, the outer catheter 210 can include at least three concentric layers, e.g., an inner layer 210', an intermediate layer 210", and an outer layer 210"". The outer layer 210"" can be constructed from Pebax or other medical grade polymer materials. The intermediate layer 210" can be a stainless steel braid to reinforce the outer catheter 210. The inner layer 210' can be constructed from PTFE or other suitable medical grade polymer materials. If present, the radiopaque marker 225 can be embedded radially between the outer layer 210"" and the intermediate layer 210".

[0120] The outer catheter 210 can include a plurality of openings 221 (e.g., at least two, five, six, eight, or more openings) disposed near a distal end 114h of the outer catheter 210, such that contrast dye can be released near the proximal side of the occlusion device (see FIG. 2M). The placement of the openings 221 can remove the pressure of the contrast on the occlusion device to mitigate the likeli-

hood of damaging the occlusion device prior to deployment. For instance, the distal most opening 221' can be positioned less than or equal to about 2.0 inches from the distal end 114h or at a location that is between about 1.5% and 2.5% of the working length from the distal end 114h. The plurality of openings 221 can be positioned in a helical configuration spanning less than or equal to about 0.5 inches measured in an axial direction (e.g., about 0.3 inches, about 0.35 inches, or about 0.4 inches). Further, the plurality of holes 221 can be equally, axially spaced apart (e.g., less than about 0.10 inches, such as about 0.05 inches). The contrast flow rate can be at least about 2 cc/second or at least about 5 cc/second under an infusion pressure of no more than about 500 psi, preferably no more than about 250 psi as measured under the Injection Protocol described herein. For example, the contrast flow rate can between about 2 cc/second and 5 cc/second under infusion pressures between about 100 psi and 200 psi or between about 100 psi and 150 psi, such as about 2.0 or 2.3 cc/min. Additionally, the openings 221 provide a sufficient flow rate to prevent the buildup of pressure distal to the openings 221 such that the occlusion device is not inadvertently deployed simply by injecting contrast. The flow rate through the openings 221 prevents a distal pressure higher than 50 psi when a 200 psi infusion pressure is applied or a distal pressure of no more than 10 psi.

[0121] FIGS. 20 and 2P illustrate the inner catheter 220 of the delivery system 200. The inner tubular body 220 has a proximal end 222 and a distal end 224. A proximal hub 226 can be positioned at the proximal end 222 of the inner catheter 220 to provide access to a lumen of the inner catheter 220. A pusher tip 227 can be positioned at the distal end 224 of the inner catheter 220. The pusher tip 227 can be tapered at a distal and/or a proximal portion of the pusher tip 227, with a uniform diameter section therebetween. If the pusher tip 227 and the inner catheter 220 are separate components, a radiopaque marker 225 can be positioned radially between the pusher tip 227 and the inner catheter 220.

[0122] As shown in FIG. 2P, a distal ramp 229 can be positioned proximal to the pusher tip 227. The distal ramp 229 can be tapered in a distal direction. As explained in further detail below, when the delivery system 200 is used with an hourglass-shaped occlusion device having a tubular membrane portion (as described below), the ramp 229 can invert a tubular section of an occlusion membrane as the inner catheter 220 is retracted through the occlusion device.

[0123] As mentioned above, the delivery system 200 can include an interlocking attachment member 231 positioned proximal to the distal ramp 229. As shown in FIG. 2P, the interlocking attachment member 231 can be ring-shaped. The interlocking attachment member 231 can interface with an occlusion device having proximal hooks, barbs, or the like (see e.g., occlusion device 1200e). The proximal hooks of the occlusion device can interface with the interlocking attachment member 231 so long as the proximal end of the occlusion device remains constrained within the outer catheter 210. The outer catheter 210 constrains the proximal end of the occlusion device, thereby allowing the occlusion device to interface with the interlocking attachment member 231.

[0124] The length of the proximal hooks of the occlusion device and the length of the interlocking attachment member 231 can be optimized to provide a controlled amount of axial clearance in between proximal hooks of the occlusion device

and the interlocking attachment member 231 (see FIGS. 2DD and 2EE). When the inner catheter 220 advances the occlusion device distally, the interlocking attachment member 231 pushes on a portion of the occlusion device distal to the proximal end of the occlusion device but does not engage the proximal hooks of the occlusion device (see FIG. 2DD). The axial clearance enables the proximal end of the occlusion device to expand when advanced out of the outer catheter 210. Prior to the proximal end of the occlusion device being advanced distally of the distal end of the outer catheter 210, retracting the inner catheter 220 causes the interlocking attachment member 231 to engage the proximal hooks and retract the occlusion device (see FIG. 2EE).

[0125] As shown in FIG. 2P, a proximal coupler 233 can be positioned proximal to the interlocking attachment member 231. The proximal coupler 233 can be tapered in a proximal direction. The proximal coupler 233 can prevent the occlusion device from moving proximally prior to deployment.

[0126] FIGS. 2Q and 2R illustrate another delivery system 200'. Portions of the delivery system 200' resemble the delivery system 200 discussed above. Accordingly, numerals used to identify features of the delivery system 200 are include an apostrophe (') to identify like features of the delivery system 200' (e.g., the outer catheter 210' can resemble the outer catheter 210).

[0127] The interlock attachment member 231' can have a number of longitudinally extending grooves 240' (indentations, openings, or the like) circumferentially positioned around the interlock attachment member 231'. These grooves 240' are shaped to receive a neck portion 244' of a marker 242' (see FIG. 2Q).

[0128] As shown in FIG. 2R, at least a proximal lobe P of the occlusion device O can include a number of markers 242'. Each of these markers 242' can include an aperture 246' (eyelet, opening, or the like) and a neck portion 244'. These markers 242' can be press-fit onto the strut endings of the proximal lobe P. The markers 242' can be radiopaque to facilitate visualization of the occlusion device O.

[0129] The method of delivering the occlusion device O is similar to the method described in FIGS. 2A to 2K. Prior to full release (see FIG. 2Q), the occlusion device O can be retracted and repositioned. The occlusion device O is configured to interface with the interlock attachment member 231' until a proximal end of the occlusion device O has been released from the delivery system 200' (see FIG. 2R).

[0130] The occlusion devices described herein can include an expandable structure configured to move between an unexpanded or constrained configuration and an expanded or unconstrained or enlarged configuration. The expandable structure can include any of a number of medical grade materials, including, but not limited to, polymers (e.g., PET) or non-ferrous metals (e.g., nitinol, stainless steel, or cobalt chrome).

[0131] The expansion ratio of the expandable structure should be sufficiently large such that the occlusion device is capable of compressing to a minimum size suitable for delivery through a catheter having an outer diameter of 6 F (i.e., 2.0 mm) or less, thereby minimizing trauma to the vessel during delivery. Further, the expansion ratio should be sufficiently large such that a single, expanded occlusion device is capable of preventing substantially all fluid from flowing past the occlusion device in vessel range of different

sized target vessels. Although, additional occlusion devices (e.g., two or three) can be delivered depending on clinical judgment.

[0132] The expandable structure can be configured to include an expansion ratio that is at least about 3:1, at least about 5:1, preferably at least about 7:1, and more preferably at least about 8:1. In some examples, the expansion ratio can be about 7:1 or about 8:1. In other words, a diameter of the expandable structure in the expanded configuration can be at least about three times, at least about five times, preferably at least about seven times, and more preferably at least about eight times, a diameter of the expandable structure in the unexpanded configuration. For example, the diameter of the expandable structure in the expanded configuration can be between about three times and about nine times greater, preferably at least about seven times greater, than the diameter of the expandable structure in the unexpanded configuration. In some examples, the diameter of the expandable structure can be at least about seven times or about eight times greater than a diameter of the expandable structure in the unexpanded configuration.

[0133] As described above, the delivery system preferably has a sufficiently small diameter to avoid causing damage to the vessel wall during delivery. Therefore, the occlusion device should be configured for delivery through a catheter having an outer diameter that is less than 7 F (2.3 mm), preferably less than 6 F (2.0 mm), for example 5F (1.67 mm), 4 F (1.33 mm), or 3 F (1.0 mm). In the unexpanded configuration, the occlusion device can include an outer diameter that is less than or equal to about 2 mm or less than or equal to about 1.75 mm, preferably less than or equal to about 1.5 mm. For example, the outer diameter of the occlusion device in the unexpanded configuration can be within about 0.5 mm, or within about 0.25 mm, of about 1.25 mm. Further, a length of the occlusion device in the unexpanded configuration can be less than or equal to about 3 cm or less than or equal to about 2.5 cm, for example, within about 0.5 cm of about 2 cm.

[0134] As explained in further detail below, the expandable structure can include one or more strands braided to form the expandable structure. Each strand can include a diameter between about 0.025 mm and about 0.05 mm. In the unexpanded configuration, the braided expandable structure can include a pore size of no more than about 1.5 sq. mm, preferably no more than about 1.25 sq. mm, for example, within about 0.25 sq. mm of about 1.0 sq. mm. Further, in the unexpanded configuration, the braided strands can form intersecting angles between about 70 degrees and about 130 degrees, for example, between about 70 degrees and 90 degrees, between about 80 degrees and about 100 degrees, between about 90 degrees and about 110 degrees, between about 100 degrees and about 120 degrees, or between about 110 degrees and about 130 degrees.

[0135] An expanded diameter of the expandable structure can vary depending on the application of the occlusion devices. For example, the diameter can vary depending on whether the occlusion device is delivered within a renal vessel, a cardiovascular vessel, a pulmonary vessel, a neurovascular vessel, or otherwise. In any of these vessels, the expanded configuration must have an acceptable diameter, length, and radial outward forces to maintain proper vessel wall apposition and resist migration. In some implementations, the aspect ratio between the expanded diameter and the expanded length can be less than or equal to about 1:1,

such as 1:2, or the length can be proportionally longer depending on the desired application.

[0136] In the unconstrained expanded configuration, a maximum diameter of the occlusion device can be between about 1.0 to about 1.5 times or more a diameter of the target site in a vessel. In some applications, the occlusion device can expand to a diameter between about 5.0 mm and about 11 mm, for example, within about 0.5 mm of each of about 6.0 mm, 7.0 mm, 8.0 mm, 9.0 mm, or 10.0 mm. In some applications, the expanded diameter can be between about 4.0 mm and about 6.0 mm, for example, within about 0.5 mm of about 4.5 mm. In other applications, the expanded diameter can be between about 2.0 mm and about 3.0 mm, for example, within about 0.25 mm of about 2.5 mm.

[0137] For example, in neurovascular applications, the expanded diameter can be between about 1.5 mm and about 4.0 mm, for example, within about 0.5 mm of each of about 2.0 mm, 2.5 mm, 3.0 mm, or 3.0 mm. Each of these occlusion devices can be delivered through a catheter having an internal diameter of less than or equal to about 0.7 mm (0.027"). The expansion ratio can be at least about 5:1, for example, between about 5:1 and 5.5:1 or between about 5.5:1 and about 6:1, such as about 5.8:1.

[0138] In some peripheral applications, the expanded diameter can be between about 4.0 mm and about 6.0 mm, for example, within about 0.25 mm of each of about 4.25 mm, 4.5 mm, 4.75 mm, 5.0 mm, 5.25 mm, 5.5 mm, or 5.75 mm. Each of these occlusion devices can be delivered through a catheter having an internal diameter of no more than about 1.0 mm (0.038"). The expansion ratio can be at least about 5:1, preferably at least about 6:1, for example, between about 6:1 and about 7:1, such as about 6.2:1.

[0139] In other peripheral applications, the expanded diameter can be between about 7.0 mm and about 12.0 mm, for example, within 0.5 mm of each of about 7.5 mm, 8.0 mm, 8.5 mm, 9.0 mm, 9.5 mm, 10.0 mm, 10.5 mm, 11.0 mm, or 11.5 mm. Each of these occlusion devices can be delivered through a catheter having an outer diameter of less than or equal to about 2.0 mm, for example, between about 1.5 mm and about 2.0 mm (e.g., 1.67 mm (5F)).

[0140] The expanded length should be between about 0.5 times and about 1.5 times the diameter of the target vessel, or greater depending on the desired performance. In some applications, the expanded length can be between about 2.5 mm to about 7.5 mm, for example, between about 4.0 mm to about 6.0 mm, or within about 0.5 mm of about 5.0 mm. In some applications, the expanded length can be between about 2.0 mm to about 6.0 mm, for example, between about 3.0 mm and about 5.0 mm, or within about 0.5 mm of about 4.5 mm. In some applications, the expanded length can be between about 1.0 mm and about 3.0 mm, for example, within about 0.5 mm of about 2.5 mm.

[0141] In some applications, the expanded lengths can vary from 1 cm to 5 cm (e.g., from 1 cm to 4 cm, from 2 cm to 5 cm, from 2 cm to 4 cm, overlapping ranges thereof, 1 cm, 1.5 cm, 2 cm, 2.5 cm, 3 cm, 3.5 cm, 4 cm, 4.5 cm, 5 cm), and the expansion diameter can vary from 1 mm to 6 mm (e.g., from 1 mm to 4 mm, from 2 mm to 6 mm, from 3 mm to 5 mm, overlapping ranges thereof, 1 mm, 2 mm, 3 mm, 4 mm, 5 mm, 6 mm) depending on the vessel to be addressed. In some applications, the expandable structure can be configured to expand to diameters larger than 5 mm (e.g., 6 mm, 7 mm, 8 mm, 9 mm, 10 mm) or less than 2 mm (e.g., 1.8 mm, 1.6 mm, 1.4 mm, 1.2 mm, 1.0 mm).

[0142] As shown in at least FIGS. 7A to 10B, in some instances, one or both ends of the occlusion device can be tapered. A proximal end which tapers down in diameter in the proximal direction can be useful to facilitate retraction. For example, an angle of a proximal tapered end can be less than or equal to about 45 degrees, for example, between about 15 degrees and about 30 degrees or between about 30 degrees and about 45 degrees.

[0143] Clinically, it can be desirable for the occlusion device to exert sufficient radial outward pressure to maintain proper vessel wall apposition and resist migration of the occlusion device after deployment. The occlusion device can have an average COP across a diameter between about 2.5 mm and about 8.0 mm (e.g., a diameter between about 3.0 mm and about 8.0 mm) of between about 20 mmHg and about 250 mmHg, such as between about 30 mmHg and about 140 mmHg, between about 30 mm Hg and 80 mmHg, between about 70 mmHg and 100 mmHg, between about 90 mmHg and 120 mmHg, or between about 100 mmHg and 140 mmHg. The occlusion devices described herein can exert a radial outward pressure between about 30 mmHg and about 50 mmHg, for example, between about 30 mmHg and about 40 mmHg, between about 35 mmHg and about 45 mmHg, or between about 40 mmHg and about 50 mmHg at the diameter of an intended target site in a vessel. In some instances, a proximal end of the occlusion device can include features to cause radial outward force to increase at the center of the occlusion device without traumatizing the vessel. The radial outward force at the center of the occlusion device can increase by up to 20 mmHg, for example, between about 10 mmHg to about 15 mmHg, or between about 15 mmHg and about 20 mmHg.

