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(71) Applicant: **CERETRIEVE LTD.** [IL/IL]; 6 HaYetsirah St., 2066722 Yokneam Illit (IL).

(72) Inventors: **MUSTAFA, Maysa**; Zichron Yaakuv (IL). **VASYLEVYTSY, Maxim**; Kfar Saba (IL). **ZIPORY, Yuval**; Modiin (IL). **BELSON, Amir**; Savyon (IL). **LEVI, Yonatan**; Tel Aviv (IL).

(74) Agent: **KAYE, Paul**; IPK Intellectual Property Ltd., Migdal HaMenorah 11, 7176051 Modiin (IL).

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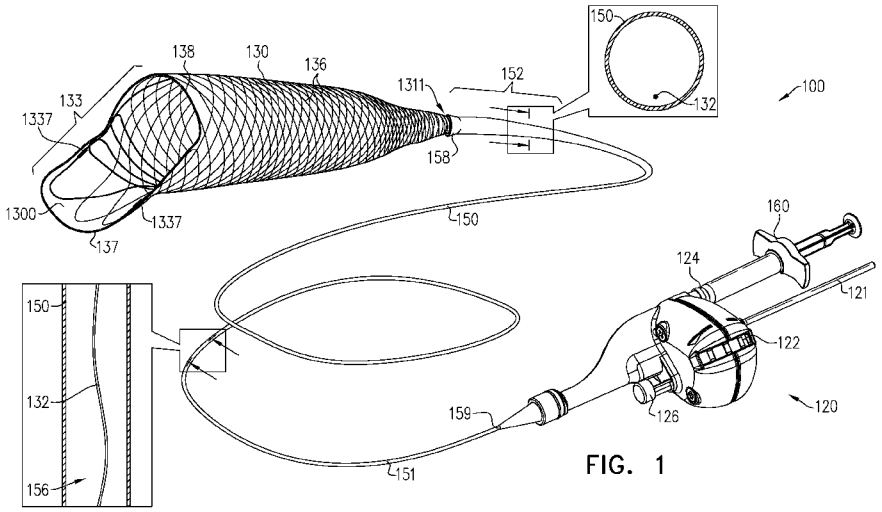

FIG. 1

(57) Abstract: Apparatus (100) for removing an embolus from a cerebral artery comprises (i) a catheter (150), (ii) a funnel (130) that is biased to assume an expanded state in which a mouth (133) of the funnel is wider than a proximal end (1311) of the funnel, (iii) a rod (132), attached to the proximal end of the funnel, and extending proximally through the catheter, and (iv) a handle (120), at a proximal portion of the catheter, the handle comprising: (a) a deployment knob (122), operatively coupled to the rod so as to be manually operable to transition the funnel towards a deployed, expanded state in which the funnel is in sealed engagement with the catheter, such that suction applied through the catheter sucks the embolus into the mouth, and (b) a stabilizer (126), configured to stabilize the apparatus in the deployed state by applying tension to the rod.

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EMBOLUS-RETRIEVAL DEVICE

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] The present application claims priority to Provisional US Patent Application 63/470,906 to Mustafa et al., filed June 4, 2023, which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] Some applications of the present invention relate in general to devices for retrieving an embolus from a blood vessel. More specifically, some applications of the present invention relate to retrieving an embolus from a cerebral blood vessel of a subject.

BACKGROUND

[0003] Vascular diseases caused by blockages of blood vessels are a leading cause of mortality and morbidity.

[0004] A brain embolism is a blockage in a blood vessel within the brain or in an artery that supplies blood to the brain. Blockages can be caused by a blood clot, fat globule, or air pocket within an artery. A brain embolism can cause an embolic stroke which accounts for a large proportion of deaths from vascular disease.

[0005] Interventional procedures are routinely used to treat vascular diseases. Treating vascular blockages located in small and remote vessels such as those within the brain can present a challenge due to navigation and/or the small diameter of the tools required.

[0006] Minimally invasive retrieval of a brain embolus is typically carried out using a retrieval catheter designed for capturing and retrieving the embolus using a mechanical trap and/or suction.

[0007] Although such retrieval devices can be effective in retrieving small clots, retrieval of large clots using suction can lead to trap collapse due to plugging of the trap opening by the clot material. Such collapse oftentimes results in incomplete clot retrieval and clot fragmentation.

[0008] In order to traverse these limitations of suction-assisted clot retrieval, operators oftentimes disconnect the source of suction (syringe or pump) to reverse collapse and then reapply suction in order to attempt to retrieve the clot or completely withdraw the system from the vasculature to unplug the trap and repeat the procedure.

[0009] Thus, there is still room for improvement in clot retrieval systems and in particular in the complete retrieval capabilities of systems utilizing suction.

SUMMARY OF THE INVENTION

[0010] This summary is meant to provide some examples and is not intended to be limiting of the scope of the invention in any way. For example, any feature included in an example of this summary is not required by the claims, unless the claims explicitly recite the features. Also, the features, components, steps, concepts, etc. described in examples in this summary and elsewhere in this disclosure can be combined in a variety of ways. Various features and steps as described elsewhere in this disclosure may be included in the examples summarized here.

[0011] Any of the techniques, methods, operations, steps, etc. described or suggested herein can be performed on a living animal (e.g., human, other mammal, etc.) or on a non-living simulation such as a cadaver, a cadaver heart, an anthropomorphic ghost, and/or a simulator device (which may include computerized and/or physical representations of body parts, tissue, etc.).

[0012] There is therefore provided, in accordance with some implementations, an apparatus for removing an obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject, the apparatus including (i) a flexible catheter, (ii) a funnel, attached to the proximal end of the funnel, (iii) a flexible rod, and/or (iv) a handle, at the proximal portion of the catheter.

[0013] In some implementations, the catheter has (a) a proximal portion, (b) a distal portion that is configured for transluminal advancement into the blood vessel (e.g., cerebral artery), the distal portion having a rim, and/or (c) a lumen, extending from the proximal portion to the rim.

[0014] In some implementations, the funnel has (a) a mouth at a distal end of the funnel, and (b) an opening at a proximal end of the funnel. In some implementations, the funnel is biased to assume an expanded state in which the mouth is wider than the opening and the rim. In some implementations, the funnel is elastically compressible into a compressed state in which the mouth is narrower than in the expanded state.

[0015] In some implementations, the rod is attached to the proximal end of the funnel, and extends proximally through the catheter.

[0016] In some implementations, the handle is at the proximal portion of the catheter, the handle including a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between: (a) a delivery state in which the funnel is in the compressed state within the catheter, and/or (b) a deployed state in which the funnel is in the expanded state, with an outer surface of the funnel being in sealed engagement with the rim, and the mouth is (i) exposed from the distal portion of the catheter, and (ii) fluidically connected to the lumen such that suction applied through the lumen sucks the obstruction (e.g., the embolus) into the funnel via the mouth. In some implementations, the handle includes a stabilizer, discrete from the deployment knob, and configured to stabilize the apparatus in the deployed state by applying tension to the rod.

[0017] In some implementations, the handle is configured to limit distal advancement of the rod in a manner that provides a predetermined limit to distal advancement of the funnel out of the distal portion of the catheter.

[0018] In some implementations, the deployment knob is a thumbwheel.

[0019] In some implementations, the deployment knob is a slider, the deployment knob being operable via sliding of the slider.

[0020] In some implementations, the stabilizer is configured to, upon actuation, inhibit further operation of the deployment knob.

[0021] In some implementations, the catheter includes a hypotube, and a polymeric cover that coats the hypotube, and the polymeric cover extends beyond the hypotube to define the rim.

[0022] In some implementations, a flexibility of the catheter increases progressively distally along the catheter.

[0023] In some implementations, a flexibility of the rod increases progressively distally along the rod.

[0024] In some implementations, the distal portion of the catheter has a curvature that is adjustable by applying an axial force to the rod.

[0025] In some implementations, the distal portion of the catheter is more flexible than the proximal portion of the catheter.

[0026] In some implementations, the distal portion of the catheter has a length of 10-30 cm.

[0027] In some implementations, the distal portion of the catheter is biased toward being curved.

[0028] In some implementations, the apparatus is configured such that a curvature of the distal portion is reducible by positioning the funnel, in its compressed state, within the distal portion of the catheter.

[0029] In some implementations, the rod is coupled to the funnel eccentrically within the lumen, such that distalward pushing of the rod applies an eccentric pushing force to the funnel, which responsively articulates with respect to the rod, thereby increasing the curvature of the catheter.

[0030] In some implementations, the rod is coupled to the funnel eccentrically within the lumen, such that distalward pushing of the rod applies an eccentric pushing force to the funnel, which responsively turns to deflect the distal portion of the catheter.

[0031] In some implementations: (i) the funnel, in its expanded state, has a flared surface distal to the opening, and/or (ii) the stabilizer is configured to stabilize the apparatus by retracting the funnel into the sealed engagement with the catheter by sealing the flared surface against the rim.

[0032] In some implementations, the rim flares distally.

[0033] In some implementations, the catheter is fixedly attached to the handle.

[0034] In some implementations, the catheter is welded onto the handle.

[0035] In some implementations, the rod includes an extracorporeal stopper that provides a predetermined limit to distal advancement of the funnel out of the distal portion of the catheter by limiting distal advancement of the rod through the handle to a predetermined distance.

[0036] In some implementations, the stabilizer is configured such that actuation of the stabilizer pulls the rod proximally by the predetermined distance.

[0037] In some implementations, the stabilizer is manually actuatable independently of the deployment knob.

[0038] In some implementations, the stabilizer includes a button, and is manually actuatable via pushing of the button.

[0039] In some implementations, the handle further includes a port that is fluidically connected to the catheter, the port adapted to receive a suction applicator adapted to apply the suction.

[0040] In some implementations, the apparatus further includes the suction applicator.

[0041] In some implementations, the suction applicator includes a syringe.

[0042] In some implementations, the suction applicator includes a foot-pedal, such that pressing the foot-pedal applies the suction.

[0043] In some implementations, the funnel is constructed from braided wires.

[0044] In some implementations, the braided wires are gathered at the proximal end in an elliptical loop that defines the opening as an elliptical opening.

[0045] In some implementations, the elliptical loop is covered in a polymer coating that reinforces the opening.

[0046] In some implementations, in the sealed engagement, the polymer coating fits snugly within the distal portion of the catheter.

[0047] In some implementations: (i) the funnel has a central longitudinal axis that passes through the mouth and the opening, and/or (ii) the elliptical opening has a major axis that is oblique to the longitudinal axis.

[0048] In some implementations: (i) the elliptical opening has: (a) a distal vertex that lies on the major axis, on a first side of the longitudinal axis, and/or (b) a proximal vertex that lies on the major axis, and is disposed on an opposite side of the longitudinal axis from the distal vertex, proximal from the distal vertex, and/or (ii) the rod is attached to the proximal end of the funnel by being attached to the elliptical opening at the proximal vertex.

[0049] In some implementations, the stabilizer includes a manually-actuatable mechanism that is adapted to stabilize the apparatus in the deployed state by applying tension to the rod upon being manually actuated.

[0050] In some implementations, the stabilizer includes a spring-loaded mechanism that is adapted to stabilize the apparatus in the deployed state by applying tension to the rod.

[0051] In some implementations, the spring-loaded mechanism is adapted to apply the tension to the rod automatically upon cessation of manual operation of the deployment knob.

[0052] In some implementations, the deployment knob is operatable via rotation.

[0053] In some implementations, the handle includes a drivewheel that is engaged with the rod and operatively coupled to the knob, such that rotating the knob in a first knob-direction rotates the drivewheel in a forward drivewheel-direction, thereby pushing the rod distally to progressively transition the apparatus from the delivery state towards the deployed state.

[0054] In some implementations, the drivewheel defines a roller, the rod passing tangentially by the roller.

[0055] In some implementations, the drivewheel defines a spool, the rod wrapped around the spool.

[0056] In some implementations, the drivewheel defines a capstan, the rod curving around the capstan.

[0057] In some implementations, the stabilizer is configured such that actuation of the stabilizer rotates the drivewheel in a reverse drivewheel-direction, thereby pulling the rod proximally.

[0058] In some implementations, the stabilizer is configured with a first position and a second position, and to be actuated by moving the stabilizer from the first position into the second position, such that actuation of the stabilizer rotates the drivewheel by a predetermined discrete amount in the reverse drivewheel-direction, thereby pulling the rod proximally by a predetermined discrete distance.

[0059] In some implementations: (i) the drivewheel has drivewheel teeth, (ii) the stabilizer has sealer teeth, and/or (iii) actuating the stabilizer engages the sealer teeth with the drivewheel teeth and moves the drivewheel in the reverse drivewheel-direction.

[0060] In some implementations, the drivewheel teeth are circumferentially distributed, the sealer teeth are linearly distributed, and actuation of the stabilizer moves the sealer teeth into a rack-and-pinion arrangement with the drivewheel teeth.

[0061] In some implementations, the engagement between the sealer teeth and the drivewheel teeth stabilizes the apparatus by inhibiting distal movement of the rod and the funnel with respect to the catheter.

[0062] There is further provided, in accordance with some implementations, apparatus for removing an obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject, the apparatus including a flexible catheter, a funnel, a flexible

rod, attached to the proximal end of the funnel, and/or a handle, at the proximal portion of the catheter.

[0063] In some implementations, the catheter has (i) a proximal portion, (ii) a distal portion that is configured for transluminal advancement into the blood vessel (e.g., cerebral artery), the distal portion having a rim, and/or (iii) a lumen, extending from the proximal portion to the rim.

[0064] In some implementations, the funnel has (i) a mouth at a distal end of the funnel, and (ii) an opening at a proximal end of the funnel.

[0065] In some implementations, the funnel is biased to assume an expanded state in which the mouth is wider than the opening and the rim.

[0066] In some implementations, the funnel is elastically compressible into a compressed state in which the mouth is narrower than in the expanded state.

[0067] In some implementations, the rod is attached to the proximal end of the funnel, and extends proximally through the catheter.

[0068] In some implementations, the handle includes a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between: (a) a delivery state in which the funnel is in the compressed state within the catheter, and/or (b) a deployed state in which the funnel is in the expanded state, with an outer surface of the funnel being in sealed engagement with the rim, and the mouth is (i) exposed from the distal portion of the catheter, and (ii) fluidically connected to the lumen such that suction applied through the lumen sucks the obstruction (e.g., embolus) into the funnel via the mouth.

[0069] In some implementations, the handle includes a stabilizer, discrete from the deployment knob, and configured to stabilize the apparatus in the deployed state by taking up slack in the rod.

[0070] There is further provided, in accordance with some implementations, apparatus for removing an obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject, the apparatus including a flexible catheter, a funnel, a flexible rod, attached to the proximal end of the funnel, and/or a handle, at the proximal portion of the catheter.

[0071] In some implementations, the catheter has (i) a proximal portion, (ii) a distal portion that is configured for transluminal advancement into the blood vessel (e.g., cerebral artery), the distal portion having a rim, and/or (iii) a lumen, extending from the proximal portion to the rim.

[0072] In some implementations, the funnel has (i) a mouth at a distal end of the funnel, and (ii) an opening at a proximal end of the funnel.

[0073] In some implementations, the funnel is biased to assume an expanded state in which the mouth is wider than the opening and the rim.

[0074] In some implementations, the funnel is elastically compressible into a compressed state in which the mouth is narrower than in the expanded state.

[0075] In some implementations, the rod is attached to the proximal end of the funnel, and extends proximally through the catheter.

[0076] In some implementations, the handle defines a flat base for resting on a surface.

[0077] In some implementations, the handle includes a thumbwheel, operatively coupled to the flexible rod such that manual operation of the thumbwheel progressively transitions the apparatus between (i) a delivery state in which the funnel is in the compressed state within the catheter, and (ii) a deployed state in which the funnel is in the expanded state and the mouth is exposed from the distal portion of the catheter.

[0078] In some implementations, the handle includes a fluid port facing proximally, and fluidically connected to the mouth of the funnel and adapted to receive a suction source such that suction applied to the fluid port is transferred via the lumen to draw the obstruction (e.g., embolus) into the funnel via the mouth.

[0079] In some implementations, the handle has a foot that extends to define an extended part of the flat base.

[0080] In some implementations, the fluid port is proximally-facing.

[0081] In some implementations, the thumbwheel is laterally-facing.

[0082] In some implementations, the proximal portion of the catheter is fixedly attached to the handle.

[0083] In some implementations, handle is shaped to be grasped by a hand of a user, with the catheter extending between fingers of the hand and away from the handle.

[0084] In some implementations, the proximal portion of the catheter is attached to the handle at a distally-facing part of the handle.

[0085] In some implementations, the handle further includes a sealer, configured to transition the apparatus into a sealed state by retracting the funnel into sealed engagement with the rim such that, in the sealed state: (i) the funnel remains in the expanded state, and/or (ii) the mouth of the funnel is fluidically connected to the lumen such that suction applied through the lumen sucks the obstruction (e.g., embolus) into the funnel via the mouth.

[0086] In some implementations, the sealer is distally-facing.

[0087] There is further provided, in accordance with some implementations, apparatus for removing an obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject, the apparatus including a flexible catheter, a funnel, a flexible rod, attached to the proximal end of the funnel, and/or a handle, at the proximal portion of the catheter.

[0088] In some implementations, the catheter has (i) a proximal portion, (ii) a distal portion that is configured for transluminal advancement into the blood vessel (e.g., cerebral artery), the distal portion having a rim, and/or (iii) a lumen, extending from the proximal portion to the rim.

[0089] In some implementations, the funnel has (i) a mouth at a distal end of the funnel, and (ii) an opening at a proximal end of the funnel.

[0090] In some implementations, the funnel is biased to assume an expanded state in which the mouth is wider than the opening and the rim.

[0091] In some implementations, the funnel is elastically compressible into a compressed state in which the mouth is narrower than in the expanded state.

[0092] In some implementations, the rod is attached to the proximal end of the funnel, and extends proximally through the catheter.

[0093] In some implementations, the handle includes a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between (i) a delivery state in which the funnel is in the compressed state within the catheter, and (ii) a deployed state in which the funnel is in the expanded state and the mouth is exposed from the distal portion of the catheter.

[0094] In some implementations, the handle includes a sealer, discrete from the deployment knob, and configured to transition the apparatus into a sealed state by retracting the funnel into sealed engagement with the rim such that, in the sealed state: (a) the funnel remains in the expanded state, and/or (b) the mouth of the funnel is fluidically connected to the lumen such that suction applied through the lumen sucks the obstruction (e.g., embolus) into the funnel via the mouth.

[0095] In some implementations, the sealer is manually actuatable independently of the deployment knob.

[0096] In some implementations, the sealer is a discrete component with respect to the deployment knob.

[0097] In some implementations, the sealer is a button, and pressing the button transitions the apparatus into the sealed state.

[0098] In some implementations, the deployment knob is a thumbwheel.

[0099] In some implementations, the catheter includes a hypotube, and a polymeric cover that coats the hypotube, and the polymeric cover extends beyond the hypotube to define the rim.

[0100] In some implementations, the handle is configured to limit distal advancement of the rod in a manner that provides a predetermined limit to distal advancement of the funnel out of the distal portion of the catheter.

[0101] In some implementations, the deployment knob is a slider, the deployment knob being operable via sliding of the slider.

[0102] In some implementations, the sealer is configured to, upon actuation, inhibit further operation of the deployment knob.

[0103] In some implementations, a flexibility of the catheter increases progressively distally along the catheter.

[0104] In some implementations, a flexibility of the rod increases progressively distally along the rod.

[0105] In some implementations, the distal portion of the catheter has a curvature that is adjustable by applying an axial force to the rod.

[0106] In some implementations, the distal portion of the catheter is more flexible than the proximal portion of the catheter.

[0107] In some implementations, the distal portion of the catheter has a length of 10-30 cm.

[0108] In some implementations, the distal portion of the catheter is biased toward being curved.

[0109] In some implementations, the apparatus is configured such that a curvature of the distal portion is reducible by positioning the funnel, in its compressed state, within the distal portion of the catheter.

[0110] In some implementations, the rod is coupled to the funnel eccentrically within the lumen, such that distalward pushing of the rod applies an eccentric pushing force to the funnel, which responsively articulates with respect to the rod, thereby increasing the curvature of the catheter.

[0111] In some implementations, the rod is coupled to the funnel eccentrically within the lumen, such that distalward pushing of the rod applies an eccentric pushing force to the funnel, which responsively turns to deflect the distal portion of the catheter.

[0112] In some implementations: (i) the funnel, in its expanded state, has a flared surface distal to the opening, and/or (ii) the sealer is configured to retract the funnel into the sealed engagement with the catheter by sealing the flared surface against the rim.

[0113] In some implementations, the rim flares distally.

[0114] In some implementations, the catheter is fixedly attached to the handle.

[0115] In some implementations, the catheter is welded onto the handle.

[0116] In some implementations, the rod includes an extracorporeal stopper that provides a predetermined limit to distal advancement of the funnel out of the distal portion of the catheter by limiting distal advancement of the rod through the handle to a predetermined distance.

[0117] In some implementations, the sealer is configured such that actuation of the sealer pulls the rod proximally by the predetermined distance.

[0118] In some implementations, the handle further includes a port that is fluidically connected to the catheter, the port adapted to receive a suction applicator adapted to apply the suction.

[0119] In some implementations, the apparatus further includes the suction applicator.

[0120] In some implementations, the suction applicator includes a syringe.

[0121] In some implementations, the funnel is constructed from braided wires.

[0122] In some implementations, the braided wires are gathered at the proximal end in an elliptical loop that defines the opening as an elliptical opening.

[0123] In some implementations, the elliptical loop is covered in a polymer coating that reinforces the opening.

[0124] In some implementations, in the sealed state, the polymer coating fits snugly within the distal portion of the catheter.

[0125] In some implementations: (i) the funnel has a central longitudinal axis that passes through the mouth and the opening, and/or (ii) the elliptical opening has a major axis that is oblique to the longitudinal axis.

[0126] In some implementations: (i) the elliptical opening has: (a) a distal vertex that lies on the major axis, on a first side of the longitudinal axis, and/or (b) a proximal vertex that lies on the major axis, and is disposed on an opposite side of the longitudinal axis from the distal vertex, proximal from the distal vertex, and/or (ii) the rod is attached to the proximal end of the funnel by being attached to the elliptical opening at the proximal vertex.

[0127] In some implementations, the sealer includes a spring-loaded mechanism that is adapted to transition the apparatus into the sealed state by applying tension to the rod.

[0128] In some implementations, the spring-loaded mechanism is adapted to apply the tension to the rod automatically upon cessation of manual operation of the deployment knob.

[0129] In some implementations, the sealer includes a manually-actuatable mechanism that is adapted to stabilize the apparatus in the deployed state by applying tension to the rod upon being manually actuated.

[0130] In some implementations, the deployment knob is operatable via rotation.

[0131] In some implementations, the handle includes a drivewheel that is engaged with the rod and operatively coupled to the knob, such that rotating the knob in a first knob-direction rotates the drivewheel in a forward drivewheel-direction, thereby pushing the rod distally to progressively transition the apparatus from the delivery state towards the deployed state.

[0132] In some implementations, the drivewheel defines a roller, the rod passing tangentially by the roller.

[0133] In some implementations, the drivewheel defines a spool, the rod wrapped around the spool.

[0134] In some implementations, the drivewheel defines a capstan, the rod curving around the capstan.

[0135] In some implementations, the sealer is configured such that actuation of the sealer rotates the drivewheel in a reverse drivewheel-direction, thereby retracting the funnel into the sealed engagement by pulling the rod proximally.

[0136] In some implementations, the sealer is configured with a first position and a second position, and to be actuated by moving the sealer from the first position into the second position, such that actuation of the sealer rotates the drivewheel by a predetermined discrete amount in the reverse drivewheel-direction, thereby pulling the rod proximally by a predetermined discrete distance.

[0137] In some implementations: (i) the drivewheel has drivewheel teeth, (ii) the sealer has sealer teeth, and/or (iii) actuating the sealer engages the sealer teeth with the drivewheel teeth and moves the drivewheel in the reverse drivewheel-direction.

[0138] In some implementations, the drivewheel teeth are circumferentially distributed, the sealer teeth a linearly distributed, and actuation of the sealer moves the sealer teeth into a rack-and-pinion arrangement with the drivewheel teeth.

