

SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

SYSTEMS FOR MECHANICALLY PREVENTING RESTENOSIS IN PERIPHERAL VASCULAR STENTS

CROSS REFERENCE TO RELATED APPLICATION(S)

- 5 [1] This application claims the benefit of U.S. Provisional Application Nos. 62/665,753, filed May 2, 2018, and 62/840,456, filed April 30, 2019, which are incorporated by reference as if disclosed herein in their entireties.

BACKGROUND

- 10 [2] Peripheral artery disease (PAD) is a condition in which fat and other deposits cause the narrowing of an artery. This results in reduced blood flow, leading to serious medical complications if left untreated. PAD affects nearly 10 million people in the United States.

- 15 [3] Depending on time of diagnosis and severity, there are three treatment options available: angioplasty and stent implantation, bypass surgery, and, ultimately, amputation. During angioplasty, a balloon-catheter is inserted into the obstructed blood vessel. An expandable stent wrapped around the balloon is then fitted into place to clear the artery for normal blood flow. The stent is left in the blood vessel to maintain healthy blood flow. During bypass, a graft is inserted to reroute blood flow around the blood vessel blockage. Bypass is usually relied upon for more severe blockages.

- 20 [4] Angioplasty is preferable to bypass where suitable at least because it is less invasive. However, the benefits of angioplasty are not necessarily permanent. Some patients with stent implants experience restenosis, a recurrence of a narrowing of the blood vessel due to the return of plaque build-up at the same site, e.g., on the stent. One solution is to apply yet more stents to the area. However, in addition to increasing costs and usual risks associated with surgical procedures for the patient, the application of
25 additional stents reduces the flow diameter of the blood vessel, essentially making the reoccurrence of restenosis, and thus additional angioplasty procedures, more likely.

SUMMARY

- 30 [5] Some embodiments of the present disclosure are directed to an apparatus for preventing restenosis including a body having an interior space and an exterior surface,

the body sized for implantation with a blood vessel, stent, or combination thereof, and one or more features positioned longitudinally along the interior space, the features positioned to generate rotational motion of the apparatus upon flow of a fluid through the apparatus. In some embodiments, the features include one or more blades extending
5 longitudinally along the interior space and extending radially into the interior space, the blades positioned at an oblique angle to the longitudinal axis of the interior space. In some embodiments, the one or more blades have a twist angle between about 100 degrees and 110 degrees. In some embodiments, the one or more blades have a twist angle of about 104 degrees. In some embodiments, the apparatus includes one or more ridges
10 disposed on the exterior surface. In some embodiments, the one or more ridges extend longitudinally along the exterior surface. In some embodiments, the body is cylindrical and includes one or more shield rings encircling the interior space, where the one or more shield rings configured to prevent intrusion into the interior space by a blood vessel or stent. In some embodiments, the apparatus has a diameter between about 3mm and
15 about 7mm. In some embodiments, the apparatus has a diameter between about 4mm and about 5mm. In some embodiments, the apparatus is composed of biocompatible polymer, metal, or combinations thereof. In some embodiments, the composition of the apparatus includes titanium, stainless steel, cobalt-chromium alloy, nickel-titanium alloy, or combinations thereof. In some embodiments, the apparatus further includes an
20 anticoagulant.

[6] Some embodiments of the present disclosure are directed to a method of preventing restenosis including providing an apparatus such as that described above, inserting the apparatus into a lumen of a blood vessel or stent, inserting a first anchor ring and a second anchor ring adjacent opposing ends of the apparatus to limit movement of
25 the apparatus within the lumen, and inducing rotational motion of the apparatus within the lumen via blood flow through the apparatus. In some embodiments, the apparatus rotates between about 5 rotations per minute and about 8 rotations per minute. In some embodiments, the apparatus rotates between about 6 rotations per minute and about 7 rotations per minute.