[0144] The expandable structure should include a wall pattern configured to facilitate proper vessel wall apposition and resist migration after delivery. At the same time, the wall pattern preferably permits the occlusion device to be collapsed inside the delivery system without negatively impacting trackability and accurate deployment. In general, the wall pattern can include struts that run diagonal or perpendicular to blood flow to maintain proper vessel wall apposition and resist migration. For example, the occlusion device can include a wall pattern configured such that a backpressure generated from the blood flow can help stabilize the occlusion device without causing trauma to the vessel wall. In some instances, the wall pattern can be substantially uniform along an entire length of the expandable structure. In some instances, the wall pattern can vary between the first and second end portions and the middle portion. In some instances, the density of the wall pattern can vary across the length of the occlusion device, for example, the pore size of the occlusion device can gradually increase across the length of the occlusion device or towards both ends from the center.

[0145] In any of these wall patterns, the pore size should be sufficiently large to maintain proper vessel wall apposition and resist migration. For example, the expanded average pore size can be greater than or equal to about 0.75 sq. mm, for example, within about 0.25 sq. mm of about 1.0 sq. mm, within about 0.5 sq. mm of about 1.25 sq. mm, or within about 0.5 sq. mm. of about 4.5 sq. mm.

[0146] Other methods for reducing migration can include incorporating one or more anchors, such as barbs, hooks, or likewise, along any portion of the occlusion device, prefer-

ably an uncovered bare strut portion, such as the middle portion or one of two end lobes of the occlusion device.

[0147] As another example, if the occlusion device is braided, the occlusion device can include one or more exposed strands or strand ends. The braided occlusion device can include one or more strands each having strand ends. At least some of those strand ends can remain exposed and can be configured to anchor the occlusion device to the vessel wall. In other words, at least some of the strand ends can be secured to another of the strand ends, looped backed and secured to the same strand, or otherwise transformed to an atraumatic end, while at least some other of the strand ends can remain unsecured and can be configured to anchor the occlusion device to the vessel wall. These unsecured strand ends can be disposed anywhere along the occlusion device, for example, at least at one of the first and second end portions.

[0148] It can also be desirable to encourage endothelial growth or the formation of blood clots to ensure the permanency of the occlusion device. For example, the occlusion device can be coated with a substance to promote endothelial growth or the formation of clots. In some instances, the occlusion device can be coated with a chemical sclerosing agent. In some instances, the occlusion device can be coated with a liquid embolic (e.g., cohesives (i.e., Onyx) or adhesives (i.e. n-BCA).

[0149] The occlusion device can be configured to occlude substantially all fluid flow through a vessel using a single occluder, although multiple occlusion devices can be delivered. Further, the single occluder can be configured to immediately occlude fluid flow through the vessel using a single occluder (e.g., upon expansion). Substantial occlusion can include occluding at least about 80%, at least about 85%, at least about 90%, at least about 95%, or at least about 98% of fluid flow through the vessel.

[0150] As described below, the occlusion device can include a cover at least partially covering the expandable structure. The cover can include a cover material including, but not limited to, PTFE, PET, silicone, latex, TecoThane, nylon, PET, Carbothane (Bionate), fluoropolymers, SIBS, TecoFlex, Pelletthane, Kynar, or PLGA.

[0151] The cover should be substantially impermeable to blood with a biostability for at least about two weeks. Preferably, the permeability is less than about 0.1 ml/sq. cm/min. In some instances, the cover can include a pore size of less than or equal to about 0.075 sq. mm. In some instances, the cover has less than or equal to about 20 percent open area, less than or equal to about 15 percent open area, or within about 2 percent of each of about 10 percent, 12 percent, 14 percent, 16 percent, or 18 percent. Further, the cover should include sufficient elasticity and lubricity to permit the occlusion device to be deployed in catheters having an outer diameter of less than or equal to about 6 F (2.0 mm) or less than or equal to about 5F (1.67 mm) and expand to a diameter at least about 2.5 mm and/or less than or equal to about 8.0 mm. In some instances, the cover can be electronically charged or chemically modified to promote thrombogenicity. However, the covering material may be coated with a material to inhibit thrombus formation temporarily (i.e. hydrophilic coating) so that the device can be retracted and repositioned prior to final placement. In addition, the cover should have sufficient tensile strength to resist yielding, stretching, or breaking under at least normal

blood pressures. For example, the cover should be able to withstand pressures of at least about 140 mmHg, preferably at least about 160 mmHg.

[0152] The length of the fibers creating the covering material allows the elongation of the covering material to far greater with less force (0.25-0.75 \times) than that of the native cover materials described above of the same thickness. The length of the fibers can be between about 5 microns and about 25 microns, such as within about 5 microns of each of about 10 microns, 15 microns, or 20 microns, although greater lengths may be used depending on desired parameters. These lengths permit the elongate of the cover material to at least two times greater. In some cases, the elongation is between about two times greater and about five times greater, for example, about three times greater or about four times greater. This elongation occurs with less than or equal to about 75 percent, less than or equal to about 50 percent, or even about 25 percent of the force necessary for native cover materials described above having the same thickness (e.g., between about 10 and about 30 microns).

[0153] It can be desirable for the cover to include a thickness that is sufficiently large to resist perforation during and after delivery, but sufficiently thin to minimize the diameter of the occlusion device in the unexpanded configuration and the diameter of the delivery device. Preferably, the thickness of the cover is less than or equal to about 30 microns, for example, within about 5 microns of each of about 15 microns, 20 microns, or 25 microns.

[0154] The cover can surround at least a portion of the expandable structure. The surrounded portion of the expandable structure should be sufficiently large to prevent fluid from flowing past the occlusion device when the occlusion device is expanded in the vessel. For example, the cover can surround the entire circumference of a covered portion of the expandable structure. Further, the cover can surround the expandable structure such that at least one end of the occlusion device is substantially closed. As shown in FIGS. 9B and 9C, the cover may only surround one of the first or second end portions of the expandable structure. In some instances, a length of the covered portion can be between about approximately 15 percent and about 35 percent of a diameter of the target vessel or the expanded occlusion device, for example, approximately 25 percent of a diameter of the target vessel or the expanded occlusion device. In other examples, as shown in at least FIG. 7A, the cover can surround the first end portion and the second end portion of the expandable structure, but leave a middle portion uncovered. In yet other examples, as shown in at least FIG. 7B, the cover can surround substantially the entire expandable structure.

[0155] In some clinical scenarios, it can be more desirable to cover only a portion of the expandable structure, such that at least the middle portion remains uncovered. The exposed wall pattern of the expandable structure can help maintain proper vessel wall apposition and resist migration of the occlusion device.

[0156] The expandable structure can be coated with the cover using an electrospinning process. Electrospinning refers generally to processes involving the expulsion of flowable material from one or more orifices, and the material forming fibers are subsequently deposited on a collector. Examples of flowable materials include dispersions, solutions, suspensions, liquids, molten or semi-molten material, and other fluid or semi-fluid materials. In some instances,

the rotational spinning processes are completed in the absence of an electric field. For example, electrospinning can include loading a polymer solution or dispersion, including any of the cover materials described herein, into a cup or spinneret configured with orifices on the outside circumference of the spinneret. The spinneret is then rotated, causing (through a combination of centrifugal and hydrostatic forces, for example) the flowable material to be expelled from the orifices. The material may then form a "jet" or "stream" extending from the orifice, with drag forces tending to cause the stream of material to elongate into a small diameter fiber. The fibers may then be deposited on a collection apparatus. Further information regarding electrospinning can be found in U.S. Publication No. 2013/0190856, filed Mar. 13, 2013, and U.S. Publication No. 2013/0184810, filed Jan. 15, 2013, which are hereby incorporated by reference in their entirety.

[0157] To facilitate occlusion of the target vessel site, the occlusion device in an over the wire embodiment should include a sufficiently small residual guide wire hole after deployment or a valve for occluding the guidewire opening. After full deployment, the occlusion device should include a residual guidewire hole having a diameter of less than or equal to about 0.25 mm. However, prior to deployment, the guide wire hole must be sufficiently large in both the unexpanded and expanded configuration to accommodate a standard guide wire having a diameter of at least about 0.25 mm, preferably at least about 0.4 mm.

[0158] Any of the occlusion devices described herein can include a number of radiopaque features that permit the fluoroscopic visualization of the occlusion device during one or more of delivery, deployment, post-deployment, and retraction. The marker bands can be positioned along the expandable structure. The marker bands can have a thickness of at least about 0.01 mm and a length of at least about 0.1 mm. Suitable marker bands can be produced from any number of a variety of materials, including platinum, gold, tantalum, and tungsten/rhenium alloy.

[0159] Turning to the figures, FIGS. 3A-3F illustrate the delivery system including any of the features of the delivery system 100 shown in FIGS. 1A and 1B. The delivery system can be used to deliver the occlusion device 300. As shown in the figures, the occlusion device can include a braided expandable structure having a tulip shape (e.g., laser cut with a woven pattern or braided from a plurality of strands). In other words, a diameter of a first end portion 302 can be smaller than a diameter of a second end portion 304. Further, a diameter of the middle portion 306 can be greater than the diameter of the first end portion 302, but smaller than the diameter of the second end portion 304. The diameter can gradually decrease from the second end portion 304 to the first end portion 302.

[0160] As shown in FIG. 3D, the occlusion device 300 can include a cover 308 surrounding at least the first end portion 302. The cover 308 can surround the entire circumference of the first end portion 302 and close the first end such that fluid cannot flow through the first end portion 302. In some instances, the cover 308 can surround at least 20 percent of a length of the expandable structure, for example, between about 20 percent and about 40 percent or between about 30 percent and about 50 percent of the length of the expandable structure. Although, in other embodiments, the cover 308 can surround substantially the entire expandable structure, leaving a second end opened or substantially closed.

[0161] As shown in FIG. 3F, the occlusion device 300 can include a central hub 310 for engaging the inner catheter 120 prior to delivery. If the occlusion device 300 is formed from a plurality of braided wire strands, the central hub can also be configured to secure the strand ends of the braided wire strands. Although the occlusion device 300 is described with the central hub 310, a central hub 310 is not necessary, and the inner catheter 120 may carry the occlusion device 300 without the central hub 310. Further, if the occlusion device 300 is formed from a plurality of braided wire strands, the braided wire strands can be heat-treated to maintain the position of the heated strands, or the strand ends can be secured to each other.

[0162] FIGS. 4A-4G illustrate the delivery system including any of the features of the delivery system 100 shown in FIGS. 1A and 1B. The delivery system can be used to deliver the occlusion device 400. As shown in the figures, the occlusion device can include a braided expandable structure having a substantially cylindrical or barrel shape (e.g., laser cut with a woven pattern or braided from a plurality of strands). In other words, a diameter of a first end portion 402 can substantially the same as a diameter of a second end portion 404. In some instances, a diameter of the middle portion 406 can substantially the same as the diameters of the first end portion 402 and the second end portion 404. In other instances, a diameter of the middle portion 406 can be no more than about 25 percent larger, or no more than about 10 percent larger, than the diameters of the first and second end portions 402, 404.

[0163] The occlusion device 400 can include a diamond wall pattern across the length of the occlusion device. As shown in FIG. 4D, the first and second end portions 402, 404 can include a different wall pattern than the middle portion 406. For example, the percentage of open area of the first and second end portions 402, 404 can be greater than the percentage of open area of the middle portion 406. Although, in other examples, the wall pattern can be substantially the same across a length of the occlusion device 400.

[0164] The first and second ends can each include a diamond pattern. Further, each end can include an inner band 412 of strand portions and an outer band 414 of strand portions. Each band 412, 414 can form the same number of apexes and form a diamond pattern therebetween. The inner band 412 can define a guide wire opening 416 at the center of the inner band 412, through which a guide wire can pass.

[0165] The occlusion device 400 can include a cover surrounding at least one of the first and second end portions 402, 404. The cover can surround the entire circumference of the first end portion 402 and/or second end portion 404 and substantially close the first and/or second ends such that fluid cannot flow through the covered end(s). In some instances, the cover can surround substantially the entire occlusion device 400. As shown in FIG. 4G, the cover portion 408a can surround the first end portion 402 and the cover portion 408b can cover the second end portion 404, thereby substantially closing both the first and second ends. In some instances, each cover portion 408a, 408b can surround at least 20 percent of a length of the occlusion device 400, for example, between about 20 percent and about 40 percent or between about 30 percent and about 50 percent.

[0166] FIGS. 5A-5G illustrate the delivery system including any of the features of the delivery system 100 shown in

FIGS. 1A and 1B. The delivery system can be used to deliver the occlusion device 500. As shown in the figures, the occlusion device can include a braided expandable structure having a substantially cylindrical or barrel shape (e.g., laser cut with a woven pattern or braided from a plurality of strands). In other words, a diameter of a first end portion 502 can be substantially the same as a diameter of a second end portion 504. In some instances, a diameter of the middle portion 506 can substantially the same as the diameter of the first end portion 502 the second end portion 504. In other instances, a diameter of the middle portion 506 can be no more than about 25 percent larger, or no more than about 10 percent larger, than the diameters of the first and second end portions 502, 504.

[0167] Similar to the occlusion device 400, the occlusion device 500 can include a diamond wall pattern across the length of the occlusion device. As shown in FIG. 5D, the wall pattern can be substantially the same across a length of the occlusion device 500. However, in other examples, the first and second end portions 502, 504 can include a different wall pattern than the middle portion 506. For example, the percentage of open area of the first and second end portions 502, 504 can be greater than the percentage of open area of the middle portion 506.

[0168] The first and second ends can each include a diamond pattern. As shown in FIGS. 5F and 5G, each end can include a band 518 of circumferentially disposed diamonds. The band 518 can define a guide wire hole 516 at the center of the inner band, through which a guide wire can pass.

[0169] The occlusion device 500 can include a cover surrounding at least one of the first and second end portions 502, 504. The cover can surround the entire circumference of the first end portion 502 and/or second end portion 504 and substantially close the first and/or second ends such that fluid cannot flow through the covered end(s). In some instances, the cover can surround substantially the entire occlusion device 500. As shown in FIG. 5G, the cover portion 508a can surround the first end portion 502, and the cover portion 508b can cover the second end portion 504, thereby substantially closing both the first and second ends. In some instances, each cover portion 508a, 508b can surround at least 20 percent of a length of the expandable structure, for example, between about 20 percent and about 40 percent or between about 30 percent and about 50 percent.

[0170] FIG. 6 illustrates an occlusion device 600 having a braided expandable structure (e.g., laser cut with a woven pattern or braided from a plurality of strands). The expandable structure can include a substantially hourglass shape. In other words, a diameter of a first end portion 602 can be substantially the same as a diameter of a second end portion 604. Further, a diameter of the middle portion 606 can be substantially smaller than the diameters of the first and second end portions 602, 604. In some instances, the diameter of the middle portion 606 can be at least about 50 percent, at least about 60 percent, at least about 70 percent, at least about 80 percent, or at least about 90 percent smaller than the diameters of the first and second end portions 602, 604. The middle portion 606 can define a guide wire passage large enough for a conventional guide wire to pass.

