(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 November 2017 (30.11.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/205486 A1

(51) International Patent Classification:
A61F 2/07 (2013.01)

(21) International Application Number:
PCT/US2017/034223

(22) International Filing Date:
24 May 2017 (24.05.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/341,234 25 May 2016 (25.05.2016) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, 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))*

(54) **Title:** STENT GRAFTS AND METHODS OF USE FOR TREATING ANEURYSMS

(57) **Abstract:** A stent graft includes a tubular aortic component that defines a lumen and a fenestration with a pocket at the fenestration. At least one proximal tunnel graft extends proximally within the lumen from the proximal opening of the pocket and is secured at a proximal end to the tubular component, and at least one distal tunnel graft extends distally within the lumen from the distal opening of the pocket and is secured at a distal end to the tubular aortic component. The stent graft can further include at least one branch stent graft, each of which extends through the fenestration and within at least one of the proximal tunnel graft or the distal tunnel graft. The stent graft can be implanted in a patient to thereby treat an aneurysm, such as a suprarenal or thoracoabdominal aortic aneurysm.

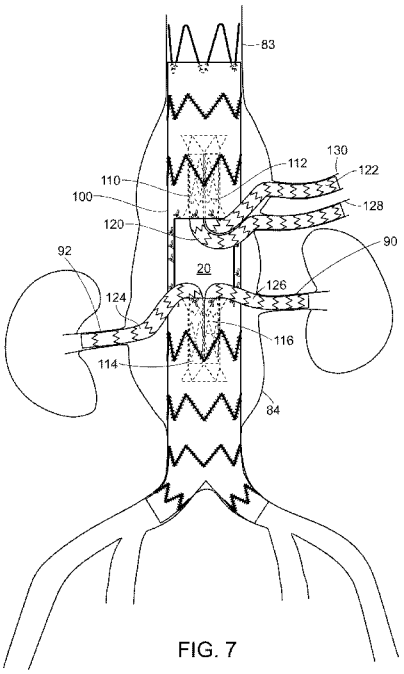

FIG. 7

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STENT GRAFTS AND METHODS OF USE FOR TREATING ANEURYSMS

RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 62/341,234. filed on May 25, 2016. The entire teachings of the above application are incorporated herein by reference.

BACKGROUND

[0002] Suprarenal abdominal aortic aneurysms (AAA) and thoracoabdominal aortic aneurysms (TAAA) are life-threatening conditions that represent surgical challenges. Although open surgical repair of these aneurysms can treat the diseased area of the aorta, there are considerable risks with open repair, primarily as a consequence of ischemic insult to the spinal cord, kidneys and surrounding abdominal viscera resulting from surgery. Currently, open surgical techniques to repair suprarenal AAA and TAAA include distal aortic perfusion via extracorporeal circuits, in-line shunts, and cold renal perfusion to reduce the potential of ischemic injury to the spinal cord and renovisceral areas.

[0003] Therefore, a need exits for new and improved endovascular repair devices and methods to treat suprarenal AAA and TAAA that minimize trauma to the patient, and loss of blood flow to the spinal cord and surrounding viscera.

SUMMARY OF THE INVENTION

[0004] The present invention relates to stent grafts and methods of using stent grafts to treat aortic vascular damage, such as vascular damage associated with suprarenal AAA and TAAA, including aneurysms, penetrating ulcers and dissection.

[0005] In an embodiment, the invention is a stent graft comprising: a tubular aortic component defining a lumen having a proximal end, a distal end, a major longitudinal axis, and defining a fenestration between the proximal end and the distal end; a pocket at the fenestration, the pocket defining a pocket proximal opening and a pocket distal opening opposite the pocket proximal opening within the lumen; at least one proximal tunnel graft having a proximal tunnel graft proximal end, and at least one proximal tunnel graft distal end, and defining a proximal tunnel graft lumen, the proximal tunnel graft extending proximally within the lumen from the pocket proximal opening and being secured at its proximal end to the tubular aortic component;

and at least one distal tunnel graft having a distal tunnel graft proximal end and a distal tunnel graft distal end, and defining at least one distal tunnel graft lumen, the distal tunnel graft extending distally within the lumen from the distal opening of the pocket and being secured at its distal end to the tubular aortic component.