[0139] In some implementations, the engagement between the sealer teeth and the drivewheel teeth stabilizes the apparatus in the sealed state by holding the funnel in sealed engagement with the rim by inhibiting distal movement of the rod and the funnel with respect to the catheter.

[0140] There is further provided, in accordance with some implementations, apparatus for removing an obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject, the apparatus including a flexible catheter and/or a funnel.

[0141] In some implementations, the catheter has (a) a proximal portion, (b) a distal portion that is configured for transluminal advancement into the blood vessel (e.g., cerebral artery),

the distal portion having a rim, and/or (c) a lumen, extending from the proximal portion to the rim.

[0142] In some implementations, the funnel is formed from a set of braided wires covered in a covering. In some implementations, the funnel has (i) a mouth at a distal end of the funnel, (ii) at the mouth, a scoop that protrudes distally, the scoop defined by: (a) a first lateral petal, formed from a bight of a first wire of the set, (b) a second lateral petal, formed from a bight of a second wire of the set, (c) a medial petal disposed between, and overlapping with, the first and second lateral petals, the medial petal formed from a bight of a third wire of the set, the third wire being more flexible than the first wire and more flexible than the second wire, and/or (d) an opening at a proximal end of the funnel.

[0143] In some implementations, the funnel is biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or is elastically compressible into a compressed state in which the mouth is narrower than in the expanded state.

[0144] In some implementations, for each of the first, second, and third petals, the respective wire defines two tails that diverge from each other away from the bight, to extend with opposite helical handedness along the funnel toward the opening.

[0145] In some implementations: (i) the funnel has a central longitudinal axis that passes through the mouth and the opening, and/or (ii) in the expanded state, the scoop flares radially outwards from the central longitudinal axis.

[0146] In some implementations: (i) each of the first and second lateral petals defines a lateral tail and a medial tail, the lateral tail extending away from the bight and the medial petal, and helically along the funnel toward the opening, and the medial tail extending away from the bight to overlap with the medial petal and extend helically along the funnel toward the mouth, and/or (ii) the set of wires includes at least one respective petal-support wire for each of the lateral petals, each petal-support wire defining a loop that, at the mouth, loops around the lateral tail of the respective lateral petal to support the respective lateral petal.

[0147] In some implementations, the set of wires includes exactly two respective petal-support wires for each of the lateral petals.

[0148] In some implementations, each of the petal-support wires defines a pair of tails that extend proximally away from the loop and helically along the funnel toward the opening.

[0149] In some implementations, for each of the petal-support wires, the tails of the pair extend, in parallel, and with the same helical handedness as each other, along the funnel toward the opening.

[0150] In some implementations, for each of the lateral petals, the set of wires includes a first petal-support wire and a second petal-support wire, the tails of the first petal-support wire extending along the funnel toward the opening in parallel, and with the same helical handedness, as each other as the tails of the second petal-support wire.

[0151] In some implementations, the loop of the first petal-support wire is distal to the loop of the second petal-support wire, and the first petal-support wire is stiffer than the second petal-support wire.

[0152] In some implementations: (i) the scoop is a first scoop, (ii) the funnel has an opposing scoop at the mouth, the opposing scoop defined by at least two arc-wires of the set collectively, by each arc-wire forming an arc partway around the mouth, the arcs overlapping with each other, and/or (iii) the opposing scoop is opposite the first scoop.

[0153] In some implementations, in response to a compressive force applied to the funnel, the opposing scoop is configured to extend distally by the arcs deforming to have a decreased radius of curvature.

[0154] In some implementations, the opposing scoop is defined by exactly two arc-wires forming exactly two arcs.

[0155] In some implementations, the first scoop is defined by no further wires of the set other than the first wire defining the first lateral petal, the second wire defining the second lateral petal, and the third wire defining the medial petal.

[0156] In some implementations, the first scoop protrudes distally beyond the opposing scoop.

[0157] In some implementations, the first scoop is longer than the opposing scoop.

[0158] In some implementations, each of the arc-wires is an arc-wire of a pair of parallel extending arc-wires, each pair facing distally.

[0159] In some implementations, the opposing scoop further includes a single arc-wire that forms an arc in between, and proximally from, the two-arc wires.

[0160] There is further provided, in accordance with some implementations, a method for advancing an embolus-retrieval device into a real or simulated blood vessel (e.g., artery, such as a cerebral artery, or a vein, such as a cerebral vein) of a real or simulated subject, the method including: (i) transluminally advancing a distal portion of a flexible catheter into the blood vessel (e.g., cerebral artery) while: (a) a funnel is compressed within a lumen of the catheter, and/or (b) a flexible rod that is attached to the proximal end of the funnel extends proximally through the catheter; (ii) via a rod that extends, from the proximal end of the funnel and proximally through the lumen, adjusting a curvature of the distal portion by applying an axial force to the rod; and/or (iii) subsequently, advancing the funnel out of the distal portion such that the funnel expands within the blood vessel (e.g., cerebral artery).

[0161] In some implementations, transluminally advancing the distal portion of the catheter into the blood vessel (e.g., cerebral artery) includes transluminally advancing the distal portion of the catheter into the blood vessel (e.g., cerebral artery) while the funnel is disposed within the lumen proximally from the distal portion.

[0162] In some implementations, the method further includes applying suction to aspirate a real or simulated obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) into the funnel.

[0163] In some implementations, the distal portion of the catheter is biased toward being curved, and adjusting the curvature of the distal portion by applying the axial force to the rod includes reducing the curvature of the distal portion by pushing the funnel distally, in its compressed state, within the distal portion of the catheter.

[0164] In some implementations, the distal portion of the catheter is biased toward being curved, and adjusting the curvature of the distal portion by applying the axial force to the rod includes increasing the curvature of the distal portion by pulling the funnel proximally, in its compressed state, within the distal portion of the catheter.

[0165] In some implementations, the rod extends eccentrically within the lumen, and adjusting the curvature of the distal portion by applying the axial force to the rod includes advancing the rod and the funnel distally within the lumen to increase the curvature by the funnel and the rod applying an eccentric, compressive force on the catheter.

[0166] In some implementations, the method further includes rotating the catheter within the subject prior to adjusting the curvature of the distal portion.

[0167] In some implementations, the rod extends eccentrically within the lumen, and adjusting the curvature of the distal portion by applying the axial force to the rod includes pulling the rod and the funnel proximally within the lumen to decrease the curvature.

[0168] There is further provided, in accordance with some implementations, a method for removing a real or simulated obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a real or simulated blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a real or simulated subject, the method including: (i) transluminally advancing a distal portion of a flexible catheter into the blood vessel (e.g., cerebral artery) while: (a) a funnel is compressed within a lumen of the catheter, and/or (b) a rod extends, from a proximal end of the funnel, proximally through the lumen, to a handle; (ii) using a deployment knob on the handle that is operatively coupled to the rod, advancing the funnel out of the distal portion of the catheter, such that the funnel self-expands in a manner that a mouth at a distal end of the funnel is wider than the distal portion and an opening of the funnel at the proximal end; (iii) actuating a sealer on the handle to retract the funnel into sealed engagement with the distal portion such that, in the sealed engagement, the funnel remains expanded, and the mouth of the funnel is fluidically connected to the lumen; and/or (iv) subsequently applying suction through the lumen, such that the suction sucks the obstruction (e.g., embolus) into the funnel via the mouth.

[0169] There is further provided, in accordance with some implementations, a method for removing a real or simulated obstruction (e.g., embolus) from a real or simulated blood vessel (e.g., cerebral artery) of a real or simulated subject, the method including: (a) transluminally advancing a distal portion of a flexible catheter into the cerebral artery while: (i) a funnel is compressed within a lumen of the catheter, and/or (ii) a rod extends, from a proximal end of the funnel, proximally through the lumen, to a handle; (b) using a deployment knob on the handle that is operatively coupled to the rod, deploying the funnel out of the distal portion of the catheter, such that the funnel self-expands in a manner that a mouth at a distal end of the funnel is wider than the distal portion and an opening of the funnel at the proximal end; (c) subsequently, actuating a stabilizer on the handle to stabilize the funnel in sealed engagement with the catheter; and/or (d) while the funnel remains stabilized in sealed engagement with the distal portion: (i) sucking the embolus into the funnel via the mouth by applying suction through the lumen, and/or (ii) retracting the funnel and the catheter from the cerebral artery and the subject while continuing to apply suction through the lumen.

[0170] In some implementations, step (b) of the method includes the steps of: (i) deploying the funnel out of the distal portion of the catheter until the mouth is exposed: (I) applying suction to the mouth via the lumen, (II) determining a degree of resistance to the suction, and/or (III) responsively to the determination, identifying whether there is contact with the embolus.

[0171] In some implementations, step (b) of the method further includes, subsequently to the identification: (I) retracting the funnel back into the distal portion such that the funnel becomes compressed within the lumen, (II) advancing the catheter distally within the artery, and/or (III) repeating the steps of step (b) until contact with the embolus is identified.

[0172] In some implementations, transluminally advancing the distal portion of the catheter into the cerebral artery includes transluminally advancing the distal portion of the catheter into the cerebral artery while the funnel is disposed within the lumen proximally from the distal portion.

[0173] There is further provided, in accordance with some implementations, a method for removing a real or simulated embolus from a real or simulated cerebral artery of a real or simulated subject, the method including: (a) transluminally advancing a distal portion of a flexible catheter into the cerebral artery while a funnel is compressed within a lumen of the catheter, the funnel formed from a set of braided wires covered in a covering, and having: (i) a mouth at a distal end of the funnel, (ii) at the mouth, a scoop that protrudes distally, the scoop defined by: (I) a first lateral petal, formed from a bight of a first wire of the set, (II) a second lateral petal, formed from a bight of a second wire of the set, (III) a medial petal disposed between, and overlapping with, the first and second lateral petals, the medial petal formed from a bight of a third wire of the set, the third wire being more flexible than the first wire and more flexible than the second wire, and/or (IV) an opening at a proximal end of the funnel; (b) progressively advancing the funnel out of the distal portion of the catheter, such that the funnel self-expands in a manner that the mouth is wider than the distal portion and the opening; and/or (c) applying suction through the lumen, such that the suction sucks the embolus into the funnel via the mouth.

[0174] There is further provided, in accordance with some implementations, apparatus for removing an embolus from a cerebral artery of a subject, the apparatus including a flexible catheter and/or a funnel.

[0175] In some implementations, the catheter has (i) a proximal portion, (ii) a distal portion that is configured for transluminal advancement into the cerebral artery, the distal portion having a rim, and/or (iii) a lumen, extending from the proximal portion to the rim.

[0176] In some implementations, the funnel has a central longitudinal axis that passes through the mouth and the opening, and has (i) a mouth at a distal end of the funnel, and (ii) an opening at a proximal end of the funnel.

[0177] In some implementations, the funnel is elastically compressible into a compressed state.

[0178] In some implementations, the funnel is biased to assume an expanded state in which the mouth is wider than (i) the opening and the rim, and (ii) the mouth in the compressed state, and in which the funnel defines: (a) a distal section that includes the mouth, and that is generally cylindrical, (b) a proximal section that includes the opening, and that is generally cylindrical, (c) an intermediate section, tapering from the distal section to the proximal section to fluidically connect the distal section to the proximal section, and/or (d) at the mouth, a first scoop and an opposing scoop that extend distally from the distal section, and that flare away from the other and from the longitudinal axis.

[0179] There is further provided, in accordance with some implementations, apparatus for removing an embolus from a cerebral artery of a subject, the apparatus including a flexible catheter, a funnel, a flexible rod, attached to the proximal end of the funnel, and/or a handle, at the proximal portion of the catheter.

[0180] In some implementations, the catheter has (i) a proximal portion, (ii) a distal portion that is configured for transluminal advancement into the cerebral artery, the distal portion having a rim, and/or (iii) a lumen, extending from the proximal portion to the rim.

[0181] In some implementations, the funnel has (i) a mouth at a distal end of the funnel, and (ii) an opening at a proximal end of the funnel.

[0182] In some implementations, the funnel is biased to assume an expanded state in which the mouth is wider than the opening and the rim.

[0183] In some implementations, the funnel is elastically compressible into a compressed state in which the mouth is narrower than in the expanded state.

[0184] In some implementations, the rod is attached to the proximal end of the funnel, and extends proximally through the catheter.

[0185] In some implementations, the handle includes a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between (i) a delivery state in which the funnel is in the compressed state within the catheter, and (ii) a deployed state in which the funnel is in the expanded state and the mouth is exposed from the distal portion of the catheter.

[0186] In some implementations, the handle includes a sealer, discrete from the deployment knob, and configured to transition the apparatus into a sealed state by retracting the funnel into sealed engagement with the rim such that, in the sealed state: (a) the funnel remains in the expanded state, and/or (b) the mouth of the funnel is fluidically connected to the lumen such that suction applied through the lumen sucks fluid into the funnel via the mouth.

[0187] There is further provided, in accordance with some implementations, a method for removing a real or simulated embolus from a real or simulated cerebral artery of a real or simulated subject, the method including: (a) transluminally advancing a distal portion of a flexible catheter into the cerebral artery while a funnel is compressed within a lumen of the catheter, the funnel formed from a set of braided wires covered in a covering, and having: (i) a mouth at a distal end of the funnel, (ii) at the mouth, a scoop that protrudes distally, the scoop defined by: (I) a first lateral petal, formed from a bight of a first wire of the set, (II) a second lateral petal, formed from a bight of a second wire of the set, (III) a medial petal disposed between, and overlapping with, the first and second lateral petals, the medial petal formed from a bight of a third wire of the set, the third wire being more flexible than the first wire and more flexible than the second wire, and/or (IV) an opening at a proximal end of the funnel; (b) advancing the funnel out of the distal portion of the catheter, such that: (i) the funnel self-expands in a manner that the mouth is wider than the distal portion and the opening, and (ii) the scoop expands the artery in a manner in which the scoop dislodges the embolus from a wall of the artery; and/or (c) applying suction through the lumen, such that the suction sucks the embolus into the funnel via the mouth.

[0188] The present invention will be more fully understood from the following detailed description of applications thereof, taken together with the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0189] Figs. 1, 2A-F, 3A-C, 4A-B, 5A-B, 6A-B, 7A-B, and 8A-B illustrate a device for removing an embolus from a blood vessel of a subject using a funnel of the device that is distally advanceable out of a catheter of the device;

[0190] Figs. 9A-C and 10A-D illustrate various mechanisms for maintaining sealing between the funnel and the catheter, in accordance with some implementations; and

[0191] Figs. 11A-B and 12A-C illustrate various methods and systems for adjusting a curvature of a distal portion of the catheter by applying an axial force to a rod that is attached to the funnel, in accordance with some applications.

DETAILED DESCRIPTION OF EMBODIMENTS

[0192] Reference is now made to Figs. 1, 2A-F, 3A-C, 4A-B, 5A-B, 6A-B, 7A-B, 8A-B, and 9A-C, which illustrate a device (e.g., a system or apparatus) 100, for removing an obstruction 15 (e.g., an embolus, a thrombus, a mass, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject. In some implementations, device 100 can be used to remove an embolus from a blood vessel (e.g., from an artery, such as from a cerebral artery, a peripheral artery, and/or a pulmonary artery), or from a vein, such as from a cerebral vein, a peripheral vein, and/or a pulmonary vein). In other implementations, device 100 can be used to remove an embolus from any other blood vessel of a subject, such as from a blood vessel within a lung, a renal artery, or a limb of a subject. It is to be understood that although numeral 15 is referenced as an embolus throughout the application, numeral 15 could similarly be referring to another type of obstruction, such as a thrombus, a mass, a clot, plaque, or any other obstruction.

[0193] In some implementations, device 100 can be used to remove a mass, body and/or obstruction from an organ. For example, device 100 can be used to remove a kidney stone from a kidney of a subject. For such implementations, numeral 20 can therefore be understood to indicate any body lumen, not limited to a blood vessel.

[0194] Device 100 comprises a funnel 130 for receiving (e.g., funneling) the obstruction (e.g., embolus) into the device, a flexible catheter 150 out of which the funnel is advanceable, and a handle 120 for controlling the distal advancement of the funnel out of the catheter. Handle 120 also comprises a fluid port 124 that is fluidically connected to funnel 130 and is adapted to receive a suction source 160 (e.g., a syringe, or a vacuum source), such that suction applied to the fluid port is transferred via catheter 150 to the funnel to draw embolus 15 into the funnel. In some implementations, suction source 160 can be operated via a foot pedal (e.g., by the user manually pressing the pedal to apply the suction). In some

implementations, suction source 160 is electrically operable – e.g. includes an electrical pump.

[0195] A distal portion 152 of catheter 150 is configured for transluminal advancement into a blood vessel 20 of a subject while funnel 130 is disposed in a delivery state (e.g., a compressed state) within the catheter (e.g., within distal portion 152 thereof, such as as-shown in Fig. 2A).

[0196] A flexible rod 132 is attached to a proximal end 1311 of the funnel, and extends proximally through the catheter (e.g., through lumen 156 thereof) to handle 120 where a deployment knob 122 is operatively coupled to the rod. Operating (e.g., rotating) deployment knob 122 pushes rod 132 distally, thereby progressively transitioning funnel 130 from the delivery state within catheter 150 towards an expanded state.

[0197] In some implementations, once distal portion 152 has been advanced into a blood vessel 20 suspected of housing embolus 15, funnel 130 is partially deployed out of the catheter (e.g., to the state shown in Fig. 2B, such that a mouth 133 of the funnel is deployed out of the catheter), and suction is applied to the funnel via lumen 156. Based on the resistance to suction experienced by mouth 133, it can be determined whether funnel is immediately proximal to embolus 15, or whether further distal advancement of catheter 150 is required prior to full deployment of funnel 130 and/or further application of suction, in order to achieve a closer proximity to the embolus. If it is determined that further distal advancement is required, in order to prevent the funnel from contacting the walls of the blood vessel and thus interfering with the distalward advancement of the device through the blood vessel, funnel 130 may first be retracted proximally back into distal portion 152 - e.g., via actuation (e.g., rotation) of deployment knob in a reverse direction.

[0198] Once it has been determined that mouth 133 has contacted, or is immediately proximal to, embolus 15 (Fig. 2C), funnel 130 is progressively deployed out of distal portion 152 such that the funnel transitions to its deployed, expanded state in the blood vessel. Embolus 15 may thus become progressively trapped, or captured within the funnel. In some implementations, suction is applied via fluid port 124 concurrently with the deployment of funnel 130 in order to draw embolus 15 into the funnel via the mouth (Figs. 2C-F). At this stage, in some scenarios, the suction applied via suction source 160 may be sufficient to suck embolus 15 into funnel 130, through lumen 156, and proximally along the catheter until it

reaches handle 120 (e.g., and optionally is sucked into suction source 160). Alternatively, in other scenarios, and as shown in Figs. 2D-F, embolus 15 may become captured within, or at the mouth of, funnel 130 during or after the deployment of the funnel, and, while the funnel remains in the deployed state out of distal portion, and in sealed engagement with a rim 158 of the catheter, device 100 is retracted from out of the blood vessel and the subject, bringing embolus therealong. In such cases, suction may be applied during the withdrawal of the device from the body (e.g., to ensure that the embolus remains trapped by funnel 130 and does not migrate elsewhere). Mouth 133 may advantageously be elliptical and/or rounded, thereby having an increased area, e.g., to increase the patency of the funnel and/or to allow for the uninterrupted passage of embolus 15 therethrough. In some implementations, and as will be explained in more detail hereinbelow, mouth 133 can retain its elliptical shape as funnel 130 is deployed out of distal portion 152.

[0199] In some implementations, suction may continuously be applied through lumen 156 during the deployment of funnel 130 from out of distal portion 152. For example, once mouth 133 is in contact with embolus 15 (Fig. 2C), suction may continuously be applied through lumen 156 until the withdrawal of catheter 150 from the subject. In some implementations, the suction is applied iteratively with the deployment of the funnel. In some implementations, suction is applied in pulses.

[0200] In some implementations, funnel 130 is shaped so as to be able to expand the wall of blood vessel 20 by applying a radially expansive force on the walls (e.g., as illustrated in Figs. 2D-F). In some such implementations, mouth 133, or the body of the funnel, may be shaped in order to achieve this (e.g., as will be explained in more detail hereinbelow). In some such implementations, using the funnel to apply a radially expanding force on the blood vessel wall may advantageously dislodge (e.g., loosen) the embolus from its lodged position within the blood vessel, allowing for funnel to more easily capture the embolus therewithin.

[0201] In some implementations, once funnel 130 is at least partially deployed at a proximal edge of embolus 15, in order to assist in the retrieval of the embolus, a wire (e.g., a guide wire and/or a microcatheter used to guide the advancement of catheter 150) can be advanced distally out of catheter 150 and funnel 130 and through the embolus such that the wire crosses through the embolus and reaches a distal (e.g., far) side of the embolus. In some such implementations, the wire can deploy a stent retriever on the distal side of the embolus. In

some implementations, the stent retriever can be used to pull the embolus against, or into, mouth 133 of the funnel.

[0202] In some implementations, funnel 130 advantageously provides a seal (e.g., plug) to blood vessel 20 proximally to embolus 15 (e.g., as the embolus is being sucked into funnel 130), thereby preventing small pieces of the embolus from migrating downstream (e.g., proximally).

[0203] In some implementations, in order to assist in the dislodgment of embolus 15 from the walls of blood vessel 20, an embolus-breaking device is passed through the working channel of device 100 (e.g., through lumen 156 and funnel 130) and out of mouth 133 into the embolus. The embolus-breaking device can be a vibrating element, an ultrasound device, a heating element and/or a laser-applicator. The embolus-breaking device can be adapted to apply energy to break the embolus into smaller pieces, thereby dislodging the embolus from the walls of the blood vessel and allowing for suction of the embolus into funnel 130. In some implementations, the embolus-breaking device can apply pulses of energy to the embolus in order to break it up. In some implementations, funnel 130 advantageously provides a seal (e.g., plug) to blood vessel 20 proximally to embolus 15 (e.g., as the embolus is being broken up into pieces by clot-breaker device), e.g., thereby preventing small pieces of the embolus from migrating during the breaking up of the embolus. Funnel 130 may provide a complete seal, or a partial seal (e.g., allowing some blood flow around the funnel).

[0204] Figs. 3A-C illustrate various views of funnel 130, and specifically the braided arrangement of the funnel and its mouth 133 thereof. In some implementations, funnel 130 is formed from a set of braided wires 136 that are biased to assume an expanded state in which mouth 133 is wider than an opening 131 at proximal end 1311 of the funnel, and are elastically compressible into a compressed state in which the mouth is narrower than in the expanded state. Wires 136 may comprise a superelastic or shape memory material such as a polymer or metal alloy such as nitinol. In some implementations, wires 136 may comprise other materials, such as a fabric (e.g., laser-perforated fabric), a string, and/or a polymer. Funnel 130 (e.g., wires 136 thereof) can be covered in a covering (e.g., jacket) 1300, e.g., as illustrated in Fig. 1. Covering 1300 can be a polymeric covering. In some implementations, covering 1300 defines a plurality of holes therein, e.g., such that the covering does not completely seal wires 136. This may prevent the funnel from losing patency during application of suction, e.g., by preventing the funnel from kinking and/or collapsing radially

inwards. In some implementations, covering 1300 does not define a plurality of holes therein, e.g., such that the covering completely seals wires 136.

[0205] In some implementations, in order to achieve the required flexibility of funnel 130 while ensuring that the funnel has the required strength to dislodge and scoop up embolus 15 from blood vessel 20, wires of varying rigidity are used to provide both rigidity and flexibility to the funnel. For example, in some implementations, the wires in the vicinity of mouth 133 are more rigid than the more proximal wires, e.g., thereby providing a flexible funnel with a rigid, and thus increased-strength, mouth. In some implementations, an alternating pattern of rigid/less-rigid wires may be used in order to provide both the strength and flexibility required.

[0206] In some implementations, mouth 133 can be specifically designed to grab, or dislodge, the embolus. For example, funnel 130, e.g., braided wires 136 thereof, defines a scoop 137 at mouth 133 that protrudes distally, in order to assist in the dislodging of the embolus from the walls of the blood vessel and to scoop it into funnel 130. As illustrated in Fig. 3C, scoop 138 can define a first lateral petal 1372, formed from a bight of a first wire 1376 of set 136, a second lateral petal 1374, formed from a bight of a second wire 1378 of the set, and a medial petal 1373 disposed between, and overlapping with, the first and second lateral petals. In some implementations, medial petal 1373 is formed from a bight of a third wire 1377 of the set, the third wire being more flexible than first wire 1376 and more flexible than second wire 1378. In some implementations, scoop 137 is formed from exactly three petals, e.g., as described hereinabove and as shown, e.g., the scoop does not comprise other petals.