[0171] The occlusion device 600 can include a cover surrounding the outside surface or the inside surface on at least one of the first and second lobes or end portions 602,

604. The cover can surround the entire circumference of the first end portion **602** and/or second end portion **604**. In some instances, the cover can surround substantially the entire occlusion device **600**. As shown in FIG. 6, the cover **608** can surround the second end portion **604**. In some instances, each cover **608** can surround at least 25 percent of a length of the expandable structure, for example, between about 40 percent and about 60 percent of the length of the expandable structure, such as about 50 percent of the length of the expandable structure.

[0172] FIGS. 7A-7B illustrate the occlusion device **700**. As shown in the figures, the occlusion device **700** can include a braided, elongate expandable structure (e.g., laser cut with a woven pattern or braided from a plurality of strands). As shown in the figures, the expandable structure can define a diamond wall pattern along a length of the expandable structure. Further, the expandable structure can include tapered first and second end portions **702**, **704**. The first and second end portions **702**, **704** can each define a guide wire hole large enough to permit a conventional guide wire to pass through the occlusion device.

[0173] A diameter of a middle portion **706** can be greater than a diameter of a first end portion **702** and a diameter of a second end portion **704**. The diameter of the middle portion **706** can be no more than about 60 percent, 50 percent, or 40 percent larger than the diameters of the first and second end portions **702**, **704**. In some instances, the middle portion **706** can be at least as long as the first and second end portions **702**, **704** combined.

[0174] The occlusion device **700** can include a cover surrounding at least one of the first and second end portions **702**, **704**. The cover can surround the entire circumference of the first end portion **702** and/or second end portion **704** and substantially close the first and/or second ends such that fluid cannot flow through the covered end(s). As shown in FIG. 7A, the cover portion **708a** can surround the first end portion **702**, and the cover portion **708b** can cover the second end portion **704**, thereby substantially closing both the first and second ends. In some instances, each cover portion **708a**, **708b** can surround at least 10 percent of a length of the expandable structure, for example, between about 10 percent and about 20 percent or between about 20 percent and about 30 percent. In some instances, as shown in FIG. 7B, the cover **708c** can surround substantially the entire occlusion device **700**.

[0175] FIG. 8 illustrates an occlusion device **800** formed from one or more strands woven to form an expandable structure. The expandable structure can include a first portion **802**, a second portion **804**, and a middle portion **806** therebetween. The first and second end portions **802**, **804** can include tapered ends. Further, the first and second end portions **802**, **804** can each include a smallest diameter that is at least large enough to permit a conventional guide wire to pass through.

[0176] The middle portion **806** can include a diameter that is substantially larger than a diameter of the first and second end portions **802**, **804**. For example, the diameter of the middle portion **806** can be at least about 50 percent or at least about 75 percent larger than a diameter of the first and second end portions **802**, **804**. In some instances, the diameter of the middle portion **806** can be between about 60 percent and 80 percent larger or between about 70 percent and about 90 percent larger. Further, as shown in FIG. 8, the

middle portion **806** can include a non-uniform diameter; for example, the middle portion **806** can be generally rounded to form a bulbous shape.

[0177] Although not shown, the occlusion device **800** can include a cover surrounding at least one of the first and second end portions **802**, **804**. The cover can surround the entire circumference of the first end portion **802** and/or second end portion **804** and substantially close the first and/or second ends such that fluid cannot flow through the covered end(s). In some instances, each cover portion can surround at least 10 percent of a length of the expandable structure, for example, between about 10 percent and about 20 percent or between about 20 percent and about 30 percent. In some instances, the cover can surround substantially the entire occlusion device **800**.

[0178] FIG. 9A illustrates an occlusion device **900** formed from one or more strands woven to form an expandable structure. The expandable structure can include a first portion **902**, a second portion **904**, and a middle portion **906** therebetween. The first and second end portions **902**, **904** can include tapered ends. Further, the first and second end portions **902**, **904** each include a smallest diameter that is at least large enough to permit a conventional guide wire to pass through.

[0179] The middle portion **906** can include a diameter that is substantially larger than a diameter of the first and second end portions **902**, **904**. For example, the diameter of the middle portion **906** can be at least about 50 percent, or at least about 75 percent larger than a diameter of the first and second end portions **902**, **904**. In some instances, the diameter of the middle portion **906** can be between about 60 percent and 80 percent larger or between about 70 percent and about 90 percent larger. Further, as shown in FIG. 9, the middle portion **906** can include a substantially uniform diameter.

[0180] The occlusion device **900** can include a cover **908** surrounding at least one of the first and second end portions **902**, **904**. The cover **908** can surround the entire circumference of the first end portion **902** and/or second end portion **904** and substantially close the first and/or second ends such that fluid cannot flow through the covered end(s). In some instances, each cover portion can surround at least 10 percent of a length of the expandable structure, for example, between about 10 percent and about 20 percent or between about 20 percent and about 30 percent. As shown in the figures, the cover **908** surrounds the first end portion **902**. However, in some instances, the cover can surround the second end portion **904** or substantially the entire occlusion device **900**.

[0181] FIGS. 10A-10B illustrate the occlusion device **1000**. As shown in the figures, the expandable structures can define a diamond wall pattern along a length of the expandable structure. Further, the expandable structure can include tapered first end portion **1002** and an opened second end portion **1004**. Although the first end portion **1002** is tapered, the first end portion **1002** still defines a guide wire hole large enough to permit a conventional guide wire to pass through the occlusion device. A diameter of a middle portion **1006** can be substantially the same as a diameter of the second end portion **1004**.

[0182] As shown in FIG. 10B, the occlusion device **1000** can include a cover **1008** surrounding at least the first end portion **1002**. The cover **1008** can surround the entire circumference of the first end portion **1002** such that fluid

cannot flow through the covered end. In some instances, the cover **1008** can surround at least 10 percent of a length of the expandable structure, for example, between about 10 percent and about 20 percent or between about 20 percent and about 30 percent. As shown in FIG. 10A, the cover **1008** can surround substantially the entire expandable structure.

[0183] FIGS. 11A-11C illustrate another exemplary embodiment of an occlusion device **1100**. As shown in the figures, the occlusion device **1000** can include a substantially uniform diameter. The occlusion device **1100** also defines a substantially uniform diamond wall pattern along a length of the occlusion device **1100**.

[0184] As shown in FIG. 11C, the occlusion device **1100** can include a drumhead **1120** disposed within the first end portion **1102**. The drumhead **1120** can be configured to close the first end **1102** such that fluid is prevented from flowing through the occlusion device **1100**.

[0185] Further, the occlusion device **1100** can include a cover **1108** surrounding at least a portion of the occlusion device **1100**. For instance, the cover **1108** can cover the drumhead **1120**, or, as shown in FIGS. 11A-11C, the cover **1108** can surround at least the middle portion **1106** and the second end portion **1104**. Although, depending on the desired performance of the cover **1108**, the cover **1108** can extend along different lengths of the occlusion device. In some scenarios, it may be desirable to have greater overlap between the cover **1108** and the frame to adequately anchor the cover **1108** to the frame. For example, the cover **1108** can extend along at least about 50 percent, as at least about 60 percent, at least about 70 percent, at least about 80 percent, or at least about 90 percent of the length of the occlusion device **1100**. In some examples, the cover **1108** extends along substantially the entire length of the occlusion device **1100**. In other scenarios, it may be desirable to leave a higher percentage of the frame uncovered to facilitate endothelialization, for example, across less than about 50 percent, less than about 40 percent, less than about 30 percent, or less than about 20 percent of the length of the occlusion device **1100**. Preferably, to achieve both endothelialization and sufficient overlap, the cover **1108** should extend across at least about 25 percent of the length of the frame and no more than about 50 percent of the length of the frame, for example, within about 5 percent of each of about 30 percent, 35 percent, 40 percent, or 45 percent.

[0186] Although certain embodiments have been described herein within respect to the illustrated expandable structures, the occlusion devices described herein can include differently shaped or differently formed expandable structures. For example, the expandable structure can be substantially conical, coiled, or any other conventional stent shape. As another example, the expandable structure can include a laser cut frame. In some instances, the frame can include a first closed end and a second opened end. The percentage of open area of the second opened end can be greater than the percentage of open area of the first closed end.

[0187] The specific examples described above in connection with FIGS. 3A-11C are for illustrative purposes only and should not be construed as limiting. Any combination of the configuration, shape, or wall pattern of the expandable structure can be combined with any type or amount of covering described herein.

[0188] Further, any of the features of the occlusion devices (e.g., expansion ratio, shapes, dimensions, materials, covers,

etc.) disclosed herein can be accomplished in a stent, having two open ends and a central lumen to maintain vascular patency and permit perfusion.

[0189] FIGS. 12A and 12F illustrate an occlusion device **1200a** having a first lobe or end portion **1202a**, a second lobe or end portion **1204a**, and a central or neck portion **1205a** extending between the first and second end portions **1202a**, **1204a**. The first end portion **1202a** can generally refer to the distal end portion or the anchor portion of the occlusion device **1200a** and the second end portion **1204a** can generally refer to the proximal end portion or the occlusive portion of the occlusion device **1200a** when the occlusion device **1200a** is introduced into the patient. As described in further detail below, the second end portion **1204a** can be coated such that the second end portion **1204a** provides occlusion, while the first end portion **1202a** maintains an open cell structure to anchor the occlusion device **1200a** and permit lateral flow. Further, the open cell structure of the first end portion **1202a** enables the clinician to partially deploy the occlusion device **1200a** against the wall of the vessel (e.g., just the first end portion **1202a**) and confirm the position of the occlusion device **1200a** by injecting contrast (e.g., by using delivery system **200**) without materially impeding flow or raising hydrostatic pressure. In contrast, if a mechanically occlusive element were partially deployed, the mechanically occlusive element would impede flow and raise hydrostatic pressure.

[0190] As shown in FIG. 12A, the diameter of the central portion **1205a** can be less than a diameter of the first or second end portions **1202a**, **1204a**, e.g., the occlusion device **1200a** can have a generally hourglass shape (see FIG. 12A). For example, the diameter D_1 of the central portion **1205a** can be between about 5% and about 25% of the diameter D_2 of the first or second end portions **1202a**, **1204a**, preferably less than or equal to about 15%, or less than or equal to about 10% of the diameter D_2 of the first or second end portions **1202a**, **1504**.

[0191] The occlusion device **1200a** can be asymmetrical about a transverse axis T-T of the occlusion device **1200a** in the expanded and/or unexpanded configurations (see FIG. 12A). For example, in the expanded configuration, the occlusion device **1200a** can be asymmetrical about a transverse axis T-T.

[0192] As shown in FIG. 12A, a uniform portion **1204a'** of the second end portion **1204a** can have a generally uniform diameter (e.g., cylindrical) and a tapered portion **1204a''** of the second end portion **1204a** can taper towards the central portion **1205a**. The tapered portion **1204a''** of the second end portion **1204a** can form an angle α between about 45 degrees and about 75 degrees, between about 55 degrees and about 65 degrees, preferably about 60 degrees with respect to the longitudinal axis.

[0193] Similarly, a uniform portion **1202a'** (e.g., cylindrical) of the first end portion **1202a** can have a generally uniform diameter and a tapered portion **1202a''** of the first end portion **1202a** can taper toward the central portion **1205a**. The tapered portion **1202a''** of the first end portion **1202a** can form an angle β . Angle β can be substantially the same as angle α .

[0194] Even if the angle of the tapered portions **1202a''**, **1204a''** is substantially the same, an angle γ can be different from an angle δ relative to the longitudinal axis. The angle γ can be measured from a line extending through a transition point T_1 (between the tapered portion **1204a''** and the cylind-

drical portions **1204a'**) and the axial center C of the occlusion device **1200a**. The angle δ can be measured from a line extending through a transition point T_2 (between the tapered portion **1202a''** and the cylindrical portions **1202a'**) and the axial center C of the occlusion device **1200a**. Angle δ can be less than angle γ to reduce the force necessary to retract the first end portion **1202a** into the delivery system.

[0195] As illustrated in FIG. 13B, each of the proximal (covered) **1204e** and distal (typically bare strut) **1202e** lobes are connected to the central hub **1205e'** by a plurality of struts **1210e** which incline radially outwardly in their respective directions away from the hub **1205c'**. In the illustrated embodiment, a shallower distal lobe strut **1280e** launch angle between the curved axis of the strut and the longitudinal axis of the implant is clinically desirable because it provides a ramped surface that facilitates easy resheathing of the deployed distal lobe of the implant as it is pulled proximally back into the tubular deployment catheter. Preferably, the expanded implant is bilaterally asymmetrical, with the proximal struts **1282c** exhibiting a steeper launch angle from the hub. This enables the implant to reach the fully expanded diameter of the proximal lobe **1204e** over the shortest possible axial length. Thus, the shallow launch angle distal struts **1280e** and steeper launch angle proximal struts **1282e** optimize retrievability of the partially deployed implant while at the same time minimizes overall implant length. The wall pattern of the implant may in one embodiment exhibit bilateral symmetry in the collapsed configuration but expands to demonstrate the bilateral asymmetry described above due to a preset shape in the Nitinol or other shape memory material of the frame.

[0196] The distal struts **1280e** are concave outwardly in a side elevational view, defining a generally trumpet shaped or flared configuration. The curvature of the struts **1280c** as they leave the hub **1205e'** and incline radially outwardly do not necessarily have a constant radius of curvature, but can be considered to conform to a best fit circle A having a constant radius (see FIG. 13B). The radius is generally at least about 25%, in some embodiments at least about 30% or 35% or more of the unconstrained diameter of the expanded distal lobe **1202c**. For example, in an implant having an unconstrained distal lobe diameter of about 10 mm, the radius is generally within the range of from about 2.5 mm to about 5.5 mm, and in some embodiments between about 3 mm and 5 mm, or approximately 4 mm.

[0197] The proximal lobe struts **1282e** can have a steeper launch angle to enable the proximal lobe **1202e** to reach full diameter over a short axial distance from the hub. Thus, the radius of circle B which best fits the launch geometry of the proximal struts is generally less than about 25%, preferably less than about 20% or 15% or less of the expanded diameter of the proximal lobe **1202c**, depending upon the physical properties and dimensions of the strut material (see FIG. 13B).

[0198] The best fit circles A, B described above will preferably be located against the strut such that it is approximately symmetrical about the midpoint of the arc of the struts that define the concave outwardly concave curvature section. Thus, the midpoint of the arc in the distal strut **1280e** illustrated in FIG. 13B is a greater radial distance from the longitudinal axis of the implant than is the midpoint of the arc in the proximal strut **1282e** due to the proximal

strut transitioning from the arc to a substantially linear shoulder which extends out to the generally cylindrical body of the proximal lobe.

[0199] As shown in FIG. 12A, a length L_1 of the second end portion **1204a** (including the tapered portion **1204a''** and generally uniform portion **1204a'**) can be greater than a length L_2 of the first end portion **1202a** (including the tapered portion **1202a''** and generally uniform portion **1202a'**). For example, L_2 can be between about 25% and about 75% of L_1 , such as between about 50% and about 60%. Forces directed at a concave surface of the second end portion **1204a** can provide a radially outward directed force to push the second end portion **1204a** open and increase radial outward forces acting on the occlusion device **1200a** and the vessel wall, when the occlusive concave side is facing an upstream direction with respect to blood flow in the vessel. The occlusive lobe (e.g., the second end portion **1204a**) also places the hub under axial compression, which increases the radial force on the bare metal strut lobe (e.g., the first end portion **1202a**). In certain aspects, the length of the second end portion L_1 can be about the same as a diameter of the second end portion **1204a**. This ensures that the second end portion **1204a** does not rotate perpendicular to an axis of the vessel and ensures that other anti-migration features remain properly aligned and positioned.