[0006] In another embodiment, the invention is a method for treating a suprarenal or a thoracoabdominal aortic aneurysm. A stent graft is delivered through an aorta to an aneurysm site of a patient, the stent graft being radially and releasably constrained by a distal end of a control catheter of a delivery device. The stent graft includes: a tubular aortic component defining a lumen having a proximal end, a distal end, a major longitudinal axis, and defining a fenestration between the proximal end and the distal end; a pocket at the fenestration, the pocket defining a proximal opening and a distal opening opposite the proximal opening within the lumen; at least one proximal tunnel graft having a proximal tunnel graft proximal end and a proximal tunnel graft distal end, and defining at least one proximal tunnel graft lumen, the proximal tunnel graft extending proximally within the lumen from the proximal opening of the pocket and being secured at its proximal end to the tubular aortic component; and at least one distal tunnel graft having a distal tunnel graft proximal end and a distal tunnel graft distal end, and defining at least one distal tunnel graft lumen, the distal tunnel graft extending distally within the lumen from the distal opening of the pocket and being secured at its distal end to the tubular aortic component. The fenestration is aligned at the aneurysm site of the patient with at least one branch of the aorta at the aneurysm site. The tubular aortic component (stent graft) is released from the delivery device, such as by retracting a control catheter of the delivery device. Each of at least one branch stent graft is delivered through the distal end and the proximal end of the stent graft and through the distal tunnel graft or the proximal tunnel graft to the fenestration, and through the fenestration to a branch of the aorta at the aneurysm site of the patient, whereby the branch stent graft is secured into the distal tunnel graft lumen or the proximal tunnel graft lumen while being radially constrained at the opposite end of the branch stent graft by a branch delivery device. Each branch stent graft is released from the branch delivery device to thereby complete implantation of the branch stent graft and treat the suprarenal or thoracoabdominal aortic aneurysm.

[0007] The stent grafts and methods of the invention have several advantages, including, for example, defining a fenestration that reduces the profile of the stent graft which, in turn, has the advantage of accommodating branch stent grafts within tunnel grafts to minimize the diameter of a prosthesis placed in a diseased aorta. The length and diameter of the fenestration can be

customized for individual patients depending upon the degree and extent of the suprarenal AAA and TAAA to permit the surgeon to minimize trauma in the area of the diseased aorta while providing the surgeon with a decreased profile for introducing branch stent grafts to branch vessels of organs and tissues in the area of the diseased aorta.

[0008] The stent grafts and methods of the invention also have the advantage of providing greater flexibility of choice to the surgeon introducing branch stent grafts, arranging them in either an antegrade or retrograde configuration, to accommodate the anatomical features specific to tissue surrounding the aneurysm. In the case of arteries, antegrade is the flow of blood away from the heart and in the case of veins antegrade is the flow of blood towards the heart. In the case of arteries, retrograde is the flow of blood towards the heart and in the case of veins retrograde is the flood of blood away from the heart. For example, antegrade placement of a branch stent graft in an aorta refers to the implantation of a branch stent graft that results in a portion of the branch stent graft extending from the fenestration in the tubular aortic component (stent graft with fenestration implanted in the aorta at the site of an aneurysm) in the same direction as the flow of blood. In contrast, retrograde placement of a branch stent graft in an aorta refers to the implantation of a branch stent graft that results in a portion of the branch stent graft extending from the fenestration in the aortic stent graft component in a direction that is opposite the flow of blood from the heart.

[0009] Further, the proximal and distal tunnel grafts are each secured to the aortic graft component at their proximal and distal ends, respectively. As a result, implantation of branch stent grafts which, in abdominal aortic aneurysms or thoracoabdominal aortic aneurysm surgeries, must be through either the proximal or distal end of the aortic stent graft component, is facilitated by relatively stable positioning of the proximal end of the proximal tunnel graft and the distal end of the distal tunnel graft within the aortic stent graft component.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The foregoing will be apparent from the following more particular description of example embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The same number in different drawings represents the same item. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating embodiments of the present invention.

[0011] FIG. 1 is a side view of one embodiment of a stent graft of the invention.

[0012] FIG. 2A is a side view of another embodiment of a stent graft of the invention, like that of FIG. 1 but lacking a distal bare stent and rotated 90° about a major longitudinal axis.

[0013] FIG. 2B is a side view of the embodiment of FIG. 2A showing, in dashed-lines, a pocket and tunnel grafts within an aortic stent component of the invention.

[0014] FIG. 3A is a side view of another embodiment of a stent graft of the invention, wherein the proximal end of a proximal tunnel graft and a distal end of a distal tunnel graft of the embodiment are flared.

[0015] FIG. 3B is a side view of the embodiment of FIG. 3A rotated 90° about a major axis of the stent graft of the invention.

[0016] FIG. 4A is a side view of yet another embodiment of a stent graft of the invention after implantation at an aneurysm site in a subject, wherein the distal end of the aortic graft component is bifurcated.

[0017] FIG. 4B is a cross-sectional view of the embodiment of the stent graft of the invention shown in FIG. 4A taken along line 4B-4B therein, and showing an end view of the proximal tunnel graft of FIG. 4A.