[0207] In some implementations, for each of first petal 1372, second petal 1374, and medial petal 1373, the respective wire defines two tails that diverge from each other away from the bight, to extend with opposite helical handedness along the funnel toward opening 131. For example, the wire 1378 of second petal 1374 defines two tails – a medial tail 1378a extending away from the bight to overlap with medial petal 1373 and extend helically along the funnel toward the mouth and a lateral tail 1378b extending away from the bight and the medial petal, and helically along the braid toward the opening, and the medial tail. The wire 1376 of first petal 1372 defines a similar lateral and medial tail.

[0208] In some implementations, the set of wires 136 includes at least one respective petal-support wire (e.g., exactly two petal-support wires 1371, 1379) for each of the lateral petals 1372, 1374, each petal-support wire defining a loop that, at the mouth, loops around the

lateral tail of the respective lateral petal 1372, 1374, to support the respective lateral petal. In some implementations, and as illustrated in Fig. 3B for petal-support wire 1371, each of the petal-support wires defines a pair of tails 1371a, 1371b that extend proximally away from the loop and helically along the funnel toward the opening. In some implementations, and as shown, for each of the petal-support wires, the tails of the pair extend, in parallel, and with the same helical handedness as each other, along the funnel toward the opening. In some implementations, and as shown, the tails of each pair extend, in parallel, and with the same helical handedness as, with the tails of the other pair. In some implementations, for each of lateral petals 1372 and 1374, the loop of the more distal petal-support wire 1371 is stiffer than the loop of the more proximal petal-support wire 1379. Scoop 137 (e.g., petals 1372, 1373, and 1374) typically flare outwardly and away from a central longitudinal axis ax1 of the funnel.

[0209] In some implementations, petals 1372, 1373, and 1374, and additionally petal-support wires 1371 and 1379, extend from mouth 133, helically towards proximal end 1311. Fig. 3A shows an opposite side of funnel 130 to the side shown in Fig. 3C, illustrating the aforementioned petals/wires forming a septet (e.g., group of 7 wires) 1365 on the opposite side of the funnel to the side shown in Fig. 3C that extend helically along the funnel towards proximal end 1311 while being parallel with each other. Septet 1365 can be comprised of, in sequence, wires 1378b, 1377, 1376, and the two pairs of petal-support wires 1371 and 1379 respectively. That is, septet 1365 is formed from a single stiff wire 1378b separated from a group of three stiff (e.g., more rigid, or thicker) wires 1376, 1371a, 1371b by a single intervening flexible wire 1377, the group of three stiff wires 1376, 1371a, and 1371b having a pair of more flexible wires 1379 extending parallel with the group, proximally from the group of three. In some implementations, there is more than one intervening flexible wire. In some implementations, no other rigid wires other than the ones mentioned above are used. In some implementations, other rigid wires are implemented within the braided arrangement in order to provide rigidity and/or strength to funnel 130.

[0210] In some implementations, and as illustrated in Fig. 3A, funnel 130 has an opposing scoop 138 that is opposite scoop 137 at mouth 133. Opposing scoop 138 may protrude distally, but is typically shorter than scoop 137 (such that scoop 137 protrudes distally beyond the opposing scoop), e.g., such that mouth 133 has an elliptical shape.

[0211] In some implementations, opposing scoop 138 is defined by at least two arc-wires 1381, 1382 of set 136 collectively, by each arc-wire forming an arc partway around the

mouth, the arcs overlapping with each other, as shown. In some implementations, opposing scoop 138 is formed from two pairs of parallel arcs (or chevrons) – 1382 and 1384; and 1381 and 1383 - that point distally, each respective pair being disposed laterally to (e.g., on opposite sides of) a line of symmetry s1 of the funnel – e.g. as shown in Fig. 3A. In some implementations, opposing scoop 138 additionally includes a central arc (or chevron) 1389 disposed and/or centered on line s1. Central arc 1389 may be proximal from arcs 1381, 1383, 1382, and 1384. This arrangement of the wires within opposing scoop 138 may provide the opposing scoop with advantageous characteristics and/or behavior. For example, this arrangement of the wires may, compared with other wire arrangements, result in opposing scoop 138 protruding further distally when funnel 130 is expanded only partially (e.g. see Figs. 2B-C). This may provide mouth 133 with a shape that, while funnel 130 is partially expanded, is rounder and/or otherwise more optimal for engaging (e.g. sealing against) embolus 15, thereby providing improved suction – e.g. compared with a sloped (and possibly narrow) elliptical shape that a mouth might assume in the absence of such an opposing scoop. Such optimal engagement and/or sealing against embolus 15 may be particularly advantageous during the steps described with reference to Figs. 2C-E.

[0212] In some implementations, at least one of scoop 137 and/or opposing scoop 138 flare away from the other scoop and away from longitudinal axis ax1. In some implementations, and as illustrated in Figs. 2D-F, scoops 137 and 138 assist in the dislodgment of embolus 15, e.g., by easing the embolus away from the walls of blood vessel 20, and/or by extending around the embolus such that mouth 133 can envelope the embolus therewithin. In some implementations, only scoop 137 flares outwardly at the mouth, (e.g., scoop 138, and the other wires at the outer perimeter of mouth 133 do not flare outwardly). In some implementations, only scoops 137 and 138 flare outwardly at the mouth, (e.g., the parts of mouth 133 between the two scoops do not flare outwardly).

[0213] In some implementations, and as illustrated in Fig. 1, at least one imaging marker 1337 is disposed at mouth 133, e.g., in order to provide an indication that the mouth is deployed out of distal portion 152 and/or is in the vicinity of embolus 15. In some implementations, imaging marker 1337, or a pair of imaging markers, are mounted on at least one of lateral petals 1372, 1374. In some such implementations, deploying funnel 130 out of distal portion 152 may cause imaging markers 1337 to separate from each other, thereby providing an indication of the position of funnel 130 (e.g., and specifically of mouth 133 thereof) within blood vessel 20. For example, determining the distance of the two

imaging markers 1337 from each other may provide the user with an indication of the extent of expansion of funnel 130 (e.g., mouth 133 thereof) within the blood vessel.

[0214] Figs. 4A-B illustrate funnel 130 in its expanded state. Fig. 4B shows a view of funnel 130 that has been rotated ninety degrees to the view shown in Fig. 4A, with catheter 150 partly cutaway. In some implementations, and as illustrated in Fig. 4A, funnel 130 defines (i) a distal section 1301 that includes mouth 133, and that is generally cylindrical, (ii) a proximal section 1303 that includes opening 131, and that is generally cylindrical, and (iii) an intermediate section 1302, tapering from the distal section to the proximal section to fluidically connect the distal section to the proximal section. In some implementations, scoop 137 (and optionally opposing scoop 138) extend distally from the distal section, to flare away from each other and from longitudinal axis ax1. In some implementations, this specific shape of funnel 130 (e.g., the cylindrical-conical-cylindrical-flared shape) advantageously assists in maintaining patency of the funnel during suction. In some implementations, this shape advantageously causes the funnel to apply a radially expansive force on the wall of the blood vessel during expansion of the funnel therewithin, thereby assisting with the dislodgment of the clot.

[0215] In some implementations, braided wires 136 are gathered at proximal end 1311 of funnel 130 in an elliptical loop 1312 that defines opening 131 as an elliptical opening. In some implementations, and similarly to as described with reference to mouth 133, having an elliptical opening at the proximal end increases the cross-sectional area of the opening, allowing better funnel patency, and for a less interrupted passage of embolus 15 therethrough. In some implementations, elliptical loop 1312 is reinforced with a wire that circumscribes proximal end 1311, e.g., numeral 1312 can be understood as pointing to a reinforcing wire. In some implementations, elliptical loop 1312 (e.g., reinforcing wire 1312) is covered in a polymer coating 135 that reinforces the opening. Polymer coating 135 can be discrete from (e.g., consisting of a different material and/or having an increased thickness to) polymer covering 1300 of funnel 130.

[0216] Polymer coating and/or wire 1312 may assist in the maintenance of patency of proximal end 1311, and/or can prevent sliding between braid wires 136 at the proximal end during suctioning and deployment of the funnel out of the catheter. In some implementations, polymer coating 135 and/or wire 1312 facilitates pushing of funnel 130 out of distal portion 152, by inhibiting radial expansion of the funnel against an inner surface of catheter 150 that may occur during pushing of the funnel out of the catheter, and/or by inhibiting buckling

(e.g., collapse) of the proximalmost part of proximal end 1311 during pushing and/or suctioning.

[0217] In some implementations, elliptical opening 131 has a major axis ax2 that is oblique to longitudinal axis ax1. Elliptical opening 131 has a distal vertex 1316 that lies on major axis ax2, on a first side of longitudinal axis ax1, and a proximal vertex 1315 that lies on the major axis, and is disposed on an opposite side of the longitudinal axis from the distal vertex, proximal from the distal vertex. Rod 132 can be attached to proximal end 1311 of the funnel by being attached to elliptical opening 131 at proximal vertex 1315.

[0218] In some implementations, and as illustrated in Figs. 2E and 2F, while the funnel is in sealed engagement with distal portion 152 (e.g., within rim 158), polymer coating 135 fits snugly within the distal portion of the catheter, thereby providing sealing between these two components.

[0219] In some implementations, catheter 150 comprises a hypotube, and a polymeric cover that coats the hypotube. In some implementations, the polymeric cover of the catheter extends beyond the hypotube to define rim 158. In some implementations, rim 158 flares outwardly away from the hypotube, such that a flared section (e.g., intermediate section 1302, or coating 135) of the funnel can sit snugly within the rim.

[0220] Reference is now made to Figs. 5A-B, 6A-B, 7A-B, 8A-B, and 9A-C which illustrate handle 120 in further detail.

[0221] As shown in Fig. 1, rod 132 is flexible, and may be free within lumen 156 – e.g., rather than within a side-lumen of catheter 150. Thus, pushing rod 132 distally via actuation of deployment knob 122 may introduce slack to the rod – e.g., within lumen 156 the rod may assume a serpentine, or sinusoidal shape.

[0222] In some implementations, handle 120 comprises a component or mechanism 126 that draws and/or maintains funnel 130 into/in sealed engagement with distal portion 152, by moving rod 132 proximally, taking up slack on the rod, and/or by applying tension to the rod. Component/mechanism 126 may therefore be referred to as a sealer 126 (i.e., that draws funnel 130 into the sealed engagement) or a stabilizer 126 (i.e., that stabilizes device 100 in its deployed state in which the funnel is in the sealed engagement). Nonetheless, for simplicity, the name "sealer" is generally used for this component throughout the specification.

[0223] In some implementations, sealer 126 passively maintains the device in the sealed engagement, e.g., by applying and/or maintaining tension on rod 132. In some such implementations, sealer 126 may be a spring-loaded mechanism. In some implementations, sealer 126 may apply a predetermined amount of tension or proximal motion to rod 132, or may take up a predetermined amount of slack of rod 132, each time the rod is advanced distally, e.g., as described with reference to Fig. 10A-D.

[0224] Figs. 9A-C illustrate an implementation in which sealer 126 is a component on handle 120 that is actuatable independently of deployment knob 122. Fig. 9A schematically shows device 100 in its delivery state – e.g., as though distal portion 152 of catheter 150 has just arrived at the blood vessel. Fig. 9B schematically shows device 100 after funnel 130 has been deployed by pushing rod 132, thereby introducing slack into the rod.

[0225] In some implementations, sealer 126 comprises a button, a slider, a knob, or any other actuator that can be manually operated to apply tension to rod 132. In some such implementations, once a user has advanced funnel 130 out of distal portion 152 (Fig. 9B), and optionally prior to applying suction, sealer 126 is actuated (e.g., pressed, rotated, and/or slid), thereby taking up slack in, and/or applying tension to, rod 132 (Fig. 9C). This may advantageously maintain proximal end 1311 in sealed engagement with distal portion 152 (e.g., within rim 158 thereof), even as device 100 is later retracted from the subject. In a scenario in which funnel 130 has lost sealed engagement with catheter 150 (e.g., during its advancement out of the catheter), actuating sealer 126 may draw proximal end 1311 of funnel 130 proximally into sealed engagement with the catheter.

[0226] In some implementations, sealer 126 is operatively coupled to deployment knob 122 such that actuation of the sealer locks, or inhibits, further operation of the deployment knob (e.g., thereby inhibiting further pushing of rod 132 distally). This may advantageously prevent funnel 130 from leaving sealed engagement with catheter 150, e.g., due to inadvertent movement of knob 122 during retraction of the embolus. In some implementations, once sealer 126 has been actuated, further operation of deployment knob 122 may be possible, but may only be done by applying a predetermined amount of force and/or actuation to the deployment knob, e.g., in order to overcome the locking mechanism between the sealer and the knob.

[0227] In some implementations, handle 120 comprises a drivewheel 129 that is engaged with rod 132, the drivewheel being operatively coupled to knob 122 (e.g. via gearing), such that rotating the knob in a first knob-direction rotates the drivewheel in a forward

drivewheel-direction (Fig. 9B), thereby pushing the rod distally to progressively transition device 100 from the delivery state towards the deployed state (e.g., as shown in the transition of funnel 130 between Fig. 9A and 9B). In some implementations, and as shown, drivewheel 129 defines or serves as a roller, by which the rod passes tangentially. Alternatively, drivewheel 129 may serve as or define a spool (e.g., around which the rod is wrapped) or a capstan (e.g., around which the rod curves).

[0228] In some implementations, a complementary roller 1291 is positioned on an opposite side of rod 132 to drivewheel 129, to maintain contact/grip between the drivewheel and the rod. Complementary roller 1291 may be spring-loaded, e.g., as shown. Complementary roller 1291 may be a passive roller that rotates in response to axial movement of rod 132.

[0229] In some implementations, drivewheel 129 includes, or is rotationally fixed to, drivewheel teeth 1271, which may be circumferentially distributed around a cogwheel 127. Sealer 126 may have sealer teeth 1261 (e.g., linearly distributed on an internal portion 125 of the sealer), such that actuating the sealer (i) engages the sealer teeth with drivewheel teeth 1271 and (ii) moves the cogwheel and the drivewheel in the reverse direction (Fig. 9C). In some implementations, and as shown, actuation of sealer 126 (i) engages sealer teeth 1261 in a rack-and-pinion arrangement with drivewheel teeth 1271, and (ii) moves the cogwheel and the drivewheel in the reverse direction via operation of this rack-and-pinion arrangement. For example, and as shown, actuation of sealer 126 may move sealer teeth 1261 along a tangent of cogwheel 127.

[0230] A spring 1267 may urge sealer 126 outwardly (Fig. 8B), e.g., thereby preventing the sealer from inadvertently engaging with drivewheel 129 (e.g., with cogwheel 127 thereof). In such implementations, actuating the sealer strains (e.g., compresses) spring 1267.

[0231] In some implementations, and as described hereinabove, once there is engagement between sealer teeth 1261 and drivewheel teeth 1271 (e.g., once sealer 126 has been activated) further advancement of the rod and funnel via deployment knob 122 may be impeded (Fig. 9C). That is engagement between sealer teeth 1261 and drivewheel teeth 1271 may stabilize funnel 130 in sealed engagement with distal portion 152 by inhibiting distal movement of the rod and the funnel with respect to the catheter.

[0232] Additionally or alternatively, actuating sealer 126 may cause a detent 1255 that is disposed on sealer 126 to engage with a tab 1269 or recess that is disposed within the handle,

thereby stabilizing the device in the sealed state by the tab preventing the detent, and thus the sealer, from returning to its unactuated state, thus inhibiting distal movement of rod 132.

[0233] In some implementations, it is possible to re-advance funnel 130 after sealer 126 has been actuated by reversing or overcoming the sealer. In the example shown, this is achieved simply by operating deployment knob 122 in the first knob-direction, thereby rotating drivewheel 129 (and cogwheel 127) in the forward drivewheel-direction. This thereby pushes sealer teeth 1261 out of engagement with drivewheel teeth 1271. For implementations in which handle 120 includes spring 1267, this disengagement triggers the spring to responsively push sealer teeth 1261 clear of drivewheel teeth 1271, pushing sealer 126 outwardly from the housing. For implementations in which handle 120 includes detent 1255, this rotation of drivewheel 129 also overcomes the detent. A predetermined amount of force and/or rotation of the knob may be required to achieve such disengagement.

[0234] It is to be understood that although sealer 126 is a discrete component to deployment knob 122, these two components are interlinked. For example, as shown, actuation of sealer 126 reverses drivewheel 129 (e.g., to which deployment knob 122 is rotationally coupled) and may even cause rotation of the deployment knob itself. Therefore, the meaning of this independence (e.g., discreteness) between these two components is that the sealer is a discrete component that can be actuated without touching the deployment knob.

[0235] In some implementations, handle 120 is configured to limit distal advancement of rod 132 in a manner that provides a predetermined limit to distal advancement of the funnel out of distal portion 152 of catheter 150. For example, and as shown in Figs. 9A-C, and Fig. 6B, handle 120 can comprise a stopper 123 that prevents over-advancement of rod 132 in a distalward direction. Rod 132 can have a backstop 139 at a proximal end portion thereof, such that over-advancement of rod, and therefore funnel 130, distally causes the backstop to abut against stopper 123. This may advantageously prevent the funnel from losing sealed engagement with the catheter, by preventing the funnel from leaving the catheter due to over advancement of the rod and/or by preventing the rod from becoming overly slack and therefore allowing the funnel to slip distally within the catheter. In some implementations, the predetermined limit of distalward advancement of rod 132 that stopper 123 enforces is linked to the extent that sealer 126 moves rod 132 proximally. For example, in a scenario in which catheter and/or rod 132 is compressed and therefore shortened, stopper 123 may allow proximal end 1311 of funnel 130 to leave the catheter by a predetermined amount, and sealer 126 may move rod proximally by a similar, or the same, extent to this predetermined amount.

[0236] Reference is now made to Figs. 10A-D which illustrate a sealer/stabilizer 126a, which can be considered to be a variant of sealer 126, in accordance with some implementations. Sealer 126a is typically housed within, or disposed in the vicinity of, handle 120.

[0237] Sealer 126a comprises a pair of grippers 1262 that are optionally slidably housed within a housing 1268. Housing 1268 can be adapted to limit the amount of movement of the grippers proximally and distally. Grippers 1262 grip rod 132 (e.g., by the rod being sandwiched between the grippers). A pair of springs 1266 may be positioned on opposing sides of each end of grippers 1262, pushing (e.g., urging) the grippers medially against rod 132. As illustrated in Fig. 10B, moving (e.g., pushing) rod distally (e.g., by rotating deployment knob 122 that subsequently rotates drivewheel 129 to push the rod distally) causes grippers 1262 to slide (e.g., skid) distally within housing 1268 while gripping the rod. As shown, a pair of springs 1264 connects a distal wall of housing 1268 to grippers 1262, such that this distalward motion of grippers 1262 towards the distal wall causes the springs to become compressed. As illustrated in Fig. 10C, once springs 1264 are fully compressed, no further distalward motion is possible, and further distal movement of rod 132 (e.g., via rotation of the deployment knob which in turn rotates drivewheel 129) simply causes skidding (e.g., sliding) of rod 132 through grippers 1262 without further movement of the grippers distally. Drivewheel 129 (e.g., together with an opposing, passive drivewheel on the opposite side of the rod) may exert a stronger force on rod 132 than grippers 1262, thereby allowing for this skidding, or slippage, of the rod through the grippers. As described hereinabove, moving rod 132 distally advances funnel 130 distally out of distal portion1 152, thereby deploying the funnel within the blood vessel.

[0238] As shown in Fig. 10D, once the user stops applying a distalward force to rod 132 (i.e., upon cessation of manual operation of the deployment knob), springs 1264 are free to expand, thereby pushing grippers 1262 proximally (e.g., until the grippers contact a proximal wall of housing 1268 and/or until the springs are fully expanded). This proximalward movement of grippers 1262 pull (e.g., drag) rod 132 proximally therealong. In some scenarios, and as shown in the transition of rod 132 between Figs. 9B and 9C, this proximalward movement of rod 132 may simply tension the rod, thereby increasing the stability of the device by ensuring that the rod is not excessively slack, which could cause the funnel to slip distally out of distal portion 152. In some implementations, this proximalward movement of rod 132 may move funnel 130 proximally within catheter 150,

which may return proximal end 1311 of the funnel to sealed engagement with distal portion 152 if the funnel has inadvertently left the catheter and has lost sealing therewith.

[0239] Thus, whereas sealer/stabilizer 126 is manually operated, sealer/stabilizer 126a operates automatically upon cessation of manual operation and/or release of the deployment knob.

[0240] Handle 120 can be designed to provide optimal ease of access to a user (e.g., physician) during the embolus-retrieval procedure. For example, and as illustrated in Figs. 5A-7B, in some implementations, handle 120 has a flat base 128 for resting on a surface such as the bed or the patient during the procedure. In some implementations, handle 120 has a foot 1281 that protrudes to define at least part of the flat base 128, to further increase the stability of the handle. That is, foot 1281 extends to define an extended part of the flat base.

[0241] In some implementations, a root (e.g., proximal end 159) of catheter 150 is attached (e.g., welded or connected) to handle 120, e.g., as illustrated in Fig. 6B. Proximal end 159 can be attached to the handle at a distally-facing part of the handle 120, e.g., as shown.

[0242] In some implementations, sealer 126 is a button that faces distally on the handle, e.g., it may be parallel to catheter 150, as shown.

[0243] Deployment knob 122 can be a thumbwheel that is mounted on the handle (e.g., on an opposite side of the handle to base 128, or laterally on the handle), allowing the user to easily position a thumb or finger on the thumbwheel while the base rests on a surface (e.g., with proximal end 159 of catheter extending between the user's fingers). That is, handle 120 can be shaped to be grasped by a hand of a user, with the catheter extending between fingers of the hand of the user and away from the handle. In some implementations, knob 122 is a knob, a slider, a button, and/or a pusher. In some implementations, rather than being manually actuatable via knob 122, the knob can be replaced with a drivewheel-actuator (e.g., a button) that drives drivewheel 129 electrically (e.g., via a motor). That is, drivewheel 129 can be actuated via a motor to push rod 132 distally. In some such implementations, the drivewheel-actuator can be actuated robotically e.g., the funnel can be advanced out of catheter 150 via a robotic control. In some implementations, rather than sealer 126 being manually actuatable, sealer 126 can be replaced with a sealer-actuator (e.g., discrete from the drivewheel-actuator) that drives the aforementioned motor to apply tension to rod 132 and/or to drive the drivewheel 129 to move the rod proximally. In some such

implementations, , the sealer-actuator applies tension until excess slack is consumed within the rod (e.g., until rod 132 is tensioned). In some implementations, actuating the sealer-actuator locks the motor. In some implementations, sealer-actuator and/or drivewheel-actuator can be robotically actuated, voice-operated, actuatable by pressing a button on a user-interface, and/or operatable via a foot-pedal.

[0244] In some such implementations, the coupling between deployment knob 122 and rod 132 ensures that funnel 130 is stable during movement (e.g., inadvertent or intentional) of catheter 150, and/or handle 120 during the procedure, i.e., the funnel does not move distally or proximally with respect to the catheter without intentionally rotating the thumbwheel.

[0245] In some implementations, and as illustrated in Fig. 6B, rod 132 extends from lumen 156, proximally through the handle where it is engaged with deployment knob 122 (e.g., via drivewheel 129), and further proximally through the handle where it sticks out of a proximal end of the handle, e.g., parallel to fluid port 124. In some such implementations, the rod is housed in a housing 121, on an opposite side of the handle to the catheter. In some implementations, stopper 123 can be housed within housing 121, e.g., such that backstop 139 does not pass through the main body of handle 120. In some such implementations, stopper 123 is disposed proximally from the main body of handle 120, e.g., the stopper is dimensioned to not pass through the main body of the handle.