[0200] A length L_3 of the uniform portion **1204a'** of the second end portion **1204a** can be longer than a length L_4 of the uniform portion **1202a'** of the first end portion **1202a'** (see FIG. 12A). For example, in the unconstrained configuration, the uniform portion **1204a'** can include a greater number of circumferential rings R1, R2, R3 of open cells **1212a** than the uniform portion **1202a'**. For example, the uniform portion **1204a'** can include three circumferential rings R1, R2, R3 of open cells **1212a**, while the uniform portion **1202a'** can include one circumferential ring R4 of open cells **1212a**. A size of an open cell **1212a** in circumferential ring R1 can be substantially the same size as the size of an open cell **1212a** in circumferential ring R4. In the constrained configuration, the second end portion **1204a** can include a greater number of circumferential rings of struts than the first end portion. For example, the second end portion **1204a** can include six circumferential rings C1, C2, C3, C4, C5, C6, of struts **1210a**, while the first end portion **1202a** can include four circumferential rings C7, C8, C9, C10 of struts **1210a**.

[0201] The occlusion device **1200a** can have an aspect ratio less than or equal to about 2:1 (unconstrained length to unconstrained lobe diameter), such as between about 1:1 and about 2:1 or between about 1.5:1 and about 2:1. An unconstrained length of the occlusion device **1200a** can be between about 10 mm and about 25 mm, in some implementations from about 15 mm to about 22 mm. The first end portion **1202a** having an unconstrained length of less than about 50% of a length of the occlusion device **1200a** (e.g., when the unconstrained length is 20 mm, the length of the proximal portion is less than about 10 mm), less than about 40% of a length of the occlusion device **1200a** (e.g., when the unconstrained length is 20 mm, the length of the proximal portion is less than about 8 mm), or less than about 30% of a length of the occlusion device **1200a** (e.g., when the unconstrained length is 20 mm, the length of the proximal portion is less than about 6 mm). An unconstrained

expanded diameter of the occlusion device **1200a** can be between about 5 mm and about 15 mm, such as about 10 mm.

[0202] The occlusion device **1200a** can include an expandable frame **1206a** and a membrane **1208a** carried by the expandable frame **1206a**. The expandable frame **1206a** can define a lumen therethrough to facilitate delivery of the occlusion device **1200a** over a guide wire (e.g., a 0.018-inch guidewire). Further, the expandable frame **1206a** can have a wall thickness of less than or equal to about 0.003 inches, such as about 0.002 inches.

[0203] The expandable frame **1206a** can be at least partially covered by a thin membrane **1208a** (e.g., between about 10 microns and about 30 microns thick). The membrane **1208a** should be sufficiently thick to facilitate occlusion, while still minimizing the profile of the collapsed occlusion device **1200a**. Possible materials for the membrane **1208a** can include PTFE, PET, silicone, latex, TecoThane, nylon, PET, Carbothane (Bionate), fluoropolymers, SIBS, TecoFlex, Pellethane, Kynar, or PLGA.

[0204] The membrane **1208a** can be applied to the expandable frame **1206a** in a manner that encapsulates at least some of the struts **1210a**, such that the membrane **1208a** is present along either or both an interior surface and an exterior surface of the expandable frame **1206a**. Possible methods of applying the membrane **1208a** are described in further detail below.

[0205] The membrane **1208a** can cover at least one end of the expandable frame **1206a** and extend across at least a partial length of the expandable frame **1206a**. In some embodiments, the membrane **1208a** at least coats a portion of the occlusion device **1200a** that is concave to the direction of the blood flow, which can be more occlusive and resist more migration than occlusion devices that only coat a surface convex to the direction of the blood flow or coat the entire occlusion device or coat the entire occlusion device. For example, the membrane **1208a** can cover at least a portion of or the entire the second end portion **1204a** and the first end portion **1202a** can be a bare frame. When the bare first end portion **1202a** is deployed before the covered second end portion **1204a**, the bare first end portion **1202a** can at least partially anchor the occlusion device **1200a** in the vessel and allow visualization before deploying the covered second end portion **1204a**, which facilitates precise placement of the occlusion device **1200a**.

[0206] When the covered second end portion **1204a** is upstream (i.e., anatomically proximal) from the bare first end portion **1202a**, the increase in arterial pressure at the second end portion **1204a** increases the radially outward forces directed toward the membrane **1208a**, which helps the occlusion device **1200a** resist migration. A higher blood pressure difference between the proximal and distal ends of the occlusion device **1200a** will cause higher outward forces. Further, when the covered second end portion **1204a** is upstream from the bare first end portion **1202a**, forward pressure from blood flow acts on the central portion **1205a**. After the occlusion device **1200a** expands, forces acting on the central portion **1205a** cause the tapered portion **1202a'** of the first end portion **1202a** (e.g., struts closer to or adjacent to the central portion **1205a**) to collapse (e.g., bend inward), which causes the uniform portion **1202a'** (e.g., struts closer to or at a distal end of the occlusion device) to move outward and further anchor the first end portion **1202a** in the vessel.

[0207] Additionally, the membrane **1208a** can be positioned on portions of the expandable frame **1206a** on which hydraulic pressure will force the expandable frame **1206a** outward. In some embodiments, portions of the expandable frame **1206a** where the hydraulic pressure would force the expandable frame **1206a** inward are not coated.

[0208] The membrane **1208a** can extend to form a thin extended tubular section of coating **1250a** through which the guidewire (e.g., a 0.018" guidewire) can be introduced. The thin tube **1250a** can extend through the first end portion **1202a** or the second end portion **1204a**. As described in further detail below, the thin tube **1250a** can be configured to invert from a position extending through the first end portion **1202a** such as during deployment to a position extending through the second end portion **1204a** following deployment. The thin tube **1250a** can extend across less than or equal to about 85% (e.g., between about 75% and about 85%), less than or equal to about 75%, less than or equal to about 60%, or less than or equal to about 50% of the length of the second end portion **1204a**. In use, the thin tube **1250a** can have sufficiently low collapse resistance such that blood pressure will cause the thin tube **1250a** to collapse (e.g., kink, fold, buckle, flop over, or likewise) when the guidewire is removed. The thin tube **1250a** acts like a valve (e.g., a duckbill valve) to occlude the guidewire lumen **1252a** and aid in the capture and formation of clots. The tube **1250a** may be formed integrally with the formation of the membrane, during the spin coating process. Alternatively, the tube **1250a** may be separately formed and attached to the hub and/or membrane using suitable adhesives, solvent bonding, heat bonding, or other techniques known in the art. Alternatively, one, two, or more flaps or leaflets may be provided, to occlude the guidewire opening following removal of the guidewire, preferably on the upstream blood flow side of the hub.

[0209] After the occlusion device **1200a** has been deployed, the occlusion device **1200a** can resist migration (e.g., migrate less than about 5.0 mm from the deployed position, preferably less than about 4.0 mm, or less than about 2.0 mm) for at least 10 minutes under pressures of at least about 100 mmHg and/or less than or equal to about 300 mmHg, for example, between about 100 mmHg and 150 mmHg, between about 150 mmHg and about 300 mmHg, between about 200 mmHg and about 300 mmHg, between about 250 mmHg and about 300 mmHg, such as about 270 mmHg, as determined by the Migration Protocol described below.

[0210] In at least a straight 8 mm vessel or curved 8 mm vessel with a 20 mm radius to centerline of vessel, the structure of the deployed occlusion device **1200a** permits the device to resist migration under at least average blood pressure (e.g., 120 mmHg) according to the Migration Protocol described below. In at least a straight 8 mm vessel or curved 8 mm vessel with a 20 mm radius to centerline of vessel, under retrograde venous deployment conditions, the structure of the deployed occlusion device **1200a** permits the device to resist migration under at least 7 mmHg of pressure according to the Migration Protocol described below. Migration is defined as continuous movement of the embolic device or movement of the proximal end of the embolic device by greater than 5 mm from the initial location.

[0211] When the occlusion device **1200a** is deployed in the vessel, the occlusion device **1200a** can occlude at least about 80% of blood flow within 30 seconds, at least about

90% of blood flow within about 3 minutes, and/or about 100% of blood flow within about five minutes, without reliance on biological processes. Because of the mechanical mechanism of occlusion, performance is the same whether or not the patient has been anticoagulated (e.g., heparin, aspirin, warfarin, Plavix, etc.). In some implementations, the occlusion device **1200a** can achieve complete occlusion within about two minutes or within about one minute. Using the Occlusion Protocol described below, the occlusion device **1200a** can limit the flow rate through a vessel to no more than about 200 cc/min at 20 mmHg, such as to between about 50 cc/min and about 150 cc/min, preferably less than about 130 cc/min, less than about 100 cc/min at 20 mmHg or less than about 65 cc/min at 20 mmHg within about five minutes. Further, the occlusion device **1200a** can limit the flow rate through a vessel to no more than about 400 cc/min at 60 mmHg or no more than about 330 cc/min at 60 mmHg, such as to between about 150 cc/min and about 250 cc/min, preferably less than or equal to about 175 cc/min at 60 mmHg within about five minutes. The occlusion device **1200a** can limit the flow rate through a vessel to about no more than 600 cc/min at about 100 mmHg or 430 cc/min at 100 mmHg, such as to between about 200 mmHg and about 250 mmHg, preferably less than about 225 cc/min at about 100 mmHg within about five minutes.

[0212] In at least a 3 mm curved vessel with a 7.5 mm radius to centerline of vessel or a 8 mm vessel with a 20 mm radius to centerline of vessel, using the Occlusion Protocol described below, the occlusion device **1200a** will permit a maximum flow rate of 130 cc/min at 20 mmHg (e.g., a maximum flow rate of 70 cc/min at 20 mmHg or 40 cc/min at 20 mmHg), 330 cc/min at 60 mmHg (e.g., a maximum flow rate of 175 cc/min at 60 mmHg or 125 cc/min at 60 mmHg), or 430 cc at 100 mmHg (e.g., a maximum flow rate of 315 cc/min at 100 mmHg or 185 cc/min at 100 mmHg) after about one minute. In at least a 3 mm curved vessel with a 7.5 mm radius to centerline of vessel or an 8 mm vessel with a 20 mm radius to centerline of vessel, under retrograde venous deployment conditions, using the Occlusion Protocol described below, the occlusion device **1200a** will permit a maximum flow rate of 130 cc/min at 20 mmHg after about one minute.

[0213] The occlusion device **1200a** has an expansion ratio of at least about 5:1. The expansion ratio of the occlusion device **1200a** allows the occlusion device **1200a** to treat different sized vessels between about 2.5 mm and about 8.0 mm. For example, the same occlusion device **1200a** that can occlude a 2.5 mm vessel can occlude a 6.0 mm vessel.

[0214] The expansion ratio of the occlusion device **1200a** can be between about 5:1 to about 10:1, such as at least about 5:1, at least about 6:1, at least about 7:1, at least about 8:1, or at least about 9:1. In some implementations, the expansion ratio can be at least about 10:1. In other words, a diameter of the occlusion device **1200a** in the expanded configuration can be between about five times and about ten times greater than the diameter of the occlusion device **1200a** in the unexpanded configuration, such as at least about five times, at least about six times, at least about seven times, at least about eight times, or at least about nine times. In some implementations, the diameter of the expanded configuration can be at least about ten times greater than the diameter of the unexpanded configuration. The expansion ratio of the occlusion device **1200a** is sufficiently large such that the occlusion device **1200a** is capable of compressing to

a minimum size suitable for delivery through a catheter having a diameter of less than about 5 F, thereby minimizing trauma to the vessel during delivery. Further, the expansion ratio of the occlusion device **1200a** is sufficiently large that a single, expanded occlusion device is capable of preventing substantially all fluid from flowing past the occlusion device in the target vessel. Generally, the expansion ratio of each lobe is equal to the ratio of the hub to the lobe in an unconstrained expansion.

[0215] A single occlusion device **1200a** can be used to treat a wide range of vessel diameters. For example, the occlusion device **1200a** can have an expansion range when delivered from a lumen having an internal diameter of at least about 2.0 mm up to at least about 8.0 mm or 10.0 mm or more, such as at least about 3.0 mm, at least about 4.0 mm, or at least about 5.0 mm. For instance, a single occlusion device **1200a** can treat vessels having a diameter between about 2.5 mm and about 8.0 mm, or between about 3.0 mm and 7.0 mm. Using a single occlusion device **1200a** to treat a wide range of vessels can be desirable to reduce the total stock of occlusion devices that must be kept on hand, and the ability to occlude large vessels with a single occlusion device **1200a** can reduce costs.

[0216] Further, the single occlusion device **1200a** having an expansion range of at least about 2.0 mm, 4.0 mm, or more, and also exhibits less than 20 percent elongation when moving from the unexpanded configuration to the expanded configuration, preferably less than about 15 percent. Minimizing elongation can help ensure accurate positioning of the occlusion device **1200a**.

[0217] In the expanded state, the occlusion device **1200a** can have an unconstrained diameter that is between about 30% and about 50% larger than the vessel diameter. For vessels sized between about 2.0 mm and about 8.5 mm in diameter, the diameter of the expanded occlusion device **1200a** can be at least about 2.6 mm and/or less than or equal to about 12.75 mm, e.g., between about 9 mm and about 11 mm, such as about 10 mm.

[0218] The occlusion device **1200a** may provide a chronic outward pressure ("COP"). As used herein, COP is the radial pressure (expressed in terms of mmHg) necessary to maintain stability of the occlusion device in a vessel under normal physiological blood pressure (i.e., about 135 mmHg). Radial forces used to determine the following COP values were based on data collected using the Migration Protocol described below. Further, the calculation of the COP assumes that the occlusion device **1200a** forms a complete seal, and thus the flow rate equals zero and shear forces equal zero. The calculation also assumes that the occlusion device **1200a** is rigid, and thus the normal force due to transfer of hydraulic force to the vessel wall equals zero.

[0219] Using these assumptions, the occlusion device can provide a COP between about 20 mmHg and about 250 mmHg, such as between about 30 mmHg and about 140 mmHg, between about 30 mm Hg and 80 mmHg, between about between about 70 mmHg and 100 mmHg, between about 90 mmHg and 120 mmHg, or between about 100 mmHg and 140 mmHg., for vessels having a diameter between about 3 mm and about 8 mm under a physiological pressure of about 135 mmHg, preferably between about 20 N/mm² (2.67 kPa) and about 50 N/mm² (6.67 kPa). For example, the occlusion device **1200a** can provide about 48 mmHg (6.4 kPa) of radial pressure in a 7 mm vessel with a physiological pressure of about 135 mmHg pressure when

the length of the contact area between an exemplary embodiment of the occlusion device **1200a** and the vessel wall is about 12.5 mm (e.g., $L_1=4.5$ mm, $L_2=8.0$ mm). The occlusion device **1200a** can provide about 20 mmHg (2.67 kPa) of radial pressure in a 7 mm vessel with a physiological pressure of about 135 mmHg pressure when the length of the contact area is about 30.0 mm, the entire length of an exemplary embodiment of the occlusion device **1200a**. The latter calculation assumes that a thrombus will form and that the occlusion device **1200a** will transfer radial force through the thrombus and across the entire length of the occlusion device **1200a**.

