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Inventor(s)

Montgomery; William D. et al.

EMBOLIC FILTER SYSTEM

Abstract

Various aspects of the present disclosure are directed toward an embolic filter system. The embolic filter system generally includes a filter and an elongated element. In some examples, the elongate element extends to a position distal to a proximal end of the filter and operates to protect against medical devices entangling with the filter. In some examples, the elongate element is soft and compliant and operates with a hemostatic seal to provide for a hemostatic seal within a lumen of the elongate element while maintaining the lumen as a working lumen through which medical devices can be passed.

Inventors: Montgomery; William D. (Flagstaff, AZ), Shaw; Edward E. (Flagstaff, AZ)

Applicant: W. L. Gore & Associates, Inc. (Newark, DE)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] This application is a continuation of U.S. patent application Ser. No. 17/716,049, filed Apr. 8, 2022, which is a continuation of U.S. patent application Ser. No. 16/478,712, filed Jul. 17, 2019, now U.S. Pat. No. 11,298,218, issued Apr. 12, 2022, which is a national phase application of PCT Application No. PCT/US2018/014395, internationally filed on Jan. 19, 2018, which claims the benefit of Provisional Application No. 62/448,802, filed Jan. 20, 2017, all of which are herein incorporated by reference in their entireties for all purposes.

BACKGROUND

[0002] Endovascular procedures address a broad array of medical needs, including endovascular access, diagnosis, and/or repair through minimally invasive or relatively less invasive means than surgical approaches. During some endovascular procedures, embolic debris may become dislodged or circulated in the vasculature. Circulation of embolic debris can cause mild to extreme cardiovascular complications, leading to stroke and even death.

[0003] Some conventional embolic protection devices used in connection with such endovascular procedures capture embolic debris in the device. For some designs, the device must be subsequently removed with the embolic debris captured therein. However, a common risk of these procedures is the unintentional release of some or all of the captured embolic debris back into the vasculature during the removal process.

[0004] Some other conventional embolic protection devices redirect the embolic debris to areas of the vasculature where its presence is associated with a lower risk of harm to the patient. Redirecting embolic debris bears with it the risk that complications may arise as a result of the redirected embolic debris migrating to another anatomical region.

SUMMARY

[0005] According to one example, (“Example 1”), an embolic filter includes an elongate element having a proximal end and a distal end, the elongate element including a first structural element and a first covering material, the elongate element having sufficient structural integrity to support being advanced within a delivery sheath, and a filter portion positioned at the distal end of the elongate element, the filter portion including a second structural element and a second covering material, wherein a portion of the second covering material includes a plurality of perforations configured to filter embolic debris from blood flowing into the filter portion.

[0006] According to another example, (“Example 2”) further to Example 1, the first structure element is a self-expanding wire braid.

[0007] According to another example, (“Example 3”) further to Examples 1 to 2, a distally directed force applied to the proximal end of the elongate element is operable to cause a distal translation of the elongate element and the filter portion relative to a delivery sheath.

[0008] According to another example, (“Example 4”) further to Examples 1 to 3, the elongate element has sufficient structural integrity to support being advanced within a delivery sheath without requiring an introducer.

[0009] According to another example, (“Example 5”) further to Examples 1 to 4, the filter portion is blood permeable and wherein the plurality of perforations have an average size of one hundred microns.

[0010] According to another example, (“Example 6”) further to Examples 1 to 5, the second covering material of the filter portion is blood impermeable, and wherein plurality of perforations are formed in the second covering material such that blood is operable to flow through the second covering material of the filter portion.

[0011] According to another example, (“Example 7”) further to Examples 1 to 6, the elongate element is blood impermeable.

[0012] According to another example, (“Example 8”) further to Examples 1 to 7, the elongate element is configured to be advanced through a valve that operates control a flow of blood through a lumen of the elongate element during a clinical procedure.

[0013] According to another example, (“Example 9”) further to Examples 1 to 8, one of the first and second covering materials include ePTFE.

[0014] According to another example, (“Example 10”) an embolic filter includes a filter assembly having two ends and an elongated intermediate portion, and a structural element, wherein at a first end the filter assembly comprises an expandable filter element having an expandable frame and a filter material, and wherein the intermediate portion comprises a thin, unsupported polymer material configured to be mounted over the structural element for advancement within a catheter lumen for delivery to a treatment site, and configured to remain in place at the treatment site while the structural element is removed.

[0015] According to another example, (“Example 11”) further to Example 10, the structural element is configured to advance the first end of the filter assembly from an end of the catheter for deployment at the treatment site.

[0016] According to another example, (“Example 12”) further to Examples 10 to 11, the intermediate portion is configured to be advanced through a valve that operates control a flow of blood through a lumen of the intermediate portion during a clinical procedure.

[0017] According to another example, (“Example 13”) further to Example 12, the lumen of the intermediate portion is configured to accommodate the advancement of one or more medical devices through the lumen of the intermediate portion during a clinical procedure, and wherein the valve is configured to control blood flow through the lumen of the intermediate portion during the clinical procedure.

[0018] According to another example, (“Example 14”) further to Examples 10 to 13, the filter material is blood permeable and includes a plurality of perforations having an average size of one hundred microns.

[0019] According to another example, (“Example 15”) further to Examples 10 to 14, the polymer material of the intermediate portion is blood impermeable.

[0020] According to another example, (“Example 16”) further to Examples 10 to 15, one of the filter material and the polymer material include ePTFE.

[0021] According to another example, (“Example 17”), an endoprosthesis delivery device includes an expandable filter element mounted on a catheter shaft, having a capture area within the expandable filter element when the expandable filter element is deployed, and an elongated conduit configured to extend through and beyond the expandable filter element when the expandable filter element is deployed at a treatment site, the conduit configured to allow for delivery of an endoprosthesis beyond the expandable filter element, wherein the elongated conduit includes at least one aperture through a side wall providing fluid communication between the capture area and an interior of the elongated conduit.

[0022] According to another example, (“Example 18”) further to Example 17, the elongated conduit extends from the catheter shaft.

[0023] According to another example, (“Example 19”) further to Examples 17 to

[0024] 18, the elongated conduit and the catheter shaft form a single monolithic unit. According to another example, (“Example 20”) further to Examples 17 to

[0025] 19, the at least one aperture is configured to facilitate a transfer of embolic debris captured

within the filter to the elongated conduit.

[0026] While multiple embodiments are disclosed, still other embodiments will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The accompanying drawings are included to provide a further understanding of the disclosure and are incorporated in and constitute a part of this specification, illustrate examples, and together with the description serve to explain the principles of the disclosure.

[0028] FIG. 1A is an illustration of an embolic filter system consistent with various aspects of the present disclosure.

[0029] FIG. 1B is an illustration of an embolic filter system consistent with various aspects of the present disclosure.

[0030] FIG. 2 is an illustration of an embolic filter system consistent with various aspects of the present disclosure.

[0031] FIG. 3 is an illustration of an introducer consistent with various aspects of the present disclosure.

[0032] FIGS. 4A-4C are illustrations of an embolic filter system consistent with various aspects of the present disclosure.

[0033] FIG. 4D is a detailed view of various components of the embolic filter system illustrated in FIGS. 4A-4C.

[0034] FIG. 4E is an illustration of an embolic filter system consistent with various aspects of the present disclosure.

[0035] FIG. 5A is an illustration of an embolic filter system being delivered within the aortic arch consistent with various aspects of the present disclosure.

[0036] FIG. 5B is an illustration of an embolic filter system being deployed within the aortic arch consistent with various aspects of the present disclosure.

[0037] FIGS. 5C-5D include illustrations of an embolic filter system deployed in the aortic arch consistent with various aspects of the present disclosure.

[0038] FIG. 6A is an illustration of an embolic filter system consistent with various aspects of the present disclosure.

[0039] FIG. 6B is an illustration of the embolic filter system of FIG. 6A in a deployed configuration consistent with various aspects of the present disclosure.

[0040] FIG. 7 is an illustration of an embolic filter system consistent with various aspects of the present disclosure.

[0041] FIG. 8 is an illustration of an embolic filter system consistent with various aspects of the present disclosure.

DETAILED DESCRIPTION

[0042] Persons skilled in the art will readily appreciate that various aspects of the present disclosure can be realized by any number of methods and apparatuses configured to perform the intended functions. It should also be noted that the accompanying drawing figures referred to herein are not necessarily drawn to scale, but may be exaggerated to illustrate various aspects of the present disclosure, and in that regard, the drawing figures should not be construed as limiting. In describing various examples, the term distal is used to denote a position along an exemplary device proximate to or alternatively nearest to the treatment region within a patient's body. The term proximal is used to denote a position along the exemplary device proximate to or alternatively

nearest to the user or operator of the device.

[0043] Various aspects of the present disclosure are directed toward an embolic filter device, system, and method. An exemplary embolic filter system **1000** is illustrated in FIG. **1A**. In some examples, the embolic filter system **1000** includes a distal end **1002** and a proximal end **1004**. In some examples, the distal end **1002** is situated opposite the proximal end **1004**.

[0044] In various examples, the embolic filter is deployed in a region of a patient's vasculature corresponding to a treatment site. Generally, the system is advanced to a target site such that one or more components of the system (such as the filter or deflector portion) is antegrade or "downstream" of the treatment. Those of skill will appreciate that positioning the system in such a manner provides that that embolic and other debris dislodged from the treatment area during a treatment procedure will migrate with the flow of blood toward the system. The system is deployable, collapsible, and removed from the vasculature from either a distal or a proximal approach direction (e.g., antegrade or retrograde directions) to facilitate, for example, intravascular removal of the devices from different access locations.

[0045] Once deployed, the embolic filter system **1000** interacts with blood flowing through the region of the vasculature within which the embolic filter system **1000** is deployed. In some examples, embolic filter system **1000** may be adapted or otherwise configured to filter blood and/or embolic debris as it flows through or otherwise interacts with the embolic filter system **1000**. In some examples, the embolic filter system **1000** additionally or alternatively redirects blood flow and/or embolic debris from what would otherwise be a normal or unimpeded flow of blood and/or embolic debris through the surrounding vasculature. Thus, in various examples, the embolic filter system **1000** can be deployed within a region of a patient's vasculature such that blood and/or embolic debris is filtered and/or redirected as it flows through that region of the patient's vasculature.