[0246] In some implementations, fluid port 124 is positioned on the handle facing proximally, e.g., lateral to, and parallel with housing 121, and is fluidly connected to lumen 156 via a fluid lumen 1242 that extends laterally and towards catheter 150 within the handle, e.g., as shown in Fig. 6B.

[0247] Reference is again made to Figs. 1-10D. In some implementations, catheter 150 (e.g., distal portion 152 thereof) is actively steerable (e.g., via pull-wires that are embedded in the catheter wall). In some implementations, catheter 150 (e.g., distal portion 152 thereof) is passively steerable (e.g., is not actively steerable). In some implementations, prior to advancing catheter 150 into the subject, a guide wire is first advanced through handle 120 (e.g., through fluid port 124 and lumen 1242) into lumen 156 of the catheter and into the vasculature of the subject (e.g., into a femoral artery or vein, or a jugular artery or vein). In this way, the guide wire can be used to lead catheter 150 along the vasculature. In some implementations, a micro catheter is additionally threaded over the guidewire and through the catheter, such that the microcatheter additionally assists in the guidance of catheter 150

towards blood vessel 20. In some implementations, the guidewire and/or microcatheter lead catheter 150 by 10-20 cm.

[0248] In some implementations, the rigidity and/or width of catheter 150 decreases progressively distally along the catheter. That is, the catheter can be more flexible and/or thinner towards, or at, distal portion 152, to increase the flexibility and the advanceability of the distalmost portions of the catheter into the increasingly narrow blood vessels. In some implementations, distal portion 152 is more flexible than a stiffer proximal portion 151 of catheter. In some such implementations, distal portion 152 can be approximately 20 cm, and proximal portion 151 can be approximately 100 cm.

[0249] In some implementations, the rigidity and/or width of rod 132 decreases distally along the length of the rod, such that the rod is more rigid towards handle 120, and has increased flexibility towards funnel 130. In some implementations, this increasing, proximalward rigidity is provided by rod 132 having an increasingly large cross-sectional area along its length. In some implementations, rod 132 has a generally circular cross-section (e.g., as illustrated in Fig. 1). In some implementations, this increasing, proximalward rigidity of rod 132 is provided by the rod defining a variety of geometrical cross-sectional shapes along its length. For example, different cross-sectional shapes may provide different rigidities to the rod. In some such implementations, rod 132 may have a triangular cross-section, a square cross-section, an ovular cross-section, or any combination thereof along different sections of its length, in order to provide these varying (e.g., progressively increasing) rigidities. In some such implementations, the cross-sectional area of the rod does not necessarily vary significantly along its length. In some such implementations, the cross-sectional area of the rod does vary (e.g., increase) proximally along the length of the rod. In some such implementations, the rigidity of the rod increases proximally in association with the rigidity of the catheter, e.g., as the catheter becomes more rigid and/or having an enlarged diameter towards proximal end 159, the rigidity and/or diameter of the rod increases in concert.

[0250] In some implementations, in order to provide optimal flexibility to distal portion 152 during advancement of the catheter through the vasculature, funnel 130 is initially disposed proximally from distal portion 152, e.g., is constrained within lumen 156 20-50 cm proximally from rim 158. This may allow distal portion 152 to more easily navigate the tortuous vasculature, e.g., by allowing for easier steerability of the curvatures of the vasculature.

[0251] Reference is now made to Figs. 11A-B and 12A-C which illustrate various methods and systems for adjusting a curvature of the distal portion, in accordance with some applications. During advancement of catheter towards embolus 15, it may be desired to deflect, or curve the distal portion in order to steer the catheter towards the blood vessel 20 in which embolus 15 is situated. For example, if distal portion is proximal to a fork in the vasculature, it may be desired to curve, or deflect, the distal end towards a specific blood vessel of the fork in which it is suspected that embolus 15 is situated. In some implementations, and as described hereinabove, catheter 150 can be manufactured such that distal portion 152 is more flexible than a more proximal portion of the catheter, e.g., to facilitate this steering. Distal portions 152a and 152b can be variants, or substantially identical to, distal portion 152. It is to be understood that catheter 150 could be modified to have distal portion 152a and/or distal portion 152b.

[0252] In some implementations, and as shown in Figs 11A-B, rod 132 extends eccentrically within lumen 156, such that advancing the rod and the funnel distally within the lumen increases the curvature by the rod (e.g., and the funnel therewith) applying an eccentric, compressive force on the catheter (e.g., as shown in the transition between Fig. 11A and 11B). In some implementations, rod 132 extends eccentrically within lumen 156 due to the rod being joined to proximal end 1311 at proximal vertex 1315, e.g., eccentrically to funnel 130 (e.g., as illustrated in Fig. 4B). Retracting rod 132 and funnel 130 therealong proximally within lumen 156 may cause distal portion 152a to straighten, e.g., thereby decreasing the curvature of the distal portion.

[0253] A user may choose to rotate the distal portion, in order to achieve the desired angle of distal portion 152a with respect to the vasculature. In some implementations, this is done prior to advancing the funnel distally within the distal portion (e.g., prior to increasing the curvature of the device). In some implementations, this is done subsequently to advancing the funnel distally within the distal portion.

[0254] Figs. 12A-C illustrate an implementation in which distal portion 152b is biased toward being curved. For example, distal portion 152b may be shape-set (e.g., heat set) to having a pre-curved form. In some such implementations, pushing the funnel distally, in its compressed state, within the distal portion of the catheter reduces the curvature of the catheter (e.g., straightens the catheter, as illustrated in the transition of distal portion 152b between Figs. 12B and 12A), and pulling the funnel proximally increases the curvature of the catheter (as illustrated in the transition of distal portion 152b between Figs. 12A and

12B). That is, funnel 130 may act like a spine that stiffens the distal portion while the funnel is disposed therewithin. For example, as a greater extent of funnel 130 becomes disposed within distal portion 152, the distal portion becomes stiffer and/or has a reduced curvature.

[0255] As illustrated in Fig. 12C, a user may choose to rotate the distal portion, in order to achieve the desired angle of distal portion 152b with respect to the vasculature. In some implementations, this is done prior to advancing the funnel distally within the distal portion. In some implementations, this is done subsequently to advancing the funnel distally within the distal portion.

[0256] Reference is again made to Figs. 1-12C. In some implementations, device 100 can be used as a flow-restriction and/or stabilizing device during a treatment of a subject. For example, rather than using device 100 for retrieving an obstruction from a blood vessel, the device could be used as part of a delivery system during a medical treatment. As described hereinabove, funnel 130 can be designed such that expanding the funnel within a blood vessel obstructs (e.g., partially and/or fully obstructs) blood flow therethrough. Similarly, funnel 130 can be designed such that expanding the funnel within a blood vessel stabilizes catheter 150 e.g., by funnel 130 pressing against the blood vessel wall and preventing the device from slipping distally and/or proximally. In some implementations, device 100 can be used during a procedure in which an occluder (e.g., coils and/or beads) is implanted within a blood vessel (e.g., during treatment of an aneurysm, an arteriovenous malformation and/or a hemorrhagic stroke). In some such implementations, an occluder-delivery device is passed through the working channel of device 100 (e.g., through lumen 156 and funnel 130, and out of mouth 133) and towards the treatment site. In some such implementations, device 100 can be positioned proximally from the treatment site, e.g., such that mouth 133 faces, but is positioned proximally to, the treatment site. During treatment (e.g., during implantation of the occluder within the treatment site), the occluder-delivery device may rebound proximally, e.g., responsively to a distalward force applied by the delivery of the occluder. Funnel 130 may prevent this rebound effect, e.g., due to its stabilizing presence against the walls of the blood vessel. Similarly, should the occluder migrate downstream (e.g., proximally) during the treatment, funnel 130 would advantageously catch the occluder and prevent it from becoming lodged inside a blood vessel. This may be especially advantageous if the occluder is a drug-delivery device (e.g., delivering radiation and/or chemotherapy to the treatment site). In some implementations, funnel 130 only partially obstructs the blood vessel, e.g., it allows some blood flow through the funnel.

[0257] The present disclosure includes different variants of some elements. Variants of a given element typically have the same structure and/or function as each other except for any differences described. For any given element for which different variants are disclosed, the identical name is used for each variant, in order to denote that they are, in fact, variants the same given element. Unless stated otherwise, applications of the devices, systems, and techniques described herein may include any arrangement in which one variant of an element is substituted with another identically-named variant of that element. Furthermore, throughout the figures, suffixes are used to denote different variants of the same element. Unless stated otherwise, such variants may be substituted with each other, mutatis mutandis. That is, unless stated otherwise, any element having a given reference numeral may be substituted with any other element (i.e., any other variant of the element) having the same reference numeral, independent of any suffix.

[0258] In order to avoid undue clutter from having too many reference numbers and lead lines on a particular drawing, some elements are introduced via one or more drawings and not explicitly identified in every other drawing that contains that element.

[0259] The described systems, apparatuses, devices, methods, etc. should not be construed as limiting in any way. Instead, the present disclosure is directed toward all novel and nonobvious features and aspects of the various disclosed implementations and applications, alone and in various combinations and sub-combinations with one another. The disclosed systems, apparatuses, devices, methods, etc. are not limited to any specific aspect, feature, or combination thereof, nor do the disclosed systems, apparatuses, devices, methods, etc. require that any one or more specific advantages be present or problems be solved.

[0260] The various systems, devices, apparatuses, etc. in this disclosure can be sterilized (e.g., with heat, radiation, ethylene oxide, hydrogen peroxide, etc.) to ensure they are safe for use with patients, and the methods herein can comprise such sterilization of the associated system, device, apparatus, etc. Furthermore, the scope of the present disclosure includes, for some applications, sterilizing one or more of any of the various systems, devices, apparatuses, etc. in this disclosure.

[0261] Any of the techniques, methods, operations, steps, etc. described or suggested herein can be performed on a living animal (e.g., human, other mammal, etc.) or on a non-living simulation, such as a cadaver, a cadaver heart, an anthropomorphic ghost, and/or a simulator device (which may include computerized and/or physical representations of body parts, tissue, etc.).

[0262] Various implementations of systems, devices, methods, etc. are disclosed herein, and any combination of their features, components, and options can be made unless specifically excluded.

[0263] Although the operations of some of the disclosed methods are described in a particular, sequential order for convenient presentation, it should be understood that this manner of description encompasses rearrangement, unless a particular ordering is required by specific language set forth herein. For example, operations described sequentially can in some cases be rearranged or performed concurrently. Moreover, for the sake of simplicity, the attached figures may not show the various ways in which the disclosed systems, apparatuses, devices, methods, etc. can be used in conjunction with other systems, apparatuses, devices, methods, etc.

[0264] **Example Implementations** (some non-limiting examples of the concepts herein are recited below):

[0265] Example 1. Apparatus for removing an obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject, the apparatus comprising: (A) a flexible catheter, having: (a) a proximal portion, (b) a distal portion that is configured for transluminal advancement into the blood vessel (e.g., cerebral artery), the distal portion having a rim, and/or (c) a lumen, extending from the proximal portion to the rim; (B) a funnel: (a) having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal end of the funnel, (b) being biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or (c) elastically compressible into a compressed state in which the mouth is narrower than in the expanded state; (C) a flexible rod, attached to the proximal end of the funnel, and/or extending proximally through the catheter; and (D) a handle, at the proximal portion of the catheter, the handle comprising: (a) a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between: (I) a delivery state in which the funnel is in the compressed state within the catheter, and/or (II) a deployed state in which the funnel is in the expanded state, with an outer surface of the funnel being in sealed engagement with the rim, and/or the mouth is (i) exposed from the distal portion of the catheter, and/or (ii) fluidically connected to the lumen such that suction applied through the lumen sucks the obstruction (e.g., embolus) into the funnel via the mouth, and/or (b) a stabilizer, discrete

from the deployment knob, and/or configured to stabilize the apparatus in the deployed state by applying tension to the rod.

[0266] Example 2. The apparatus according to example 1, wherein the handle is configured to limit distal advancement of the rod in a manner that provides a predetermined limit to distal advancement of the funnel out of the distal portion of the catheter.

[0267] Example 3. The apparatus according to any one of examples 1-2, wherein the deployment knob is a thumbwheel.

[0268] Example 4. The apparatus according to any one of examples 1-3, wherein the deployment knob is a slider, the deployment knob being operable via sliding of the slider.

[0269] Example 5. The apparatus according to any one of examples 1-4, wherein the stabilizer is configured to, upon actuation, inhibit further operation of the deployment knob.

[0270] Example 6. The apparatus according any one of examples 1-5, wherein the catheter comprises a hypotube, and/or a polymeric cover that coats the hypotube, and/or wherein the polymeric cover extends beyond the hypotube to define the rim.

[0271] Example 7. The apparatus according to any one of examples 1-6, wherein a flexibility of the catheter increases progressively distally along the catheter.

[0272] Example 8. The apparatus according to example 7, wherein a flexibility of the rod increases progressively distally along the rod.

[0273] Example 9. The apparatus according to any one of examples 1-8, wherein the distal portion of the catheter has a curvature that is adjustable by applying an axial force to the rod.

[0274] Example 10. The apparatus according to example 9, wherein the distal portion of the catheter is more flexible than the proximal portion of the catheter.

[0275] Example 11. The apparatus according to example 9, wherein the distal portion of the catheter has a length of 10-30 cm.

[0276] Example 12. The apparatus according to example 9, wherein the distal portion of the catheter is biased toward being curved.

[0277] Example 13. The apparatus according to example 12, wherein the apparatus is configured such that a curvature of the distal portion is reducible by positioning the funnel, in its compressed state, within the distal portion of the catheter.

[0278] Example 14. The apparatus according to example 9, wherein the rod is coupled to the funnel eccentrically within the lumen, such that distalward pushing of the rod applies an eccentric pushing force to the funnel, which responsively articulates with respect to the rod, thereby increasing the curvature of the catheter.

[0279] Example 15. The apparatus according to example 9, wherein the rod is coupled to the funnel eccentrically within the lumen, such that distalward pushing of the rod applies an eccentric pushing force to the funnel, which responsively turns to deflect the distal portion of the catheter.

[0280] Example 16. The apparatus according to any one of examples 1-15, wherein: (i) the funnel, in its expanded state, has a flared surface distal to the opening, and/or (ii) the stabilizer is configured to stabilize the apparatus by retracting the funnel into the sealed engagement with the catheter by sealing the flared surface against the rim.

[0281] Example 17. The apparatus according to example 16, wherein the rim flares distally.

[0282] Example 18. The apparatus according to any one of examples 1-17, wherein the catheter is fixedly attached to the handle.

[0283] Example 19. The apparatus according to example 18, wherein the catheter is welded onto the handle.

[0284] Example 20. The apparatus according to any one of examples 1-19, wherein the rod comprises an extracorporeal stopper that provides a predetermined limit to distal advancement of the funnel out of the distal portion of the catheter by limiting distal advancement of the rod through the handle to a predetermined distance.

[0285] Example 21. The apparatus according to example 20, wherein the stabilizer is configured such that actuation of the stabilizer pulls the rod proximally by the predetermined distance.

[0286] Example 22. The apparatus according to any one of examples 1-21, wherein the stabilizer is manually actuatable independently of the deployment knob.

[0287] Example 23. The apparatus according to example 22, wherein the stabilizer comprises a button, and/or is manually actuatable via pushing of the button.

[0288] Example 24. The apparatus according to any one of examples 1-23, wherein the handle further comprises a port that is fluidically connected to the catheter, the port adapted to receive a suction applicator adapted to apply the suction.

[0289] Example 25. The apparatus according to example 24, further comprising the suction applicator.

[0290] Example 26. The apparatus according to example 25, wherein the suction applicator comprises a syringe.

[0291] Example 27. The apparatus according to any one of examples 1-26, wherein the funnel is constructed from braided wires.

[0292] Example 28. The apparatus according to example 27, wherein the braided wires are gathered at the proximal end in an elliptical loop that defines the opening as an elliptical opening.

[0293] Example 29. The apparatus according to example 28, wherein the elliptical loop is covered in a polymer coating that reinforces the opening.

[0294] Example 30. The apparatus according to example 29, wherein, in the sealed engagement, the polymer coating fits snugly within the distal portion of the catheter.

[0295] Example 31. The apparatus according to example 28, wherein: (i) the funnel has a central longitudinal axis that passes through the mouth and the opening, and/or (ii) the elliptical opening has a major axis that is oblique to the longitudinal axis.

[0296] Example 32. The apparatus according to example 31, wherein: (i) the elliptical opening has: (a) a distal vertex that lies on the major axis, on a first side of the longitudinal axis, and/or (b) a proximal vertex that lies on the major axis, and/or is disposed on an opposite side of the longitudinal axis from the distal vertex, proximal from the distal vertex, and/or (ii) the rod is attached to the proximal end of the funnel by being attached to the elliptical opening at the proximal vertex.

[0297] Example 33. The apparatus according to any one of examples 1-32, wherein the stabilizer comprises a manually-actuatable mechanism that is adapted to stabilize the apparatus in the deployed state by applying tension to the rod upon being manually actuated.

[0298] Example 34. The apparatus according to any one of examples 1-33, wherein the stabilizer comprises a spring-loaded mechanism that is adapted to stabilize the apparatus in the deployed state by applying tension to the rod.

[0299] Example 35. The apparatus according to example 34, wherein the spring-loaded mechanism is adapted to apply the tension to the rod automatically upon cessation of manual operation of the deployment knob.

[0300] Example 36. The apparatus according to any one of examples 1-35, wherein the deployment knob is operatable via rotation.

[0301] Example 37. The apparatus according to example 36, wherein the handle comprises a drivewheel that is engaged with the rod and operatively coupled to the knob, such that rotating the knob in a first knob-direction rotates the drivewheel in a forward drivewheel-direction, thereby pushing the rod distally to progressively transition the apparatus from the delivery state towards the deployed state.

[0302] Example 38. The apparatus according to example 37, wherein the drivewheel defines a roller, the rod passing tangentially by the roller.

[0303] Example 39. The apparatus according to example 38, wherein the drivewheel defines a spool, the rod wrapped around the spool.

[0304] Example 40. The apparatus according to example 38, wherein the drivewheel defines a capstan, the rod curving around the capstan.

[0305] Example 41. The apparatus according to example 37, wherein the stabilizer is configured such that actuation of the stabilizer rotates the drivewheel in a reverse drivewheel-direction, thereby pulling the rod proximally.

[0306] Example 42. The apparatus according to example 41, wherein the stabilizer is configured with a first position and a second position, and/or to be actuated by moving the stabilizer from the first position into the second position, such that actuation of the stabilizer rotates the drivewheel by a predetermined discrete amount in the reverse drivewheel-direction, thereby pulling the rod proximally by a predetermined discrete distance.

[0307] Example 43. The apparatus according to example 41, wherein: (i) the drivewheel has drivewheel teeth, (ii) the stabilizer has sealer teeth, and/or (iii) actuating the stabilizer engages the sealer teeth with the drivewheel teeth and moves the drivewheel in the reverse drivewheel-direction.

[0308] Example 44. The apparatus according to example 43, wherein the drivewheel teeth are circumferentially distributed, the sealer teeth are linearly distributed, and/or actuation of

the stabilizer moves the sealer teeth into a rack-and-pinion arrangement with the drivewheel teeth.

[0309] Example 45. The apparatus according to example 43, wherein the engagement between the sealer teeth and the drivewheel teeth stabilizes the apparatus by inhibiting distal movement of the rod and the funnel with respect to the catheter.

[0310] Example 46. Apparatus for removing an obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject, the apparatus comprising: (A) a flexible catheter, having: (a) a proximal portion, (b) a distal portion that is configured for transluminal advancement into the blood vessel (e.g., cerebral artery), the distal portion having a rim, and/or (c) a lumen, extending from the proximal portion to the rim; (B) a funnel: (a) having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal end of the funnel, (b) being biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or (c) elastically compressible into a compressed state in which the mouth is narrower than in the expanded state; (C) a flexible rod, attached to the proximal end of the funnel, and/or extending proximally through the catheter; and (D) a handle, at the proximal portion of the catheter, the handle comprising: (a) a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between: (I) a delivery state in which the funnel is in the compressed state within the catheter, and/or (II) a deployed state in which the funnel is in the expanded state, with an outer surface of the funnel being in sealed engagement with the rim, and/or the mouth is (i) exposed from the distal portion of the catheter, and/or (ii) fluidically connected to the lumen such that suction applied through the lumen sucks the obstruction (e.g., embolus) into the funnel via the mouth, and/or (b) a stabilizer, discrete from the deployment knob, and/or configured to stabilize the apparatus in the deployed state by taking up slack in the rod.

[0311] Example 47. Apparatus for removing obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject, the apparatus comprising: (A) a flexible catheter, having: (a) a proximal portion, (b) a distal portion that is configured for transluminal advancement into the blood vessel (e.g., cerebral artery), the distal portion having a rim, and/or (c) a lumen, extending from the proximal portion to the rim; (B) a funnel: (a) having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal

end of the funnel, (b) being biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or (c) elastically compressible into a compressed state in which the mouth is narrower than in the expanded state; (C) a flexible rod, attached to the proximal end of the funnel, and/or extending proximally through the catheter; and (D) a handle, at the proximal portion of the catheter, the handle defining a flat base for resting on a surface, the handle comprising: (a) a thumbwheel, operatively coupled to the flexible rod such that manual operation of the thumbwheel progressively transitions the apparatus between (i) a delivery state in which the funnel is in the compressed state within the catheter, and/or (ii) a deployed state in which the funnel is in the expanded state and the mouth is exposed from the distal portion of the catheter, and/or (b) a fluid port facing proximally, and/or fluidically connected to the mouth of the funnel and adapted to receive a suction source such that suction applied to the fluid port is transferred via the lumen to draw the obstruction (e.g., embolus) into the funnel via the mouth.

[0312] Example 48. The apparatus according to example 47, wherein the handle has a foot that extends to define an extended part of the flat base.

[0313] Example 49. The apparatus according to any one of examples 47-48, wherein the fluid port is proximally-facing.

[0314] Example 50. The apparatus according to any one of examples 47-49, wherein the thumbwheel is laterally-facing.

[0315] Example 51. The apparatus according to any one of examples 47-50, wherein the proximal portion of the catheter is fixedly attached to the handle.

[0316] Example 52. The apparatus according to example 51, wherein handle is shaped to be grasped by a hand of a user, with the catheter extending between fingers of the hand and away from the handle.

[0317] Example 53. The apparatus according to example 51, wherein the proximal portion of the catheter is attached to the handle at a distally-facing part of the handle.

[0318] Example 54. The apparatus according to example 53, wherein the handle further comprises a sealer, configured to transition the apparatus into a sealed state by retracting the funnel into sealed engagement with the rim such that, in the sealed state: (i) the funnel remains in the expanded state, and/or (ii) the mouth of the funnel is fluidically connected to the lumen such that suction applied through the lumen sucks the embolus into the funnel via the mouth.

[0319] Example 55. The apparatus according to example 54, wherein the sealer is distally-facing.

[0320] Example 56. Apparatus for removing obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject, the apparatus comprising: (A) a flexible catheter, having: (a) a proximal portion, (b) a distal portion that is configured for transluminal advancement into the blood vessel (e.g., cerebral artery), the distal portion having a rim, and/or (c) a lumen, extending from the proximal portion to the rim; (B) a funnel: (a) having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal end of the funnel, (b) being biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or (c) elastically compressible into a compressed state in which the mouth is narrower than in the expanded state; (C) a flexible rod, attached to the proximal end of the funnel, and/or extending proximally through the catheter; and (D) a handle, at the proximal portion of the catheter, the handle comprising: (a) a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between (i) a delivery state in which the funnel is in the compressed state within the catheter, and/or (ii) a deployed state in which the funnel is in the expanded state and the mouth is exposed from the distal portion of the catheter, and/or (b) a sealer, discrete from the deployment knob, and/or configured to transition the apparatus into a sealed state by retracting the funnel into sealed engagement with the rim such that, in the sealed state: (I) the funnel remains in the expanded state, and/or (II) the mouth of the funnel is fluidically connected to the lumen such that suction applied through the lumen sucks the obstruction (e.g., embolus) into the funnel via the mouth.

[0321] Example 57. The apparatus according to example 56, wherein the sealer is manually actuatable independently of the deployment knob.

[0322] Example 58. The apparatus according to any one of examples 56-57, wherein the sealer is a discrete component with respect to the deployment knob.