[0220] FIGS. 13A and 13B illustrate another hourglass-shaped occlusion device **1200e** having the same general structure and properties as occlusion device **1200a**. In generally, the occlusion device **1200e** is adapted to move between a constrained configuration (FIG. 13B) and an unconstrained configuration (FIG. 13A). The occlusion device **1200e** can have any number of the characteristics (e.g., dimensions, construction, performance, etc.) as the occlusion device **1200a** except as described below.

[0221] Similar to the occlusion device **1200a**, as shown in FIG. 13A, the occlusion device **1200e** can have a first lobe or end portion **1202e**, a second lobe or end portion **1204e**, and a central or neck portion **1205e** extending between the first and second end portions **1202e**, **1204e**. The first end portion **1202e** can generally refer to the distal end portion, the downstream portion, or the anchor portion of the occlusion device **1200e** and the second end portion **1204e** can generally refer to the proximal end portion, the upstream portion, or the occlusive portion of the occlusion device **1200e** when the occlusion device **1200e** is introduced into the patient. The second end portion **1204e** can be coated such that the second end portion **1204e** provides occlusion, while the first end portion **1202e** maintains an open cell structure to anchor the occlusion device **1200e** and permit lateral flow. Further, the open cell structure of the first end portion **1202e** enables the clinician to partially deploy the occlusion device **1200e** against the wall of the vessel (e.g., just the first end portion **1202e**) and confirm the position of the occlusion device **1200a** by injecting contrast (e.g., by using delivery system **200**) without materially impeding flow or raising hydrostatic pressure. In contrast, if a mechanically occlusive element were partially deployed, the mechanically occlusive element would impede flow and raise hydrostatic pressure.

[0222] As shown in FIG. 13A, the diameter of the central portion **1205e** can be less than a diameter of the first or second end portions **1202e**, **1204e**, e.g., the occlusion device **1200e** can have a generally hourglass shape (see FIG. 13A). For example, the diameter D_1 of the central portion **1205e** can be between about 5% and about 25% of the diameter D_2 of the first or second end portions **1202e**, **1204e**, preferably less than or equal to about 15%, or between about 10% and about 15% of the diameter D_2 of the first or second end portions **1202e**, **1204e**. The diameter of the hub can be substantially equal to the diameter of the proximal and distal lobes when in the collapsed configuration.

[0223] As shown in FIG. 13A, the occlusion device **1200e** can be asymmetrical about a transverse axis T-T of the occlusion device **1200a** in the expanded. As shown in FIG. 13B, in an constrained position, the length L_1 of the first end portion **1202e** can be substantially the same as the length L_2 of the second end portion **1204e**. For example, in the

constrained configuration, the second end portion **1204e** can include the same number of circumferential rings as the first end portion, such as six rings C1, C2, C3, C4, C5, C6, of struts **1210e** (or four or five or more) in the first end portion **1202e** and six rings C7, C8, C9, C10, C11, C12, of struts **1210c** (or four or five or more) in the second end portion **1204c**.

[0224] However, as shown in FIG. 13A, in the unconstrained position, the length L_3 of the generally uniform portion **1204e'** of the second end portion **1204e** can be less than the length L_a of the generally uniform portion **1202e'** of the first end portion **1202e**. For example, L_3 can span about two circumferential rings R₄, R₅ or less than three full circumferential rings of open cells **1212e**, while L_a can span about three full circumferential rings R1, R2, R3 of open cells **1212e**. Although the first end portion **1202e** and the second end portion **1204e** have the same length in the unconstrained configuration, the first end portion **1202e** and the second end portion **1204e** to expand into different configurations. A size of an open cell **1212e** in circumferential ring R1 can be substantially the same size as the size of an open cell **1212e** in circumferential ring R4.

[0225] As shown in FIG. 13A, the angle α of the tapered portion **1204e''** or angle β of the tapered portion **1202e''** can be between about 45 degrees and about 75 degrees, between about 55 degrees and about 65 degrees, preferably about 60 degrees with respect to the longitudinal axis. The angle α can be substantially the same as angle β .

[0226] However, even if the angle of the tapered portions **1202e''**, **1204e''** is substantially the same, an angle γ can be different from an angle δ relative to the longitudinal axis. The angle γ can be measured from a line extending through a transition point (between the tapered portion **1204e''** and the cylindrical portions **1204e'**) and the axial center of the occlusion device **1200e**. The angle δ can be measured from a line extending through a transition point (between the tapered portion **1202e''** and the cylindrical portions **1202e'**) and the axial center of the occlusion device **1200e**. Angle δ can be less than angle γ to reduce the force necessary to retract the first end portion **1202e** into the delivery system.

[0227] During the manufacturing process, after the hypotube is laser cut, two different sized mandrels are inserted into the occlusion device **1200e**. A first mandrel having a desired shape of the first end portion **1202e** can be inserted through a distal end of the occlusion device **1200e** and a second mandrel having a desired shape of the second end portion **1204e** can be inserted through a proximal end of the occlusion device **1200e**. The first mandrel can be locked together with the second mandrel. With the occlusion device **1200e** loaded on the first and second mandrels, the occlusion device **1200e** can be heat treated to the shape described herein.

[0228] The occlusion device **1200e** can have an aspect ratio less than or equal to about 2:1 (unconstrained length to unconstrained lobe diameter), such as between about 1:1 and about 2:1 or between about 1.5:1 and about 2:1. An unconstrained length of the occlusion device **1200e** can be between about 10 mm and about 25 mm, in some implementations from about 15 mm to about 22 mm. The first end portion **1202e** having an unconstrained length of less than about 50% of a length of the occlusion device **1200e** (e.g., when the unconstrained length is 20 mm, the length of the proximal portion is less than about 10 mm), less than about 40% of a length of the occlusion device **1200e** (e.g., when

the unconstrained length is 20 mm, the length of the proximal portion is less than about 8 mm), or less than about 30% of a length of the occlusion device **1200e** (e.g., when the unconstrained length is 20 mm, the length of the proximal portion is less than about 6 mm). An unconstrained expanded diameter of the occlusion device **1200e** can be between about 5 mm and about 15 mm, such as about 10 mm.

[0229] The occlusion device **1200e** can include an expandable frame **1206c** and a membrane **1208e** (not shown) carried by the expandable frame **1206e** (see FIG. 13A). The expandable frame **1206e** can define a lumen G therethrough to facilitate delivery of the occlusion device **1200e** over a guide wire (e.g., a 0.018 inch guidewire). Further, the expandable frame **1206e** can have a wall thickness of less than or equal to about 0.003 inches, such as about 0.002 inches.

[0230] The first end portions and the second end portions **1202e**, **1204e** of the expandable frame **1206e** can include a plurality of interconnected struts **1210e** that can be laser cut from a Nitinol hypotube. At least a portion of the central portion **1205e** can be a bare hypotube section **1205c'** (e.g., uncut).

[0231] A length of each strut **1210e** can generally vary from an end of the occlusion device **1200e** toward the central portion **1205e** of the occlusion device **1200c**. For example, a length of each strut **1210e** can generally increase from one or both ends of the occlusion device **1200e** to a central portion **1205c** of the occlusion device (e.g., from about 0.05 cm at the proximal and distal ends to about 0.25 cm at the central portion **1205e**). For example, a length of a strut closest to the center can be about 150% of a length of a strut closest to an end of the occlusion device **1200c**. For example, a length of a strut closest to the center of the occlusion device can be about 0.09 inches and a length of a strut closest to an end of the occlusion device can be about 0.06 inches.

[0232] As an example, a first ring of struts R1 can have an axial length that is about 115% of a length of a second, adjacent ring of struts R2. For example, a first ring of struts R1 can have an axial length of about 0.0910 inches and a second ring of struts R2 can have an axial length of about 0.0785 inches. A second ring of struts R2 can have an axial length that is about 112% of a length of a third, adjacent ring of struts R3. For example, a second ring of struts R2 can have an axial length of about 0.0785 inches and a third ring of struts R3 can have an axial length of about 0.0700 inches. A third ring of struts R3 can have an axial length that is about 113% of a length of a fourth, adjacent ring of struts R4. For example, a third ring of struts R3 can have an axial length of about 0.0700 inches and a second ring of struts R2 can have an axial length of about 0.0620 inches. A fourth ring of struts R4 can have an axial length that is about the same as a fifth adjacent ring of struts R5. For example, a fourth ring of struts R4 and a fifth ring of struts R5 can have an axial length of about 0.0620 inches. A fifth ring of struts R5 can have an axial length that is about 103% of a length of a sixth, adjacent ring of struts R6. For example, a fifth ring of struts R5 can have an axial length of about 0.0620 inches and a sixth ring of struts R6 can have an axial length of about 0.06 inches.

[0233] A thickness in a circumferential direction of each strut **1210e** can generally vary from an end of the occlusion device **1200e** toward the central portion **1205e** of the occlu-

sion device **1200e**. For example, a thickness of each strut **1200e** can generally decrease from one or both ends of the occlusion device toward the central portion **1205e** of the occlusion device **1200e**. Varying the lengths and thicknesses of the struts can evenly distribute force across the occlusion device **1200e**, which can decrease the chronic outward pressure the occlusion device **1200e** exerts on the vessel or decrease the total length of the occlusion device **1200c**. In the constrained configuration, a diameter of the occlusion device **1200e** can decrease from the ends of the occlusion device **1200e** toward the central portion **1205e** of the occlusion device **1200e**. For example, there can be a gradual decrease in diameter at an intermediate portion of the first end portion **1202e** and an intermediate portion of the second end portion **1204c**. The intermediate portions can be positioned the same distance from a center of the occlusion device **1200c**. The intermediate portions can extend across a same axial length of the occlusion device **1200e**. For example, each of the intermediate portions can extend across about less than 5 percent of an axial length of the entire length of the occlusion device **1200c**, such as about three percent. The intermediate portions can begin at a position about 20 percent to about 40 percent of the axial length from an end of the occlusion device, such as between about 20 percent and about 30 percent or between about 30 percent and about 40 percent. Although the profile of the occlusion device **1200e** can be symmetrical in the constrained position, as described above, the first and second end portions **1202e**, **1204e** can expand into different configurations (see FIG. 13A).

[0234] When the occlusion device **1200e** is deployed using the delivery system **200** (described above), the angle θ of the proximal hooks **1217e** of the occlusion device **1200e** can be optimized to maintain engagement between the occlusion device **1200e** and the interlocking attachment member **231** during retraction (described above). For example, the angle θ can be between about 60 degrees and about 90 degrees, such as about 75 degrees.

[0235] When expanded, the ratio of strut width/thickness causes the struts and the hooks to twist approximately 90 degrees. Twisting the hooks allows for a relatively “tall” hook while keeping the embolic strut thickness low to provide a greater profile for secure fixation.

[0236] Similar to the occlusion device **1200a**, the expandable frame **1206e** can be at least partially covered by a thin membrane (partially removed to show tubular section **1250c**) (e.g., between about 10 microns and about 30 microns thick) (see FIG. 13A). The membrane should be sufficiently thick to facilitate occlusion, while still minimizing the profile of the collapsed occlusion device **1200e**. Possible materials for the membrane can include PTFE, PET, silicone, latex, TecoThane, nylon, PET, Carbothane (Bionate), fluoropolymers (e.g., PVDF), SIBS, TecoFlex, Pelletane, Kynar, or PLGA.

[0237] As described below, the membrane (not shown) can be applied to the expandable frame **1206e** in a manner that encapsulates at least some of the struts **1210e**, such that the membrane **1208e** is present along either or both an interior surface and an exterior surface of the expandable frame **1206e**. Possible methods of applying the membrane **1208e** are described in further detail below.

[0238] The membrane can cover a portion of the occlusion device **1200e** that is concave to the direction of the blood flow, which can be more occlusive and resist more migration

than occlusion devices that only coat a surface convex to the direction of the blood flow or coat the entire occlusion device or coat the entire occlusion device. For example, the membrane **1208e** can cover at least a portion of or the entire the second end portion **1204e** and the first end portion **1202e** can be a bare frame. When the bare first end portion **1202e** is deployed before the covered second end portion **1204e**, the bare first end portion **1202e** can at least partially anchor the occlusion device **1200e** in the vessel and allow visualization before deploying the covered second end portion **1204e**, which facilitates precise placement of the occlusion device **1200c**.

[0239] The membrane can extend to form a thin extended tubular section of coating **1250e** through which the guidewire (e.g., a 0.018" guidewire) can be introduced (see FIGS. 13A). The thin tube **1250e** acts like a valve (e.g., a duckbill valve) to occlude the guidewire lumen **1252e** and aid in the capture and formation of clots. An end portion **1251e** of the thin tube **1250e** can have a reduced diameter compared to a remaining portion of the thin tube **1250e** to facilitate the closing of the valve. The thin tube **1250e** can include a portion **1253e** that tapers toward the reduced diameter end portion **1251e**.

[0240] The central portion **1205e** enables the occlusion device **1200e** to bend around approximately a 90 degree bend at a vessel bifurcation according to the Trackability Protocol described below (e.g., in a simulated 3 mm vessel having a 7.5 mm radius to centerline of vessel or in a simulated 8 mm vessel having a 20 mm radius to centerline of vessel). The central portion **1205e** can include flexibility features to increase the flexibility of the occlusion device **1200c**. For example, the thickness of the struts **1210e** near or at the central portion **1205e** can be less than the thickness of the struts **1210e** near or at the ends of the occlusion device **1200c**.

[0241] FIGS. 14A-14C illustrate another embodiment of a vascular occlusion device. The vascular occlusion device can have any of the features recited in the above-mentioned vascular occlusion devices.

[0242] As shown in FIG. 14A, the vascular occlusion device **1400** can include an expandable frame **1406**. The expandable frame **1406** can include an upstream lobe **1404** and a downstream lobe **1402** separated by a neck portion **1405**. The upstream lobe **1404** is sometimes referred to herein as an upstream portion, a proximal portion, proximal lobe, occlusive portion, or likewise. The downstream lobe **1402** is sometimes referred to herein as a downstream portion, a distal portion, a distal lobe, anchoring portion, or likewise. The neck portion **1405** is sometimes referred to herein as a central portion or likewise.

[0243] The upstream lobe **1404** can include a concave configuration that is concave in a direction opposite or away from a concave configuration of the downstream lobe **1402**. As shown in FIG. 14A, the expandable frame can be generally asymmetric in that the upstream lobe **1404** can be longer in a longitudinal direction than the downstream lobe **1402**. Although, in other configurations, the downstream lobe **1402** can be longer than the upstream lobe **1404** or the expandable frame **1406** can be generally symmetrical in that the upstream lobe **1404** and the downstream lobe **1402** can be about the same length.