30 BRIEF DESCRIPTION OF THE DRAWINGS

[7] The drawings show embodiments of the disclosed subject matter for the purpose of illustrating the invention. However, it should be understood that the present

application is not limited to the precise arrangements and instrumentalities shown in the drawings, wherein:

[8] FIG. 1A is a schematic drawing of a system for preventing restenosis according to some embodiments of the present disclosure;

5 [9] FIG. 1B is a schematic drawing of a system for preventing restenosis according to some embodiments of the present disclosure;

[10] FIG. 2 is an apparatus for preventing restenosis according to some embodiments of the present disclosure; and

10 [11] FIG. 3 is a chart of a method for preventing restenosis according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

[12] Referring now to FIG. 1A, some aspects of the disclosed subject matter include an system 100 for preventing restenosis. In some embodiments, system 100 includes an apparatus 102. Apparatus 102 is configured and sized to be inserted into and positioned
15 within the lumen L of a flow path. While the exemplary embodiments shown and described in the present disclosure portray apparatus 102 in use within flow paths such as blood vessel 103, stent 104, blood vessels into which a stent has already been inserted, etc., or combinations thereof, the present invention is not limited in this regard, as apparatus 102 can be configured for use generally in tubes, pipes, conduits, etc. where
20 there is a desire to inhibit material build-up and prevent clogging of the flow paths. Referring now to FIG. 1B, in some embodiments, apparatus 102 is held in place within lumen L via one or more anchors 106. In some embodiments, anchors 106 include a first anchor ring 106A and a second anchor ring 106B which are positioned at ends 102A and 102B of apparatus 102 respectively. In some embodiments, anchors 106 are sized
25 and positioned to limit longitudinal movement of apparatus 102. In some embodiments, anchors 106 limit movement of apparatus 102 within lumen L. In some embodiments, anchors 106 are inflatable. In some embodiments, apparatus has a length of about 10mm and about 50mm. The embodiments of FIGs. 1A and 1B show an exemplary embodiment of apparatus 102 inserted within a stent 104 such that the stent is disposed between the
30 apparatus and a wall of a blood vessel 103. In some embodiments, apparatus 100 is

approximately as long as stent 104. In some embodiments, apparatus 100 is longer than the length of stent 104. In some embodiments, apparatus 100 is shorter than the length of stent 104.

[13] Referring now to FIG. 2, apparatus 102 includes a body 200. In some
5 embodiments, body 200 is cylindrical, spherical, conical, polyhedral, or combinations thereof. In some embodiments, cylindrical body 200 defines an interior space 202. In some embodiments, body 200 includes one or more shield rings 204 encircling interior space 202. In some embodiments, body 200 includes a plurality of shield rings 204 encircling interior space 202. In some embodiments, adjacent shield rings are connected
10 via one or more connectors 206C. In some embodiments, shield rings 204 are configured to prevent intrusion into interior space 202 by the tube, pipe, conduit, etc. into which apparatus 102 is installed, e.g., stent 104 as shown in FIGs. 1A-1B. In some embodiments, cylindrical body includes an exterior surface 206. In some embodiments, exterior surface 206 is configured for contact with an interior surface of tube, pipe, conduit, etc. into which apparatus 102 is installed, e.g., a blood vessel or stent. In some
15 embodiments, apparatus 102 is sized for implantation in a tube, pipe, conduit, etc., e.g., a blood vessel, stent, or combination thereof. In some embodiments, apparatus 102 has a diameter between about 3mm and about 7mm. In some embodiments, apparatus 102 has a diameter between about 4mm and about 5mm. In some embodiments, apparatus 102 is
20 composed of a biocompatible material to allow insertion and prolonged operation within the body. In some embodiments, apparatus 102 is composed of biocompatible polymer, metal, or combinations thereof. In some embodiments, the composition of apparatus 102 includes titanium, stainless steel, cobalt-chromium alloys, nickel-titanium alloy, or combinations thereof. In some embodiments, apparatus 102 includes an
25 anticoagulant, e.g., as a part of its composition, as a layer disposed on one or more structural components, as a controlled release medicament, e.g., integrated with the apparatus, etc., or combinations thereof.