[0046] In various examples, the embolic filter system **1000** has one or more components that operate together to filter and/or redirect blood flow and embolic debris as mentioned above. For example, with reference now to FIGS. **1A** and **1B**, the embolic filter system **1000** includes an elongate element **1100**, a filter **1200**, and a constraining element **1300**. It should be appreciated that various cutaways of the constraining element **1300** have been made in FIGS. **1A** and **1B** to illustrate portions of the elongate element **1100** otherwise obstructed from view by the constraining element **1300**. In some examples, the elongate element **1100** operates as a conduit through which one or more medical devices can be delivered to a treatment site, as explained in greater detail below. In some examples, the constraining element **1300** is a catheter. In some examples, one or more components outside of the patient's body are coupled to and operate with the elongate element **1100**, the filter **1200**, and the constraining element **1300**. For instance, one or more components **1400**, such as handles, control units, and/or hemostatic valves may be coupled to the elongate element **1100**, the filter **1200**, and the constraining element **1300** as discussed in greater detail below. In various examples, the filter **1200** is coupled to the elongate element **1100**, and the constraining element **1300** is configured to constrain the elongate element **1100** and the filter **1200** in a delivery (or collapsed) configuration.

[0047] In various examples, the elongate element **1100** is a longitudinally extending structure having a distal end **1102**, a proximal end **1104**, and an intermediate portion **1106** situated between the distal and proximal ends **1102** and **1104**. In some examples, the elongate element **1100** is configured to receive blood and/or embolic debris. In some such examples, the elongate element **1100** filters and/or redirects blood and embolic debris flowing through the portion of the patient's vasculature within which the embolic filter system **1000** is deployed. Thus, in various examples, the elongate element **1100** includes an inner lumen, such as lumen **1108** (FIG. **1B**). In some examples, blood and/or embolic debris entering the elongate element **1100** flows through the lumen **1108**.

[0048] In various examples, the lumen **1108** extends through the elongate element **1100** from the

distal end **1102** to the proximal end **1104**. That is, in some examples, the distal and proximal ends **1102** and **1104** are open to the lumen **1108**. In some examples, the lumen **1108** forms a working lumen through which one or more medical devices can be passed to treatment sites proximal to the embolic filter system **1000**. Thus, in various examples, the lumen **1108** operates as both a working lumen for medical device delivery as well as a structure for redirecting and/or filtering the flow of blood and/or embolic debris.

[0049] Examples of medical devices that may be passed through the lumen **1108** include but are not limited to catheters, thromectomy devices, atherectomy devices, embolectomy devices, and tools associated therewith, contrasting agents, drug delivery agents, endovascular prostheses including stents, stent-grafts, and valves, for example. Additionally or alternatively, the lumen **1108** is configured to house one or more release lines, steering lines, guide wires, structural support elements, and/or introducers, and related components as will be explained further below.

[0050] In various examples, the filter **1200** is a structure configured to interact with blood and/or embolic debris flowing through the patient's vasculature in the region within which the embolic filter system **1000** is deployed. In some examples, the filter **1200** is configured to direct or funnel blood and embolic debris such that the blood and embolic debris enter the filter **1200** and, in some examples, the elongate element **1100**.

[0051] In various examples, the filter **1200** includes a distal end **1202**, a proximal end **1204**, and an intermediate portion **1206**. As shown in FIGS. **1A** and **1B**, in some examples, the filter **1200** includes a membrane **1210** and a structural support **1212**. The structural support **1212** may be formed of nitinol or other suitable materials and may be laser cut, braided, or wire-wound. In some examples, the structural support **1212** is formed of a laser cut nitinol tube, as those of skill will appreciate.

[0052] In some examples, the membrane or covering material **1210** is disposed about and covering the structural support **1212**. In some examples, the structural support **1212** is disposed about the membrane **1210**. In various examples, the structural support **1212** provides structural support to the membrane **1210**. In some examples, as discussed in greater detail below, the filter **1200** is self-expanding and/or radially collapsible. The filter **1200** may be of any suitable size for endovascular delivery and deployment.

[0053] In some examples, both the distal and proximal ends **1202** and **1204** of the filter **1200** are open such that the flow of blood can enter the filter **1200** at the distal end **1202** and exit the filter **1200** at the proximal end **1204**. Thus, in some examples, the membrane **1210** is configured such that the filter **1200** has a lumen extending therethrough. Generally, this lumen operates as an area for capturing blood and embolic debris. In some examples, the proximal end **1204** of the filter **1200** is coupled to the elongate element **1100** such that the blood exiting the proximal end **1204** of the filter **1200** enters or otherwise interacts with the elongate element **1100**.

[0054] In such examples, the coupling between the elongate element **1100** and the filter **1200** can be permanent or temporary. In some examples, the elongate element **1100** is coupled to the filter **1200** such that the elongate element **1100** and the filter **1200** form a single monolithic unit. In some other examples, the filter **1200** is removable from the elongate element **1100**. In some examples, the filter **1200** is slidable relative to the elongate element **1100**.

[0055] In some examples, the filter **1200** is coupled or otherwise secured at or proximate to an end of the elongate element **1100**, such as a distal end **1102** of the elongate element **1100**. For example, the embolic filter system **1000** illustrated in FIG. **1A** includes a filter **1200** coupled at a distal end **1102** of the elongate element **1100**.

[0056] In some other examples, however, the filter **1200** is coupled to the elongate element **1100** at some position along the elongate element **1100** proximal to the distal end **1102** of the elongate element **1100**. For example, the illustrated embolic filter system **1000** illustrated in FIG. **1B** includes a filter **1200** that is coupled to the elongate element **1100** at a position along the elongate element **1100** proximal of the distal end **1102** of the elongate element **1100**. In some such

examples, the filter **1200** is coupled to the elongate element **1100** such that a distal end **1202** of the filter **1200** is situated proximal of the distal end **1102** of the elongate element **1100**. Thus, in some examples, the distal end **1102** of the elongate element **1100** extends distal to the distal end **1202** of the filter **1200** and thus corresponds with or otherwise defines a distal end **1002** of the embolic filter system **1000**. As explained in greater detail below, such a distally projecting portion of the elongate element **1100** protects against entanglement between the filter **1200** and the medical devices being delivered to the treatment site through the lumen **1108**.

[0057] It will be appreciated, that in some examples, the filter **1200** is coupled to the elongate element **1100** such that the distal end **1102** of the elongate element **1100** is situated between the distal end **1202** and a proximal end **1204** of the filter **1200**. That is, although the filter **1200** is coupled to the elongate element **1100** at a position along the elongate element **1100** proximal to the distal end **1102** of the elongate element **1100**, the distal end **1202** of the filter **1200** corresponds with or otherwise defines a distal end **1002** of the embolic filter system **1000** (i.e., the distal end **1202** of the filter **1200** is positioned distal to the distal end **1102** of the elongate element **1100**). In some other examples, the filter **1200** is coupled to the elongate element **1100** such that the distal end **1102** of the elongate element **1100** and the distal end **1202** of the filter **1200** are positioned equally distal relative to one another. In other words, the distal end **1102** of the elongate element **1100** is not (or is not substantially) positioned distal the distal end **1202** of the filter **1200** and vice versa.

[0058] In some examples, a proximal end of the filter is coupled to a distal end a first elongate element, and a second elongate element is coupled to the filter and/or the first elongate element such that the second elongate element extends within or through an interior region of the filter distal the first elongate element. In some examples, similar to the discussion above, the distal end of the second elongate element is positioned distal to, at, or proximal to the distal end of the filter.

[0059] In some examples, the filter **1200** deflects or otherwise redirects blood and/or embolic debris such that the blood and/or embolic debris flows into the filter **1200**. In some examples, the filter **1200** operates to filter or otherwise condition the blood and embolic debris flowing therethrough. In some examples, the filter **1200** is permeable to certain blood media (e.g., blood-permeable) and impermeable to certain other blood media and/or embolic debris. Specifically, in some examples, the membrane **1210** of the filter **1200** is configured such that certain blood media (e.g., red blood cells, white blood cells, plasma, platelets, etc.) flowing through the filter **1200** can permeate the membrane **1210** of the filter **1200** and re-enter the vasculature while the filter **1200** is impermeable to certain other blood media and embolic debris. In some examples, the filter **1200** is impermeable to embolic debris of a designated size or larger. That is, in some examples, the membrane **1210** of the filter **1200** operates to obstruct embolic debris of a designated size or larger from permeating the membrane **1210** of the filter **1200** and re-entering the vasculature.

[0060] In some examples, the blood media and embolic debris flowing through the filter **1200** that does not permeate back into the vasculature is either captured and retained within the filter **1200** or is further directed into the elongate element **1100**. In some examples, as explained in greater detail below, the filter **1200** is collapsible such that the blood media and embolic debris that is retained within the filter **1200** can be subsequently removed from the patient's body.

[0061] As mentioned above, in some examples, some or all of the blood and/or embolic debris flowing into the filter **1200** is further directed into the elongate element **1100**. In some examples, the blood and/or embolic debris that is directed into the elongate element **1100** enters the lumen **1108** of the elongate element **1100**. In some examples, as explained in greater detail below, the filter **1200** is configured to filter the blood and/or embolic debris entering the inner lumen **1108**. Thus, in some examples, the elongate element **1100** is configured to filter the blood and/or embolic debris that did not permeate through the filter **1200**.

[0062] As mentioned above, in some examples, the filter **1200** and/or the elongate element **1100** operate to filter embolic debris from a patient's blood flowing through the embolic filter system

1000. Generally, the permeability of the elongate element **1100** and/or the membrane **1210** can be controlled by manipulating one or more of the material properties of the material of which the elongate element **1100** and/or the membrane **1210** is comprised. For example, a node and fibril configuration of an expanded fluoropolymer can be optimized based on the desired permeability. In some examples, an expanded fluoropolymer can be processed such that a node and fibril configuration of the expanded fluoropolymer is generally impermeable to embolic debris (and other blood media) of a designated size.

[0063] It will thus be appreciated that the elongate element **1100** and the filter **1200** can comprise various materials including, but not limited to polymers such as fluoropolymers like an expanded polytetrafluoroethylene (“ePTFE”), expanded PTFE, expanded modified PTFE, expanded copolymers of PTFE, nylons, polycarbonates, polyethylenes, polypropylenes and the like.

[0064] In various examples, one or more regions of a material may be further or alternatively modified by forming one or more perforations therein. For example, a material such as an expanded fluoropolymer (or another suitable polymer) can be further modified by perforating one or more regions of the material to achieve a designated porosity in those regions. Examples include laser cutting holes or perforations into a material. Other materials having a woven, knitted or lattice configuration may also serve as adequate materials based on their permeability/porosity.

[0065] Additionally, in some examples, a material can be configured such that one or more portions or regions of the elongate element **1100** and/or the membrane **1210** of the filter **1200** are permeable to a media up to a designated size while one or more other portions or regions of the elongate element **1100** and/or the membrane **1210** are impermeable to the media. In some examples, the elongate element **1100** and/or the filter **1200** can have a variable pore or perforation size, for example, from a proximal end to a distal end and/or at one or more discrete locations (e.g., such as at one or more of the permeable windows discussed below). For example, a distal region of the elongate element **1100** and/or the filter **1200** can have a smaller average perforation size to avoid smaller embolic debris entering the great vessels, whereas a more proximal region of the elongate element **1100** and/or the filter **1200** can have a larger average perforation size beyond a point where entry of the smaller embolic debris into the great vessels is not a concern.