[0323] Example 59. The apparatus according to any one of examples 56-58, wherein the sealer is a button, and/or wherein pressing the button transitions the apparatus into the sealed state.

[0324] Example 60. The apparatus according to any one of examples 56-59, wherein the deployment knob is a thumbwheel.

[0325] Example 61. The apparatus according to any one of examples 56-60, wherein the catheter comprises a hypotube, and/or a polymeric cover that coats the hypotube, and/or wherein the polymeric cover extends beyond the hypotube to define the rim.

[0326] Example 62. The apparatus according to any one of examples 56-61, wherein the handle is configured to limit distal advancement of the rod in a manner that provides a predetermined limit to distal advancement of the funnel out of the distal portion of the catheter.

[0327] Example 63. The apparatus according to any one of examples 56-62, wherein the deployment knob is a slider, the deployment knob being operable via sliding of the slider.

[0328] Example 64. The apparatus according to any one of examples 56-63, wherein the sealer is configured to, upon actuation, inhibit further operation of the deployment knob.

[0329] Example 65. The apparatus according to any one of examples 56-64, wherein a flexibility of the catheter increases progressively distally along the catheter.

[0330] Example 66. The apparatus according to example 65, wherein a flexibility of the rod increases progressively distally along the rod.

[0331] Example 67. The apparatus according to any one of examples 56-66, wherein the distal portion of the catheter has a curvature that is adjustable by applying an axial force to the rod.

[0332] Example 68. The apparatus according to example 67, wherein the distal portion of the catheter is more flexible than the proximal portion of the catheter.

[0333] Example 69. The apparatus according to example 67, wherein the distal portion of the catheter has a length of 10-30 cm.

[0334] Example 70. The apparatus according to example 67, wherein the distal portion of the catheter is biased toward being curved.

[0335] Example 71. The apparatus according to example 70, wherein the apparatus is configured such that a curvature of the distal portion is reducible by positioning the funnel, in its compressed state, within the distal portion of the catheter.

[0336] Example 72. The apparatus according to example 67, wherein the rod is coupled to the funnel eccentrically within the lumen, such that distalward pushing of the rod applies an

eccentric pushing force to the funnel, which responsively articulates with respect to the rod, thereby increasing the curvature of the catheter.

[0337] Example 73. The apparatus according to example 67, wherein the rod is coupled to the funnel eccentrically within the lumen, such that distalward pushing of the rod applies an eccentric pushing force to the funnel, which responsively turns to deflect the distal portion of the catheter.

[0338] Example 74. The apparatus according to any one of examples 56-73, wherein: (i) the funnel, in its expanded state, has a flared surface distal to the opening, and/or (ii) the sealer is configured to retract the funnel into the sealed engagement with the catheter by sealing the flared surface against the rim.

[0339] Example 75. The apparatus according to example 74, wherein the rim flares distally.

[0340] Example 76. The apparatus according to any one of examples 56-75, wherein the catheter is fixedly attached to the handle.

[0341] Example 77. The apparatus according to example 76, wherein the catheter is welded onto the handle.

[0342] Example 78. The apparatus according to any one of examples 56-77, wherein the rod comprises an extracorporeal stopper that provides a predetermined limit to distal advancement of the funnel out of the distal portion of the catheter by limiting distal advancement of the rod through the handle to a predetermined distance.

[0343] Example 79. The apparatus according to example 78, wherein the sealer is configured such that actuation of the sealer pulls the rod proximally by the predetermined distance.

[0344] Example 80. The apparatus according to any one of examples 56-79, wherein the handle further comprises a port that is fluidically connected to the catheter, the port adapted to receive a suction applicator adapted to apply the suction.

[0345] Example 81. The apparatus according to example 80, further comprising the suction applicator.

[0346] Example 82. The apparatus according to example 81, wherein the suction applicator comprises a syringe.

[0347] Example 83. The apparatus according to any one of examples 56-82, wherein the funnel is constructed from braided wires.

[0348] Example 84. The apparatus according to example 83, wherein the braided wires are gathered at the proximal end in an elliptical loop that defines the opening as an elliptical opening.

[0349] Example 85. The apparatus according to example 84, wherein the elliptical loop is covered in a polymer coating that reinforces the opening.

[0350] Example 86. The apparatus according to example 85, wherein, in the sealed state, the polymer coating fits snugly within the distal portion of the catheter.

[0351] Example 87. The apparatus according to example 84, wherein: (i) the funnel has a central longitudinal axis that passes through the mouth and the opening, and/or (ii) the elliptical opening has a major axis that is oblique to the longitudinal axis.

[0352] Example 88. The apparatus according to example 87, wherein: (i) the elliptical opening has: (a) a distal vertex that lies on the major axis, on a first side of the longitudinal axis, and/or (b) a proximal vertex that lies on the major axis, and/or is disposed on an opposite side of the longitudinal axis from the distal vertex, proximal from the distal vertex, and/or (ii) the rod is attached to the proximal end of the funnel by being attached to the elliptical opening at the proximal vertex.

[0353] Example 89. The apparatus according to any one of examples 56-88, wherein the sealer comprises a spring-loaded mechanism that is adapted to transition the apparatus into the sealed state by applying tension to the rod.

[0354] Example 90. The apparatus according to example 89, wherein the spring-loaded mechanism is adapted to apply the tension to the rod automatically upon cessation of manual operation of the deployment knob.

[0355] Example 91. The apparatus according to any one of examples 56-90, wherein the sealer comprises a manually-actuatable mechanism that is adapted to stabilize the apparatus in the deployed state by applying tension to the rod upon being manually actuated.

[0356] Example 92. The apparatus according to any one of examples 56-91, wherein the deployment knob is operatable via rotation.

[0357] Example 93. The apparatus according to example 92, wherein the handle comprises a drivewheel that is engaged with the rod and operatively coupled to the knob, such that

rotating the knob in a first knob-direction rotates the drivewheel in a forward drivewheel-direction, thereby pushing the rod distally to progressively transition the apparatus from the delivery state towards the deployed state.

[0358] Example 94. The apparatus according to example 93, wherein the drivewheel defines a roller, the rod passing tangentially by the roller.

[0359] Example 95. The apparatus according to example 94, wherein the drivewheel defines a spool, the rod wrapped around the spool.

[0360] Example 96. The apparatus according to example 94, wherein the drivewheel defines a capstan, the rod curving around the capstan.

[0361] Example 97. The apparatus according to example 93, wherein the sealer is configured such that actuation of the sealer rotates the drivewheel in a reverse drivewheel-direction, thereby retracting the funnel into the sealed engagement by pulling the rod proximally.

[0362] Example 98. The apparatus according to example 97, wherein the sealer is configured with a first position and a second position, and/or to be actuated by moving the sealer from the first position into the second position, such that actuation of the sealer rotates the drivewheel by a predetermined discrete amount in the reverse drivewheel-direction, thereby pulling the rod proximally by a predetermined discrete distance.

[0363] Example 99. The apparatus according to example 97, wherein: (i) the drivewheel has drivewheel teeth, (ii) the sealer has sealer teeth, and/or (iii) actuating the sealer engages the sealer teeth with the drivewheel teeth and moves the drivewheel in the reverse drivewheel-direction.

[0364] Example 100. The apparatus according to example 99, wherein the drivewheel teeth are circumferentially distributed, the sealer teeth a linearly distributed, and/or actuation of the sealer moves the sealer teeth into a rack-and-pinion arrangement with the drivewheel teeth.

[0365] Example 101. The apparatus according to example 99, wherein the engagement between the sealer teeth and the drivewheel teeth stabilizes the apparatus in the sealed state by holding the funnel in sealed engagement with the rim by inhibiting distal movement of the rod and the funnel with respect to the catheter.

[0366] Example 102. Apparatus for removing an obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a subject, the apparatus comprising: (A) a flexible catheter, having: (a) a proximal portion, (b) a distal portion that is configured for transluminal advancement into the blood vessel (e.g., cerebral artery), the distal portion having a rim, and/or (c) a lumen, extending from the proximal portion to the rim; (B) a funnel: (a) formed from a set of braided wires covered in a covering, (b) having: (i) a mouth at a distal end of the funnel, (ii) at the mouth, a scoop that protrudes distally, the scoop defined by: (I) a first lateral petal, formed from a bight of a first wire of the set, (II) a second lateral petal, formed from a bight of a second wire of the set, (III) a medial petal disposed between, and/or overlapping with, the first and second lateral petals, the medial petal formed from a bight of a third wire of the set, the third wire being more flexible than the first wire and more flexible than the second wire, and/or (IV) an opening at a proximal end of the funnel, (c) being biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or (d) elastically compressible into a compressed state in which the mouth is narrower than in the expanded state.

[0367] Example 103. The apparatus according to example 102, wherein for each of the first, second, and/or third petals, the respective wire defines two tails that diverge from each other away from the bight, to extend with opposite helical handedness along the funnel toward the opening.

[0368] Example 104. The apparatus according to any one of examples 102-103, wherein: (i) the funnel has a central longitudinal axis that passes through the mouth and the opening, and/or (ii) in the expanded state, the scoop flares radially outwards from the central longitudinal axis.

[0369] Example 105. The apparatus according to any one of examples 102-104, wherein: (i) each of the first and second lateral petals defines a lateral tail and a medial tail, the lateral tail extending away from the bight and the medial petal, and/or helically along the funnel toward the opening, and/or the medial tail extending away from the bight to overlap with the medial petal and extend helically along the funnel toward the mouth, and/or (ii) the set of wires includes at least one respective petal-support wire for each of the lateral petals, each petal-support wire defining a loop that, at the mouth, loops around the lateral tail of the respective lateral petal to support the respective lateral petal.

[0370] Example 106. The apparatus according to example 105, wherein the set of wires includes exactly two respective petal-support wires for each of the lateral petals.

[0371] Example 107. The apparatus according to example 105, wherein each of the petal-support wires defines a pair of tails that extend proximally away from the loop and helically along the funnel toward the opening.

[0372] Example 108. The apparatus according to example 107, wherein, for each of the petal-support wires, the tails of the pair extend, in parallel, and/or with the same helical handedness as each other, along the funnel toward the opening.

[0373] Example 109. The apparatus according to example 108, wherein, for each of the lateral petals, the set of wires includes a first petal-support wire and a second petal-support wire, the tails of the first petal-support wire extending along the funnel toward the opening in parallel, and/or with the same helical handedness, as each other as the tails of the second petal-support wire.

[0374] Example 110. The apparatus according to example 109, wherein the loop of the first petal-support wire is distal to the loop of the second petal-support wire, and/or the first petal-support wire is stiffer than the second petal-support wire.

[0375] Example 111. The apparatus according to any one of examples 102-110, wherein: (i) the scoop is a first scoop, (ii) the funnel has an opposing scoop at the mouth, the opposing scoop defined by at least two arc-wires of the set collectively, by each arc-wire forming an arc partway around the mouth, the arcs overlapping with each other, and/or (iii) the opposing scoop is opposite the first scoop.

[0376] Example 112. The apparatus according to example 111, wherein, in response to a compressive force applied to the funnel, the opposing scoop is configured to extend distally by the arcs deforming to have a decreased radius of curvature.

[0377] Example 113. The apparatus according to example 111, wherein the opposing scoop is defined by exactly two arc-wires forming exactly two arcs.

[0378] Example 114. The apparatus according to example 113, wherein the first scoop is defined by no further wires of the set other than the first wire defining the first lateral petal, the second wire defining the second lateral petal, and/or the third wire defining the medial petal.

[0379] Example 115. The apparatus according to example 111, wherein the first scoop protrudes distally beyond the opposing scoop.

[0380] Example 116. The apparatus according to example 111, wherein the first scoop is longer than the opposing scoop.

[0381] Example 117. The apparatus according to example 111, wherein each of the arc-wires is an arc-wire of a pair of parallel extending arc-wires, each pair facing distally.

[0382] Example 118. The apparatus according to example 111, wherein the opposing scoop further comprises a single arc-wire that forms an arc in between, and/or proximally from, the two-arc wires.

[0383] Example 119. A method for advancing an embolus-retrieval device into a real or simulated blood vessel (e.g., an artery, such as a cerebral artery, or a vein, such as a cerebral vein) of a real or simulated subject, the method comprising: (i) transluminally advancing a distal portion of a flexible catheter into the blood vessel (e.g., cerebral artery) while: (a) a funnel is compressed within a lumen of the catheter, and/or (b) a flexible rod that is attached to the proximal end of the funnel extends proximally through the catheter; (ii) via a rod that extends, from the proximal end of the funnel and proximally through the lumen, adjusting a curvature of the distal portion by applying an axial force to the rod; and (iii) subsequently, advancing the funnel out of the distal portion such that the funnel expands within the blood vessel (e.g., cerebral artery).

[0384] Example 120. The method according to example 119, wherein transluminally advancing the distal portion of the catheter into the cerebral artery comprises transluminally advancing the distal portion of the catheter into the cerebral artery while the funnel is disposed within the lumen proximally from the distal portion.

[0385] Example 121. The method according to example 119, wherein the method further comprises applying suction to aspirate a real or simulated embolus into the funnel.

[0386] Example 122. The method according to example 119, wherein the distal portion of the catheter is biased toward being curved, and/or wherein adjusting the curvature of the distal portion by applying the axial force to the rod comprises reducing the curvature of the distal portion by pushing the funnel distally, in its compressed state, within the distal portion of the catheter.

[0387] Example 123. The method according to example 119, wherein the distal portion of the catheter is biased toward being curved, and/or wherein adjusting the curvature of the distal portion by applying the axial force to the rod comprises increasing the curvature of the distal portion by pulling the funnel proximally, in its compressed state, within the distal portion of the catheter.

[0388] Example 124. The method according to example 119, wherein the rod extends eccentrically within the lumen, and/or wherein adjusting the curvature of the distal portion by applying the axial force to the rod comprises advancing the rod and the funnel distally within the lumen to increase the curvature by the funnel and the rod applying an eccentric, compressive force on the catheter.

[0389] Example 125. The method according to example 119, wherein the method further comprises rotating the catheter within the subject prior to adjusting the curvature of the distal portion.

[0390] Example 126. The method according to example 119, wherein the rod extends eccentrically within the lumen, and/or wherein adjusting the curvature of the distal portion by applying the axial force to the rod comprises pulling the rod and the funnel proximally within the lumen to decrease the curvature.

[0391] Example 127. A method for removing a real or simulated obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a real or simulated blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a real or simulated subject, the method comprising: (i) transluminally advancing a distal portion of a flexible catheter into the blood vessel (e.g., cerebral artery) while: (a) a funnel is compressed within a lumen of the catheter, and/or (b) a rod extends, from a proximal end of the funnel, proximally through the lumen, to a handle; (ii) using a deployment knob on the handle that is operatively coupled to the rod, advancing the funnel out of the distal portion of the catheter, such that the funnel self-expands in a manner that a mouth at a distal end of the funnel is wider than the distal portion and an opening of the funnel at the proximal end; (iii) actuating a sealer on the handle to retract the funnel into sealed engagement with the distal portion such that, in the sealed engagement, the funnel remains expanded, and/or the mouth of the funnel is fluidically connected to the lumen; and (iv) subsequently applying suction through the lumen, such that the suction sucks the obstruction (e.g., embolus) into the funnel via the mouth.

[0392] Example 128. A method for removing a real or simulated obstruction (e.g., an embolus, a clot, plaque, or any other obstruction) from a real or simulated blood vessel (e.g., from an artery, such as from a cerebral artery, or from a vein, such as from a cerebral vein) of a real or simulated subject, the method comprising: (a) transluminally advancing a distal portion of a flexible catheter into the blood vessel (e.g., cerebral artery) while: (i) a funnel is compressed within a lumen of the catheter, and/or (ii) a rod extends, from a proximal end of the funnel, proximally through the lumen, to a handle; (b) using a deployment knob on the handle that is operatively coupled to the rod, deploying the funnel out of the distal portion of the catheter, such that the funnel self-expands in a manner that a mouth at a distal end of the funnel is wider than the distal portion and an opening of the funnel at the proximal end; (c) subsequently, actuating a stabilizer on the handle to stabilize the funnel in sealed engagement with the catheter; and (d) while the funnel remains stabilized in sealed engagement with the distal portion: (i) sucking the obstruction (e.g., embolus) into the funnel via the mouth by applying suction through the lumen, and/or (ii) retracting the funnel and the catheter from the blood vessel (e.g., cerebral artery) and the subject while continuing to apply suction through the lumen.

[0393] Example 129. The method according to example 128, wherein step (b) of the method comprises the steps of: (i) deploying the funnel out of the distal portion of the catheter until the mouth is exposed, (ii) applying suction to the mouth via the lumen, (iii) determining a degree of resistance to the suction, and/or (iv) responsively to the determination, identifying whether there is contact with the embolus.

[0394] Example 130. The method according to example 129, wherein step (b) of the method further comprises, subsequently to the identification: (i) retracting the funnel back into the distal portion such that the funnel becomes compressed within the lumen, (ii) advancing the catheter distally within the artery, and/or (iii) repeating the steps of step (b) until contact with the embolus is identified.

[0395] Example 131. The method according to any one of examples 128-130, wherein transluminally advancing the distal portion of the catheter into the cerebral artery comprises transluminally advancing the distal portion of the catheter into the cerebral artery while the funnel is disposed within the lumen proximally from the distal portion.

[0396] Example 132. A method for removing a real or simulated embolus from a real or simulated cerebral artery of a real or simulated subject, the method comprising: (a) transluminally advancing a distal portion of a flexible catheter into the cerebral artery while

a funnel is compressed within a lumen of the catheter, the funnel formed from a set of braided wires covered in a covering, and/or having: (i) a mouth at a distal end of the funnel, (ii) at the mouth, a scoop that protrudes distally, the scoop defined by: (I) a first lateral petal, formed from a bight of a first wire of the set, (II) a second lateral petal, formed from a bight of a second wire of the set, (III) a medial petal disposed between, and/or overlapping with, the first and second lateral petals, the medial petal formed from a bight of a third wire of the set, the third wire being more flexible than the first wire and more flexible than the second wire, and/or (IV) an opening at a proximal end of the funnel; (b) progressively advancing the funnel out of the distal portion of the catheter, such that the funnel self-expands in a manner that the mouth is wider than the distal portion and the opening; and (c) applying suction through the lumen, such that the suction sucks the embolus into the funnel via the mouth.

[0397] Example 133. Apparatus for removing an embolus from a cerebral artery of a subject, the apparatus comprising: (a) a flexible catheter, having: (i) a proximal portion, (ii) a distal portion that is configured for transluminal advancement into the cerebral artery, the distal portion having a rim, and/or (iii) a lumen, extending from the proximal portion to the rim; (b) a funnel, having a central longitudinal axis that passes through the mouth and the opening, and/or: (I) having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal end of the funnel, (II) elastically compressible into a compressed state, and/or (III) biased to assume an expanded state in which the mouth is wider than (i) the opening and the rim, and/or (ii) the mouth in the compressed state, and/or in which the funnel defines: (a) a distal section that includes the mouth, and/or that is generally cylindrical, (b) a proximal section that includes the opening, and/or that is generally cylindrical, (c) an intermediate section, tapering from the distal section to the proximal section to fluidically connect the distal section to the proximal section, and/or (d) at the mouth, a first scoop and an opposing scoop that extend distally from the distal section, and/or that flare away from the other and from the longitudinal axis.

[0398] Example 134. Apparatus for treating a subject, the apparatus comprising: (A) a flexible catheter, having: (i) a proximal portion, (ii) a distal portion that is configured for transluminal advancement into a cerebral artery of the subject, the distal portion having a rim, and/or (iii) a lumen, extending from the proximal portion to the rim; (B) a funnel: (I) having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal end of the funnel, (II) being biased to assume an expanded state in which the mouth is wider than

the opening and the rim, and/or (III) elastically compressible into a compressed state in which the mouth is narrower than in the expanded state; (C) a flexible rod, attached to the proximal end of the funnel, and/or extending proximally through the catheter; and (D) a handle, at the proximal portion of the catheter, the handle comprising: (a) a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between (i) a delivery state in which the funnel is in the compressed state within the catheter, and/or (ii) a deployed state in which the funnel is in the expanded state and the mouth is exposed from the distal portion of the catheter, and/or (b) a sealer, discrete from the deployment knob, and/or configured to transition the apparatus into a sealed state by retracting the funnel into sealed engagement with the rim such that, in the sealed state: (i) the funnel remains in the expanded state, and/or (ii) the mouth of the funnel is fluidically connected to the lumen such that suction applied through the lumen sucks fluid into the funnel via the mouth.

[0399] Example 135. A method for removing a real or simulated embolus from a real or simulated cerebral artery of a real or simulated subject, the method comprising: (A) transluminally advancing a distal portion of a flexible catheter into the cerebral artery while a funnel is compressed within a lumen of the catheter, the funnel formed from a set of braided wires covered in a covering, and/or having: (i) a mouth at a distal end of the funnel, (ii) at the mouth, a scoop that protrudes distally, the scoop defined by: (a) a first lateral petal, formed from a bight of a first wire of the set, (b) a second lateral petal, formed from a bight of a second wire of the set, (c) a medial petal disposed between, and/or overlapping with, the first and second lateral petals, the medial petal formed from a bight of a third wire of the set, the third wire being more flexible than the first wire and more flexible than the second wire, and/or (d) an opening at a proximal end of the funnel; (B) advancing the funnel out of the distal portion of the catheter, such that: (i) the funnel self-expands in a manner that the mouth is wider than the distal portion and the opening, and/or (ii) the scoop expands the artery in a manner in which the scoop dislodges the embolus from a wall of the artery; and (C) applying suction through the lumen, such that the suction sucks the embolus into the funnel via the mouth.

[0400] It is to be understood that throughout this application, the term "proximal" means closest to the operator (less into the body) and the term "distal" means furthest from the operator (further into the body).

[0401] The present invention is not limited to the examples that have been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove, as well as variations and modifications thereof that are not in the prior art, which would occur to persons skilled in the art upon reading the foregoing description.

CLAIMS

1. Apparatus for removing an embolus from a cerebral artery of a subject, the apparatus comprising:

a flexible catheter, having:

a proximal portion,

a distal portion that is configured for transluminal advancement into the cerebral artery, the distal portion having a rim, and/or

a lumen, extending from the proximal portion to the rim;

a funnel:

having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal end of the funnel,

being biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or

elastically compressible into a compressed state in which the mouth is narrower than in the expanded state;

a flexible rod, attached to the proximal end of the funnel, and/or extending proximally through the catheter; and

a handle, at the proximal portion of the catheter, the handle comprising:

a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between:

a delivery state in which the funnel is in the compressed state within the catheter, and/or

a deployed state in which the funnel is in the expanded state, with an outer surface of the funnel being in sealed engagement with the rim, and/or the mouth is (i) exposed from the distal portion of the catheter, and/or (ii) fluidically connected to the lumen such that suction applied through the lumen sucks the embolus into the funnel via the mouth, and/or

a stabilizer, discrete from the deployment knob, and/or configured to stabilize the apparatus in the deployed state by applying tension to the rod.

2. The apparatus according to claim 1, wherein the catheter is fixedly attached to the handle.

3. The apparatus according to any one of claims 1-2, wherein the handle further comprises a port that is fluidically connected to the catheter, the port adapted to receive a suction applicator adapted to apply the suction.

4. The apparatus according to any one of claims 1-3, wherein the stabilizer comprises a manually-actuatable mechanism that is adapted to stabilize the apparatus in the deployed state by applying tension to the rod upon being manually actuated.

5. The apparatus according to any one of claims 1-4, wherein the handle is configured to limit distal advancement of the rod in a manner that provides a predetermined limit to distal advancement of the funnel out of the distal portion of the catheter.

6. The apparatus according to any one of claims 1-5, wherein the stabilizer is configured to, upon actuation, inhibit further operation of the deployment knob.

7. The apparatus according to any one of claims 1-6, wherein the catheter comprises a hypotube, and/or a polymeric cover that coats the hypotube, and/or wherein the polymeric cover extends beyond the hypotube to define the rim.

8. The apparatus according to any one of claims 1-7, wherein a flexibility of the catheter increases progressively distally along the catheter.

9. The apparatus according to claim 8, wherein a flexibility of the rod increases progressively distally along the rod.

10. The apparatus according to any one of claims 1-9, wherein the distal portion of the catheter has a curvature that is adjustable by applying an axial force to the rod.