[14] In some embodiments, one or more features 208 are positioned longitudinally along interior space 202. In some embodiments, a plurality of features 208 are positioned
30 longitudinally along interior space 202. Features 208 are shaped and positioned to generate rotational motion of apparatus 102 upon flow of a fluid, e.g., blood, water, etc., through the apparatus. As used herein, flow of a fluid “through” apparatus 102 is used to

refer any fluid flow through interior space 202, around cylindrical body 200, or any combination thereof. In some embodiments, interior space 202 is defined by an interior surface 210. In some embodiments, features 208 extend into interior space 202. In some embodiments, features 208 extend from interior surface 210 into interior space 202. In some
5 some embodiments, features 208 extend outward, e.g., towards stent 104. In some embodiments, features 208 include blades, rods, bristles, loops, tubes, fans, or combinations thereof.

[15] In some embodiments, features 208 include one or more blades 208A. In some embodiments, blades 208A extend longitudinally along interior space 202. In some
10 embodiments, blades 208A extend radially into interior space 202. In some embodiments, blades 208A extend radially from interior surface 210 into interior space 202. In some embodiments, blades 208A extend radially outward, e.g., towards stent 104. In some embodiments, blades 208A are positioned at an oblique angle Θ to longitudinal axis A. In some embodiments, blades 208A have a twist angle between
15 about 100 degrees and 110 degrees. In some embodiments, blades 208A have a twist angle of about 104 degrees. In some embodiments, blades 208A include an exterior edge 208E. In some embodiments, exterior surface 206 and exterior edge 208E are substantially coplanar. In some embodiments, exterior edge 208E is recessed with respect to exterior surface 206. In some embodiments, exterior edge 208E is within interior
20 space 202. In some embodiments, blades 208A connect adjacent rings 204 to produce an integrated body.

[16] Upon fluid flow, e.g., water, blood flow, etc., through apparatus 102, features 208 are deflected, resulting in rotation R of the apparatus. As apparatus 102 rotates, exterior surface 206 and/or features 208 brush against interior walls of the flow path, e.g., blood
25 vessel 103/stent 104, and/or the space directly adjacent interior walls of the flow path, dislodging material, e.g., plaque, build-up and inhibiting restenosis. In some embodiments, rotation speed of apparatus 102 is variable. Without wishing to be bound by theory, the speed of rotation R depends at least in part on the flow rate of fluid through apparatus 102. In embodiments where apparatus 102 is installed in a blood vessel or stent
30 of a patient, the patient's intrinsic pulsed blood flow may cause the apparatus to exhibit pulsed rotation speeds, e.g., will rotate alternatingly faster and slower in a generally sinusoidal manner. In some embodiments, apparatus 102 is configured so as to rotate

faster than about .5 rotations per minute. In some embodiments, apparatus 102 is configured so as to rotate faster than about 1 rotation per minute. In some embodiments, apparatus 102 is configured so as to rotate between about 2 rotations per minute and about 11 rotations per minute. In some embodiments, apparatus 102 is configured so as to rotate between about 3 rotations per minute and about 10 rotations per minute. In some embodiments, apparatus 102 is configured so as to rotate between about 4 rotations per minute and about 9 rotations per minute. In some embodiments, apparatus 102 is configured so as to rotate between about 5 rotations per minute and about 8 rotations per minute. In some embodiments, apparatus 102 is configured so as to rotate between about 6 rotations per minute and about 7 rotations per minute. In some embodiments, apparatus 102 is configured so as to exert a shear stress, e.g., on interior walls of the blood vessel/stent, of less than 150 Pa.