[0066] In some examples, varying permeability may be achieved by varying a number of layers of a material along the elongate element **1100** and/or the filter **1200**. For example, a first region of a material having a first number of layers of an expanded fluoropolymer is associated with a first degree of permeability while a second region of the material having a second number of layers of an expanded fluoropolymer is associated with a second degree of permeability. In some such examples, the permeability of a region of such a material is inversely related to the number of layers of the expanded fluoropolymer integrated into the material in that region.

[0067] In some other examples, a varying degree of permeability can be achieved by alternatively or additionally varying a diameter or area of each of the perforations or the perforation density made in one region of the material relative to another region of the material. In one such example, a first area or region (e.g., distal) may be associated with one or more perforations having a first average perforation size and a second area or region (e.g., proximal) may be associated with one or more perforations having a second average perforation size. Thus, in various examples, the filter **1200** and/or the elongate element **1100** may include areas or regions with variable pore sizes. It will be appreciated that by varying the pore size or permeability, the filtration of embolic debris along the embolic filter system **1000** can be controlled and the risk of potentially harmful embolic debris perfusing into critical areas can be minimized.

[0068] In various examples, the perforations or pore sizes discussed above may be selected such that a region or area of the elongate element **1100** and/or the membrane **1210** of the filter **1200** is impermeable to embolic debris greater than or equal to about 100 μm . In such examples, it will be appreciated that the average pore size in such areas is less than 100 μm . However, in other examples, the pore sizes may be selected such that a region or area of the material is impermeable

to embolic debris smaller than 100 μm , such as embolic debris in the range of 40 μm to 99 μm . In yet other examples, other regions or areas of the material may be permeable to embolic debris greater than 100 μm , such as embolic debris in the range of 101 μm to 150 μm . It will be appreciated that the average pore size in such areas is greater than or equal to 101 μm to 150 μm . [0069] Referring still to FIGS. 1A and 1B, in various examples, the filter **1200** is expandable such that the filter **1200** occupies the area (or a substantial portion of the area) of the vessel within which it is deployed. In various examples, the filter **1200** is expanded once it is advanced to a target site at or proximate to a treatment area. Thus, in various examples, a filter **1200** is transitionable between a radially collapsed delivery configuration and a radially expanded deployed configuration. In some examples, the filter **1200** is self-expanding. In some examples, one or more expandable elements are utilized to transition the filter **1200** between the radially collapsed delivery configuration and the radially expanded deployed configuration. For example, a balloon may be utilized to transition the filter **1200** to the radially expanded deployed configuration from the radially collapsed delivery configuration.

[0070] In the deployed configuration, the filter **1200** adopts a generally trumpeted, conical, or frustoconical shape in that a transverse cross-sectional area of the filter **1200** is different at two different locations along the filter **1200** between the distal and proximal ends **1202** and **1204** of the filter **1200**. In one such example, the transverse cross-sectional area of the distal end **1202** is greater than the transverse cross-sectional area of the proximal end **1204**. In some examples, the filter **1200** generally tapers from the distal end **1202** to the proximal end **1204**. Such a configuration provides that the filter **1200** operates to funnel the blood into the filter **1200** and/or into the elongate element **1100** as disclosed herein.

[0071] In some examples, one or more constraining members, such as constraining element **1300**, operate to maintain the filter **1200** and/or a portion thereof in the radially collapsed delivery configuration. In some examples, the constraining element **1300** is releasable or removable such that the filter **1200** is transitionable to the radially expanded deployed configuration.

[0072] Generally, depending on the desired configuration, the constraining element **1300** can comprise various materials including, but not limited to polymers, such as fluoropolymers like an expanded polytetrafluoroethylene (“ePTFE”), expanded PTFE, expanded modified PTFE, expanded copolymers of PTFE, nylons, polycarbonates, polyethylenes, polypropylenes and the like. Thus, in some examples, the constraining element **1300** can be advanced or retracted relative to the filter **1200**.

[0073] Referring still to FIGS. 1A and 1B, in various examples, the embolic filter system **1000** includes a constraining element **1300**. In some examples, the constraining element **1300** is an elongated member having a distal end **1302** and a proximal end **1304**. In some examples, the constraining element **1300** is cylindrical, however, constraining elements having oblong cross sections are also envisioned. In various examples, an interior lumen **1306** extends through the constraining element **1300** from the distal end **1302** to the proximal end **1304**. In some examples, as mentioned above, the interior lumen **1306** is configured to receive the elongate element **1100** therein. Thus, in some such examples, the elongate element **1100** and the constraining element **1300** are coaxial. Likewise, in various examples, a portion of or all of the filter **1200** is received within the constraining element **1300** such that the filter **1200** is maintained in a radially collapsed delivery configuration.

[0074] In various examples, the elongate element **1100** is received within the constraining element **1300** such that the elongate element **1100** and the constraining element **1300** can be moved relative to one another. As explained in greater detail below, moving the elongate element **1100** and the constraining element **1300** relative to one another facilitates both the deployment and the collapsing of the filter **1200**.

[0075] In some examples, the constraining element **1300** is retractable such that the distal end **1302** of the constraining element **1300** translates proximally away from the distal end **1202** of the filter

1200. In some such examples, the elongate element **1100** and/or the filter **1200** are held fixed while the constraining element **1300** is retracted. In other examples, the elongate element **1100** and/or the filter **1200** are advanced while the constraining element **1300** is retracted. In some examples, the elongate element **1100** and/or the filter **1200** are advanced relative to the constraining element **1300** such that the filter **1200** moves distally away from the proximal end **1304** of the constraining element **1300**. In some examples, the constraining element **1300** is held fixed while the elongate element **1100** and/or the filter is advanced. In other examples, the constraining element **1300** is retracted while the elongate element **1100** and/or the filter is advanced.

[0076] In various examples, the advancement of the filter **1200** distally away from the distal end **1302** of the constraining element **1300** facilitates deployment of the filter **1200**. That is, the filter **1200** can be transitioned from the radially collapsed delivery configuration to the radially expanded deployed configuration by advancing the filter **1200** distally away from the distal end **1302** of the constraining element **1300** and/or retracting the distal end **1302** of the constraining element **1300** away from the distal end **1202** of the filter **1200**.

[0077] As mentioned above, in some examples, the filter **1200** can be transitioned from the radially expanded deployed configuration to the radially collapsed delivery configuration. In some examples, with the filter **1200** transitioned to the radially collapsed delivery configuration, the embolic filter system **1000** can be withdrawn from the patient's vasculature. In some examples, a deployed filter **1200** is transitioned to the radially collapsed delivery configuration by advancing the constraining element **1300** toward the distal end **1202** of the filter **1200** until the filter **1200** is radially collapsed and retained by the constraining element **1300**, as discussed in greater detail below. Alternatively or additionally, the filter **1200** can be withdrawn proximally relative to the constraining element **1300**.

[0078] As discussed above, in various examples, the filter **1200** is coupled to the elongate element **1100** at a position along the elongate element **1100** proximal to the distal end **1102** of the elongate element **1100** such that a distal end **1102** of the elongate element **1100** is positioned distal to the proximal end **1204** of the filter **1200**. With specific reference to FIG. 1B, an exemplary embolic filter system **1000** includes an elongate element **1100** having a distal end **1102** that is positioned distal to a proximal end **1204** of the filter **1200** such that a distal portion **1110** of the elongate element **1100** extends distally beyond the proximal end **1204** of the filter **1200**. As mentioned above, in various examples, the elongate element **1100** includes an inner lumen **1108** through which one or more medical devices can be delivered to a treatment site located distally of the distal end **1002** of the embolic filter system **1000**.

[0079] In some examples, the distal portion **1110** provides that such medical devices can be delivered with a decreased risk that such medical devices will become entangled with the filter **1200**. In other words, the portion (distal portion **1110**) of the elongate element **1100** that extends distal to the proximal end **1204** of the filter **1200** operates as a barrier between the medical device being delivered and the filter **1200**. Accordingly, such a configuration is associated with a decreased risk that the delivered medical device will interfere with the filter **1200** as the delivered medical device exits the distal end **1102** of the elongate element **1100**. Those of skill in the art will appreciate that such a configuration helps minimize a risk of tearing or otherwise damaging of the filter **1200** as a result of a medical device entangling with the filter **1200**.

[0080] In addition to protecting against entanglement between the filter **1200** and a delivered medical device, in some examples, the distal portion **1110** of the elongate element **1100** operates to capture embolic material trapped in the filter **1200** as the filter is radially collapsed for removal of the embolic filter system **1000**. Specifically, in some examples, the distal portion **1110** includes one or more apertures **1112** that extend from an exterior surface **1114** of the distal portion **1110** to the inner lumen **1108** of the elongate element **1100**. Accordingly, the one or more apertures **1112** provide a pathway for embolic debris captured by the filter **1200** to enter the lumen **1108**. In some examples, such a configuration additionally or alternatively facilitates the aspiration of the embolic

debris from the embolic filter system **1000**. In some such examples, aspiration of the embolic debris can be achieved before or after radially collapsing the filter **1200** and/or withdrawing the embolic filter system **1000** from the patient's vasculature. Those of skill will appreciate that by providing a mechanism for evacuating embolic debris that is otherwise captured within the filter **1200**, the embolic filter system **1000** helps minimize the risk that the captured embolic debris will be accidentally released back into the patient's vasculature during removal of the embolic filter system **1000** from the patient's vasculature.

[0081] For example, a known risk during embolic debris filtering procedures is the risk of tearing the filter (or filter material) during removal. Generally, embolic filters filled with embolic debris generally occupy a larger cross sectional area than do embolic filters free of embolic debris. This increased cross section can be associated with difficulty in sufficiently collapsing the embolic filter to a configuration wherein the embolic filter can be completely retracted within a constraining sheath. Even where the filter is not retracted within a constraining sheath, withdrawing a filter having a larger diameter as a result of being filled with embolic debris through tortuous vasculature can be difficult. Providing a mechanism that enables the evacuation of some or all of the embolic debris from the filter helps minimize the above-discussed risks.

[0082] In some examples, a cross sectional area of the distal portion **1110** of the elongate element **1100** is less than a cross sectional area of the portion of the elongate element **1100** situated proximal of the proximal end **1204** of the filter **1200**. In some such examples, the distal portion **1110** of the elongate element **1100** has an outside diameter that is less than an outside diameter of the portion of the elongate element **1100** situated proximal of the proximal end **1204** of the filter **1200**. In one such example, however, an inside diameter of the distal portion **1110** is the same as (or substantially the same as) an inside diameter of the portion of the elongate element **1100** situated proximal of the proximal end **1204** of the filter **1200**. In other words, although a cross section area (or an outside diameter) of the distal portion **1110** is less than that of the portion of the elongate element **1100** situated proximal of the proximal end **1204** of the filter **1200**, a diameter or cross sectional area of the inner lumen **1108** is generally constant between the distal and proximal ends **1102** and **1104** of the elongate element **1100**. Thus, in some examples, it will be appreciated that the elongate element **1100** has a varying wall thickness along its length.