11. The apparatus according to claim 10, wherein the distal portion of the catheter is biased toward being curved.

12. The apparatus according to claim 11, wherein the apparatus is configured such that a curvature of the distal portion is progressively reducible by progressively moving the funnel, in its compressed state, distally within the distal portion of the catheter.

13. The apparatus according to claim 10, wherein the rod is coupled to the funnel eccentrically within the lumen, such that distalward pushing of the rod applies an eccentric pushing force to the funnel, which responsively articulates with respect to the rod, thereby increasing the curvature of the catheter.

14. The apparatus according to claim 10, wherein the rod is coupled to the funnel eccentrically within the lumen, such that distalward pushing of the rod applies an eccentric pushing force to the funnel, which responsively turns to deflect the distal portion of the catheter.

15. The apparatus according to any one of claims 1-14, wherein:

the funnel, in its expanded state, has a flared surface distal to the opening, and/or

the stabilizer is configured to stabilize the apparatus by retracting the funnel into the sealed engagement with the catheter by sealing the flared surface against the rim.

16. The apparatus according to claim 15, wherein the rim flares distally.

17. The apparatus according to any one of claims 1-16, wherein the rod comprises an extracorporeal stopper that provides a predetermined limit to distal advancement of the funnel out of the distal portion of the catheter by limiting distal advancement of the rod through the handle to a predetermined distance.

18. The apparatus according to claim 17, wherein the stabilizer is configured such that actuation of the stabilizer pulls the rod proximally by the predetermined distance.

19. The apparatus according to any one of claims 1-18, wherein the stabilizer is manually actuatable independently of the deployment knob.

20. The apparatus according to claim 19, wherein the stabilizer comprises a button, and/or is manually actuatable via pushing of the button.

21. The apparatus according to any one of claims 1-20, wherein the funnel is constructed from braided wires.

22. The apparatus according to claim 21, wherein the braided wires are gathered at the proximal end in an elliptical loop that defines the opening as an elliptical opening.

23. The apparatus according to claim 22, wherein the elliptical loop is covered in a polymer coating that reinforces the opening.

24. The apparatus according to claim 23, wherein, in the sealed engagement, the polymer coating fits snugly within the distal portion of the catheter.

25. The apparatus according to claim 22, wherein:

the funnel has a central longitudinal axis that passes through the mouth and the opening, and/or

the elliptical opening has a major axis that is oblique to the longitudinal axis.

26. The apparatus according to claim 25, wherein:

the elliptical opening has:

a distal vertex that lies on the major axis, on a first side of the longitudinal axis, and/or

a proximal vertex that lies on the major axis, and/or is disposed on an opposite side of the longitudinal axis from the distal vertex, proximal from the distal vertex, and/or

the rod is attached to the proximal end of the funnel by being attached to the elliptical opening at the proximal vertex.

27. The apparatus according to any one of claims 1-26, wherein the stabilizer comprises a spring-loaded mechanism that is adapted to stabilize the apparatus in the deployed state by applying tension to the rod.

28. The apparatus according to claim 27, wherein the spring-loaded mechanism is adapted to apply the tension to the rod automatically upon cessation of manual operation of the deployment knob.

29. The apparatus according to any one of claims 1-28, wherein the deployment knob is operatable via rotation.

30. The apparatus according to claim 29, wherein the handle comprises a drivewheel that is engaged with the rod and operatively coupled to the knob, such that rotating the knob in a first knob-direction rotates the drivewheel in a forward drivewheel-direction, thereby pushing the rod distally to progressively transition the apparatus from the delivery state towards the deployed state.

31. The apparatus according to claim 30, wherein the drivewheel defines a roller, the rod passing tangentially by the roller.

32. The apparatus according to claim 30, wherein the stabilizer is configured such that actuation of the stabilizer rotates the drivewheel in a reverse drivewheel-direction, thereby pulling the rod proximally.

33. The apparatus according to claim 32, wherein the stabilizer is configured with a first position and a second position, and/or to be actuated by moving the stabilizer from the first position into the second position, such that actuation of the stabilizer rotates the drivewheel

by a predetermined discrete amount in the reverse drivewheel-direction, thereby pulling the rod proximally by a predetermined discrete distance.

34. The apparatus according to claim 32, wherein:

the drivewheel has drivewheel teeth,

the stabilizer has sealer teeth, and/or

actuating the stabilizer engages the sealer teeth with the drivewheel teeth and moves the drivewheel in the reverse drivewheel-direction.

35. The apparatus according to claim 34, wherein the drivewheel teeth are circumferentially distributed, the sealer teeth are linearly distributed, and/or actuation of the stabilizer moves the sealer teeth into a rack-and-pinion arrangement with the drivewheel teeth.

36. The apparatus according to claim 34, wherein the engagement between the sealer teeth and the drivewheel teeth stabilizes the apparatus by inhibiting distal movement of the rod and the funnel with respect to the catheter.

37. Apparatus for removing an obstruction from a blood vessel of a subject, the apparatus comprising:

a flexible catheter, having:

a proximal portion,

a distal portion that is configured for transluminal advancement into the blood vessel, the distal portion having a rim, and/or

a lumen, extending from the proximal portion to the rim;

a funnel:

having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal end of the funnel,

being biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or

elastically compressible into a compressed state in which the mouth is narrower than in the expanded state;

a flexible rod, attached to the proximal end of the funnel, and/or extending proximally through the catheter; and

a handle, at the proximal portion of the catheter, the handle defining a flat base for resting on a surface, the handle comprising:

a thumbwheel, operatively coupled to the flexible rod such that manual operation of the thumbwheel progressively transitions the apparatus between (i) a delivery state in which the funnel is in the compressed state within the catheter, and/or (ii) a deployed state in which the funnel is in the expanded state and the mouth is exposed from the distal portion of the catheter, and/or

a fluid port facing proximally, and/or fluidically connected to the mouth of the funnel and adapted to receive a suction source such that suction applied to the fluid port is transferred via the lumen to draw the obstruction into the funnel via the mouth.

38. The apparatus according to claim 37, wherein the handle has a foot that extends to define an extended part of the flat base.

39. The apparatus according to any one of claims 37-38, wherein the thumbwheel is laterally-facing.

40. The apparatus according to any one of claims 37-39, wherein the proximal portion of the catheter is fixedly attached to the handle.

41. The apparatus according to claim 40, wherein handle is shaped to be grasped by a hand of a user, with the catheter extending between fingers of the hand and away from the handle.

42. The apparatus according to claim 40, wherein the proximal portion of the catheter is attached to the handle at a distally-facing part of the handle.

43. The apparatus according to claim 42, wherein the handle further comprises a sealer, configured to transition the apparatus into a sealed state by retracting the funnel into sealed engagement with the rim such that, in the sealed state:

the funnel remains in the expanded state, and/or

the mouth of the funnel is fluidically connected to the lumen such that suction applied through the lumen sucks the obstruction into the funnel via the mouth.

44. The apparatus according to claim 43, wherein the sealer is distally-facing.

45. Apparatus for removing an obstruction from a blood vessel of a subject, the apparatus comprising:

a flexible catheter, having:

a proximal portion,

a distal portion that is configured for transluminal advancement into the blood vessel, the distal portion having a rim, and/or

a lumen, extending from the proximal portion to the rim;

a funnel:

formed from a set of braided wires covered in a covering,

having:

a mouth at a distal end of the funnel,

at the mouth, a scoop that protrudes distally, the scoop defined by:

a first lateral petal, formed from a bight of a first wire of the set,

a second lateral petal, formed from a bight of a second wire of the set,

a medial petal disposed between, and/or overlapping with, the first and second lateral petals, the medial petal formed from a bight of a third wire of the set, the third wire being more flexible than the first wire and more flexible than the second wire, and/or

an opening at a proximal end of the funnel,

being biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or

elastically compressible into a compressed state in which the mouth is narrower than in the expanded state.

46. The apparatus according to claim 45, wherein for each of the first, second, and/or third petals, the respective wire defines two tails that diverge from each other away from the bight, to extend with opposite helical handedness along the funnel toward the opening.

47. The apparatus according to any one of claims 45-46, wherein:

the funnel has a central longitudinal axis that passes through the mouth and the opening, and/or

in the expanded state, the scoop flares radially outwards from the central longitudinal axis.

48. The apparatus according to any one of claims 45-47, wherein:

each of the first and second lateral petals defines a lateral tail and a medial tail, the lateral tail extending away from the bight and the medial petal, and/or helically along the

funnel toward the opening, and/or the medial tail extending away from the bight to overlap with the medial petal and extend helically along the funnel toward the mouth, and/or

the set of wires includes at least one respective petal-support wire for each of the lateral petals, each petal-support wire defining a loop that, at the mouth, loops around the lateral tail of the respective lateral petal to support the respective lateral petal.

49. The apparatus according to claim 48, wherein the set of wires includes exactly two respective petal-support wires for each of the lateral petals.

50. The apparatus according to claim 48, wherein each of the petal-support wires defines a pair of tails that extend proximally away from the loop and helically along the funnel toward the opening.

51. The apparatus according to claim 50, wherein, for each of the petal-support wires, the tails of the pair extend, in parallel, and/or with the same helical handedness as each other, along the funnel toward the opening.

52. The apparatus according to claim 51, wherein, for each of the lateral petals, the set of wires includes a first petal-support wire and a second petal-support wire, the tails of the first petal-support wire extending along the funnel toward the opening in parallel, and/or with the same helical handedness, as each other as the tails of the second petal-support wire.

53. The apparatus according to claim 52, wherein the loop of the first petal-support wire is distal to the loop of the second petal-support wire, and/or the first petal-support wire is stiffer than the second petal-support wire.

54. The apparatus according to any one of claims 45-53, wherein:

the scoop is a first scoop,

the funnel has an opposing scoop at the mouth, the opposing scoop defined by at least two arc-wires of the set collectively, by each arc-wire forming an arc partway around the mouth, the arcs overlapping with each other, and/or

the opposing scoop is opposite the first scoop.

55. The apparatus according to claim 54, wherein, in response to a compressive force applied to the funnel, the opposing scoop is configured to extend distally by the arcs deforming to have a decreased radius of curvature.

56. The apparatus according to claim 54, wherein the opposing scoop is defined by exactly two arc-wires forming exactly two arcs.

57. The apparatus according to claim 56, wherein the first scoop is defined by no further wires of the set other than the first wire defining the first lateral petal, the second wire defining the second lateral petal, and/or the third wire defining the medial petal.

58. The apparatus according to claim 54, wherein the first scoop protrudes distally beyond the opposing scoop.

59. The apparatus according to claim 54, wherein the first scoop is longer than the opposing scoop.

60. The apparatus according to claim 54, wherein each of the arc-wires is an arc-wire of a pair of parallel extending arc-wires, each pair facing distally.

61. The apparatus according to claim 54, wherein the opposing scoop further comprises a single arc-wire that forms an arc in between, and/or proximally from, the two-arc wires.

62. Apparatus for removing an obstruction from a blood vessel of a subject, the apparatus comprising:

a flexible catheter, having:

a proximal portion,

a distal portion that is configured for transluminal advancement into the blood vessel, the distal portion having a rim, and/or

a lumen, extending from the proximal portion to the rim;

a funnel, having a central longitudinal axis that passes through the mouth and the opening, and/or:

having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal end of the funnel,

elastically compressible into a compressed state, and/or

biased to assume an expanded state in which the mouth is wider than (i) the opening and the rim, and/or (ii) the mouth in the compressed state, and/or in which the funnel defines:

a distal section that includes the mouth, and/or that is generally cylindrical,

a proximal section that includes the opening, and/or that is generally cylindrical,

an intermediate section, tapering from the distal section to the proximal section to fluidically connect the distal section to the proximal section, and/or

at the mouth, a first scoop and an opposing scoop that extend distally from the distal section, and/or that flare away from the other and from the longitudinal axis.

63. Apparatus for treating a subject, the apparatus comprising:

a flexible catheter, having:

a proximal portion,

a distal portion that is configured for transluminal advancement into a blood vessel of the subject, the distal portion having a rim, and/or

a lumen, extending from the proximal portion to the rim;

a funnel:

having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal end of the funnel,

being biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or

elastically compressible into a compressed state in which the mouth is narrower than in the expanded state;

a flexible rod, attached to the proximal end of the funnel, and/or extending proximally through the catheter; and

a handle, at the proximal portion of the catheter, the handle comprising:

a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between (i) a delivery state in which the funnel is in the compressed state within the catheter, and/or (ii) a deployed state in which the funnel is in the expanded state and the mouth is exposed from the distal portion of the catheter, and/or

a sealer, discrete from the deployment knob, and/or configured to transition the apparatus into a sealed state by retracting the funnel into sealed engagement with the rim such that, in the sealed state:

the funnel remains in the expanded state, and/or

the mouth of the funnel is fluidically connected to the lumen such that suction applied through the lumen sucks fluid into the funnel via the mouth.

64. Apparatus for removing an obstruction from a blood vessel of a subject, the apparatus comprising:

a flexible catheter, having:

a proximal portion,

a distal portion that is configured for transluminal advancement into the blood vessel, the distal portion having a rim, and/or

a lumen, extending from the proximal portion to the rim;

a funnel:

having (i) a mouth at a distal end of the funnel, and/or (ii) an opening at a proximal end of the funnel,

being biased to assume an expanded state in which the mouth is wider than the opening and the rim, and/or

elastically compressible into a compressed state in which the mouth is narrower than in the expanded state;

a flexible rod, attached to the proximal end of the funnel, and/or extending proximally through the catheter; and

a handle, at the proximal portion of the catheter, the handle comprising:

a deployment knob, operatively coupled to the flexible rod so as to be manually operable to progressively transition the apparatus between (i) a delivery state in which the funnel is in the compressed state within the catheter, and/or (ii) a deployed state in which the funnel is in the expanded state and the mouth is exposed from the distal portion of the catheter, and/or

a sealer, discrete from the deployment knob, and/or configured to transition the apparatus into a sealed state by retracting the funnel into sealed engagement with the rim such that, in the sealed state:

the funnel remains in the expanded state, and/or

the mouth of the funnel is fluidically connected to the lumen such that suction applied through the lumen sucks the obstruction into the funnel via the mouth.

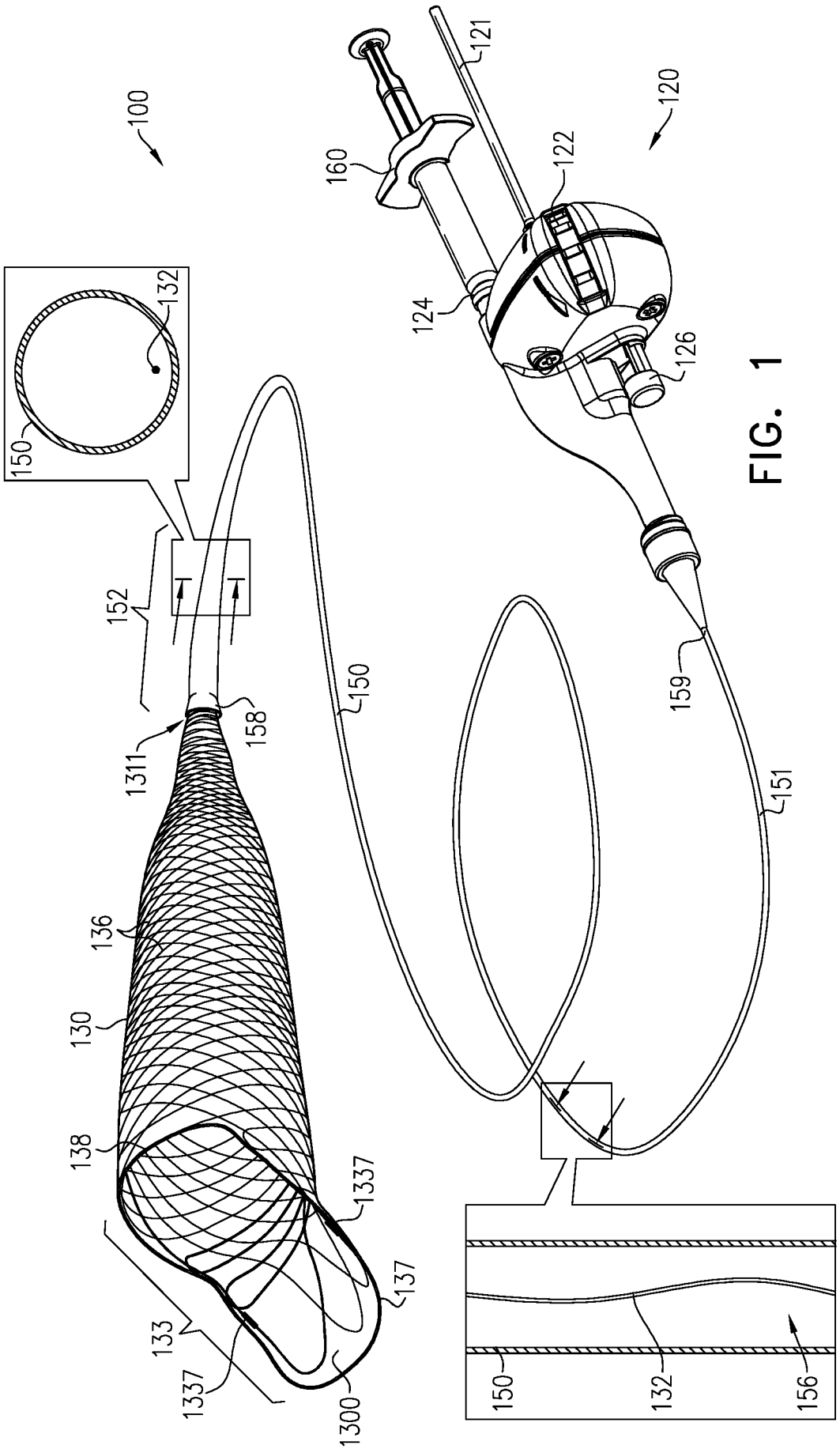
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FIG. 1