[17] In some embodiments, apparatus 102 includes one or more ridges 212. In some embodiments, apparatus 102 includes a plurality of ridges 212. In some embodiments, ridges 212 are disposed on exterior surface 206, exterior edge 208E, or combinations thereof. In some embodiments, ridges 212 extend longitudinally along exterior surface 206. In these embodiments, rotation R of apparatus 102 due to flow through the apparatus also results in rotation of ridges 212, which aid in the brushing of interior walls of the blood vessel/stent and/or the space directly adjacent interior walls of the blood vessel/stent and dislodging plaque build-up.

[18] Referring now to FIG. 3, some embodiments of the present disclosure are directed to a method 300 of preventing restenosis in a patient. At 302, a restenosis prevention apparatus consistent with the above identified embodiments is provided. At 304, the apparatus is inserted at a site at risk for restenosis, e.g., the lumen of a recently cleared blood vessel, the lumen of an implanted stent, etc., or combinations thereof. At 306, a first anchor ring and a second anchor ring are inserted adjacent opposing ends of the apparatus to limit movement of the apparatus at the site, e.g., within the lumen. At 308, rotational motion of the implanted apparatus is induced via fluid flow, e.g., blood flow, through the apparatus. As discussed above, in some embodiments, the apparatus rotates between about 5 rotations per minute and about 8 rotations per minute. In some embodiments, the apparatus rotates between about 6 rotations per minute and about 7 rotations per minute.

[19] Systems and methods of the present disclosure are advantageous to significantly reduce risk of restenosis, e.g., in patients with peripheral artery disease, via mechanical disruption. The gentle, substantially continuous rotational motion of the apparatus prevents plaque build-up without damaging vessel walls or implanted stents. The apparatus is easily added to existing stent application protocols, as it is an “add-on” compatible for use with existing stents, and can be implanted using the same or similar procedures, e.g., with the use of a balloon-catheter. As such, the apparatus is easily inserted, removed, or replaced, though the apparatus can be a longer term solution to restenosis due to its biocompatibility, gentle action, and use of the patient’s own blood stream to provide the rotational motion. Finally, the apparatus is suitable for use outside of peripheral artery disease applications. For example, apparatus of the present disclosure are also candidates for discouraging active biological tissue regrowth over implanted foreign materials, such as that hindering development of removable artificial valves for transcatheter aortic valve replacement. The apparatus can also be configured for use in non-medical applications, such as plumbing systems, oil delivery pipelines, etc., where there is a desire to inhibit or prevent flow path clogging via material build-up.

[20] Although the disclosed subject matter has been described and illustrated with respect to embodiments thereof, it should be understood by those skilled in the art that features of the disclosed embodiments can be combined, rearranged, etc., to produce additional embodiments within the scope of the invention, and that various other changes, omissions, and additions may be made therein and thereto, without parting from the spirit and scope of the present invention.

CLAIMS

What is claimed is:

1. An apparatus for preventing restenosis, comprising:
 - 5 a body having an interior space and an exterior surface, the body sized for implantation with a blood vessel, stent, or combination thereof; and
 - one or more features positioned longitudinally along the interior space, the features positioned to generate rotational motion of the apparatus upon flow of a fluid through the apparatus.
2. The apparatus according to claim 1, wherein the features include one or more
10 blades extending longitudinally along the interior space and extending radially into the interior space, the blades positioned at an oblique angle to the longitudinal axis of the interior space.
3. The apparatus according to claim 2, wherein the one or more blades have a twist angle between about 100 degrees and 110 degrees.
4. The apparatus according to claim 3, wherein the one or more blades have a twist
15 angle of about 104 degrees.
5. The apparatus according to claim 1, further comprising one or more ridges disposed on the exterior surface.
6. The apparatus according to claim 5, wherein the one or more ridges extend
20 longitudinally along the exterior surface.
7. The apparatus according to claim 1, wherein the body is cylindrical and includes one or more shield rings encircling the interior space, the one or more shield rings configured to prevent intrusion into the interior space by a blood vessel or stent.
8. The apparatus according to claim 1, the apparatus having a diameter between
25 about 3mm about 7mm.
9. The apparatus according to claim 8, the apparatus having a diameter between about 4mm and about 5mm.