[0244] The neck portion **1405** can be expandable and/or flexible. For example, as shown in FIG. 14A, the neck portion **1405** can include a cell structure enables expansion.

Different configurations of neck portions that facilitate expansion and/or flexibility are described in more detail in U.S. Publication No. 2015/0039017, titled "METHODS AND DEVICES FOR ENDOVASCULAR EMBOLIZATION," which is hereby incorporated by reference in its entirety herein. In other configurations, the neck portion **1405** may not be expandable and may, for example, be formed by a section of hypotube or other tubular structure. The neck portion **1405** can include a guidewire opening or other through-hole that provides access between the downstream lobe **1402** and the upstream lobe **1404**.

[0245] At least the upstream lobe **1404** of the frame **1406** can carry a covering **1408** (also referred to herein as a cover or a membrane). As shown in FIG. 14A, the covering **1408** can be carried entirely by (e.g., supported by or likewise) the upstream lobe **1404**. However, in other configurations at least a portion of the covering **1408** may be carried by the downstream lobe **1402** and/or the neck portion **1405**.

[0246] The covering **1408** can include a tubular portion **1450** having a lumen at least partially aligned with the guidewire opening of the neck portion **1405**. The tubular portion **1450** can be configured to transition between an open configuration in which the tubular portion **1450** is configured to receive a guidewire and a closed configuration in which the tubular portion **1450** is configured to occlude blood flow therethrough, e.g., by collapsing inward and/or by folding over.

[0247] The tubular portion **1450** can be integrally formed with a remaining portion of the covering **1408**. Although, in other configurations, the tubular portion **1450** may be separately formed and attached to the remaining portion of the covering **1408** and/or frame **1406**.

[0248] As shown in FIG. 14B, the tubular portion **1450** can include a reinforced portion **1450a** anchored at its distal end with respect to the expandable frame **1406** and a free portion **1450b** extending proximally into upstream lob **1404**. The reinforced portion **1450a** can extend along a majority of a length of the tubular portion **1450** from the distal end in a proximal direction. For example, the reinforced portion **1450a** can extend along between about 50% and about 75% of a length of the tubular portion **1450**, between about 60% and about 85% of a length of the tubular portion **1450**, or more. The reinforced portion **1450a** can be integrally formed with the free portion **1450b**. However, in other configurations, the reinforced portion **1450a** and the free portion **1450b** may be separately formed and attached to each other. For example, the free portion **1450b** may be a valve that is separately attached to a tubular reinforced portion **1450a**. The valve may be an elastomeric valve, such as a duckbill valve or an umbrella valve, or the valve may be a metal valve, such as a nitinol spring clip.

[0249] The tubular portion **1450** can extend in an upstream direction and at least partially through the upstream lobe **1404**, such that the free portion **1450b** extends upstream of the reinforced portion **1450a** (see FIG. 14B). As explained further below, the tubular portion **1450** can extend in the upstream direction prior to deployment and post-deployment. Although, in other configurations, the tubular portion **1450** may extend in the downstream direction prior to deployment and in the upstream direction post-deployment, or vice versa.

[0250] A wall thickness of at least a distal portion of the reinforced portion **1450a** can be at least 2× (or at least 3×, 4×, 5×, or more) greater than a minimum wall thickness of

the free portion **1450b**. The wall thickness of each of the reinforced portion **1450a** and the free portion **1450b** can be generally uniform along a length of that portion. The transition in wall thickness between the anchored portion and the free portion can be a stepped transition. However, in other configurations, the change in thickness can be gradual. The thicker wall of the reinforced portion **1450a** can prevent inversion of the tubular portion **1450** at least at pressures of at least about: 20 mmHg, 50 mmHg, 80 mmHg, 120 mmHg, or 150 mmHg. The thinner wall portion of the free portion **1450b** can facilitate closure or occlusion of the free portion **1450b** at least at pressures of less than or equal to about 150 mmHg, 120 mmHg, 80 mmHg, 50 mmHg, or 20 mmHg.

[0251] To further prevent inversion at the reinforced portion **1450a** and/or facilitate closure or occlusion of the free portion **1450b**, an average density of the wall of the reinforced portion **1450a** can be greater than an average density of the wall of the free portion **1450b**, e.g., at least about 5× greater, 8× greater, or 10× greater. In some configurations, the reinforced portion **1450a** and the free portion **1450b** can differ in other respects. For example, the reinforced portion **1450a** can be non-porous, while the free portion **1450b** can be porous. As another example, the reinforced portion **1450a** can be substantially homogenous, while the free portion **1450b** is not homogenous.

[0252] The tubular portion **1450** can be tapered such as from a larger diameter to a smaller diameter in the upstream direction and across at least a majority of a length, substantially the entire length, or the entire length of the tubular portion **1450**. As shown in FIG. 14B, the tubular portion **1450** can be generally tapered from the anchor portion **1450a** to the free portion **1450b**. The tubular portion **1450** can be tapered at an angle of less than about: 15 degrees, 10 degrees, or 5 degrees, such as between about 0 degrees and about 4 degrees.

[0253] A diameter of the tubular portion **1450** can be between about 0.04" and about 0.08" at the downstream end and between about 0.03" and about 0.05" at the upstream end. A length of the tubular portion **1450** in the longitudinal direction can be between about 0.31" and about 0.35". A ratio between a length of the tubular portion **1450** and a length of the upstream lobe **1404** can be between about 1:2 and about 3:2. For example, the length of the tubular portion **1450** can be about the same as the axial length of the upstream lobe **1404**. As another example, the length of the tubular portion **1450** can be at least about 50% or at least about 75% of the length of the upstream lobe, or greater than the length of the upstream lobe **1404**, such that an end of the tubular portion **1450** extends outward of an open end of the upstream lobe **1404**.

[0254] As mentioned above, the covering **1408** can be carried by at least the interior surface, exterior surface, or both the interior and exterior surface of the upstream lobe **1404**. The covering **1408** can extend from a junction **1407** between the neck portion **1405** to the open end of the upstream lobe **1404**. The covering **1408** can include a first portion **1408a** extending from the junction **1407** to a shoulder portion **1409** of the upstream lobe **1404** and a second portion **1408b** extending from the shoulder portion **1409** toward or to the open end of the upstream lobe **1404**. The first portion **1408a** and the second portion **1408b** can be porous or woven to provide flexibility and prevent tearing when the expandable structure **1406** expands. The expansion ratio can be at least about: 5:1, 6:1, 7:1, or more. A wall

thickness of the first portion **1408a** can be thicker than a wall thickness of the second portion **1408b** and/or a wall thickness of the reinforced portion **1450a**, e.g., at least about 3x, 5x, or 10x thicker.

[0255] Although the above described occlusion device **1400** is described with a tubular portion **1450** that may fold over to occlude blood flow or include a valve that occludes blood flow through the tubular portion **1450**, the occlusion device and/or delivery system may include alternative or additional features to facilitate closure of the tubular portion **1450** (if present) or other guidewire lumen or opening.

[0256] In some embodiments, the occlusion device **1400** may include a valve instead of the tubular portion **1450**. The valve can be configured to occlude the guidewire opening in the neck portion **1405** when the guidewire is removed. The valve may be an elastomeric valve, such as a duckbill valve or an umbrella valve, or the valve may be a metal valve, such as a nitinol spring clip.

[0257] In some embodiments, the neck portion **1450** may be pre-deformed to a closed configuration (e.g., to occlude the guidewire opening). Prior to delivering the occlusion device **1400**, the occlusion device **1400** can be loaded into the delivery system with an elongate support tube or other tubular structure extending through the neck portion **1450**. The support tube can maintain the guidewire opening in an open configuration so the occlusion device **1400** can be advanced over a guidewire. When the elongate support tube is removed, the neck portion can collapse to the pre-deformed, closed configuration. For example, with a nitinol frame, the neck portion **1450** can be heat set to a closed configuration.

[0258] In some embodiments, the occlusion device **1400** may include an inflatable member within the tubular portion **1450** or the neck portion **1405**. After the occlusion device **1400** has been delivered to the target site, the inflatable member may be inflated to occlude the tubular portion **1450** or neck portion **1405**. The delivery system may include an inflation lumen to inflate the inflatable member after the guidewire is removed.

[0259] In some embodiments, the guidewire or elongate support tube extending through the guidewire opening may support (e.g., external to the guidewire or elongate support tube) a plug or other occluding element distal to the occlusion device **1400**. After the occlusion device **1400** has been delivered to the target site, the guidewire or elongate support tube may be retracted. As the plug reaches the tubular portion **1450** or guidewire opening, the plug can be deposited to occlude the tubular portion **1450** or guidewire opening and removed from the guidewire or elongate support tube.

[0260] Although the embodiment shown in FIGS. 14A-14C is described with respect to an expandable frame having downstream and upstream lobes **1402**, **1404** with opposing concave configurations, any features of the covering **1408** can be used with any of the expandable frame structures described herein or in U.S. Publication No. 2015/0039017, titled "METHODS AND DEVICES FOR ENDOVASCULAR EMBOLIZATION," which is hereby incorporated by reference in its entirety. For example, the covering **1408**, with or without the tubular portion **1450**, can be applied to an expandable frame in which the concave configurations of an upstream portion and a downstream portion face each other (see e.g., FIGS. 9A-9C). The expandable frame may include guidewire openings at either end of the expandable

frame, such that the expandable frame may be delivered over a guidewire. The covering 1408 can be supported by the downstream and/or the upstream portion. Any of the alternative features described above for occluding a guidewire lumen or opening in the neck portion 1405 of occlusion device 1400 may also be used to occlude guidewire openings in the alternative frame configurations.

[0261] Any of the alternative frame configurations may also include an inner tubular structure extending through the expandable frame that serves as a guidewire lumen. The inner tubular structure may be occluded using any of features described above. For example, the inner tubular structure may be pre-deformed to a collapsed configuration. The delivery system can include an elongate support tube or tubular structure that maintains the inner tubular structure in an open configuration during delivery. When the inner tubular structure is removed, the inner tubular structure can collapse to the pre-deformed, closed configuration.

[0262] The occlusion device 1400 can be deployed using any of the delivery systems described herein or in U.S. Publication No. 2015/0039017, titled "METHODS AND DEVICES FOR ENDOVASCULAR EMBOLIZATION," which is hereby incorporated by reference in its entirety.

[0263] In use, the delivery system may be advanced over a guidewire and into a target vessel. The delivery system may carry the occlusion device 1400 in a collapsed configuration by extending a support shaft longitudinally through the occlusion device and/or by interfacing with markers 1442 of the occlusion device. As shown in FIG. 14A, one or more markers 1442 may be positioned at proximal or distal end of the device, e.g., the markers 1442 may be press-fit onto the strut endings of the expandable frame 1406. The markers 1442 may have eyelets or any other feature described in U.S. Publication No. 2015/0039017, titled "METHODS AND DEVICES FOR ENDOVASCULAR EMBOLIZATION," which is hereby incorporated by reference in its entirety herein. These markers 1442 may be radiopaque and provide visual guidance of the ends of the expandable frame 1406. These markers 1442 may form an interference fit with an interference feature of the delivery system.

[0264] While the delivery system is being advanced to the target vessel, the tubular portion 1450 extends upstream and through the upstream lobe 1404 with the guidewire extending through the tubular portion 1450. When the occlusion device 1400 is properly positioned, the occlusion device 1400 can be expanded by retracting an outer sheath and/or by advancing the support shaft to remove the radial restraint. Depending on the delivery system, if the occlusion device 1400 is improperly positioned, it may be possible to re-collapse the occlusion device 1400. For example, if the markers 1442 at a proximal end of the occlusion device 1400 form an interference fit with an interference feature of the delivery system. The occlusion device 1400 may be proximally retracted back into the delivery sheath. The occlusion device 1400 may be re-collapsed so long as the markers 1442 have not been released from the interference feature.

[0265] After the occlusion device has been released, the delivery system and the guidewire may be withdrawn. As the guidewire is removed from the tubular portion 1450, the tubular portion 1450 continues to extend in the upstream direction and through the upstream lobe 1404. Once the guidewire is removed, the tubular portion 1450 transitions from an open configuration with a thru-lumen to a closed

configuration in response to arterial pressure in which the tubular portion 1450 occludes blood flow at pressures of at least about: 20 mmHg, 50 mmHg, 80 mmHg, 120 mmHg, 150 mmHg, or ranges inbetween. For example, as shown in FIG. 14C, the tubular portion 1450 may occlude blood flow by collapsing the free portion 1450b. A wall thickness of the free portion 1450b is sufficiently thin that the walls of the free portion 1450b collapse inward to occlude the tubular portion. Additionally or alternatively, the tubular portion 1450 may fold over, e.g., at a position between an anchored end and a free end of the tubular portion 1450, to further occlude blood flow through the tubular portion 1450.

[0266] In an alternative configuration, the delivery system may be advanced over a guidewire without advancing the occlusion device over the guidewire. For example, the delivery system may include an outer catheter with a single lumen. When the delivery system is advanced over the guidewire, the guidewire is positioned radially outward of the occlusion device or radially between the occlusion device and the outer catheter when the occlusion device is positioned at a distal portion of the outer catheter. As another example, the delivery system may include an outer catheter with at least two lumens. The guidewire may extend through a first lumen, while the occlusion device is advanced through or positioned in a second lumen.

Radiopacity

[0267] As shown in FIG. 12A, a tubular marker 1214a can be positioned around a central portion 1205a, such that the expanded first and second end portions 1202a, 1204a prevent migration of the tubular marker 1214a.

[0268] The shape of the expandable frame fully constrains the tubular marker without crimping the marker to the frame, which reduces stress applied to the underlying frame. Further, since the diameter of the tubular markers is no greater than the outer diameter of the occlusion device, the tubular markers do not increase the delivery profile of the occlusion device. In certain aspects, a coating can be applied over the tubular markers.

[0269] In some embodiments, at least one radiopaque marker (e.g., two, three, or four) can be positioned (e.g., crimped, press-fit) on at least one end of the expandable frame. For example, one radiopaque marker 1214' can be positioned at the second end portion 1204' of the occlusion device 1200a', and another radiopaque marker can be positioned at the second end portion of the occlusion device (not shown). Positioning these markers on the ends of an occlusion device having expanding ends (e.g., occlusion device 1200a-1) facilitates visualization of the occlusion device moving between the compressed and expanded configurations. FIGS. 2Q and 2R illustrate another occlusion device O having markers 242' press-fit onto strut endings of the occlusion device O. The markers 242' can include an aperture 246' and a neck portion 244' (e.g., a lollipop shape) to facilitate certain retraction capabilities, as described above.

[0270] In some embodiments, a fine radiopaque powder can be added to the membrane material to make the entire coating visible. Integrating the radiopaque marker into the coating eliminates the manufacturing step of having to secure a marker to the occlusion device. Alternatively, the fine radiopaque powder can be painted onto the occlusion device or the occlusion device can be dipped into the radiopaque powder.