[0018] FIG. 5 is a side view of the stent graft of the invention of FIGs. 4A and 4B, and further including two branch stent grafts extending from the fenestration of the tubular aortic component of the invention after implantation at an aneurysm site in a subject.

[0019] FIG. 6A is a side view of another embodiment of a stent graft of the invention, having a bifurcated distal end, and wherein the proximal and distal tunnel grafts are partitioned into sublumens, as shown after implantation at an aneurysm site in a subject.

[0020] FIG. 6B is a cross sectional view of the embodiment of the stent graft of the invention shown in FIG. 6A taken along line 6B-6B therein, and showing an end view of the sublumens of proximal tunnel graft of FIG. 6A.

[0021] FIG. 7 is a side view of the stent graft of the invention of FIGs. 6A and 6B, and further including four branch stent grafts extending from a fenestration of a tubular aortic component of the invention after implantation at an aneurysm site of a subject.

DETAILED DESCRIPTION OF THE INVENTION

[0022] The invention is generally directed to prostheses for use in treating vascular disease, such as implantation of the prostheses at a site of an aortic aneurysm.

[0023] The features and other details of the invention, either as steps of the invention or as combinations of parts of the invention will now be more particularly described and pointed out in

the claims. It will be understood that the particular embodiments of the invention are shown by way of illustration and not as limitations of the invention. The principle features of this invention can be employed in various embodiments without departing from the scope of the invention.

[0024] A description of example embodiments of the invention follows.

[0025] When reference is made herein to a prosthesis to be delivered, or implanted in a patient, such as a vascular repair device, the word "proximal" means that portion of the prosthesis or component of the prosthesis that is relatively close to the heart of the patient and "distal" means that portion of the prosthesis or component of the prosthesis that is relatively far from the heart of the patient.

[0026] When, however, reference is made to a delivery system or a component of a delivery system employed to deliver, or implant a vascular repair device, the word, "proximal," as employed herein, means closer to the clinician using the delivery system. "Distal," as that term is employed herein, means, when reference is made to a delivery system or a component of a delivery system, further away from the clinician using the delivery system.

[0027] For clarity, the word "proximate" means "close to," as opposed to the meanings ascribed to "proximal" or "distal" above with respect to either the vascular repair device or delivery system.

[0028] One embodiment of the stent graft of the invention is shown in FIG. 1. As shown therein, stent graft (10) includes tubular aortic component (12) defining a lumen having proximal end (14), distal end (16), major longitudinal axis (18), and defining fenestration (20) between proximal end (14) and distal end (16) of stent graft (10). Tubular aortic component (12) is made from suitable materials, such as are known to those skilled in the art, including, for example, expanded polytetrafluoroethylene (PTFE), such as expanded PTFE (ePTFE), and polyethylene terephthalate (PET), such as woven polyester. Fenestration (20) defines fenestration proximal end (22) and fenestration distal end (24). Stents (26) extend about at least a portion of the circumference of tubular aortic component (12) between proximal end (14) and distal end (16). Proximal bare stent (28) and distal bare stent (30) are secured to proximal end (14) and distal end (16), respectively. Stents (26) and bare stents (28, 30) are sutured to tubular aortic component (12) by suitable means known to those skilled in the art, such as by sutures (31), including sutures fabricated of polyester ePTFE (expanded polytetrafluoroethylene), polyglycolic acid, polylactic acid, monocryl and polydioxanone, non-absorbable nylon, polyester, PVDF (polyvinylidene difluoride) and polypropylene. Stents (26) and bare stents (28, 30) are formed

of a suitable material, such as is known to those skilled in the art, including nitinol. Suitable radiographic markers (32), such as are known to those skilled in the art, are sutured to periphery (34) of fenestration (20).

[0029] FIG. 2A is a side view of another embodiment of the invention. Therein, stent graft 36 is like that of FIG. 1, but, as shown, is rotated 90° about major longitudinal axis (18) and lacks distal bare stent (30). FIG. 2B is a side view of the embodiment of the invention shown in FIG. 2A and shows components of the invention in outline (dashed-lines) that are within the lumen defined by tubular aortic component (12). Specifically, stent graft (36) includes pocket (38) at fenestration (20). Pocket (38) defines pocket proximal opening (40) and pocket distal opening (42) opposite pocket proximal opening (40). Pocket proximal opening (40) of pocket (38) lies in plane A that is located proximally to proximal end (22) of fenestration (20). Pocket distal opening (42) lies in plane B located distally from distal end (24) of fenestration (20). As also shown in FIG. 2B, fenestration proximal end (22) lies in plane C, and fenestration distal end (24) lies in a plane D. Both plane C and plane D are essentially orthogonal to major longitudinal axis (18) of tubular aortic component (12). Plane A is parallel to and located proximal to plane C, and plane B is parallel to and lies distal to plane D.