10. The apparatus according to claim 1, wherein the apparatus is composed of biocompatible polymer, metal, or combinations thereof.
11. The apparatus according to claim 1, wherein the composition of the apparatus includes titanium, stainless steel, cobalt-chromium alloy, nickel-titanium alloy, or combinations thereof.
12. The apparatus according to claim 1, wherein the apparatus further includes an anticoagulant.
13. A method of preventing restenosis, comprising:

providing an apparatus, the apparatus including:

a cylindrical body having an interior space and an exterior surface, the body sized for implantation with a blood vessel, stent, or combination thereof; and

one or more blades extending longitudinally along the interior space and extending radially into the interior space, the blades positioned at an oblique angle to the longitudinal axis of the interior space;

inserting the apparatus into a lumen of a blood vessel or stent;

inserting a first anchor ring and a second anchor ring adjacent opposing ends of the apparatus to limit movement of the apparatus within the lumen; and

inducing rotational motion of the apparatus within the lumen via blood flow through the apparatus.

14. The method according to claim 13, wherein the apparatus rotates between about 5 rotations per minute and about 8 rotations per minute.
15. The method according to claim 14, wherein the apparatus rotates between about 6 rotations per minute and about 7 rotations per minute.
16. The method according to claim 13, wherein the one or more blades have a twist angle between about 100 degrees and 110 degrees.

17. The method according to claim 16, wherein the one or more blades have a twist angle of about 104 degrees.

18. A system for preventing restenosis, comprising:

a cylindrical body having an interior surface and an exterior surface;

5 a plurality of blades positioned longitudinally along the interior surface and extending radially from the interior surface, the blades positioned at an oblique angle to the longitudinal axis of the body;

a plurality of ridges disposed on the exterior surface and extending longitudinally along the exterior surface; and

10 a first anchor ring and a second anchor ring to limit longitudinal movement of the cylindrical body;

wherein the one or more blades have a twist angle between about 100 degrees and 110 degrees.

15 19. The system according to claim 18, the system having a maximum diameter between about 3mm and about 7mm.

20. The system according to claim 18, wherein the cylindrical body is positioned within the lumen of a stent, such that the stent is disposed between the cylindrical body and a wall of a blood vessel.