[0083] Put differently, in some examples, the distal portion **1110** has a first inner diameter and a first outer diameter, and the portion of the elongate element **1100** situated proximal of the proximal end **1204** of the filter **1200** has the first inner diameter and a second outer diameter, wherein the second outer diameter is greater than the first outer diameter.

[0084] Turning now to FIGS. 2 and 3, various components of an embolic filter system **2000** are illustrated. As shown, the embolic filter system **2000** includes an elongate element **2100**, a filter **2200** (similar to filter **1200**), and an introducer **2300**. As shown in FIG. 4, in some examples, the embolic filter system **2000** further includes a constraining member **2400** (similar to constraining element **1300**) and a hemostatic sealing member **2500**.

[0085] Similar to the elongate element **1100**, in various examples, the elongate element **2100** can comprise various materials including, but not limited to polymers, such as fluoropolymers like an expanded polytetrafluoroethylene ("ePTFE"), expanded PTFE, expanded modified PTFE, expanded copolymers of PTFE, nylons, polycarbonates, polyethylenes, polypropylenes and the like. Similar to elongate element **1100**, elongate element **2100** extends longitudinally and includes a distal end **2102**, a proximal end **2104**, and an intermediate portion **2106** situated between the distal and proximal ends **2102** and **2104**. In some examples, the elongate element **2100** is configured to receive blood and/or embolic debris. In some such examples, the elongate element **2100** filters and/or redirects blood and embolic debris flowing through the portion of the patient's vasculature within which the embolic filter system **2000** is deployed. Thus, in various examples, the elongate element **2100** includes an interior lumen, such as lumen **2108** (FIG. 2).

[0086] In various examples, the lumen **2108** extends through the elongate element **2100** from the

distal end **2102** to the proximal end **2104**. That is, in some examples, the distal and proximal ends **2102** and **2104** are open to the lumen **2108**. In some examples, the lumen **2108** forms a working lumen through which one or more medical devices can be passed to a treatments site proximal of the embolic filter system **2000**, as explained above.

[0087] In some examples, the elongate element **2100** is formed of a material, such as an expanded fluoropolymer like ePTFE. Accordingly, in some examples, the elongate element **2100** is a soft and compliant material. In some examples, the elongate element **2100** lacks sufficient structural rigidity to support its own weight and has little to no column strength when subjected to a longitudinal compressive force. Likewise, in some such examples, the elongate element **2100** is not generally torqueable in that the elongate element will not generally transfer a torque applied to its first end to its second end. However, as those of skill in the art will appreciate, an elongate element **2100** made of an expanded fluoropolymer exhibits good tensile strength in that a longitudinal tensile force applied to a first end of the elongate element **2100** is generally transferred along the elongate element **2100**.

[0088] Elongate elements formed of a fluoropolymer like ePTFE have an added advantage over other materials and designs in that an elongate element formed of a fluoropolymer like ePTFE can have a working lumen with a diameter larger than the diameters of conventional designs without increasing the outside working diameter of the system. In other words, elongate elements formed of a fluoropolymer like ePTFE can be configured with thin or very thin walls (e.g., a range of between 0.0001 and 0.010 inches) to maximize the inner diameter of the working lumen without impacting the overall size of the device. For instance, in some examples, elongate elements formed of a fluoropolymer like ePTFE can be configured with an average wall thickness of approximately 0.001 inches. It should be appreciated that the high tensile strength of a fluoropolymer like ePTFE enables a configuration having thin walls which maximizes the area of the working lumen (as further discussed herein).

[0089] In some examples, like the elongate element **1100**, the elongate element **2100** may be blood-permeable while remaining impermeable to embolic debris and other blood media in excess of a particular size or cross section. Likewise, similar to elongate element **1100**, the elongate element **2100** may include one or more perforations and/or a varying permeability or porosity along its length.

[0090] In some examples, as explained in greater detail below, the elongate element **2100** includes a stopping feature **2112** (FIG. 2). In some examples, the stopping feature **2112** is integral to the elongate element **2100**. In other examples, the stopping feature **2112** is a separate component that is coupled to the elongate element **2100**. In some examples, the stopping feature **2112** is positioned at or near the proximal end **2104** of the elongate element **2100**. In some examples, the stopping feature **2112** operates to control how far into the vasculature the elongate element **2100** may be advanced. In some examples, the stopping feature **2112** additionally or alternatively operates as a pulling feature for withdrawing the elongate element **2100** and the filter **2200** from the vasculature. Thus, in some examples, the stopping feature **2112** operates as a capture feature that facilitates capturing and withdrawing the elongate element **2100** and the filter **2200** from the vasculature. In some examples, the stopping feature **2112** is a rigid or semi-rigid and may be formed of a polymer such as polypropylene, polyethylene, polyamides, polyetheretherketone, or other suitable plastic for example.

[0091] In various examples, like the filter **1200**, the filter **2200** is a structure configured to interact with blood and/or embolic debris flowing through the patient's vasculature in the region within which the embolic filter device **2000** is deployed. In various examples, the filter **2200** includes a distal end **2202**, a proximal end **2204**, and an intermediate portion **2206**. Likewise, in some examples, the filter **2200** includes a membrane **2210** and a structural support **2212**. Thus, in some examples, like the filter **1200**, the filter **2200** is self-expanding and/or radially collapsible.

[0092] In some examples, both the distal and proximal ends **2202** and **2204** of the filter **2200** are

open such that the flow of blood can enter the filter at the distal end **2202** and exit the filter at the proximal end **2204**. In some examples, the proximal end **2204** of the filter **2200** is coupled to the elongate element **2100** such the blood exiting the proximal end **2204** of the filter **2200** enters or otherwise interacts with the elongate element **2100**. In such examples, as explained above with regard to elongate element **1100**, the coupling between the elongate element **2100** and the filter **2200** can be permanent or temporary.

[0093] Additionally, like the filter **1200**, in some examples, the filter **2200** operates to filter or otherwise condition the blood and embolic debris flowing therethrough. Thus, in some examples, the filter **2200** is permeable to certain blood media (e.g., blood-permeable) and impermeable to certain other blood media and/or embolic debris (e.g., embolic debris and blood media of a designated size or larger). Likewise, one or more regions may be permeable while one or more other regions may be impermeable (or less permeable as discussed herein). In some examples, as explained in greater detail below, the filter **2200** is collapsible such that the blood media and embolic debris that is retained within the filter **2200** can be subsequently removed from the patient's body.

[0094] As mentioned above, the permeability/porosity of an elongate element or filter, like elongate element **2100** and/or filter **2200** can be controlled by manipulating one or more of the material properties of the material of which the elongate element and/or filter is comprised (e.g., node and fibril configuration, perforation, weave, knit, and lattice configurations).

[0095] As show in FIG. 2, the filter **2200** includes a plurality of perforations **2208**. In some examples, these perforations **2208** are configured to filter embolic debris from the patient's blood. For instance, the perforations **2208** may be between 50 microns and 1000 microns, and thus may be operable to filter debris as little as 50 microns. While the perforations are illustrated as being generally circular in geometry, it will be appreciate that other shapes, such as polygonal geometries, are envisioned and may be utilized in addition to or in lieu of circular geometries without departing from the spirit or scope of the disclosure. As explained above, perforations **2208** (and/or node and fibril configurations, and/or weaves, and/or knits, and/or lattice configurations, and/or layering, etc.) can vary across a material (e.g., from a proximal end to a distal end and/or at one or more discrete locations). Additionally, while the filter **2200** illustrated in FIG. 2 show perforations along only a portion thereof, it should be appreciated that perforations may be included at any and all surfaces of the filter **2200**.

[0096] Turning now to FIG. 3, in various examples, the introducer **2300** is a longitudinally extending structure configured to facilitate delivery of the embolic filter system to a treatment site within a patient's vasculature (or to a location proximal thereto). Specifically, in some examples, the introducer **2300** is configured such that the elongate element **2100** and the filter **2200** can be loaded onto the introducer and delivered to the treatment site within the patient's vasculature. As shown, an exemplary introducer **2300** includes a distal end **2302** and a proximal end **2304**. In some examples, an intermediate portion **2306** is situated between the distal end and the proximal end **2302** and **2304**. In some examples, the introducer **2300** includes an elongate element mounting portion **2308** and a filter mounting portion **2310**. In some examples, the intermediate portion **2306** includes the elongate element mounting portion **2308** and the filter mounting portion **2310**.

[0097] In some examples, the introducer **2300** is generally cylindrically shaped, however, other profiles are envisioned. In addition, in some examples, the introducer **2300** may have any suitable cross sectional profile including, but not limited to, circular and oblong cross sections. In some examples, the introducer **2300** includes a blunt tip at its distal end **2302**. In some examples, the proximal end **2304** includes a tip that generally tapers. For example, as show in FIGS. 4A and 4B, the introducer **2300** includes a tapered tip **2312** having a distal end **2314** with a smaller cross section than a proximal end **2316**. In some examples, the distal end **2314** of the tapered tip **2312** corresponds to the distal end **2304** of the introducer **2300**. In some examples, the tapered tip **2312** extends from the filter mounting portion **2310** and is positioned distally thereof.

[0098] As mentioned above, the introducer **2300** is configured to facilitate delivery of the elongate element **2100** and the filter **2200** to the treatment site (or a position proximal thereto) such that the elongate element **2100** and the filter **2200** can operate to filter embolic debris from the patient's blood. Those of skill in the art will appreciate that due to its soft and compliant nature, the elongate element **2100** cannot be easily advanced through the vasculature without the assistance of the introducer **2300**. In short, if the elongate element **2100** is not mounted on the introducer **2300**, applying a distally directed force to the proximal end **2104** of the elongate element **2100** will have little, if any effect, on translating the distal end of the elongate element **2100**. Under such circumstances, as those of skill in the art will appreciate, the elongate element **2100** will buckle (or accordion) along its longitudinal length. Accordingly, for soft and compliant elongate elements like elongate element **2100**, an introducer **2300** is utilized to advance the elongate element (and thus the filter **2200**) through the patient's vasculature to the target site.

[0099] In some examples, the elongate element mounting portion **2308** of the introducer **2300** is complementary of the elongate element **2100** (e.g., length, shape, cross sectional area etc.) such that the elongate element **2100** can be mounted thereon. In some examples, the elongate element mounting portion **2308** is a smooth continuous surface. In some such examples, when mounted on the introducer **2300**, the elongate element **2100** is supported by the elongate element mounting portion **2308** of the introducer **2300**.