[0030] Proximal tunnel graft (44) of stent graft (36) has proximal tunnel graft proximal end (46), proximal tunnel graft distal end (48) and proximal tunnel graft lumen (50). Proximal tunnel graft (44) extends proximally within the lumen of tubular aortic component (12) from pocket proximal opening (40) and is secured to proximal opening (40). Stent graft (36) also includes distal tunnel graft (52) having distal tunnel graft proximal end (54), distal tunnel graft distal end (56) and distal tunnel graft lumen (58). Distal tunnel graft (52) extends distally within the lumen of tubular aortic component (12) from pocket distal opening (42) and is secured to distal pocket opening (42).

[0031] At least one of proximal tunnel graft (44) and distal tunnel graft (52) is secured to an interior of tubular aorta component (12) by a suitable technique, such as is known to one skilled in the art, such as by a suture or biocompatible adhesive. For example, in one embodiment, proximal end (46) of proximal tunnel graft (44) is fixed to tubular aortic component (12) by proximal suture (60), and distal end (56) of distal tunnel graft (52) is fixed to tubular aortic component (12) by distal suture (61). Alternatively, at least one of proximal tunnel graft (44) and distal tunnel graft (52) can be attached to tubular aortic component (12) by more than a single suture, such as along an intermittent or continuous length (not shown), over a portion or the entire length of proximal tunnel graft (44) and distal tunnel graft (52), respectively.

[0032] FIG. 3A is a side view of another embodiment of a stent graft of the invention. As shown therein, stent graft (62) is like that of FIGs. 2A and 2B, except that stent graft (62) includes proximal tunnel graft (64) having proximal tunnel graft proximal end (66) that is flared. Proximal tunnel graft (64) includes proximal tunnel graft stents (68) and stent graft (62) also includes distal tunnel graft (70) having distal tunnel graft distal end (56) that is flared. FIG. 3B is a side view of tunnel graft (62) but rotated 90° about axis (18). At least one stent (67, 77), supports the flared opening of at least one of proximal end (66) and distal end (72), respectively. Flared proximal tunnel graft proximal end opening (66) of proximal tunnel graft (64) and flared distal tunnel graft distal end opening (72) of distal tunnel graft (70), respectively, provides guidance to the surgeon during placement of a branch stent graft into a respective tunnel graft. In one embodiment, at least one of fenestration proximal end (22) and fenestration distal end (24) of fenestration (20) lies in plane C, D, respectively, orthogonal to major longitudinal axis (18) and has a length, L, shown in FIG. 3B. Length L is greater than the diameter of distal end (76) of the at least one proximal tunnel graft (64) or proximal end (78) of distal tunnel graft (70) extending from the respective proximal opening (40) and distal opening (42) of pocket (38).

[0033] FIG. 4A is a side view of another embodiment of a stent graft of the invention. Stent graft (80) is like that of stent graft (62) in FIGs. 3A and 3B, but includes bifurcated distal end (82). FIG. 4B is a cross-sectional view of stent graft 80 taken along line 4B-4B, of FIG. 4A. As shown in FIG. 4B, length L of the diameter of fenestration (20) is greater than that of diameter D of proximal tunnel graft (64) at proximal tunnel graft distal end (48). As shown in FIG. 5, stent graft (80) is implanted in abdominal aortic aneurysm (84) of a subject, and further includes branch stent grafts (86, 88), each implanted in a renal artery (90, 92), respectively.

[0034] FIG. 6A is a side view of yet another embodiment of the stent graft of the invention. As shown therein, stent graft (100) is like stent graft (80) of FIGs. 4A, 4B and 5, but includes partitioned proximal tunnel graft (102) and partitioned distal tunnel graft (104). It is to be understood, however, that alternative embodiments are also possible, wherein only one or the other of proximal tunnel graft (102) or distal tunnel graft (104) is bifurcated. Septums (106, 108) partition each of the respective proximal and distal tunnel graft lumens (102, 104) into two proximal sublumens (110, 112) and distal sublumens (114, 116). Septums (106, 108) partition each of the respective proximal and distal tunnel graft lumens (102, 104) into two sublumens, to a point proximal or distal to openings of the respective tunnel graft lumens. Each sublumen has a sublumen proximal end and sublumen distal end, respectively. As shown in FIG. 6B, which is a cross-sectional view of stent graft 100 taken along line 6B-6B, proximal tunnel graft septum

(106) can be formed by, for example, stitching proximal tunnel graft (102) along a center line to tubular aortic graft component (12) by stitching (118). It is to be understood that other methods of forming sublumens, such as are known in the art, can be employed in the alternative. For example, two parallel proximal or distal tunnel grafts can be employed instead of proximal and distal tunnel grafts that are stitched along a centerline to subdivide the lumens of each of them into sublumens.