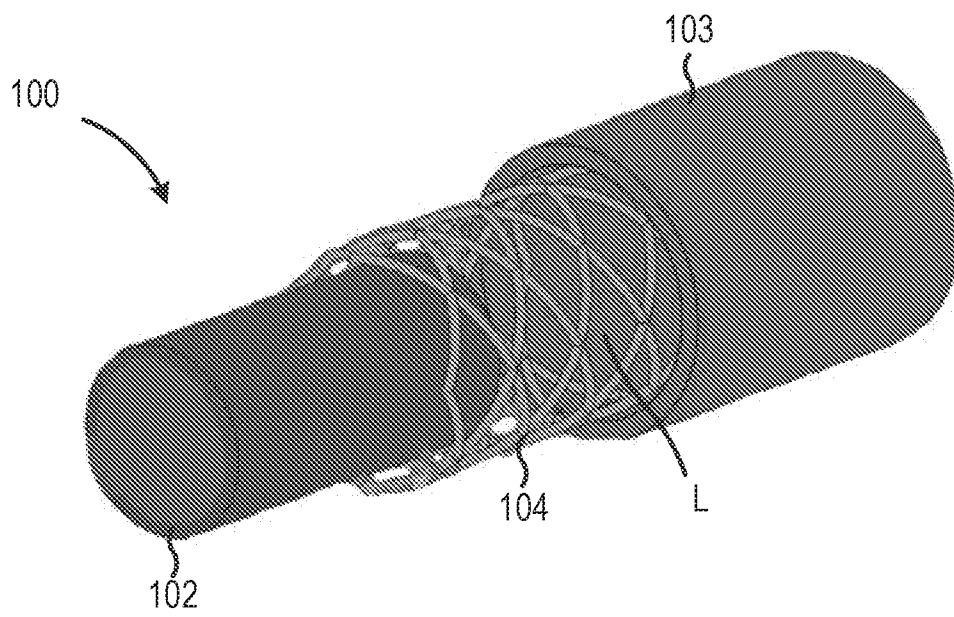


FIG. 1A

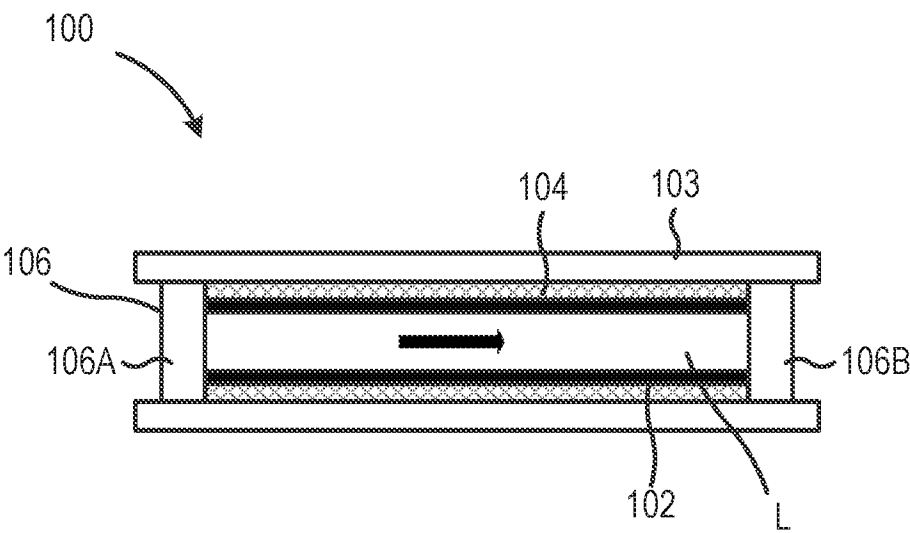


FIG. 1B

3 / 4

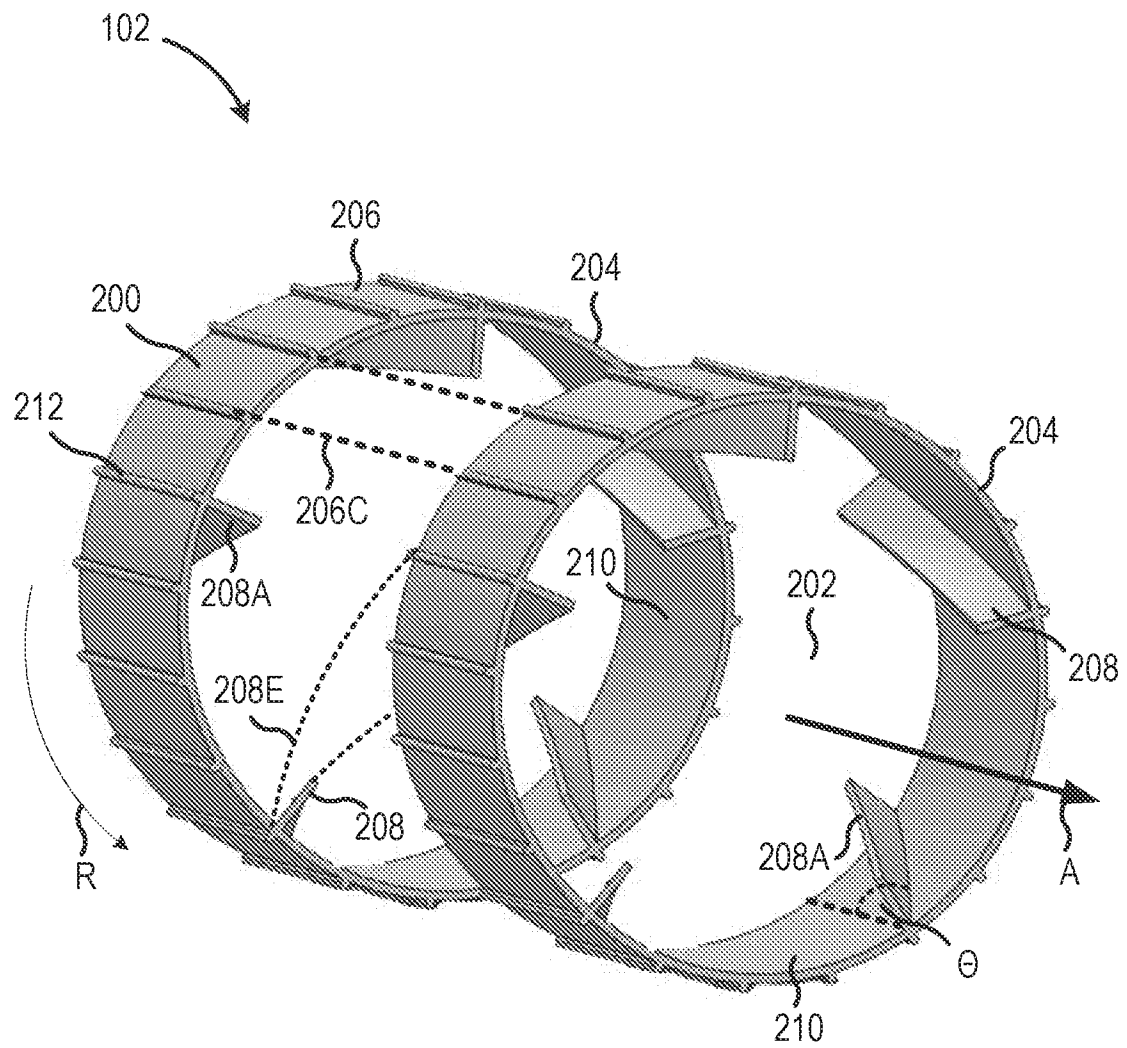


FIG. 2

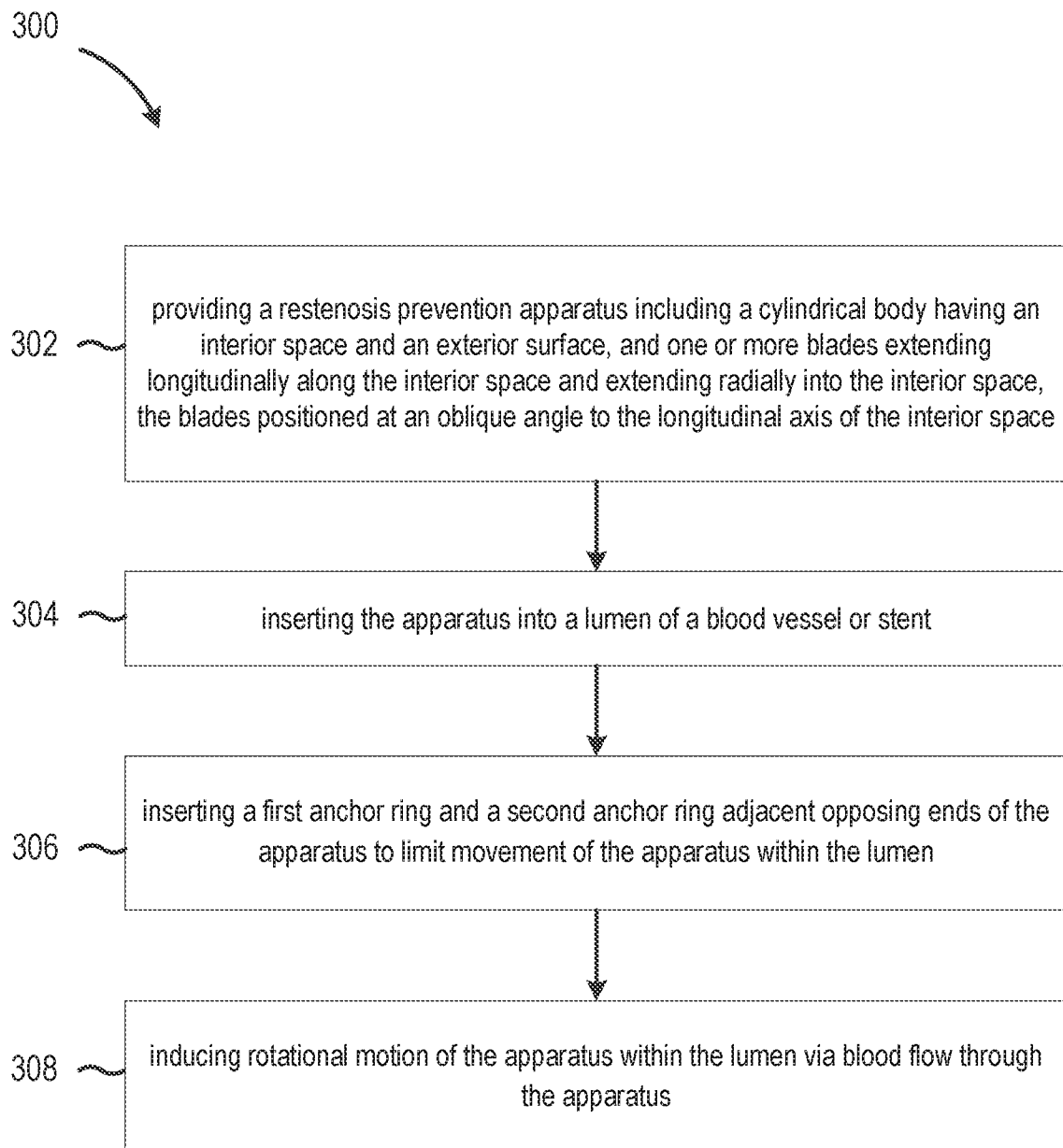


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 19/30371

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61F 2/06 (2019.01)

CPC - A61F 2/06, 2002/068

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

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

See Search History Document

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