Methods of Coating the Expandable Frame

[0271] In any of the occlusion devices described above, a membrane can be deposited at least substantially uniformly using an electrospinning process. Further, using an electrospinning process, the porosity can be controlled of the membrane can be controlled to achieve different properties. For example, the membrane can be formed having sufficient tensile strength to resist yielding, stretching, or breaking under at least normal blood pressures, preferably at least about 140 mmHg or 160 mmHg. Further, the fibers forming the membrane can have a cross-sectional diameter between about 5 microns and about 25 microns, such that the membrane can be elongated at least about two to five times greater with 25%-75% less force than that of the native material having the same thickness. An average pore size can be less than or equal to about 100 microns or less than or equal to about 50 microns. Additionally, the coated occlusion device can weigh less than or equal to about 1 gram, preferably less than or equal to about 0.6 grams.

[0272] In general, the expandable frame can be coated by applying a dissolved polymer onto the expandable frame to encapsulate at least some of the struts or strands. The membrane material can be heated to form a viscous liquid solution that is placed in a syringe. The membrane material can be advanced by a piston or plunger through a nozzle having one or more outlets, where the material flows out onto a rotating mandrel as fine fibers. The fine fibers can form a fibrous mat or covering of biocompatible covering material on the rotating mandrel. As the membrane material cools, the fibers solidify, and adjacent, contacting fibers are sintered to one another. Controlling the number of layers of fiber that are applied to the rotating mandrel provides control over the porosity of membrane.

[0273] The method can include providing a mandrel in the shape of the expandable frame. Optionally, portions of the mandrel can be masked to outline the form of an inner coating. Thereafter, an inner coating can be applied to the mandrel using an electrospinning process. When the inner coating is complete, the expandable frame can be positioned over the inner coating, such that the expandable frame is in intimate contact with the inner coating. If portions of the expandable frame are intended to remain uncovered, those uncovered portions can be masked before application of the outer coating. For example, the expandable frame can be masked by loading uncovered portions of the expandable frame into a tube. The outer coating can adhere to the inner coating to form a single coating that encapsulates at least some of struts or strand portions.

[0274] Depending on the membrane material, application of the inner coating to the membrane may be unnecessary. For example, if the membrane includes Kynar, a single outer coating can be applied to the expandable frame without the use of a mandrel. The single outer coating can flow around the struts or strands to encapsulate and adhere to the struts or strands. Application of the outer coating alone can also be useful for occlusion device designs that may be difficult to position on a mandrel.

[0275] The suitability of the membrane can be determined using a number of factors. For example, when visually inspecting the membrane, the membrane should not include any cuts, tears, or large gaps. Further, for at least a Kynar membrane, the membrane should be white or opaque, which suggests that the membrane has a porosity and that the membrane is sufficiently flexible. As another example, the

coated occlusion device should allow less than or equal to about 200 cc/min at 20 mmHg, such as to between about 50 cc/min and about 150 cc/min, preferably less than about 130 cc/min, less than about 100 cc/min at 20 mmHg or less than about 65 cc/min at 20 mmHg within about five minutes. Further, the occlusion device 1200a can limit the flow rate through a vessel to no more than about 400 cc/min at 60 mmHg or no more than about 330 cc/min at 60 mmHg, such as to between about 150 cc/min and about 250 cc/min, preferably less than or equal to about 175 cc/min at 60 mmHg within about five minutes. The occlusion device 1200a can limit the flow rate through a vessel to about no more than 600 cc/min at about 100 mmHg or 430 cc/min at about 100 mmHg, such as to between about 200 mmHg and about 250 mmHg, preferably less than about 225 cc/min at about 100 mmHg within about five minutes, according to the Occlusion Protocol described below. Additionally, the force to load the coated occlusion device should be less than or equal to about 0.5 lbs.

[0276] In some embodiments, the mandrel can have a thin, elongated section that extends through the center of the occlusion device. When the membrane 1208a is formed, the coating can be applied to the elongated section to produce a thin extended tubular section of coating 1250a through which the guide wire (e.g., a 0.018" guidewire) can be introduced (see 13A). Further, depending on the membrane material, the elongated inner mandrel can help eliminate irregular buildup of coating on the mandrel. The elongated mandrel can also aids in reducing stray charges from carrying the coating away from the mandrel.

[0277] In any of the embodiments disclosed herein configured for over the wire delivery, a small (e.g., approximately 0.020") aperture will remain in the membrane following removal of the guide wire. Occlusion will be primarily mechanical due to the membrane, but a small blood flow through the guidewire aperture will gradually stop via natural biological mechanisms. It may be desirable to achieve rapid, essentially completely mechanical occlusion, which can be done by mechanically patching the aperture. This can be accomplished in any of a variety of ways, by placing an occluder across the aperture. The occluder may take the form of a flap of material attached to the membrane or frame or a plug that is forced by blood flow into or across the opening following retraction of the guidewire.

Method of Delivering an Occlusion Device

[0278] The occlusion devices described herein can be advanced to the target vessel using any of the delivery systems described herein. In use, the access to the vasculature can be provided using conventional techniques through an incision on a peripheral artery, such as right femoral artery, left femoral artery, right radial artery, left radial artery, right brachial artery, left brachial artery, right axillary artery, left axillary artery, right subclavian artery, or left subclavian artery. An incision can also be made on right carotid artery or left carotid artery in emergencies.

[0279] The guide wire 128 (e.g., 0.018" guidewire or smaller) can be delivered to the target vessel. Thereafter, the delivery system 100, 200 can be delivered over the guide wire 128 to the target vessel with sufficient trackability as defined herein. The outer catheter 110, 210 (e.g., 5F or smaller) and the inner catheter 120, 220 can be delivered together with the occlusion device pre-loaded into the deliv-

ery system 100, 200. Alternatively, the outer catheter 110, 210 can be delivered first, followed by the inner catheter 120, 220 carrying the occlusion device. Once the delivery system 100, 200 has been delivered to the target vessel, the inner catheter 120, 220 can move axially until the occlusion device extends from the distal end 114, 224 of the outer catheter 110, 220, as shown in FIG. 3A. In some embodiments, the outer catheter 110, 210 can include features shown in FIG. 1B-1 or 2N to deliver contrast dye and monitor performance of the occlusion device. In some instances, after the performance assessment, it may be necessary to resheathe and reposition the occlusion device to position the occlusion device accurately.

[0280] The occlusion device can be released from the delivery system 100, 200 using any of the techniques described above or any other conventional technique (see e.g., FIGS. 2A to 2K and related discussion). Alternatively, as shown in FIGS. 3D-3F, the support tube 134 can move axially to push the occlusion device off the inner catheter 120. Alternatively, the delivery system 100 may utilize any of the interlock assemblies 150, 170, or 180 described herein.

[0281] As described above, in some embodiments, the occlusion device can include one opened end and one closed end (e.g., covered, structurally closed, or otherwise blocked). In some instances, the closed end can be downstream from the opened end. Preferably, the closed end would be on the upstream end of the device. This would have the tendency to minimize "wind-socking" of the device due to blood flow forces and would permit the open downstream end to act as an anchor. Blood pressure on the occluded upstream end would have the effect of foreshortening the device frame, which would secondarily cause an expansion of the distal end accentuating the anchoring force of the device. This effect is particularly evident in a braided frame in which the downstream end is open.

[0282] In other embodiments, the occlusion device can include an hourglass design (see, e.g., FIG. 12A or 13A). As described above, it can be preferable to deploy a bare, distal portion prior to deploying a covered, proximal portion. The bare end portion can at least partially anchor the occlusion device in the vessel before deploying the covered second end portion, which facilitates precise placement of the occlusion device. Further, when the covered end portion is upstream (i.e., proximal) from the bare end portion, the increase in arterial pressure at the proximal end increases the radially outward forces that can help the occlusion device resist migration.

[0283] In some instances, as shown in FIG. 2S, the delivery system can include a test balloon 132. Prior to deploying the occlusion device O, the test balloon 132 can be inflated through inflation lumen 134 to occlude the vessel temporarily. After the occlusion device O is delivered, the test balloon 132 can be deflated, and the delivery system can be withdrawn.

[0284] In certain variants, the occlusion device can be reinforced using other reinforcing devices or techniques. For example, one or more coils can be deployed within the expandable structure. As another example, the expandable structure can be reinforced with an occlusion balloon. In yet another example, the method can include ligation to close off the target vessel.

[0285] The performance characteristics of the present disclosure are verified using a series of in vitro test protocols,

including: (1) Delivery, Deployment, and Retraction Test Protocol; (2) Acute Migration Test Protocol; (3) Occlusion Effectiveness Test Protocol; and (4) Contrast injection Test Protocol. The details of the test protocols are disclosed in U.S. patent application Ser. No. 14/449,037 to Cragg et al., the disclosure of which is hereby incorporated by reference in its entirety herein.

Methods of Providing a Primary Occlusion Device and a Secondary Treatment

[0286] A common delivery system may be used to provide a primary treatment with an occlusion device and provide one or more secondary treatments, which may include delivering a therapeutic agent (see FIGS. 15A to 15D) or providing the secondary treatment with a treatment instrument (see FIGS. 16A to 16D). The occlusion device used in the primary treatment may include any of the features of the occlusion devices described above. Possible therapeutic agents include, but are not limited to, bland particles and/or beads, radioactive particles, drug eluting beads, liquids, gels, or otherwise. The secondary treatment may include embolic coils or ablation therapy.

[0287] As shown in FIGS. 15A, the delivery system 1510 may include an outer body 1514 and an inner body 1512 with one or more through-lumens. The inner body 1512 may be disposed within the outer body 1514. The one or more through-lumens may allow for tracking over a pre-placed guidewire, delivery of therapeutic agent, and/or deliver of a treatment instrument. The one or more through-lumens may also provide a passageway for contrast media to enable the clinician to visualize immediate occlusion during the procedure under fluoroscopy. In some implementations, the inner body 1512 may include a single lumen to provide each of these functions. In other implementations, the inner body 1512 may include multiple lumens, for example a guidewire lumen and a separate lumen for the delivery of therapeutic agent and/or advancement of a treatment instrument.

[0288] The occlusion device 1500 may be pre-loaded in the delivery system 1510 prior to introducing the delivery system 1510 into the patient. The occlusion device 1500 may be carried by the inner body 1512 in a position between the inner body 1512 and the outer body 1514. The outer body 1514 may radially constrain or compress the occlusion device 1500. The occlusion device 1500 may interface with the inner body 1512 using one or more interlocking features. The occlusion device 1500 may remain interlocked with the inner body 1512 until the entire occlusion device 1500 has been released from the outer body 1514.

[0289] As shown in FIGS. 15B to 15D, the occlusion device 1500 may include an expandable frame. The occlusion device 1500 may include a downstream portion 1502 and an upstream portion 1504. The downstream portion 1502 may be configured to anchor the occlusion device 1500. The upstream portion 1504 may be configured to provide occlusion. For example, the expandable frame may carry an occlusive membrane along at least a portion of the upstream portion 1504. The downstream portion 1502 may be separated from the upstream portion 1504 by a neck portion 1505. Although the occlusion device 1500 is described with respect to a downstream portion 1502 and an upstream portion 1504, features of the downstream portion 1502 and the upstream portion 1504 are interchangeable.

[0290] The upstream portion 1504 may include a concave configuration that is concave in a direction opposite or away

from a concave configuration of the downstream portion **1502**. The expandable frame may be generally asymmetric. For example, the upstream portion **1504** may be longer in a longitudinal direction than the downstream portion **1502**. In other configurations, the downstream portion **1502** may be longer than the upstream portion **1504**, or the expandable frame may be generally symmetrical in that the upstream portion **1504** and the downstream portion **1502** may be about the same length.

[0291] The neck portion **1505** may be expandable and/or flexible. For example, the neck portion **1505** may include a cell structure enables expansion. In other configurations, the neck portion **1505** may not be expandable. For example, the neck portion **1505** may be formed by a section of hypotube or other tubular structure. The occlusion device **1500** can include a guidewire opening or other through-hole, for example through the neck portion **1505** for access between the downstream portion **1502** and the upstream portion **1504**.

[0292] Similar to the occlusion device **1400**, the occlusive membrane may include a collapsible portion having a lumen at least partially aligned with the opening of the neck portion **1505**. The collapsible portion can be configured to transition between an open configuration in which the tubular portion is configured to receive a guidewire and a closed configuration in which the collapsible portion is configured to occlude blood flow therethrough, e.g., by collapsing inward and/or by folding over. The collapsible portion can extend in an upstream direction and at least partially through the upstream portion **1504**. In other configurations, the occlusion device **1500** may include a valve or other feature to occlude blood flow through the opening of the neck portion **1505**.

[0293] The occlusion device **1500** may include one or more radiopaque markers positioned at proximal or distal end of the device. These radiopaque markers may provide visual guidance of the ends of the expandable frame.

[0294] In use, the delivery system **1510** may be advanced into a target vessel (see FIG. 15A), for example over a guidewire or through an access catheter. The delivery system **1510** may carry the occlusion device **1500** by extending the inner body **1512** longitudinally through the occlusion device **1500** and/or by interfacing with the radiopaque markers on the occlusion device **1500**. The inner body **1512** may extend through an opening of the occlusion device **1500**. For example, the inner body **1512** may extend through the collapsible portion of the occlusive membrane in the upstream portion **1504**, through the opening of the neck portion **1505**, and through the downstream portion **1502**. The distal end of the inner body **1512** may extend distally beyond the downstream end of the occlusion device **1500**.

[0295] Once the delivery system **1510** reaches the vessel, the occlusion device **1500** can be at least partially deployed from the outer body **1514** of the delivery system **1510** (see FIG. 15B). The occlusion device **1500** may be expanded by retracting the outer body **1514** and/or by advancing the inner body **1512** to remove the radial restraint. As the occlusion device **1500** is released from the outer body **1514**, the downstream portion **1502** begins to expand. If the occlusion device **1500** is improperly positioned, it may be possible to re-collapse the occlusion device **1500** back into the outer body **1514**. As the upstream portion **1504** is released from the outer body **1514**, the upstream portion **1504** begins to expand (see FIG. 15C). During deployment, a distal end of

the inner body **1512** may extend beyond the opening in the neck portion **1505** of the occlusion device **1500**. The distal end of the inner body **1512** may extend into the downstream portion **1502** of the occlusion device **1500** or distally of the downstream end of the occlusion device **1500**.

[0296] At any point during the procedure, a therapeutic agent **1520** (e.g., bland particles, beads, radioactive particles, and/or chemotherapy drug eluting beads) may be delivered from the through-lumen of the inner body **1512**. The therapeutic agent **1520** may be released from the opening at the distal end of the inner body **1512**. For example, the therapeutic agent **1520** may be delivered prior to deployment of the occlusion device **1500** (see FIG. 15A), after partial deployment of the occlusion device **1500** (see FIG. 15B), and/or after full deployment of the occlusion device **1500** (see FIG. 15C). As shown in FIG. 15C, the therapeutic agent **1520** may be delivered from the through-lumen of the inner body **1512**, while the inner body **1512** extends through the occlusion device **1500**. Prior to delivering the therapeutic agent **1520**, the guidewire may be withdrawn from the inner body **1512** to increase fluid flow through the through-lumen of the inner body **1512**. The therapeutic agent **1520** may be delivered downstream of the opening in the neck portion **1505** of the occlusion device **1500**. The therapeutic agent **1520** may be delivered in the downstream portion **1502** of the occlusion device **1500** or distally of the downstream end of the occlusion device **1500**. Once the therapeutic agent **1520** has been released into the vessel, the therapeutic agent **1520** may remain generally in the region of delivery or travel downstream to a target site. Reflux of the therapeutic agent **1520** may be prevented by the upstream portion **1504** of the occlusion device **1500**. For example, reflux of therapeutic agent **1520** may be prevented by the downstream face of the occlusive membrane and/or the collapsible portion. Delivery of the therapeutic agent **1520** while the blood flow is arrested provides local delivery of the agent in a denser dose and prevents dilution of the agent as is experienced with systemic delivery. Delivery of the agent while flow is blocked can prevent the blockage of collateral blood flow. Embolization prevents distribution of therapeutic agent to non-target locations.