[0035] As can be seen in FIG. 7 branch stent grafts (120, 122, 124, 126) extend through fenestration (20) and within at sublumens (110, 112, 114 and 116), respectively. Branch stent grafts (120, 122, 124, 126) extend from fenestration into renal arteries (90, 92), celiac artery (130), and superior mesenteric artery (128), respectively.

[0036] In another embodiment, the invention is a method for treating a suprarenal or thoracoabdominal aortic aneurysm. For example, with reference to FIGs. 6A, 6B and 7, stent graft is delivered through a femoral artery to aortic aneurysm site (84) of subject by radially and releasably constraining stent graft at the distal end of a control catheter of a delivery device (not shown). The fenestration of the stent graft is aligned at aneurysm site (84) with at least one branch artery (90, 92, 128, 130) at the aneurysm site (84), and then the stent graft is released from the delivery device and the delivery device is removed from the subject. Each of at least one branch stent graft is releasably constrained by a branch delivery device. Each branch stent graft (120, 122, 124, 126) is delivered by a respective branch delivery device through a lumen of a tunnel graft of the stent graft and then through fenestration (20) to aneurysm site (84). Branch stent grafts (120, 122, 124, 126) extending from fenestration (20) are directed by the respective branch delivery device into a branch of the aorta at aneurysm site (84), and secured in a respective proximal or distal tunnel graft lumen at one end and within the branch artery at the opposite end. Each branch stent graft is then released from the respective delivery device, which is then removed, thereby completing implantation and treating the suprarenal or thoracoabdominal aortic aneurysm.

[0037] Vascular repair devices of the invention can be implanted, for example, by transfemoral access. Additional vascular repair devices that are directed into the vascular repair devices of the invention can be implanted, for example, by supraaortic vessel access (e.g., through the brachial artery), or by transfemoral access or access from some other branch or branches of major blood vessels, including peripheral blood vessels.

[0038] The relevant teachings of all patents, published applications and references cited herein are incorporated by reference in their entirety. The relevant teachings of U.S. Patent Nos.

8,292,943; 7,763,063; 8,308,790; 8,070,790; 8,740,963; 8,007,605; 9,320,631; 8,062,349; 9,198,786; 8,062,345; 9,561,124; 9,173,755; 8,449,595; 8,636,788; 9,333,104; 9,408,734; 9,408,735; 8,500,792; 9,220,617; 9,364,314; 9,101,506; 8,998,970; 9,554,929; 9,439,751; 9,592,112 and 9,655,712; U.S. Patent Application Nos. 14/226,005; 14/575,673; 15/166,818; 15/167,055; 14/272,818; 14/861,479; 15/478,424; 15/478,737 and PCT/US2017/025849 are also incorporated by reference in their entirety.

[0039] While this invention has been particularly shown and described with references to example embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

CLAIMS

What is claimed is:

1. A stent graft (10) comprising:
   a) a tubular aortic component (12) defining a lumen having a proximal end (14), a distal end (16), a major longitudinal axis (18), and defining a fenestration (20) between the proximal end (14) and the distal end (16);
   b) a pocket (38) at the fenestration, the pocket defining a pocket proximal opening (40) and a pocket distal opening (42) opposite the pocket proximal opening (40) within the lumen;
   c) at least one proximal tunnel graft (44) having a proximal tunnel graft proximal end (46) and a proximal tunnel graft distal end (48), and defining at least one proximal tunnel graft lumen (50), the proximal tunnel graft extending proximally within the lumen from the proximal opening of the pocket, and being secured at its proximal end to the tubular aortic component (12); and
   d) at least one distal tunnel graft (52) having a distal tunnel graft proximal end (54) and a distal tunnel graft distal end (56), and defining at least one distal tunnel graft lumen (58), the distal tunnel graft extending distally within the lumen from the distal opening of the pocket, and being secured at its distal end to the tubular aortic component (12).

2. The stent graft of Claim 1, wherein the distal end of the tubular aortic component (12) is bifurcated (82), thereby defining two legs of the stent graft.

3. The stent graft of Claim 1, wherein the fenestration (20) defines a fenestration proximal end (22) that lies in a plane orthogonal to the major longitudinal axis (18) of the tubular aortic component (12).

4. The stent graft of Claim 1, wherein the fenestration (20) defines a fenestration distal end (24) that lies in a plane orthogonal to the major longitudinal axis (18) of the tubular aortic component (12).