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,165,209 A (PATTERSON et al) 26 December 2000 (25.12.2000) see especially col 3, ln 35-50, col 6, ln 36 to, col 7, ln 40, col 9, ln 55 to col 10, ln 32, col 11, ln 47 to col 12, ln 16, col 13, ln 14-34, fig 6, 7, 8, 12, 13	1-11
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Y		12-20
Y	US 2007/0093744 A1 (ELMALEH) 26 april 2007 (26.04.2007) see especially para [0073]	12
Y	US 2005/0209682 A1 (ABRAHAM-FUCHS et al) 22 September 2005 (22.09.2005) see especially para [0023], [0024], fig 1-2	13-20
A	US 2014/0180392 A1 (SHOHAM et al) 26 June 2014 (26.06.2014) see whole document	1-20
A	US 2008/0269789 A1 (ELI) 30 October 2008 (30.10.2008) see whole document	1-20
A	US 2007/0204445 A1 (HOOD et al) 6 September 2007 (06.09.2007) see whole document	1-20
A	US 2004/0037986 A1 (HOUSTON et al) 26 February 2004 (26.02.2004) see whole document	1-20
A	US 6,416,540 B1 (MATHUR) 9 July 2002 (09.07.2002) see whole document	1-20

☐

Further documents are listed in the continuation of Box C.

☐

See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search 20 June 2019	Date of mailing of the international search report 09 JUL 2019
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774