[0100] Likewise, in some examples, the filter mounting portion **2310** of the introducer **2300** is complementary of the filter **2200** (e.g., length, shape, cross sectional area etc.) when the filter **2200** is radially collapsed and configured for delivery. In some examples, the filter mounting portion **2310** is formed as a relief in the introducer **2300**. In some examples, the relief is a circumferential relief, though it need not be. In some examples, a removable constraining sheath is disposed about at least the filter and/or elongate element to maintain the filter and/or the elongate element in the delivery configuration on the introducer as will be appreciated by those of skill in the art. In such examples, the constraining sheath can be removed upon delivery of the elongate element and the filter to the target site, wherein the filter can expand to its radially expanded deployed configuration. In various examples, the removable constraining sheath may be a sleeve, sheath, sock or other constraining mechanism. Those of skill in the art will appreciate that deployment of the filter can occur proximal to distal, distal to proximal, ends inward, center outward, etc.

[0101] In some examples, when the filter **2200** is radially collapsed and mounted thereon, the radially collapsed filter **2200** is received within the relief. For instance, the relief has a radial depth sufficient to accommodate the membrane and/or structural elements of the filter such that the radially collapsed filter does not project radially beyond the elongate element disposed about (or mounted on) the elongate element mounting portion **2308**. Such a configuration provides for a system having a minimal delivery profile.

[0102] In some examples, a position of the elongate element and the filter along the introducer is maintained during delivery as a result of the radially collapsed filter being received within the circumferential relief. Specifically, as will be appreciated by those of skill in the art, when the filter is radially collapsed and received by the filter mounting portion, force applied to the introducer is transferred to the filter by the relief. Thus, with the filter radially collapsed and received by the filter mounting portion, translational motion of the introducer is transferred to the filter such that the filter and the elongate element translate with the introducer.

[0103] FIGS. **4A** to **4C** illustrate an embolic filter system **2000**. FIG. **4A** is illustrative of an exemplary embolic filter system **2000** shown in a delivery configuration. As discussed above, in some examples, the elongate element **2100** and the filter **2200** are mounted on an introducer **2300**. The introducer **2300** having the elongate element **2100** and the filter **2200** mounted thereon is positioned within a constraining sheath such that the elongate element **2100** and/or the filter **2200** are configured for delivery to a target site within the patient's vasculature. Specifically, as illustrated in FIG. **4A**, the filter **2200** is in a radially collapsed delivery configuration. As discussed

above, in some examples, the elongate element **2100** and/or the filter **2200** can be advanced relative to the constraining member **2400** to facilitate delivery of the filter **2200** and the elongate element **2100** to the target site. In some examples, the constraining element **2400** is held fixed while the elongate element **2100** and/or the filter **2200** are advanced. In some examples, as explained above, the elongate element **2100** and/or the filter **2200** are advanced by way of advancing the introducer **2300** upon which the filter **2200** and/or elongate element **2100** are mounted.

[0104] FIG. **4B** is illustrative of the exemplary embolic filter system **2000** after advancing the introducer **2300** distally relative to the constraining element **2400**. Specifically, as shown, the introducer **2300** has been advanced relative to the constraining element **2400** such that the filter **2200** is advanced distally beyond a distal end **2402** of the constraining element **2400**. Accordingly, with the filter **2200** having been advanced distally beyond a distal end **2402** of the constraining element **2400**, the filter **2200** is free to expand to its radially expanded deployed configuration. Although, in some examples, removal of an additional constraining sheath may be required.

[0105] In some examples, after the filter **2200** has expanded to its radially expanded deployed configuration, the introducer **2300** can be withdrawn. That is, after the filter **2200** has expand to its radially expanded deployed configuration, the introducer **2300** can be withdrawn without displacing the position of the filter **2200** and/or the elongate element **2100** within the vasculature. In some examples, when the filter **2200** has expand to its radially expanded deployed configuration, the filter **2200** is no longer received or otherwise mounted on the filter mounting portion (e.g., the filter **2200** is no longer received within the circumferential relief). Thus, as the introducer is translated, no feature of the introducer (e.g., the filter mounting portion) engages the elongate element of the filter in a manner sufficient to cause the elongate element or the filter to translate with the introducer.

[0106] Turning now to FIG. **4C**, the introducer **2300** has been withdrawn from the elongate element **2100** and the filter **2200**. In some examples, with the introducer **2300** removed, blood flowing through vasculature within which the embolic filter system **2000** is deployed flows into the filter **2200** and/or the elongate element **2100**. In some examples, this blood flow is sufficient to inflate or otherwise prevent the elongate element **2100** from collapsing under its own weight. That is, in examples where the elongate element **2100** is a soft and compliant material that is otherwise incapable of supporting its own weight, blood flowing into the elongate element **2100** applies a pressure on the inside of the lumen that is sufficient to inflate or otherwise prevent the elongate element **2100** from collapsing. As discussed above, the elongate element may include one or more blood-permeable areas. Likewise, although not illustrated, in some examples, the constraining element **2400** may be retracted along a portion of (or all of) the length of the elongate element **2100** such that blood may perfuse through the elongate element **2100** and reenter the vasculature. It will also be appreciated that, in some examples, the constraining element includes one or more blood permeable areas or regions.

[0107] In some examples, the embolic filter system **2000** includes a hemostatic sealing member **2500**, as mentioned above. Generally, a hemostatic sealing member operates to maintain a hemostatic seal through which one or more medical devices can be passed while minimizing blood loss. Examples of hemostatic sealing members can be found in at least U.S. Pat. No. 9,314,605, issued on Apr. 19, 2016; and U.S. Patent Application Publication No. 2013/0123705, bearing Ser. No. 13/677,839, scheduled to issue on Feb. 7, 2017 as U.S. Pat. No. 9,561,347; the entire contents of each of which are incorporated herein by reference.

[0108] In some examples, the soft and compliant elongate element **2100** operates with the hemostatic sealing member **2500** to maintain a hemostatic seal while enabling one or more medical devices to be advanced through the working lumen of the elongate element **2100** to the treatment site as discussed above. Specifically, with reference to FIG. **4D**, a cross sectional view of the hemostatic sealing member **2500** and the elongate element **2100** is illustrated. As shown, the hemostatic sealing member includes one or more pressurizable elements **2502** that operate to form

a hemostatic seal inside of the hemostatic sealing member **2500**. In some examples, these pressurizable elements **2502** of the hemostatic sealing member **2500** operate to collapse the soft compliant elongate element **2100** as it passes through the hemostatic sealing member **2500**. In these examples, the pressure exerted on the inside of the elongate element **2100** by the blood therein is insufficient to overcome the pressure exerted by the pressurizable elements **2502** that operates to collapse the lumen **2108** of the elongate element **2100** in the region where it passes through the hemostatic sealing member **2500**.

[0109] For example, as shown in FIG. **4D**, the lumen **2108** of the elongate element **2100** is inflated on the distal side **2504** of the hemostatic sealing member **2500** by the pressure exerted on the inside of the lumen **2108** of the elongate element **2100** by the blood therein. Similarly, as shown, the elongate element **2100** is structurally supported by the stopping feature **2112** coupled to the material of the elongate element **2100** on the proximal side **2506** of the hemostatic sealing member **2500**.

[0110] Those of skill in the art will appreciate that as a medical device is introduced into the lumen **2108** of the elongate element **2100** on the proximal side **2506** of the hemostatic sealing member **2500** and advanced therethrough to the distal side **2504**, the pressurizable elements **2502** will apply a pressure to the elongate element **2100** and cause the elongate element **2100** to form a hemostatic seal between the interior of the lumen **2108** and the medical device being advanced therethrough.

[0111] Accordingly, the soft and compliant elongate element **2100** can be utilized in accordance with a hemostatic seal (such as the hemostatic seal referred to above) such that a hemostatic seal is formed by the lumen **2108** of the elongate element **2100** while maintaining the lumen **2108** as a working lumen through which one or more medical devices can be passed and delivered to a treatment site from a location outside of the patient's body. In some examples, the soft and compliant elongate element **2100** can be utilized in accordance with a hemostatic seal such that a hemostatic seal is formed both between the hemostatic seal and an exterior surface of the elongate element **2100** and within the lumen **2108** of the elongate element **2100** (e.g., by collapsing the interior lumen).

[0112] Turning now to FIG. **4E**, withdrawal of the elongate element **2100** and the filter **2200** is illustrated. In some examples, although an introducer **2300** is utilized when delivering the soft and compliant elongate element **2100** and filter **2200** to a target site within a patient's vasculature, the elongate element **2100** and the filter **220** can be withdrawn or otherwise removed therefrom without utilizing the introducer **2300**. Specifically, in some examples, a tensile force **2600** can be applied to the proximal end **2104** of the elongate element **2100** to withdraw the elongate element **2100** and the filter **2200** from the target site. As discussed above, despite being soft and compliant, the elongate element **2100** is constructed of a material having a tensile strength sufficient to permit its withdrawal from the target site in such a manner as will be appreciated by those of skill in the art. In at least some examples, some contemplated materials are associated with tensile strength properties of between 1400-7000 psi. However, other materials having higher and lower tensile strengths are contemplated.

[0113] As shown in FIG. **4E**, as the elongate element **2100** and the filter **2200** are withdrawn, the filter **2200** radially collapses as it is drawn into the constraining element **2400**. In some examples, the constraining element **2400** is sufficiently rigid to cause the filter **2200** to radially collapse. In some examples, the embolic debris captured by the elongate element **2100** and the filter **2200** is retained within the elongate element **2100** and the filter **2200** during removal of the elongate element **2100** and the filter **2200** from the vasculature. However, in some examples, the embolic debris captured within the filter **2200** and the elongate element **2100** can be additionally or alternatively aspirated prior to withdrawal. Such a configuration helps minimize the potential that the captured embolic debris will be released back into the vasculature as the filter **2200** and the elongate element **2100** are withdrawn.

[0114] In some examples, the elongate element **2100** and the filter **2200** can be withdrawn such the

filter **2200** passes through the hemostatic sealing member **2500**. In some examples, the hemostatic sealing member **2500** is coupled to the constraining member **2400**. Thus, in some examples, the elongate element **2100** and the filter **2200** can be withdrawn from the vasculature independent of the withdrawal of the constraining element **2400**. In some such examples, the hemostatic sealing member **2500** operates to minimize blood loss through the embolic filter system **2000** and maintain a hemostatic seal as the elongate element **2100** and the filter **2200** are drawn through the hemostatic sealing member **2500**.