5. The stent graft of Claim 1, wherein the fenestration defines at least one of a fenestration proximal end (22) and a fenestration distal end (24) that lies in a plane orthogonal to the major longitudinal axis (18) of the tubular aortic component (12).

6. The stent graft of Claim 5, wherein at least one of the fenestration proximal end (22) and the fenestration distal end (24) of the fenestration (20) lying in the plane orthogonal to the major longitudinal axis has a length greater than that of at least one of: the total diameter of the distal end of the at least one proximal tunnel graft (44); and the total diameter of the proximal end of the at least one distal tunnel graft (52).

7. The stent graft of Claim 1, wherein the proximal end of the at least one proximal tunnel graft and the distal end of at least one of the at least one distal tunnel graft defines a flared opening.

8. The stent graft of Claim 7, further including at least one stent (67, 77) supporting the flared opening of at least one of the proximal tunnel graft proximal end (46) and at least one of the distal tunnel graft distal end (56).

9. The stent graft of Claim 7, wherein the proximal tunnel graft proximal end (66) defines a flared opening (67).

10. The stent graft of Claim 7, wherein the distal tunnel graft distal end (72) defines a flared opening.

11. The stent graft of Claim 10, further including at least one stent supporting the distal tunnel graft (70) and the proximal tunnel graft (64).

12. The stent graft of Claim 8, wherein both the distal tunnel graft distal end (72) and the proximal tunnel graft proximal end (66) define, respectively, a flared opening.

13. The stent graft of Claim 1, further including a bare stent (28) having proximal apices and distal apices, the bare stent (28) affixed to the proximal end (14) of the tubular aortic component (12) at the distal apices and wherein the proximal apices extend proximally beyond the proximal end (14) of the tubular aortic component (12).

14. The stent graft of Claim 1, further including at least two branch stent grafts, each branch stent graft extending through the fenestration (20) and within at least one of the proximal tunnel graft lumen and the distal tunnel graft lumen.

15. The stent graft of Claim 14, further including at least two branch stent grafts, wherein the at least two branch stent grafts each extend through the fenestration, and wherein at least one of the branch stent grafts extends through one of the proximal tunnel graft lumen and the distal tunnel graft lumen.

16. The stent graft of Claim 1, wherein at least one of the proximal tunnel graft and the distal tunnel graft includes a septum (106, 108) that partitions at least one of the proximal tunnel graft lumen and the distal tunnel graft lumen into two sublumens, each sublumen having a proximal end and a distal end.

17. The stent graft of Claim 16, including a plurality of septums, wherein one septum partitions the proximal tunnel graft lumen into two lumens and one septum partitions the distal tunnel graft lumen into two sublumens.

18. The stent graft of Claim 16, further including at least two branch stent grafts, each branch stent graft extending through the fenestration and within one of the two sublumens of the proximal tunnel graft.

19. The stent graft of Claim 16, further including at least two branch stent grafts, each extending through the fenestration and each, independently, extending within one of the sublumens of the distal tunnel graft.

20. The stent graft of Claim 16, wherein both of the proximal tunnel graft and the distal tunnel graft is supported by a stent graft.

21. The stent graft of Claim 20, wherein each septum partitions the proximal and distal tunnel graft lumens into two sublumens to a point proximal to the flared distal opening of the distal tunnel graft or distal to the flared proximal opening of the proximal tunnel graft lumen.

22. The stent graft of Claim 20, further including four branch stent grafts, all of which extend through the fenestration, and each of which extends independently within one of the sublumens.

23. A method for treating a suprarenal or thoracoabdominal aortic aneurysm, comprising the steps of:

a) delivering a stent graft through an aorta (83) to an aneurysm site (84) of a patient, the stent graft being radially and releasably constrained by a delivery device, the stent graft including:

i) a tubular aortic component (12) having a proximal end, a distal end, and a major longitudinal axis, and defining a lumen, and defining a fenestration between the proximal end and the distal end;

ii) a pocket at the fenestration and within the lumen, the pocket defining a proximal opening and a distal opening opposite the proximal opening;

iii) at least one proximal tunnel graft defining a proximal tunnel graft proximal end and a proximal tunnel graft distal end, the proximal tunnel graft extending proximally within the lumen from the proximal opening of the pocket, and being secured at its proximal end to the tubular aortic component (12); and

iv) at least one distal tunnel graft having a distal tunnel graft proximal end and defining a distal tunnel graft distal end, the distal tunnel graft extending distally within the lumen from the distal opening of the pocket, and being secured at its distal end to the tubular aortic component (12).