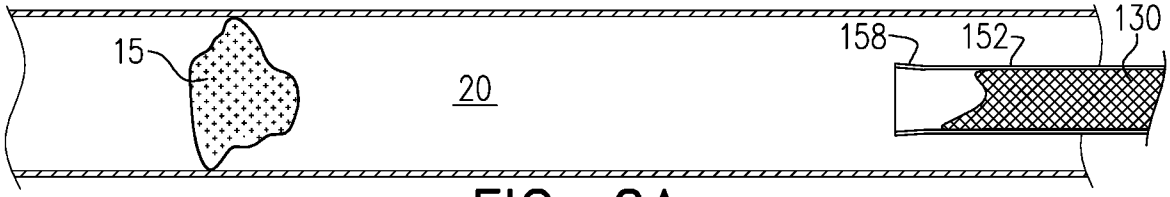


FIG. 2A

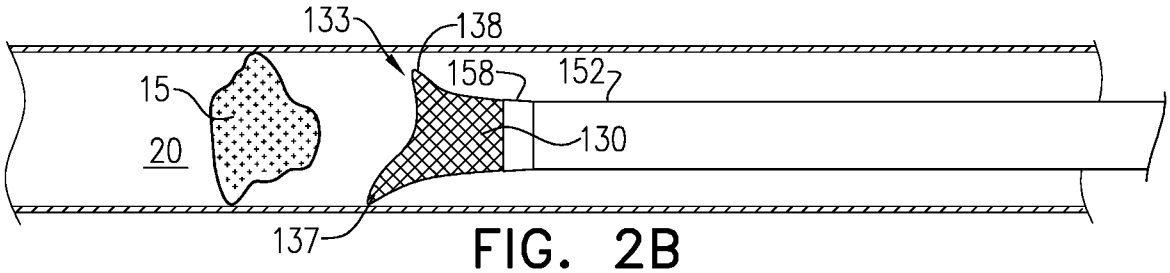


FIG. 2B

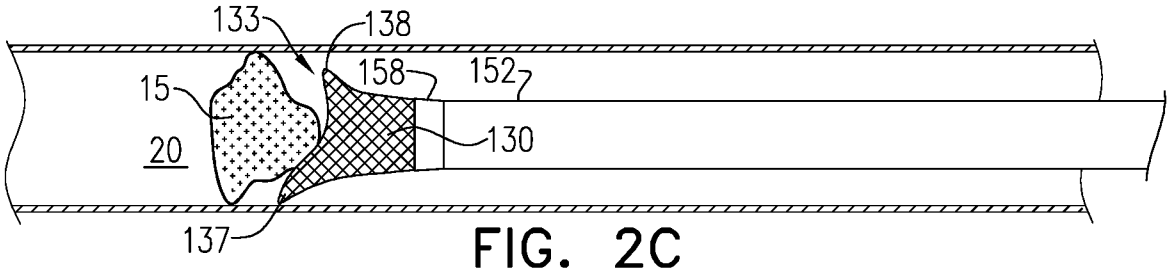


FIG. 2C

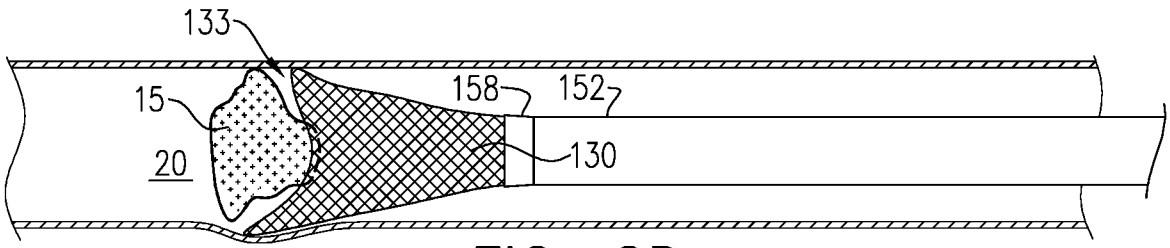


FIG. 2D

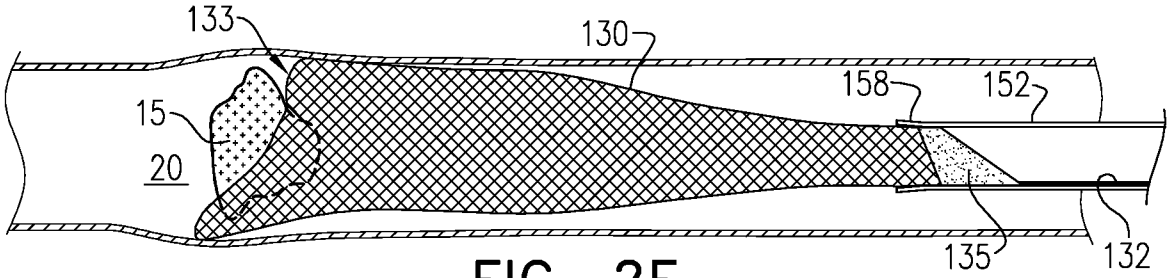


FIG. 2E

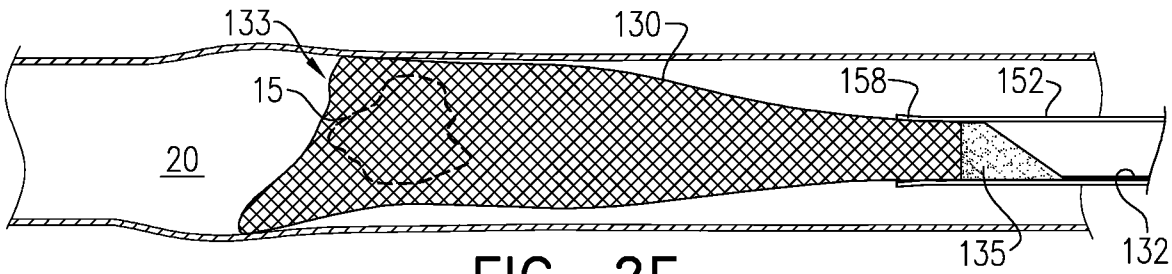


FIG. 2F

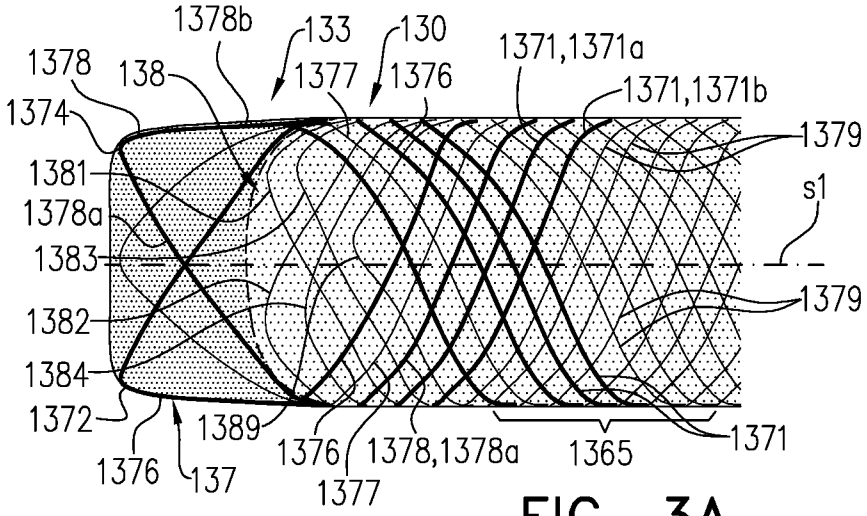


FIG. 3A

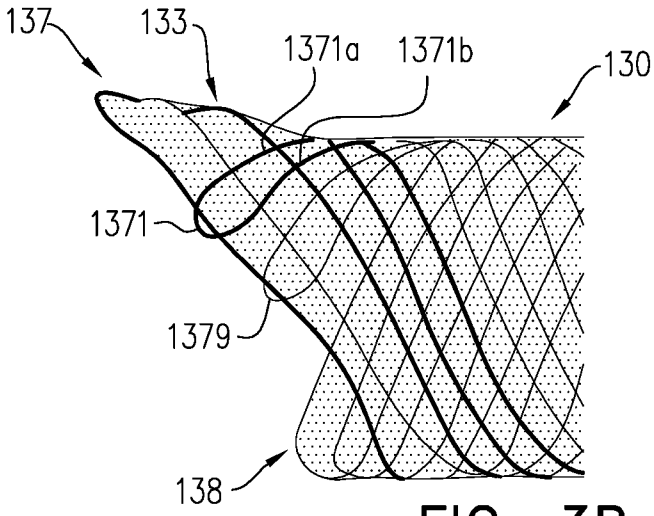


FIG. 3B

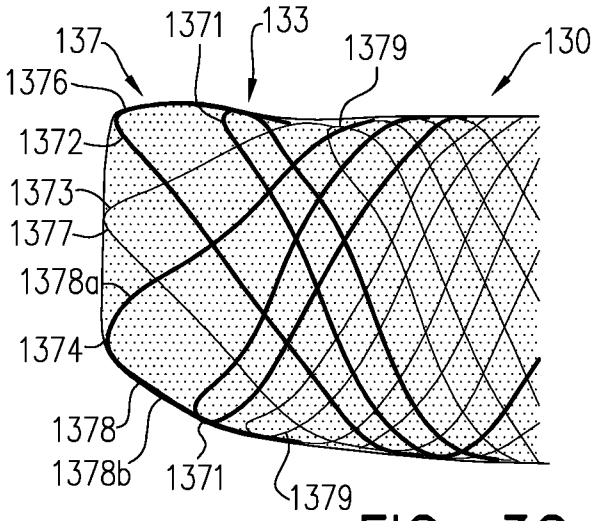
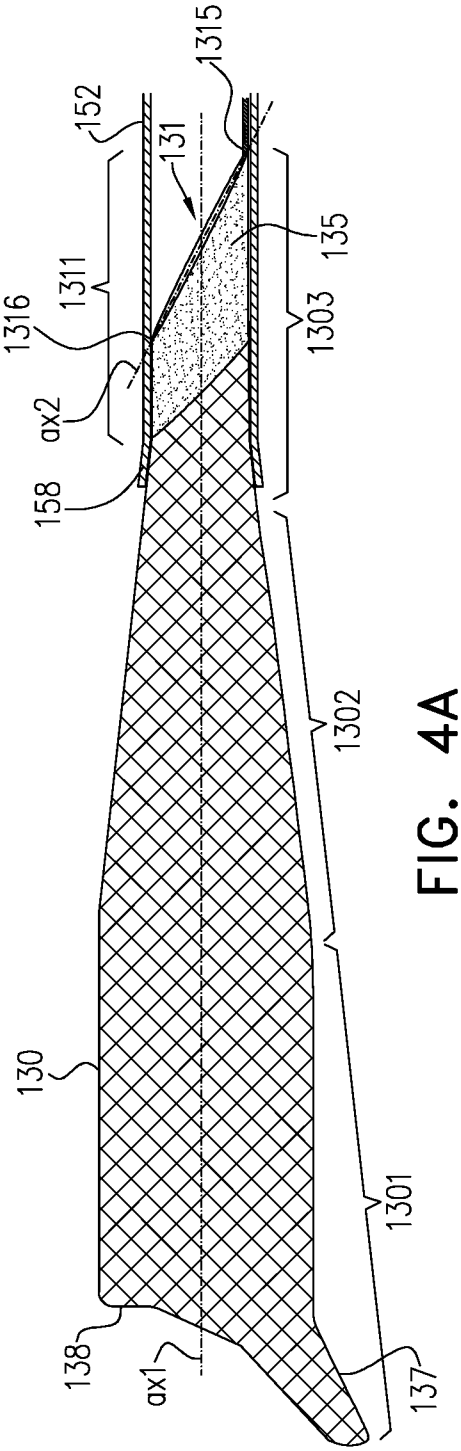


FIG. 3C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ax1
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FIG. 4A

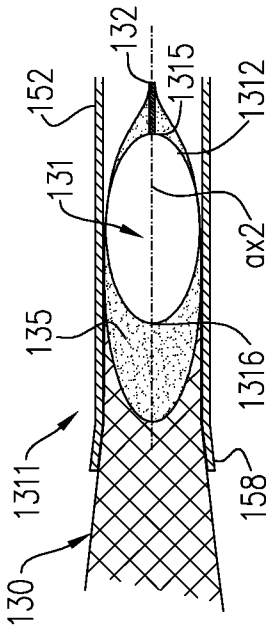
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FIG. 4B

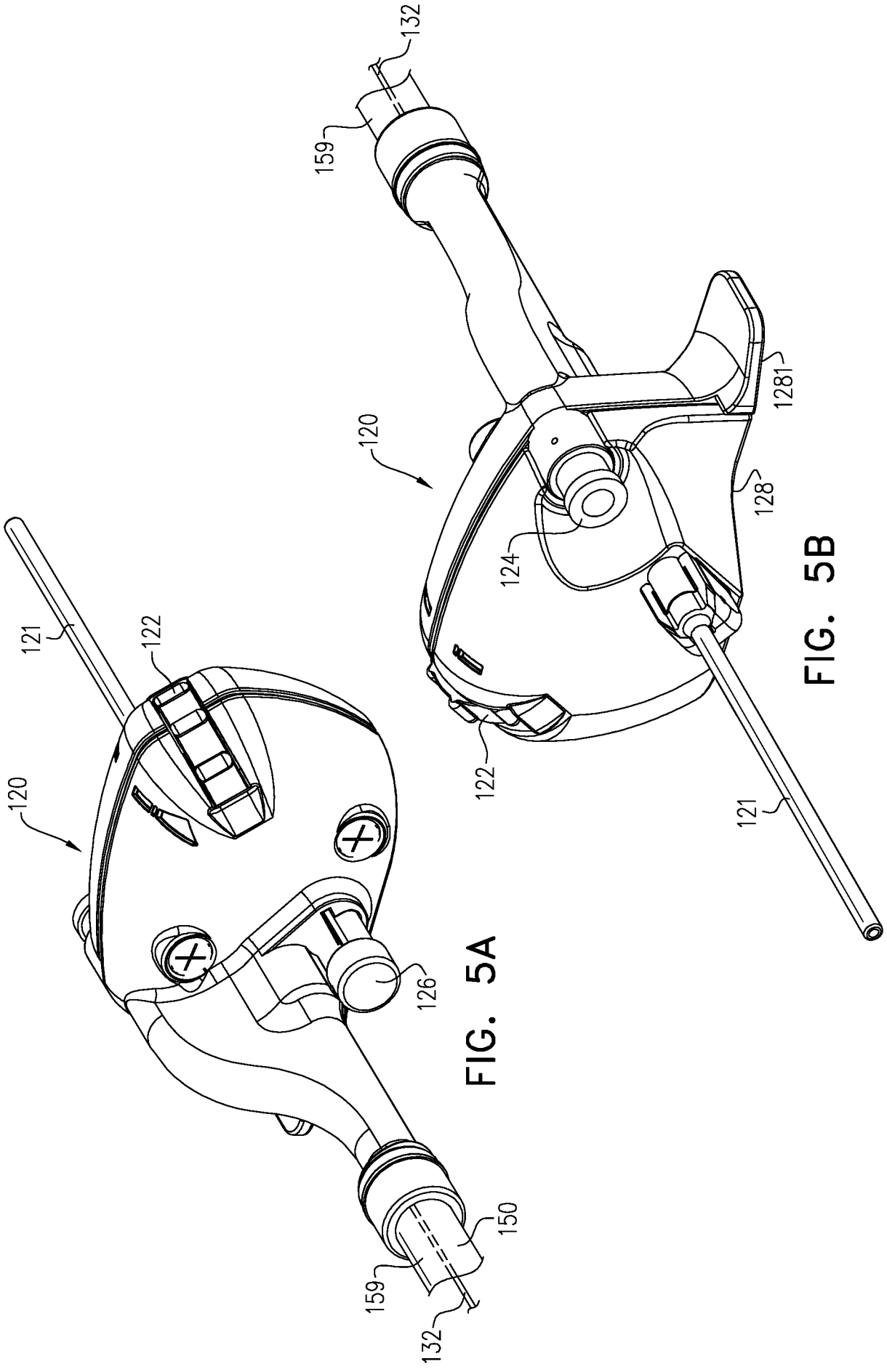
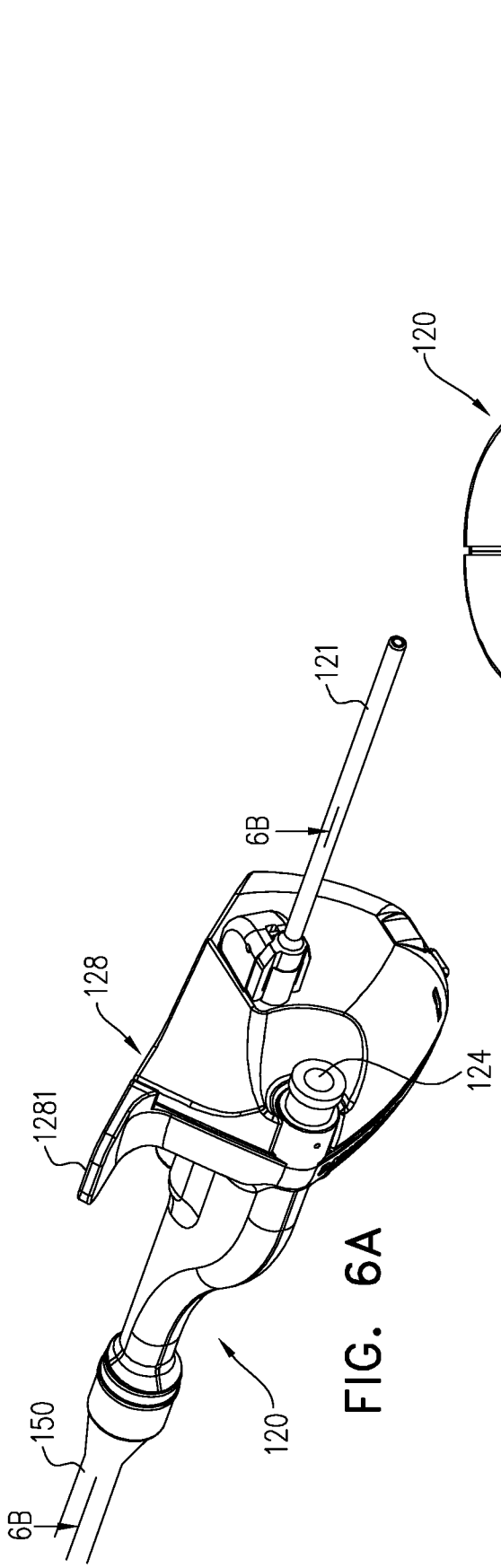


FIG. 5A

FIG. 5B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6B

FIG. 6A

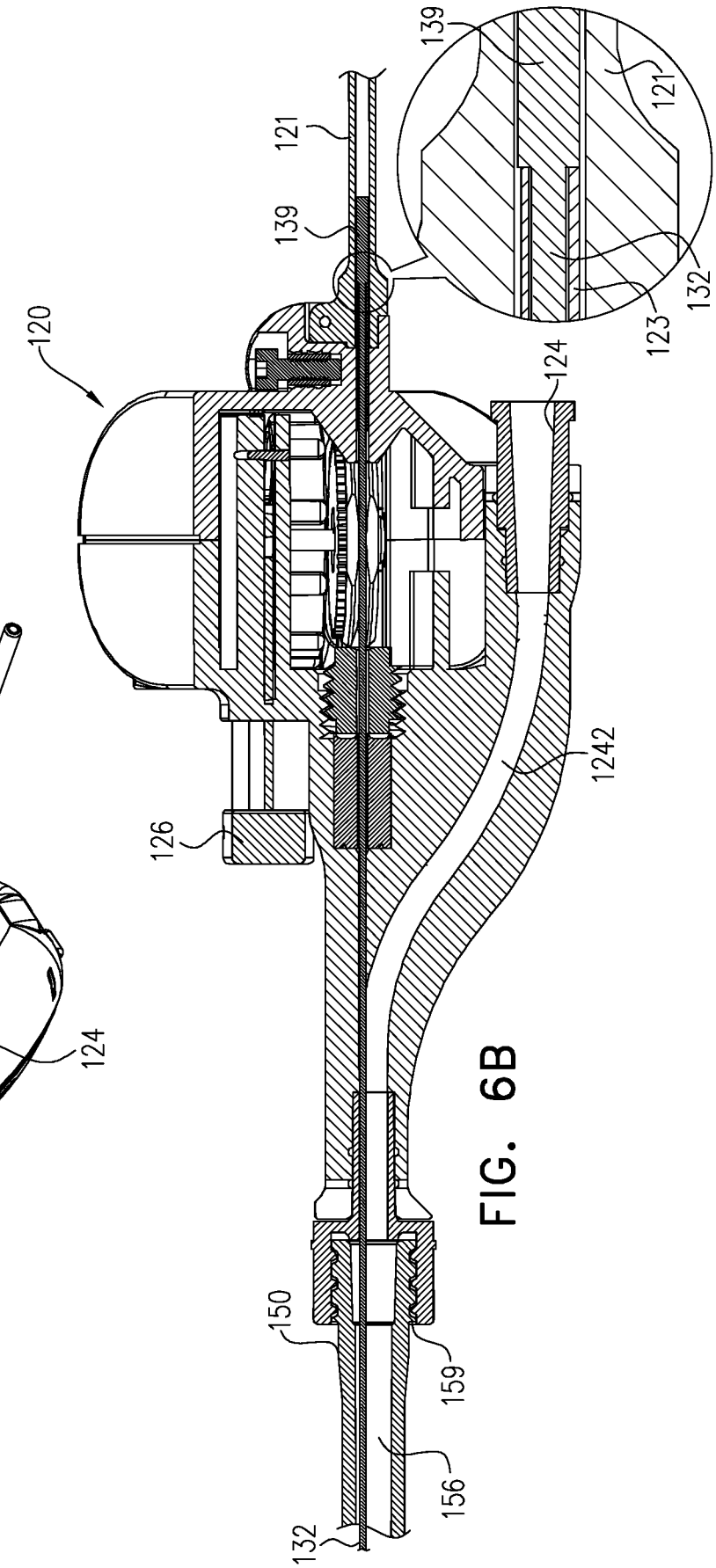
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FIG. 6B

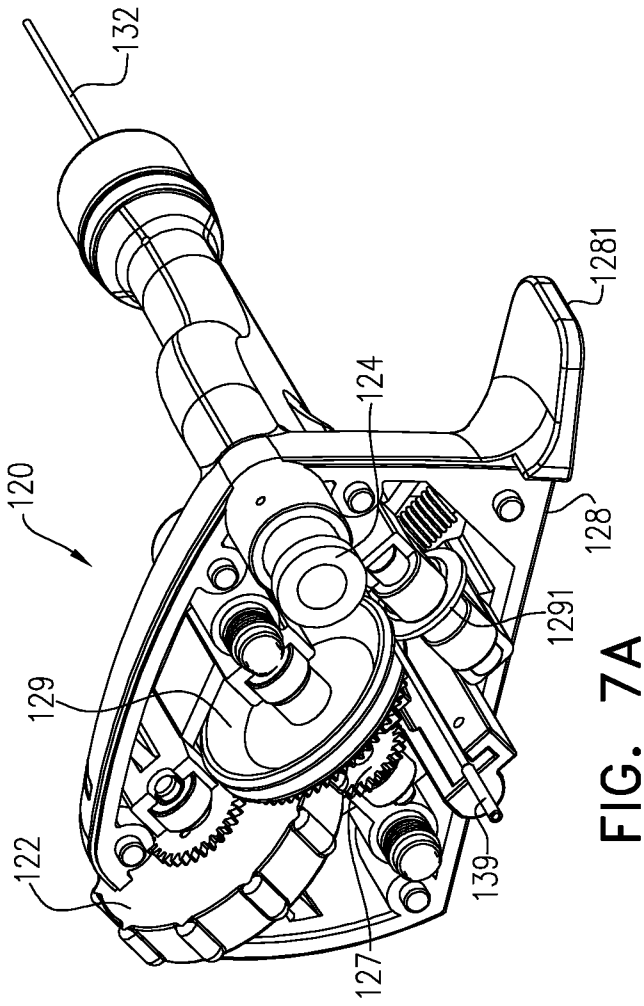
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FIG. 7A

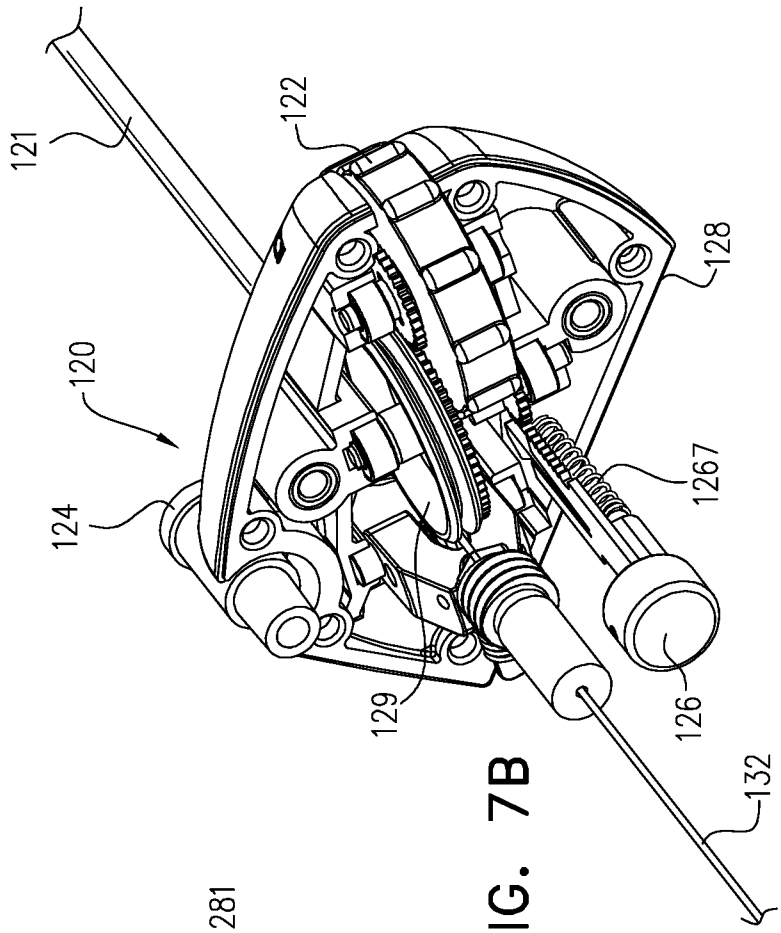
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FIG. 7B

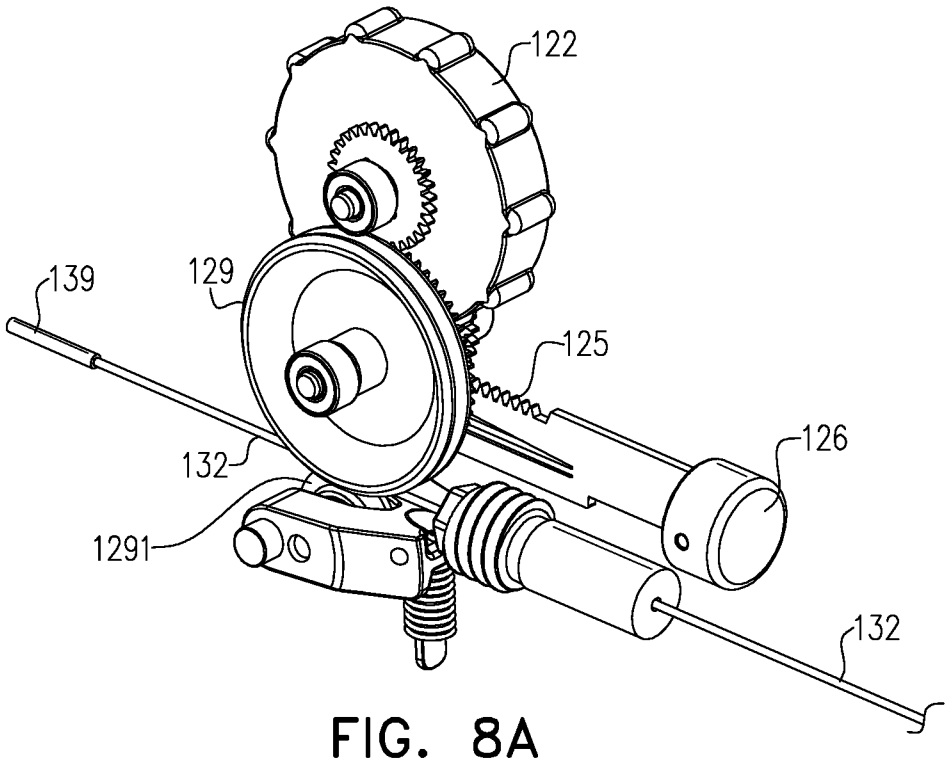
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FIG. 8A

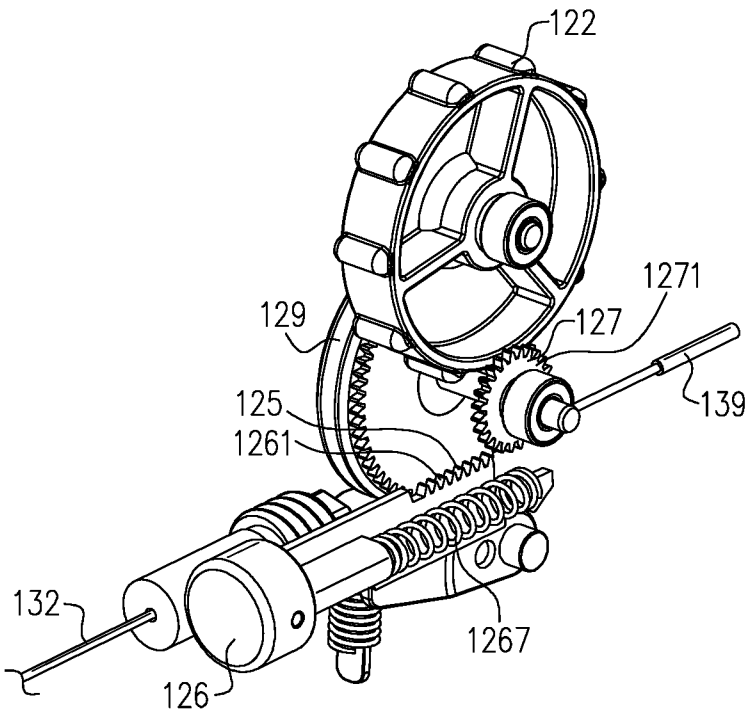
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FIG. 8B