[0115] With reference now to FIG. 5A, an embolic filter system **5000** is illustrated in a delivery configuration in aortic arch **5502**. The embolic filter system **5000** may be any of the embolic filter systems illustrated and described herein. As shown, the embolic filter system **5000** is advanced through the patient's vasculature to a target site. In this illustrated example, the embolic filter system **5000** is advanced to a location within the aortic arch **5502** at or proximate to the ascending aorta **5510**. In some examples, the embolic filter system **5000** is in the delivery configuration as it is advanced through the patient's vasculature and delivered to the target site. As discussed in greater detail above, when in the delivery configuration, the elongate element and the filter are received (or at least partially received) within a constraining member, such as constraining element **5300**. As shown, in some examples, the embolic filter system **5000** is guided along a guidewire **5600**.

[0116] In some examples, after the embolic filter system is advanced to the target site, the filter and the elongate element are deployed. Turning now to FIG. 5B, the embolic filter system **5000** is illustrated partially deployed in aortic arch **5502**. Specifically, the constraining element **5300** has been partially withdrawn to a position proximal to the proximal end of the filter **5200**, and the filter **5200** has transitioned to its deployed configuration. In the deployed configuration, as shown in FIG. 5B, the distal end **5202** of the filter **5200** has a cross-sectional surface area substantially equal to that of the portion of the aorta within which the filter **5200** is deployed. In this illustrated example, the filter **5200** contacts some of or all of the wall of the region of the aortic arch **5502** where the filter **5200** is deployed. Consequently, the filter **5200** operates to direct the blood flowing from the ascending aorta **5510** into the filter **5200**.

[0117] FIG. 5C illustrates the filter **5200** and the elongate element **5100** with the constraining element **5300** withdrawn therefrom (or at least withdrawn to a position distal the aortic arch **5502**). In some examples, because filter **5200** is blood-permeable, perfusion of blood to the brachiocephalic artery **5504**, the carotid artery **5506**, and the subclavian artery **5508**, and perfusion through the aortic arch **5502** to the descending aorta **5512** and the downstream vasculature are possible. Additionally, the elongate element **5100** is illustrated as including a blood-permeable window **5150**. Accordingly, perfusion of blood to at least the subclavian artery **5508** from the blood-permeable window **5150** is possible.

[0118] As discussed above, the degree of permeability of the embolic filter system may vary along a length of the filter and/or the elongate element. In the illustrated example of FIG. 5C, the blood-permeable window **5150** may be configured such that it is permeable to particles to which the filter is impermeable. Accordingly, larger particles that did not permeate the filter **5200** may permeate the blood-permeable window **5150**. As explained above, one methodology for achieving such a result includes configuring the filter with a plurality of first perforations having a first average size and configuring the blood-permeable window with a plurality of second perforations having second average size that is larger than the average size of the plurality of first perforations. Though certain of the above-discussed examples include a filter (e.g., **1200**) that has some degree of permeability to blood, in some examples, the filter may be impermeable to blood such that the filter operates instead as a deflector that funnels the blood and other media (e.g., embolic debris) into the elongate element.

[0119] As discussed above, in some examples, a distal portion of the elongate element may extend distally of the proximal end of the filter and may operate as a working lumen. In the illustrated example of FIG. 5D, a distal portion **5110** of the elongate element **5100** extends distally of the

proximal end 5204 of the filter 5200. As shown, the working lumen 5108 of the elongate element 5100 provides a mechanism for delivery of one or more medical devices to the treatment site, such as medical device 5700. In the illustrated example of FIG. 5D, the distal portion 5110 operates to prevent entanglement between the medical device 5700 and the filter 5200, as explained above. [0120] As discussed above, in various examples, the elongate element and/or the filter operate to filter embolic debris and other blood media from the patient's blood. In some such examples, the elongate element and/or the filter is formed of a sufficiently permeable material and/or includes one or more perforations. Likewise, as mentioned above, in some examples, the elongate element and/or the filter is configured such that the elongate element and/or the filter is permeable (e.g., blood permeable) at one or more discrete locations. In some examples, the elongate element and/or the filter can be configured such that it is blood-permeable in some locations and blood impermeable in other locations. In some examples, the elongate element and/or the filter includes one or more filtering windows configured to further filter the blood and embolic debris.

[0121] Generally, permeable windows (e.g., blood-permeable) can be located anywhere along or about the elongate element or filter and can comprise various suitable dimensions (including, but not limited to circular, ovoidal, elongated, spiral, random, etc.). In some examples, an elongate element or filter can comprise at least one window having a greater porosity than an adjacent portion of the elongate element or filter.

[0122] In various examples, one or more permeable windows (e.g., blood-permeable) can be used to reduce or eliminate the likelihood of a stagnant column of blood within the elongate element or the filter. If instance, in some examples, trapped embolic debris which are rendered stagnant can decrease porosity and increase the pressure gradient across the elongate element or the filter. In turn, embolic debris which are rendered stagnant can, over time, build up and decrease filtering efficiency, which may be especially problematic. An elongate element having one or more permeable windows (e.g., blood-permeable) on the other hand, can allow blood and redirected embolic debris to migrate down and into its lumen, where it's collection will have no detrimental effect on filtering efficiency, and where it's removal by aspiration can be accomplished by the operator.

[0123] In various examples, a permeable window can comprise a one-way flap or valve to permit perfusion of blood therethrough yet prevent blood from entering, for example, during an aspiration procedure. In some examples, a one-way valve can comprise a biocompatible material (e.g., a fluoropolymer) having one or more slits and being biased to open in one direction. In some examples, a one-way flap can comprise a biocompatible material (e.g., a fluoropolymer) with a support frame. In some examples, a one-way flap or valve can be positioned on the outer and/or inner surface of a permeable window (e.g., blood-permeable) in such a manner as to substantially cover the window.

[0124] As discussed above, in various examples, the filter includes a structural element. In various examples the structural element is comprised of one or more support elements, such as one or more braids, meshes, lattices, wires, rings, struts, or any other suitable support element. In some examples, the support elements are tubular and may be laser cut or formed separately. In some examples, one or more of the support elements may be formed of a shape-memory material such as nitinol, such that the structural element is a self-expanding structural element as would be appreciated by those of skill in the art. In other examples, however, one or more of the support elements may be formed from other resilient metals that may be expandable through the use of an expansion aid (such as a balloon). For example, one or more of the support elements may be formed from a polymer or a biocompatible metallic alloy such as stainless steel.

[0125] Moreover, those of skill will appreciate that the configurations discussed herein are scalable in that they can be scaled up or scaled down for different applications. That is, while certain of the configurations discussed herein are illustrated and described in association with placement within the aortic arch, the versatility of the system provides for implementation in virtually any other area

of the patient's vasculature. For example, the various configurations discussed herein may be scaled for application within various peripheral vessels and lumens such as the brachiocephalic artery, and/or the carotid artery, and/or the subclavian artery. Likewise, as it relates to the aortic arch, the present disclosure can be used in connection with femoral, transapical and thoracotomy approaches. Moreover, this disclosure should not be interpreted as limiting application to the vessels proximate the heart. For instance, the devices and systems described herein may be implemented throughout the vasculature of the body including vasculature above and below the heart to prevent the migration of embolic debris during various other revascularization procedures. Additionally, the embodiments can be used in connection with not just humans, but also various organisms having mammalian anatomies. Thus, it is intended that the embodiments described herein cover the modifications and variations within the scope of this disclosure.

[0126] Additionally, in some examples, more than one device or system may be deployed for a given procedure. For instance, in some cardiac procedures, one of the devices described herein may be placed in the aortic arch, and/or the brachiocephalic artery, and/or the carotid artery, and/or the subclavian artery.

[0127] Turning now to FIGS. 6A and 6B, an embolic filter system **6000** is illustrated. In various examples, the embolic filter system **6000** includes first elongate element **6100**, a filtering portion **6200**, and a second elongate element **6300**. As shown, the embolic filter system **6000** includes a distal end **6002** and a proximal end **6004**. Likewise, in some examples, the first elongate element **6100** includes a distal end **6102** (obstructed from view by the distal end of the second elongate element **6300**) and a proximal end **6104**, and the second elongate element **6300** includes a distal end **6302** and a proximal end **6304**. In various examples, each of the first and second elongate elements has lumens extending therethrough. For example, the first elongate element includes an inner lumen **6106** and the second elongate element includes an inner lumen **6306** (obstructed from view). In some examples, the inner lumen **6106** of the first elongate element operates as a working lumen as described herein.

[0128] In some examples, the first elongate element **6100** is positioned within the inner lumen of the second elongate element **6300** such that the first and second elongate elements **6100** and **6300** are coaxial. As shown in FIGS. 6A and 6B, the first elongate element **6100** extends between the distal and proximal ends of the second elongate element **6300**. In some examples, the distal end **6102** of the first elongate element **6100** is aligned with the distal end of the second elongate element.

[0129] In some examples, the second elongate element **6300** is a longitudinally extending structure having a lumen extending therethrough, as mentioned above. In some examples, the second elongate element **6300** includes a deployable filtering portion **6200** including one or more support element, such as support element **6202A**, **6202B**, **6202C**, **6202D**, **6202E**, and **6202F** (obstructed from view). Generally, the support elements are evenly distributed about the second elongate element **6300**. In some examples, the support elements are formed in the wall of the second elongate element **6300**. In some such examples, one or more slits or cut lines are formed in the wall of the second elongate element **6300**. The slits or cut lines extend longitudinally along a portion of the second elongate element **6300**. A support element is formed between adjacent longitudinally extending slits. Generally, the slits penetrate from an exterior surface to the inner lumen of the second elongate element **6300**.

[0130] In some examples, the support elements extend from a position proximal of the distal end **6302** of the second elongate element **6300** to a position proximal thereto as shown. That is, each of the support elements has a distal end, a proximal end, and an intermediate portion extending therebetween. In some examples, a length of the support elements is measure between the distal and proximal ends of the support elements. In some examples, the distal and proximal ends of the support elements terminate into the second elongate element **6300** as explained further below.

[0131] In some examples, a blood-permeable membrane **6204** (such as the membranes discussed

above) is disposed about the support elements or a portion thereof. In some examples, a distal edge of the blood-permeable membrane is positioned along the intermediate portion of the support elements. In some examples, a proximal edge of the blood-permeable membrane is positioned at or proximal to the proximal ends of the support elements. That is, in some examples, the blood-permeable membrane extends from a position along the support elements proximal to the distal ends of the support elements to the proximal ends of the support elements or proximal thereof. In some examples, as explained further below, the support elements and the blood-permeable membrane operate to filter embolic debris from the blood.

[0132] In some examples, the blood-permeable membrane is coupled or otherwise secured to the elongate element at or proximal to the proximal ends of the support elements. In some examples, the blood-permeable membrane is additionally coupled or otherwise secured to the intermediate portion of the support elements, however it need not be. In some other examples, the blood-permeable membrane includes one or more tethers that extend from the distal edge of the blood-permeable membrane to a position along either the support elements or a portion of the second elongate element **6300** distal thereof. For instance, as shown in FIGS. **6A** and **6B** the second elongate element **6300** includes a distal portion **6308** that extends between the distal end **6302** of the elongate element and the distal ends of the support elements. In some examples, the support elements terminate proximal of the distal portion **6308** such that the distal portion **6308** is free from slits.