[0297] In some methods, embolic coils or other secondary treatment devices can be delivered to other locations prior to the delivery of therapeutic agents, for example downstream or upstream of the occlusion device **1500**. The secondary treatment device may restrict the therapeutic agent **1520** to a region between the secondary treatment device and the occlusion device **1500**.

[0298] After the occlusion device **1500** has been released from the outer body **1514** and the therapeutic agent **1520** has been released, the inner body **1512** may be withdrawn from the opening of the neck portion **1505** and/or the collapsible portion of the occlusive membrane (see FIG. 15D). As the inner body **1512** is withdrawn from the collapsible portion (or other valve structure), the collapsible portion collapses to occlude blood flow through the opening of the neck portion **1505**. After the inner body **1512** has been withdrawn from the occlusion device **1500**, it may be possible to reaccess an opening of the occlusion device **1500** during the same procedure or a separate procedure, particularly if there is a valve structure disposed in the neck portion **1505**. A tubular body may be advanced through the opening of the neck portion **1505** to deliver additional therapeutic agent. As illustrated, the therapeutic agent **1520** may be delivered

downstream of the occlusion device 1500, but in other methods, the therapeutic agent 1520 may be delivered upstream of the occlusion device 1500 after the inner body 1512 has been retracted from the occlusion device 1500. After the inner body 1512 has been withdrawn, the entire delivery system 1510 may be withdrawn leaving the occlusion device 1500 in the vessel.

[0299] Examples of procedures that can utilize the above-described method include, but are not limited to, transarterial chemoembolization (TACE), drug-eluting bead chemoembolization (DEB-TACE), radioembolization (RE), and injection of sclerosants for embolization at the very small-vessel and tissue level. Liver cancer is one example of a disease where this device may be effective as the liver has two blood supplies. The portal vein feeds most of the liver cells. Cancer in the liver is fed by the hepatic artery. The occlusion device 1500 can be deployed in the hepatic artery to cut off the blood supply to the tumor and kill off the cancer cells. The healthy liver cells would still get their blood supply from the portal vein. Additional cancer treatment can be delivered to the tumor in the patient's liver by injecting an agent through the delivery system 1510 to a specific, localized site. This treatment will not be systemic since the blood flow is arrested by the occlusion device 1500.

[0300] FIGS. 16A to 16D illustrate a delivery system 1610 that may be used to deliver an implantable occlusion device 1600 and provide a secondary treatment using a treatment instrument 1622. The delivery system 1610 and the occlusion device 1600 may include any of the features described above. The secondary treatment may be provided upstream or downstream of the occlusion device 1600. As shown in FIGS. 16A, the delivery system 1610 may include an inner body 1612 and an outer body 1614. The occlusion device 1600 may be carried between the inner body 1612 and the outer body 1614. The inner body 1612 may be used as a working channel for the treatment instrument 1622. The treatment instrument 1622 may be an ablation device, for example a steerable ablation needle.

[0301] In use, the delivery system 1610 may be advanced into a target vessel (see FIG. 16A), for example over a guidewire or through an access catheter. The delivery system 1610 may carry the occlusion device 1600 in a collapsed configuration by extending the inner body 1612 longitudinally through an opening of the occlusion device 1600 and/or by interfacing with the radiopaque markers on the occlusion device 1600. For example, the inner body 1612 may extend through the collapsible portion of the occlusive membrane in the upstream portion 1604, through the opening of the neck portion 1605, and through the downstream portion 1602.

[0302] Once the delivery system 1610 reaches the vessel, the occlusion device 1600 can be at least partially deployed from the outer body 1614 of the delivery system 1610 (see FIG. 16B). The occlusion device 1600 may be expanded by retracting the outer body 1614 and/or by advancing the inner body 1612 to remove the radial restraint. As the occlusion device 1600 is released from the outer body 1614, the downstream portion 1602 begins to expand. If the occlusion device 1600 is improperly positioned, it may be possible to re-collapse the occlusion device 1600 in the outer body 1614. As the upstream portion 1604 is released from the outer body 1614, the upstream portion 1604 begins to expand (see FIG. 16C). During deployment, a distal end of the inner body 1612 may extend beyond the opening in the

neck portion 1605 of the occlusion device 1600. The distal end of the inner body 1612 may extend into the downstream portion 1602 of the occlusion device 1600 or distally of the downstream end of the occlusion device 1600.

[0303] At any point during the procedure, an end effector of a treatment instrument 1622 (e.g., an ablation device) may be advanced through the working channel of the inner body 1612. The treatment instrument 1622 may be advanced through the working channel of the inner body 1612, while the inner body 1612 extends through the opening of the neck portion 1605. The end effector of the treatment instrument 1622 may be advanced distally of the downstream end of the occlusion device 1600. The treatment instrument 1622 may be advanced distally of the occlusion device 1600 prior to deployment of the occlusion device 1600 (see FIG. 16A), after partial deployment of the occlusion device 1600 (see FIG. 16B), and/or after full deployment of the occlusion device 1600 (see FIG. 16C). The treatment instrument 1622 may perform a treatment prior to deployment of the occlusion device 1600 (see FIG. 16A), after partial deployment of the occlusion device 1600 (see FIG. 16B), and/or after full deployment of the occlusion device 1600 (see FIG. 16C). Treatment may be provided at one or more time points during a single procedure. Prior to advancing the treatment instrument 1622 through the occlusion device 1600, the guidewire may be withdrawn from the inner body 1612.

[0304] After the occlusion device 1600 has been released from the outer body 1614, the inner body 1612 may be withdrawn from the opening of the neck portion 1605 and, if present, the collapsible portion of the occlusive membrane (see FIG. 16D). As the inner body 1612 is withdrawn from the collapsible portion (or other valve structure), the collapsible portion collapses to occlude blood flow through the opening of the neck portion 1605. After the inner body 1612 has been withdrawn from the occlusion device 1600, it may be possible to reaccess the opening of the occlusion device 1600 during the same procedure or a separate procedure, particularly if there is a valve structure disposed in the neck portion 1605. A tubular body may be advanced through the opening of the neck portion 1605 to deliver additional therapeutic agent. As illustrated, the secondary treatment may be performed downstream of the occlusion device 1600, but in other methods, the secondary treatment may be performed upstream of the occlusion device 1600 after the inner body 1612 has been withdrawn from the occlusion device 1600. After the inner body 1612 has been withdrawn, the entire delivery system 1610 may be withdrawn leaving the occlusion device 1600 in the vessel.

[0305] In some implementations, the treatment instrument 1622 can be used to treat a tumor in combination with the occlusion device 1600 and/or the therapeutic agent 1620. For example, the delivery system 1610 may be used to treat liver cancer. The occlusion device 1600 can be deployed in the hepatic artery to cut off the blood supply to the tumor and kill off the cancer cells. Additionally, the tumor may be treated with ablation therapy using an ablation needle. The ablation needle can be navigated through the inner body 1612 of the delivery system 1610, which extends through the opening of the occlusion device 1600, to provide ablation therapy downstream of the occlusion device 1600. The ablation needle may include an end effector, such as an electrode for RF therapy or an antenna for microwave therapy, for treating a tumor downstream of the occlusion

device. The combination of the occlusion device **1600** and the ablation therapy would improve the overall treatment of the tumor.

Terminology

[0306] Conditional language, such as “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements, and/or steps. Thus, such conditional language is not generally intended to imply that features, elements, and/or steps are in any way required for one or more embodiments, whether these features, elements, and/or steps are included or are to be performed in any particular embodiment.

[0307] The terms “approximately,” “about,” and “substantially” as used herein represent an amount close to the stated amount that still performs a desired function or achieves a desired result. For example, depending on the context, the terms “approximately”, “about”, and “substantially” may refer to an amount that is within less than 10% of, within less than 5% of, within less than 1% of, within less than 0.1% of, and within less than 0.01% of the stated amount.

[0308] The ranges disclosed herein also encompass any and all overlap, sub-ranges, and combinations thereof. Language such as “up to,” “at least,” “greater than,” “less than,” “between” and the like includes the number recited. Numbers preceded by a term such as “about” or “approximately” include the recited numbers. For example, “about 3 mm” includes “3 mm.”

[0309] The ranges provided herein are set forth solely for illustrating typical device dimensions. The actual dimensions of a device constructed according to the principles of the present invention may obviously vary outside of the listed ranges without departing from those basic principles. For example, diameter outside of the preferred ranges may also be used, provided that the functional consequences of the diameter are acceptable for the intended purpose of the catheter. In particular, the lower limit of the diameter for any portion of catheter body **110** in a given application will be a function of the number of fluid or other functional lumen contained in the catheter, together with the acceptable minimum aspiration flow rate and collapse resistance.

[0310] Although certain embodiments and examples have been described herein, it will be understood by those skilled in the art that many aspects of the methods and devices shown and described in the present disclosure may be differently combined and/or modified to form still further embodiments or acceptable examples. All such modifications and variations are intended to be included herein within the scope of this disclosure. A wide variety of designs and approaches are possible. No feature, structure, or step disclosed herein is essential or indispensable.

[0311] Any methods disclosed herein need not be performed in the order recited. The methods disclosed herein include certain actions taken by a practitioner; however, they can also include any third-party instruction of those actions, either expressly or by implication. For example, actions such as “expanding an expandable structure” includes “instructing expansion of an expandable structure.”

[0312] Some embodiments have been described in connection with the accompanying drawings. However, it should be understood that the figures are not drawn to scale. Distances, angles, etc. are merely illustrative and do not

necessarily bear an exact relationship to actual dimensions and layout of the devices illustrated. Components can be added, removed, and/or rearranged. Further, the disclosure herein of any particular feature, aspect, method, property, characteristic, quality, attribute, element, or the like in connection with various embodiments can be used in all other embodiments set forth herein. Additionally, it will be recognized that any methods described herein may be practiced using any device suitable for performing the recited steps.

[0313] For purposes of this disclosure, certain aspects, advantages, and novel features are described herein. It is to be understood that not necessarily all such advantages may be achieved in accordance with any particular embodiment. Thus, for example, those skilled in the art will recognize that the disclosure may be embodied or carried out in a manner that achieves one advantage or a group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein.

[0314] Moreover, while illustrative embodiments have been described herein, the scope of any and all embodiments having equivalent elements, modifications, omissions, combinations (e.g., of aspects across various embodiments), adaptations and/or alterations as would be appreciated by those in the art based on the present disclosure. The limitations in the claims are to be interpreted broadly based on the language employed in the claims and not limited to the examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive. Further, the actions of the disclosed processes and methods may be modified in any manner, including by reordering actions and/or inserting additional actions and/or deleting actions. It is intended, therefore, that the specification and examples be considered as illustrative only, with a true scope and spirit being indicated by the claims and their full scope of equivalents.

1. A method of delivering a therapeutic agent, the method comprising:

advancing a delivery system over a guidewire in a vessel, the delivery system comprising an outer body and an inner body disposed within the outer body, the delivery system carrying an implantable occlusion device between the inner body and the outer body;

at least partially deploying the implantable occlusion device from the outer body of the delivery system; delivering the therapeutic agent from the inner body of the delivery system; and

releasing the implantable occlusion device from the delivery system, wherein after releasing the implantable occlusion device, the occlusion device is configured to occlude blood flow through the vessel.

2. The method of claim 1, wherein delivering the therapeutic agent comprises delivering the therapeutic agent while the inner body extends through an opening of the implantable occlusion device.

3. The method of claim 1, wherein delivering the therapeutic agent comprises delivering the therapeutic agent downstream of the implantable occlusion device.

4. The method of claim 1, further comprising withdrawing the guidewire prior to delivering the therapeutic agent from the inner body.

5. The method of claim 1, wherein delivering the therapeutic agent comprises delivering the therapeutic agent from an opening at the distal most end of the inner body.

6. The method of claim 1, wherein delivering the therapeutic agent occurs prior to at least partially deploying the implantable occlusion device from the outer body of the delivery system.
7. The method of claim 1, wherein delivering the therapeutic agent occurs prior to full deployment of the implantable occlusion device from the outer body of the delivery system.
8. The method of claim 1, wherein delivering the therapeutic agent occurs after full deployment of the implantable occlusion device from the outer body of the delivery system.
9. The method of claim 1, further comprising delivering a treatment device downstream of the occlusion device prior to delivering the therapeutic agent from the inner body.
10. The method of claim 1, wherein at least partially deploying the implantable occlusion device comprises at least partially deploying the implantable device in the hepatic artery, and wherein delivering the therapeutic agent comprises delivering the therapeutic agent to the liver.
11. A method of delivering an implantable occlusion device and providing a secondary treatment, the method comprising:
 - advancing a delivery system over a guidewire in a vessel, the delivery system comprising an outer body and an inner body disposed within the outer body, the inner body comprising a working lumen extending therethrough, the delivery system carrying an implantable occlusion device between the inner body and the outer body;
 - at least partially deploying the implantable occlusion device from the outer body of the delivery system;
 - advancing a treatment instrument through the working lumen of the inner body;
 - providing the secondary treatment using the treatment instrument; and
 - releasing the implantable occlusion device from the delivery system, wherein after releasing the implantable occlusion device, the occlusion device is configured to occlude blood flow through the vessel.
12. The method of claim 11, wherein advancing the treatment instrument comprises advancing the treatment instrument while the inner body extends through an opening of the implantable occlusion device.
13. The method of claim 11, wherein providing the secondary treatment comprises providing the secondary treatment downstream of the implantable occlusion device.
14. The method of claim 11, wherein advancing the treatment instrument occurs prior to at least partially deploying the implantable occlusion device from the outer body of the delivery system.
15. The method of claim 11, wherein advancing the treatment instrument occurs after at least partially deploying the implantable occlusion device from the outer body of the delivery system.
16. The method of claim 11, wherein advancing the treatment instrument occurs after fully deploying the implantable occlusion device from the outer body of the delivery system.
17. The method of claim 11, wherein providing the secondary treatment occurs prior to at least partially deploying the implantable occlusion device from the outer body of the delivery system.
18. The method of claim 11, wherein providing the secondary treatment occurs after at least partially deploying the implantable occlusion device from the outer body of the delivery system.
19. The method of claim 11, wherein providing the secondary treatment occurs after fully deploying the implantable occlusion device from the outer body of the delivery system.
20. The method of claim 11, wherein advancing the delivery system comprises advancing the delivery system to the hepatic artery, and wherein providing the secondary treatment comprises performing ablation therapy on the liver.

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