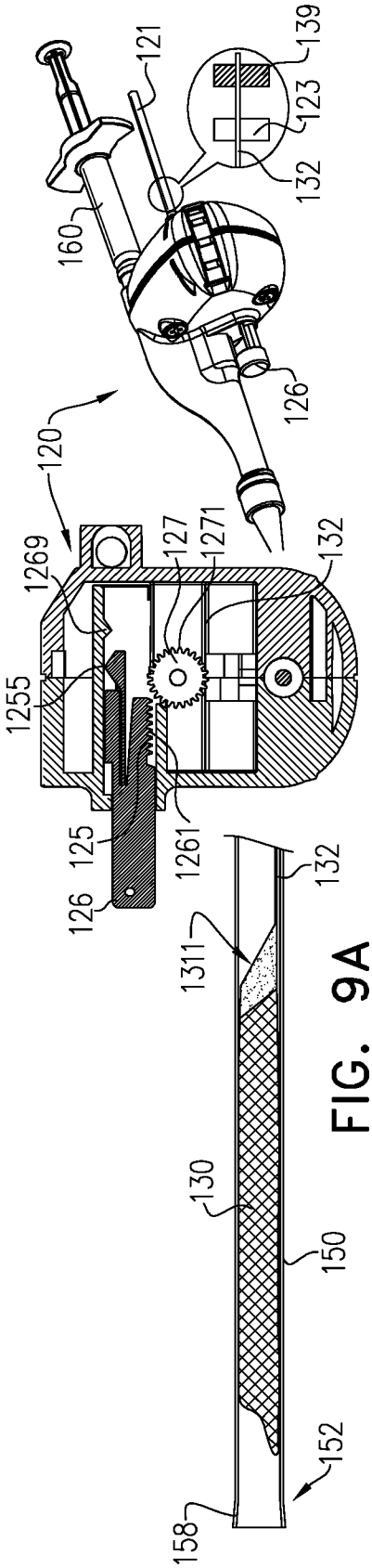

FIG. 9A

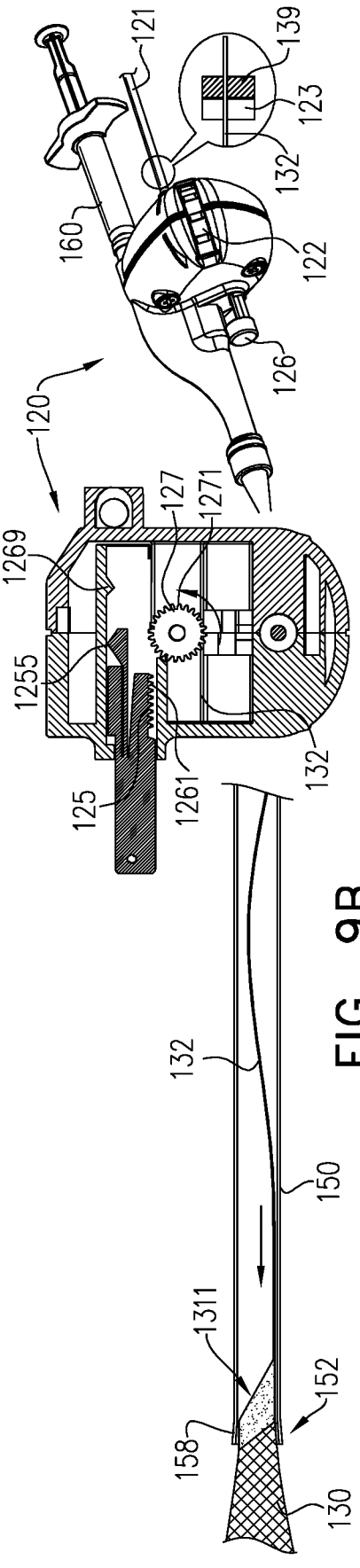

FIG. 9B

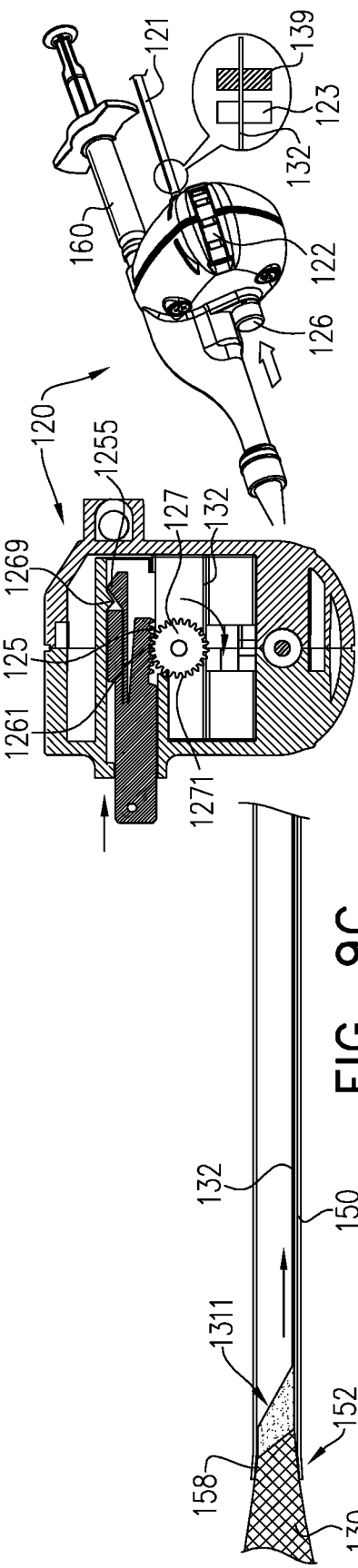

FIG. 9C

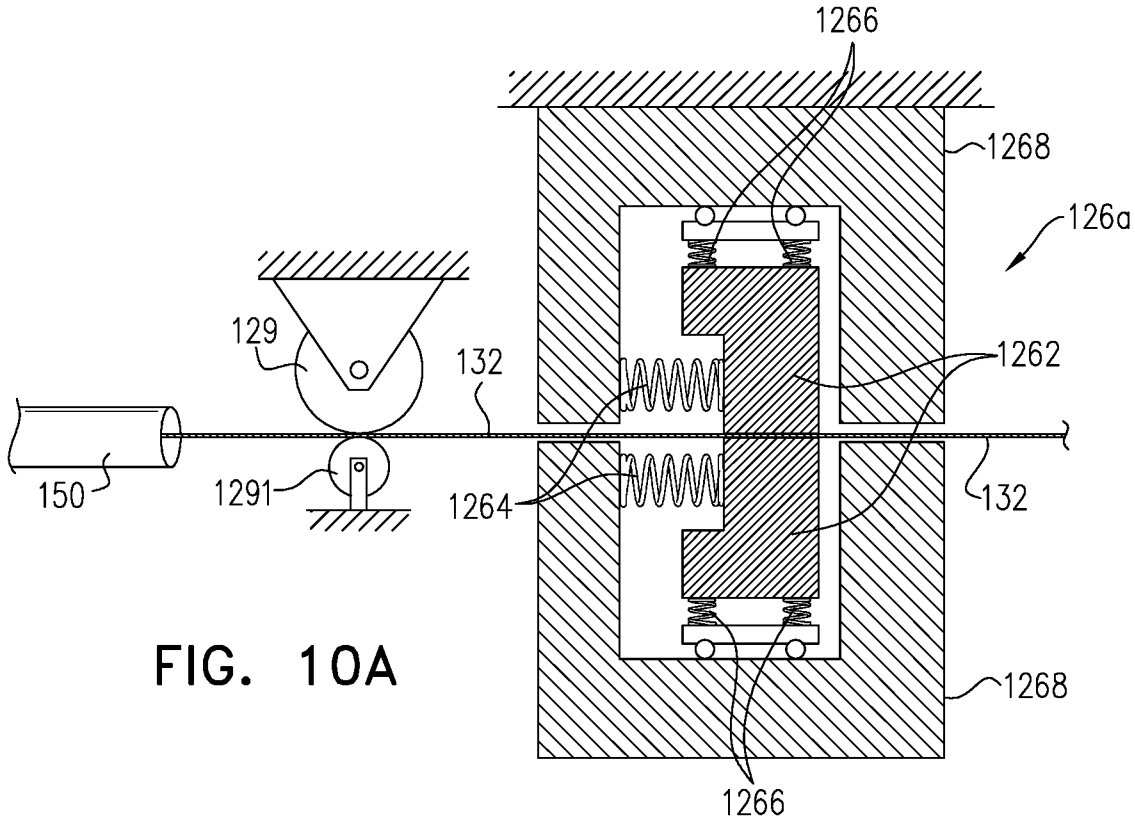

FIG. 10A

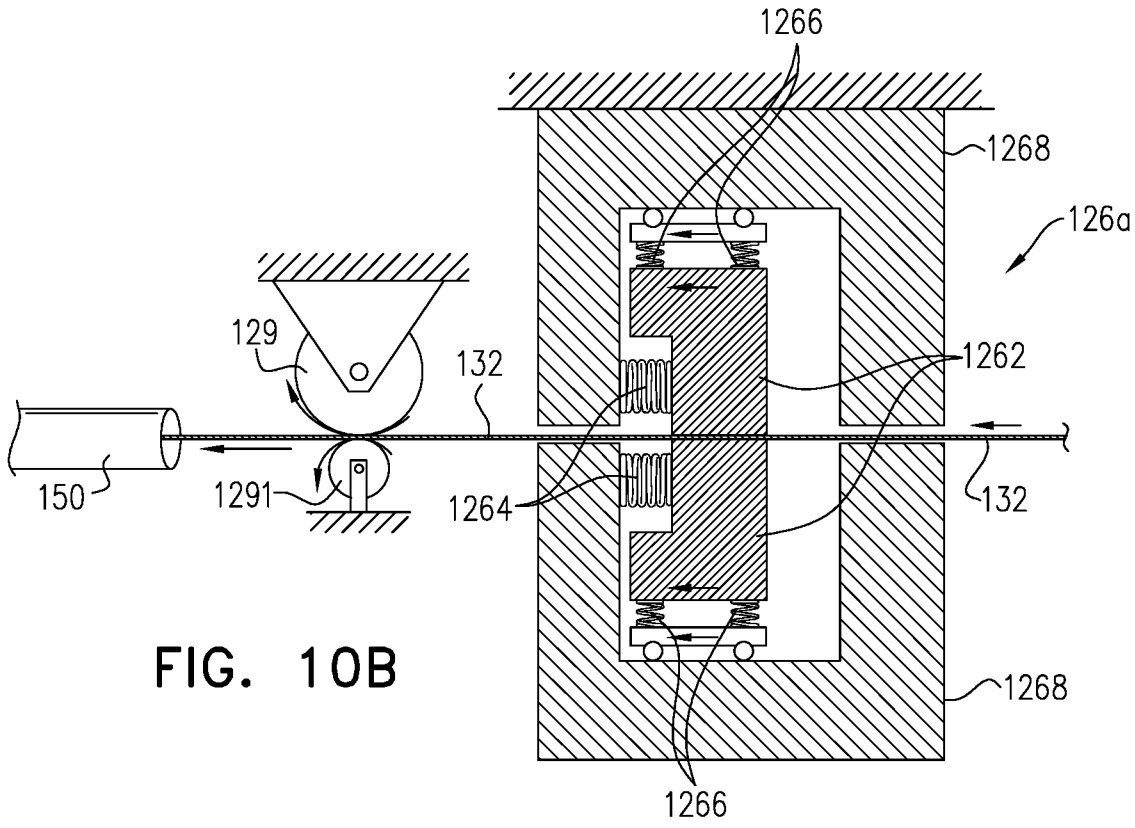

FIG. 10B

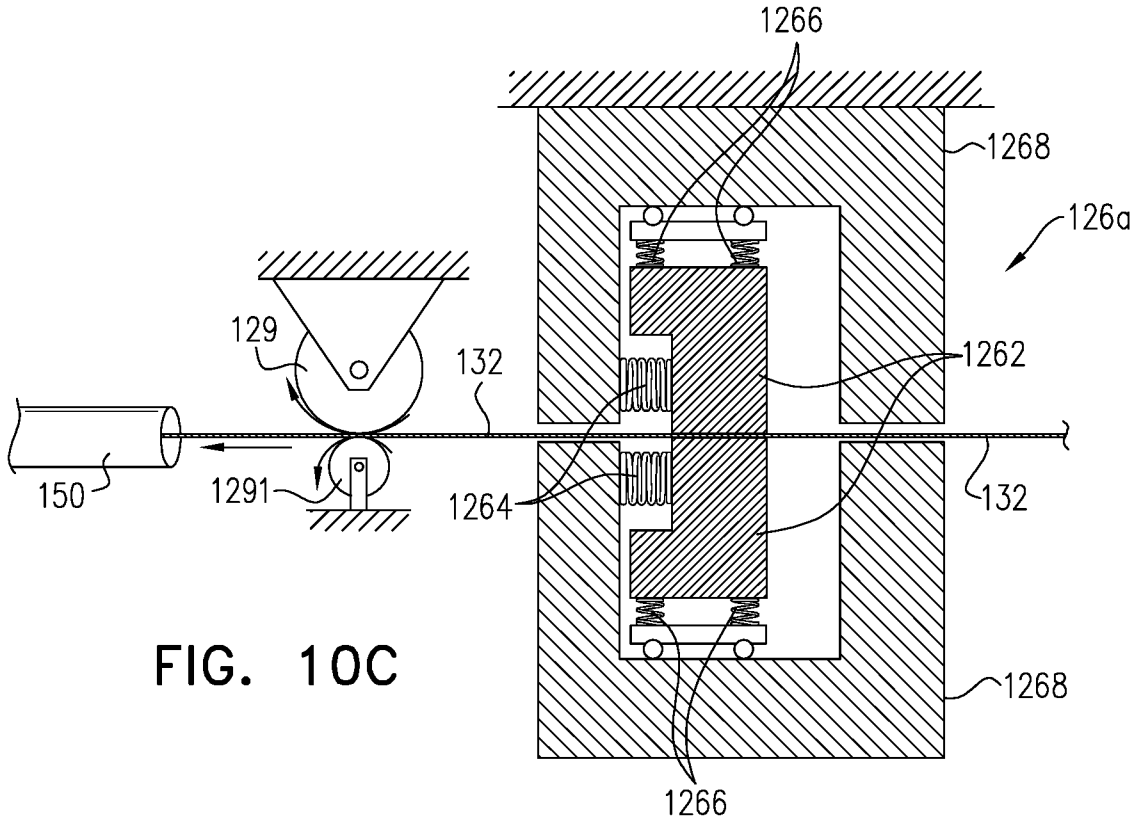

FIG. 10C

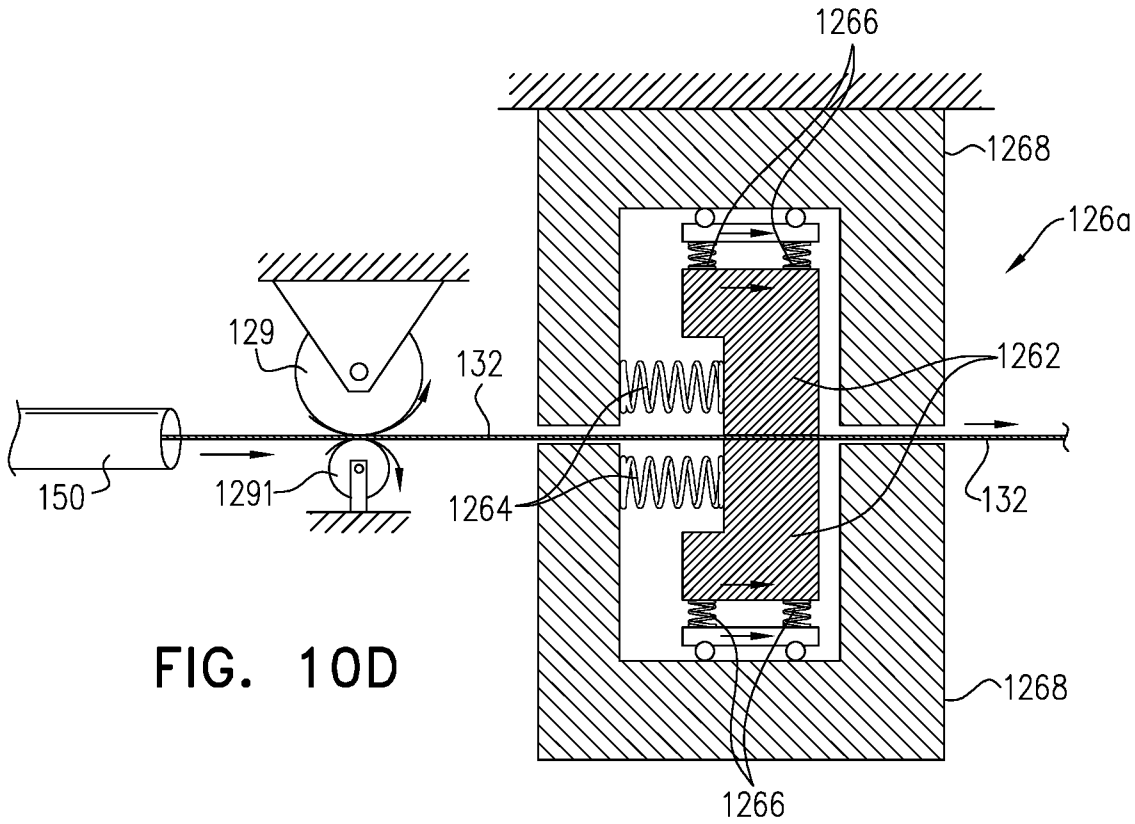

FIG. 10D

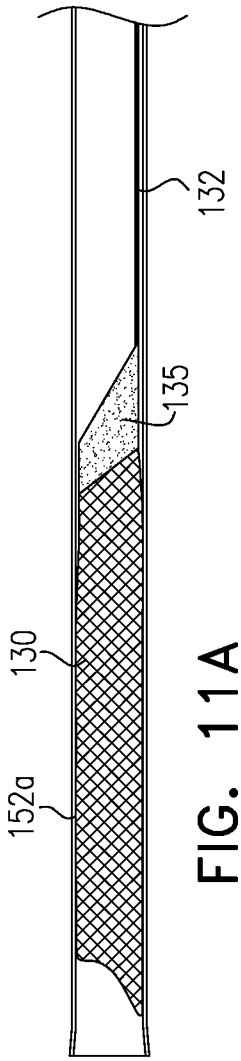

FIG. 11A

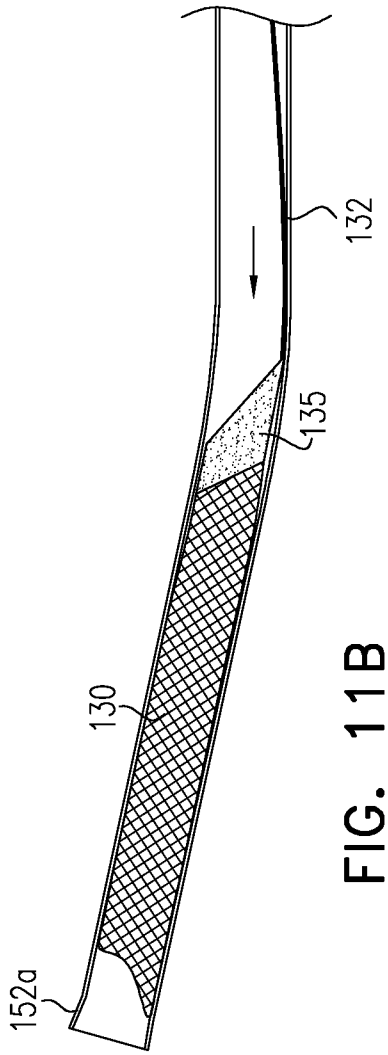

FIG. 11B

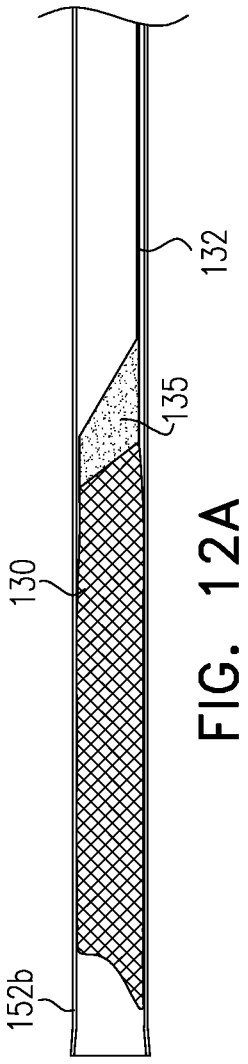

FIG. 12A

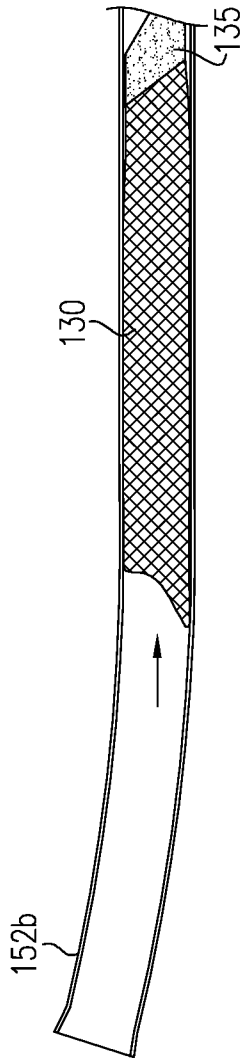

FIG. 12B

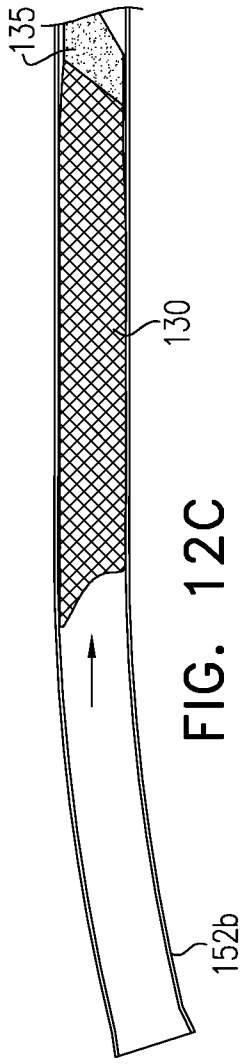

FIG. 12C

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/055442

A. CLASSIFICATION OF SUBJECT MATTER

INV. A61B17/22 A61B17/221
ADD. A61B34/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2021/077134 A1 (VALE DAVID [IE] ET AL) 18 March 2021 (2021-03-18) paragraphs [0102], [0115] - [0116]; figures 1, 3-5 figure 60	1-36
A	US 2006/116659 A1 (WAHR DENNIS W [US] ET AL) 1 June 2006 (2006-06-01) paragraphs [0126] - [0132], [0140], [0142] - [0143]; figures 10A-D	1-36
A	US 2014/276613 A1 (GOODMAN JAMES PAUL [US] ET AL) 18 September 2014 (2014-09-18) paragraphs [0006], [0048] - [0050], [0076] - [0078]; figures 1-4, 9, 9A, 10, 10A	1-36

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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

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

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

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

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 August 2024	11/09/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	van Poelgeest, A

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2024/055442

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 37-64
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 37-64

The present application contains 64 apparatus claims, of which 6 are independent. There is no clear distinction between independent apparatus claims because of overlapping scope. There are so many claims, and they are drafted in such a way that the claims as a whole are not in compliance with the provisions of clarity and conciseness of Article 6 PCT, as it is particularly burdensome for a skilled person to establish the subject-matter for which protection is sought.
Furthermore, there
are so many dependent claims, and they are drafted in such a way that the claims as a whole are not in compliance with the provisions of clarity and conciseness of Article 6 PCT, as they create a smoke screen in front of the skilled reader when assessing what should be the subject-matter of search; the non-compliance with the substantive provisions is extensive.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guidelines C-IV, 7.3), should the problems which led to the Article 17(2) PCT declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2024/055442

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2021077134 A1	18-03-2021	US 2017105743 A1	20-04-2017
		US 2021077134 A1	18-03-2021
US 2006116659 A1	01-06-2006	AT E345831 T1	15-12-2006
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US 2014276613 A1	18-09-2014	EP 2777742 A2	17-09-2014
		US 2014276613 A1	18-09-2014