[0133] In some examples, the first and second elongate elements **6100** and **6300** are secured or otherwise coupled to one another at the distal portion **6308**. In some examples, the first and second elongate elements **6100** and **6300** are secured or otherwise coupled together such that the distal ends thereof are constrained against relative axial translation. In some such examples, the portions of the first and second elongate elements **6100** and **6300** proximal to the distal portion **6308** are free to translate axially (or slide) relative to one another. As explained further below, the filtering portion of the embolic filter system **6000** is deployed by sliding the proximal end **6304** of the second elongate element **6300** relative to the proximal end **6104** of the first elongate element **6100**.

[0134] In various examples, the embolic filter system **6000** can be deployed within a region of a patient's vasculature such that the embolic filter system **6000** operates to filter embolic debris from the blood flowing through that region. In some such examples, the embolic filter system **6000** is transitionable between deployed and delivery configurations, as explained in greater detail below. FIG. **6A** illustrates the embolic filter system **6000** in the delivery configuration while FIG. **6B** illustrates the embolic filter system **6000** in the deployed configuration. In various examples

[0135] In some examples, in the delivery configuration, the embolic filter system **6000** maintains a minimal delivery profile. However, when transitioned to the deployed configuration, a filtering portion of the embolic filter system **6000** expands to occupy a portion or all of the cross sectional area of a vessel within which it is deployed (similar to the other embolic filter systems described herein). In some examples, in the deployed configuration, the support element (**6202A-6202F**) or a portion thereof are deflected away from a longitudinal axis of the second elongate element **6300**.

[0136] In some examples, the embolic filter system **6000** is transitioned to the deployed configuration by distally axially translating or sliding the proximal end **6304** of the second elongate element **6300** relative to the proximal end **6104** of the first elongate element **6100**. In some examples, the embolic filter system **6000** is transitioned to the deployed configuration by additionally or alternatively proximally axially translating or sliding the proximal end **6104** of the first elongate element **6100** relative to the proximal end **6304** of the second elongate element **6300**. It will be appreciated that, in some examples, the embolic filter system **6000** is likewise deployable by proximally translating or sliding the proximal end **6104** of the first elongate element **6100** while maintaining a constant (or substantially constant) position of the proximal end **6304** of the second elongate element **6300**. Likewise, in some examples, the embolic filter system **6000** is deployable by distally translating or sliding the proximal end **6304** of the second elongate element **6300** while

maintaining a constant (or substantially constant) position of the proximal end **6104** of the first elongate element **6100**.

[0137] Those of skill in the art will appreciate that, because the first and second elongate elements **6100** and **6300** are secured together at the distal portion **6308**, as the proximal end **6304** of the second elongate element **6300** translates distally relative to the proximal end **6104** of the first elongate element **6100**, one or more of the first and second elongate element **6100** and **6300** must buckle. In this regard, the support elements of the second elongate element **6300** are configured to deflect away from the longitudinal axis of the second elongate element **6300**. For example, as illustrated in FIG. 6B, the support elements (**6202A-6202F**) bow, buckle, or otherwise deflect as a result of the proximal end **6304** of the second elongate element **6300** translating distally relative to the proximal end **6104** of the first elongate element **6100**.

[0138] This deflection of the support elements operates to expand the blood-permeable membrane **6204** within the vessel within which the embolic filter system **6000** is deployed. Although obstructed from view in FIG. 6B, in some examples, the portion of the first elongate element **6100** extending beneath the support elements of the second elongate element **6300** may include one or more apertures (similar to apertures **1112**) that operate to allow embolic debris trapped by the blood-permeable membrane to be transferred into the lumen **6106** of the first elongate element **6100** as the embolic filter system **6000** is transitioned from the deployed configuration to the delivery configuration upon removal from the vasculature. In some examples, such apertures are positioned along the first elongate element proximal to the position of the distal edge of the blood-permeable membrane **6204** when the embolic filter system **6000** is in the deployed configuration. Such a configuration ensures that embolic debris escaping from the lumen **6106** is captured and retained by the blood-permeable membrane **6204**.

[0139] In some other examples where the first elongate element is free of apertures in portion of the first elongate element **6100** extending beneath the support elements of the second elongate element **6300**, any embolic debris captured by the blood-permeable membrane **6204** is trapped between the blood-permeable membrane (and/or the support elements) and the exterior of the portion of the first elongate element **6100** extending beneath the support elements of the second elongate element **6300** as will be appreciated by those of skill in the art.

[0140] In some examples, the embolic filter system **6000** is transitioned from the deployed configuration to the delivery configuration by proximally axially translating or sliding the proximal end **6304** of the second elongate element **6300** relative to the proximal end **6104** of the first elongate element **6100**. In some examples, the embolic filter system **6000** is transitioned from the deployed configuration to the delivery configuration by additionally or alternatively distally axially translating or sliding the proximal end **6104** of the first elongate element **6100** relative to the proximal end **6304** of the second elongate element **6300**. It will be appreciated that, in some examples, the proximal end **6104** of the first elongate element **6100** may be proximally axially translated while maintaining a constant (or substantially constant) position of the proximal end **6304** of the second elongate element **6300**. Likewise, in some examples, the proximal end **6304** of the second elongate element **6300** may be distally axially translated while maintaining a constant (or substantially constant) position of the proximal end **6104** of the first elongate element **6100**.

[0141] Although the embolic filter system **6000** is illustrated and described as including 6 support elements (**6202A-6202F**), it should be appreciated that the embolic filter system **6000** may include any number of support elements. Likewise, although the support elements are illustrated as being evenly distributed about the second elongate element **6300**, it should be appreciated that the support elements are disproportionately distributed. Likewise, the support elements need not all be of equal size (length and/or width).

[0142] As mentioned above, in some examples, the system may include one or more steering lines (or wires). Thus, in some examples, the system is steerable. In some examples, the one or more steering lines are coupled to a distal end of the elongate element. With reference to FIG. 1B, in

some examples, the one or more steering lines may be coupled to the distal portion **1110** of the elongate element **1100**, or alternatively or additionally to the distal end **1102** of the elongate element. Thus, in some examples, the one or more steering lines are coupled to the elongate element at a location that is distal the proximal end of the filter (such as the proximal end **1204** of the filter **1200**). Such a configuration provides for enhanced steering capability or deflectability of the distal end of the system, which when navigating tortuous areas of the vasculature provides for increased control and helps minimize the risk of damaging a vessel.

[0143] In some examples, the elongate element and/or the deflector can be housed in a sleeve, sheath, sock or other constraining mechanism. Such a constraining mechanism (and/or the elongate element and/or the deflector itself) can have a deployment line which, if locked (e.g., pin, wire or other), acts as a tension line (that operates as a steering line) to cause bending of the elongate element and/or the deflector. In some such examples, the sleeve, sheath, sock or other constraining mechanism within which the elongate element is housed generally terminates proximal of the area at which the steering line (i.e., locked deployment line or tension line) is coupled to the elongate element. Such a configuration provides that the elongate element and the steering line can form a bow and string configuration as tension is applied to the steering line, which in turn deflects the distal end of the system. Those of skill will appreciate that steerable embodiments can be particularly beneficial in treating the aortic arch or other tortuous vasculature. Steerable embodiments can be particularly useful in preventing the deflector from compressing against the outside of a bend in a tortuous anatomy. Such steerable embodiments can also be useful in creating an exit from the elongate element that is substantially aligned with the axis of the vessel and the axis of the deflector mechanism.

[0144] In some examples, the embolic filter system **1000** includes one or more features that operate to help transition the embolic filter system **1000** between a deployed configuration and delivery/removal configurations. Though not equivalents, in some examples, such features may be implemented in addition to or as an alternative to the constraining element **1300**. For instance, as shown in FIG. 7, in some examples, the embolic filter system **1000** includes one or more constraining elements, such as a constraining fiber **1214**. The constraining fiber **1214** is generally operable to control expansion and/or collapse of the filter **1200**. In various examples, the constraining fiber **1214** is routed about a circumference of the filter **1200** such that a length of the constraining fiber **1214** extending about the circumference of the filter **1200** can be reduced and/or increased to constrain or unconstrain the filter **1200**, and thereby transition the filter between collapsed and expanded states as those of skill will appreciate.

[0145] As shown in FIG. 7, the constraining fiber **1214** is routed circumferentially about an exterior surface of the filter **1200**. It will be appreciated, however, that the constraining fiber **1214** may alternatively be routed about an interior surface of the filter **1200**, or alternatively may be routed such that the constraining fiber **1214** traverses along one or more portions of both the interior and exterior surfaces of the filter **1200**. For instance, in some examples, the filter **1200** may include a plurality of perforations that are arranged about a circumference of the filter **1200**. In some such examples, the constraining fiber **1214** is routed through the various perforations such that the constraining fiber **1214** extends circumferentially about the filter **1200**, as those of skill will appreciate. The constraining fiber **1214** may extend about an exterior of the structural support **1212** in any of the above-referenced configurations. Alternatively, in some examples, the constraining fiber **1214** extends about an interior of the structural support **1212**. Still further, in some examples, the constraining fiber **1214** may be routed such that it extends about one or more portions of both the interior and exterior of the structural support **1212**.

[0146] In some examples, the constraining fiber **1214** is routed through one or more features of the filter **1200** that define a designated path along and/or about the filter **1200**. For example, as shown in FIG. 7, the embolic filter system **1000** includes one or more routing conduits **1218** that extend along one or more portion of the embolic filter system **1000**. In some examples, one or more

routing conduits **1218** extend along an interior and/or exterior of the constraining element **1300**. In some example, the one or more routing conduits **1218** extend along an interior and/or exterior of the filter **1200** consistent with the discussion above. In various example, the constraining fiber **1214** is routed through such routing conduits **1218** and is in a sliding relation thereto. Thus, it will be appreciated that while the routing conduits **1218** generally constrain a routing path of the constraining fiber **1214**, the constraining fiber **1214** is nevertheless free to slide within (e.g., relative to) such routing conduits **1218**. While the routing conduits **1218** are illustrated in FIG. 7 as extending longitudinally along the filter **1200**, in various examples, one or more routing conduits may extend circumferentially (partially or entirely) about the filter **1200**.

[0147] In various examples, the constraining fiber **1214** extends longitudinally from a proximal end of the embolic filter system **1000**, such as from a handle **1400** or other control mechanism as those of skill will appreciate. As shown in FIG. 7, the constraining fiber **1214** extends through an interior region of the embolic filter system **1000**, through an aperture **1308**, and along an exterior surface of the filter **1200**. In some examples, the constraining fiber **1214** extends through one or more portions of an interior lumen of the elongate element **1100**. In some examples, the constraining fiber alternatively or additionally extends through one or more portions of an interior lumen of the constraining element **1300**. Thus, in some examples, the constraining fiber **1214** extends within an annular region defined between the constraining element **1300** and the elongate element **1100**. Moreover, while the constraining fiber **1214** is illustrated as extending through an aperture **1308** in the constraining element **1300**, in some examples, the constraining fiber **1214** extends from the distal end **1302** of the constraining element **1300** (or alternatively from the distal end **1102** of the elongate element **1100**).

[0148] In various examples, the constraining fiber **1214** forms a loop about the circumference of the filter **1200** such that a diameter of the loop can be reduced or expanded to constrain and/or unconstrain the filter **1200** as those of skill should appreciate. In some example, a distal end of the constraining fiber **1214** include an eyelet **1216** or other feature that facilitates hitching of the constraining fiber **1214** upon itself such that a tension applied to the constraining fiber **1214** can be varied to cause a resulting variance in the diameter of the loop. Some examples, the constraining fiber **1214** may be used in combination with a lockwire. For instance, in some examples, a portion of the constraining fiber **1214**, such as a distal end eyelet, is constrained by an engagement with the lockwire. Such engagement with the lockwire permits a tension to be applied and removed from the constraining fiber **1214** without causing the constraining fiber **1214** to be removed from its position about the filter **1200**. In some such examples, the constraining fiber **1214** extends about the filter **1200**, hitches upon itself, and extends to a position where it engages with the lockwire. In some examples, upon withdrawal of the lockwire, the constraining fiber **1214** is disengaged from the lockwire and can be withdrawn from about the filter **1200**.

[0149] As discussed above, in some examples, the elongate element **2100** lacks sufficient structural rigidity to support its own weight, has little to no column strength, and/or is not generally torqueable, yet exhibits good tensile strength. In some other examples, the elongate element **2100** may include one or more structural elements or components that afford it sufficient structural integrity such that the elongate element **2100** is advanceable within an introduction sheath and/or a constraining element, such as constraining element **2400**. That is, in some examples, the elongate element is comprised of both a structural element and a covering material. The structural element and the covering material are consistent with those discussed herein. By providing an elongate element **2100** with a structural element, the elongate element **2100** can be introduced into the vasculature without the added requirement of an introducer. In particular, the structural element of the elongate element **2100** in combination with the covering material provides for a construct that can be advanced (e.g., is pushable) within an introducer sheath and/or a constraining sheath. That is, applying a distally directed force to the proximal end of the elongate element **2100** will operate to cause the elongate element **2100** (and the filter **2200**) to translate distally despite the embolic

filter system **2000** not being mounted on an introducer.

[0150] In some examples, such a configuration provides for a system having a delivery profile that is smaller in comparison to convention designs because, in some examples, the elongate element **2100** can be radially collapsed upon itself instead of being compressed onto an introducer or delivery catheter, as those of skill will appreciate. Likewise, by being pushable within an introducer sheath and/or within a constraining sheath, the elongate element **2100** does not require additional components for delivery, which reduces system costs, procedure time, and risk to the patient.

[0151] With reference to FIG. **8**, in some such examples, the embolic filter system **2000** includes an elongate element **2100** having a structural element **2101**, such as a braided element. In some examples, the braided element includes a nitinol wire, though other materials, including those discussed herein, are contemplated. In some examples, the braided element or the structural element **2101** is covered with a suitable covering material **2103** (e.g., a filter material), such as ePTFE or any other suitable material as discussed herein to form the elongate element **2100**. In some examples, the covering material of the elongate element **2100** is blood permeable. In other examples, the covering material of the elongate element **2100** is blood impermeable. In some examples, the blood impermeable covering material of the elongate element is modified consistent with the discussion herein such that blood is operable to flow through the perforations. In some such examples, the perforations are sized to prevent the passage of embolic debris in excess of a designated threshold size. For instance, as mentioned herein, the perforations may be between 50 microns and 1000 microns depending on the particular application. It will also be appreciated that the elongate element may be configured such that blood is operable to pass or flow through one or more portions of the elongate element **2100** while being prevented from flowing through one or more other portions of the elongate element **2100** as those of skill will appreciate.

[0152] Additionally, as shown in FIG. **8**, the embolic filter system **2000** includes a filter **2200**. The filter **2200** generally includes a braided structural support **2212** and a covering material consistent with the discussion above. In some examples, the covering material of the filter **2200** is the same as the covering material of the elongate element **2100**. In some examples, the structure support of the filter **2200** is the same as the structural support of the elongate element. In some examples, the covering material of the filter **2200** is blood permeable. In other examples, the covering material of the filter **2200** is blood impermeable. In some examples, the blood impermeable covering material of the filter **2200** is modified consistent with the discussion herein such that blood is operable to flow through the perforations. In some such examples, the perforations are sized to prevent the passage of embolic debris in excess of a designated threshold size as discussed herein. It will also be appreciated that the elongate element may be configured such that blood is operable to pass or flow through one or more portions of the filter **2200** while being prevented from flowing through one or more other portions of the filter **2200** as those of skill will appreciate.

[0153] Numerous characteristics and advantages have been set forth in the preceding description, including various alternatives together with details of the structure and function of the devices and/or methods. Moreover, the inventive scope of the various concepts addressed in this disclosure has been described both generically and with regard to specific examples. The disclosure is intended as illustrative only and as such is not intended to be exhaustive. For example, the various embodiments of the present disclosure are described in the context of medical applications but can also be useful in non-medical applications. It will be evident to those skilled in the art that various modifications may be made, especially in matters of structure, materials, elements, components, shape, size, and arrangement of parts including combinations within the principles of the invention, to the full extent indicated by the broad, general meaning of the terms in which the appended claims are expressed. To the extent that these various modifications do not depart from the spirit and scope of the appended claims, they are intended to be encompassed therein.

Claims

1.-20. (canceled)

21. An embolic filter comprising: an elongate element having a proximal portion and a distal portion, the elongate element being advanceable within a delivery sheath; a filter assembly positioned at the distal portion of the elongate element, the filter assembly including: a membrane having a proximal frustoconical portion and a distal cylindrical portion, the proximal frustoconical portion having a first plurality of perforations defining a first porosity of the proximal frustoconical portion, the distal cylindrical portion having a second plurality of perforations defining a second porosity of the distal cylindrical portion that is greater than the first porosity, the distal cylindrical portion having a distal end defining a curving distal edge; and a structural support supporting the membrane, the structural support having a distal undulating portion, a proximal tapering portion coupled with the distal portion of the elongate element, and an intermediate portion extending longitudinally between the distal undulating portion and the proximal tapering portion of the structural support, the distal undulating portion supporting the curving distal edge of the membrane, and the intermediate portion supporting the distal cylindrical portion of the membrane.

22. The embolic filter of claim 21, wherein the distal portion of the elongate element has a smaller cross sectional area than the proximal portion of the elongate element.

23. The embolic filter of claim 21, wherein the distal portion of the elongate element has a smaller outer diameter than the proximal portion of the elongate element.

24. The embolic filter of claim 23, wherein the elongate element includes an inner lumen extending between the proximal portion and the distal portion of the elongate element, the inner lumen having a diameter that is consistent from the proximal portion to the distal portion of the elongate element.

25. The embolic filter of claim 21, wherein the structural support includes one or more of: braids, meshes, lattices, wires, or struts.

26. The embolic filter of claim 21, wherein the structural support includes one or more support elements laser-cut from a tubular component.

27. The embolic filter of claim 21, wherein the structural support includes one or more support elements made of a shape-memory material with self-expanding capability.

28. The embolic filter of claim 21, wherein the first plurality of perforations have an average pore size from 40 μm to 99 μm , and the second plurality of perforations have an average pore size from 101 μm to 150 μm .

29. The embolic filter of claim 21, wherein the membrane is blood permeable and the elongate element is blood impermeable.

30. The embolic filter of claim 21, wherein the membrane includes ePTFE.

31. The embolic filter of claim 21, wherein a distally directed force applied to a proximal end of the elongate element is operable to cause distal translation of the elongate element and the filter assembly to the delivery sheath.

32. The embolic filter of claim 21, wherein the elongate element comprises a soft and compliant material.

33. The embolic filter of claim 21, wherein the elongate element includes at least one aperture through a side wall providing fluid communication between the filter assembly and an interior of the elongate element, and the elongate element and the delivery sheath form a single monolithic unit.

34. The embolic filter of claim 21, wherein the structural support comprises a self-expanding wire braid.

35. The embolic filter of claim 21, wherein the structural support is operable to advance the distal end of the filter assembly from an end of the delivery sheath for deployment at a treatment site.

36. The embolic filter of claim 21, wherein the elongate element includes at least one aperture

through a side wall providing fluid communication between the filter assembly and an interior of the elongate element, and the aperture is operable to facilitate a transfer of embolic debris captured within the filter assembly to the elongate element.

37. An endoprosthesis delivery device comprising: a constraining element having a central lumen; an elongate element having a proximal portion and a distal portion, the elongate element being advanceable within the central lumen of the constraining element; and a filter assembly positioned at the distal portion of the elongate element, the filter assembly including: a membrane having a proximal frustoconical portion and a distal cylindrical portion, the proximal frustoconical portion having a first plurality of perforations defining a first porosity of the proximal frustoconical portion, the distal cylindrical portion having a second plurality of perforations defining a second porosity of the distal cylindrical portion that is greater than the first porosity, the distal cylindrical portion having a distal end defining a curved distal edge; and a structural support supporting the membrane, the structural support having a distal undulating portion, a proximal tapering portion coupled with the distal portion of the elongate element, and an intermediate portion extending longitudinally between the distal undulating portion and the proximal tapering portion of the structural support, the distal undulating portion supporting the curved distal edge of the membrane, and the intermediate portion supporting the distal cylindrical portion of the membrane, wherein the filter assembly is configured to self-expand and transition from a radially collapsed delivery configuration to a radially expanded deployed configuration in response to being deployed from within the constraining element.

38. The endoprosthesis delivery device of claim 37, wherein the constraining element is a delivery catheter.

39. The endoprosthesis delivery device of claim 37, wherein the constraining element is operable to constrain the elongate element and the filter assembly in the radially collapsed delivery configuration.

40. The endoprosthesis delivery device of claim 39, wherein the constraining element is retractable from the filter assembly to transition the filter assembly to the radially expanded deployed configuration.

41. The endoprosthesis delivery device of claim 37, wherein the filter assembly is operable to transition from the radially expanded deployed configuration to the radially collapsed delivery configuration by advancing the constraining element toward the distal undulating portion of the filter assembly until the filter assembly is radially collapsed and retained by the constraining element.