b) aligning the fenestration at the aneurysm site (84) of the patient with at least one branch of the aorta at the aneurysm site;

c) releasing the stent graft from the delivery device;

d) delivering at least one branch stent graft through the distal end of the stent graft through the distal tunnel graft lumen to the fenestration, and through the fenestration to a branch of the aorta at the aneurysm site, whereby the branch stent graft is radially and releasably constrained by a first branch delivery device;

e) releasing the branch stent graft from the first branch delivery device;

f) retracting the first branch delivery device;

g) delivering at least one branch stent graft through the proximal end of the stent graft through the proximal tunnel graft lumen to the fenestration, and through the fenestration to a branch of the aorta at the aneurysm site, whereby the branch stent graft is radially and releasably constrained by a second branch delivery device;

h) releasing the branch stent graft from the second branch delivery device; and

i) retracting the second branch delivery device, thereby treating the suprarenal or thoracoabdominal aortic aneurysm.

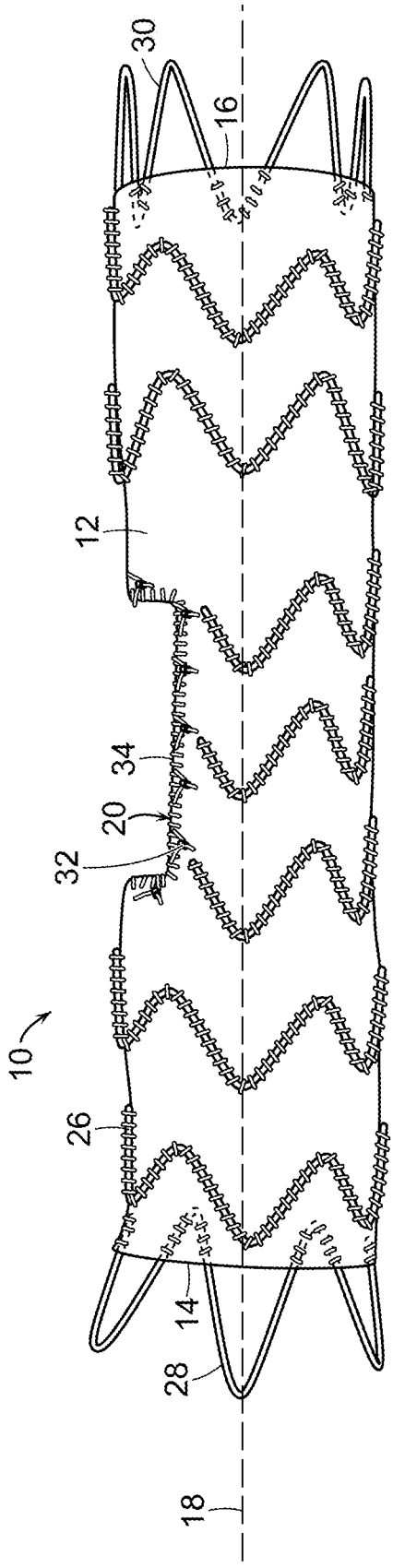

FIG. 1

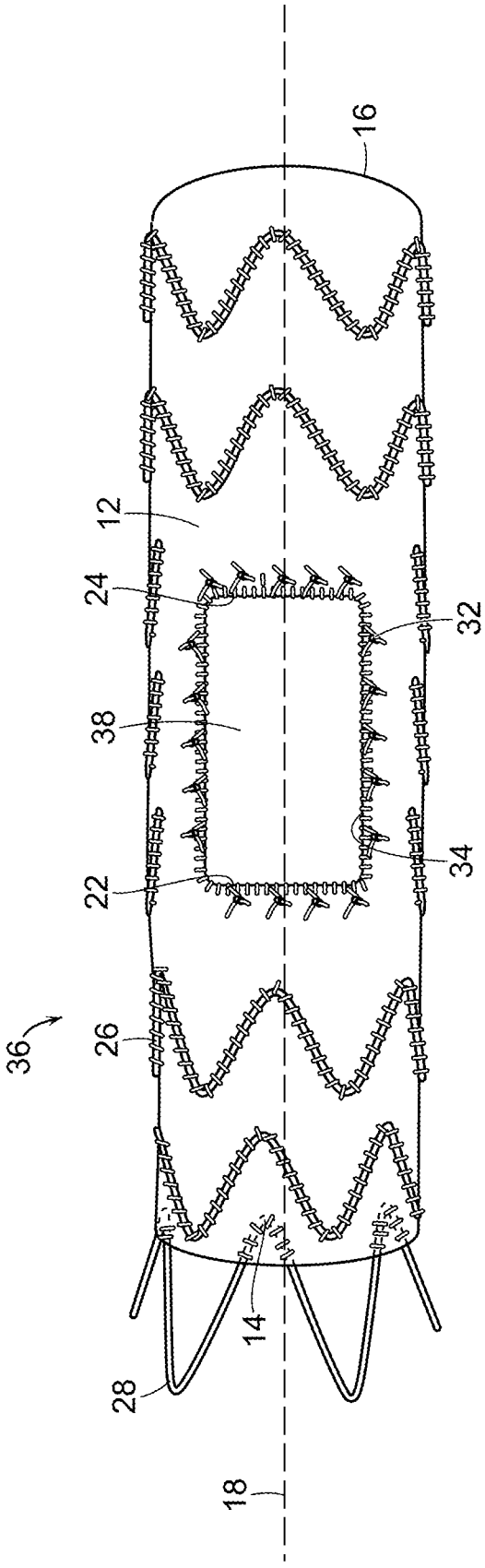

FIG. 2A

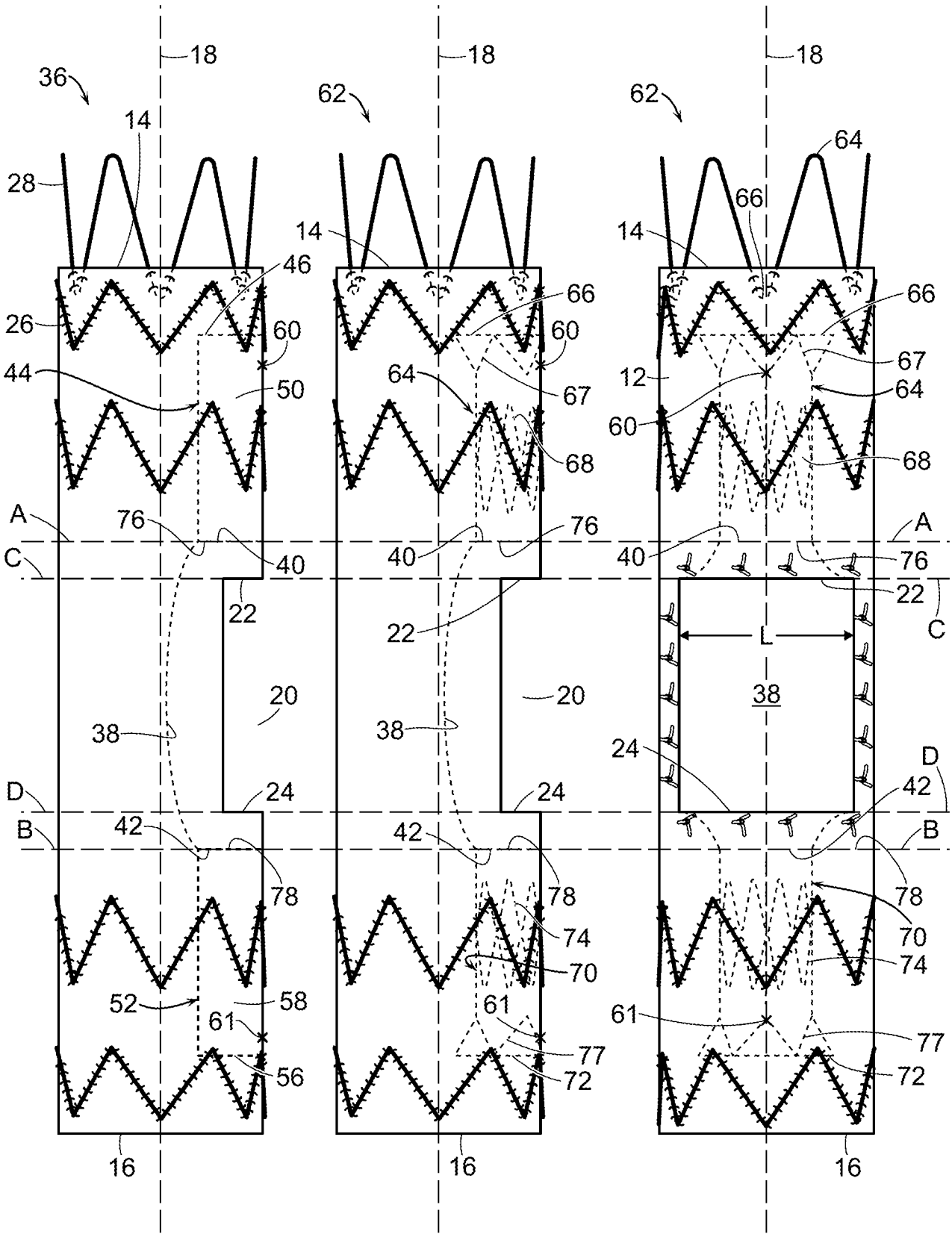

FIG. 2B FIG. 3A FIG. 3B

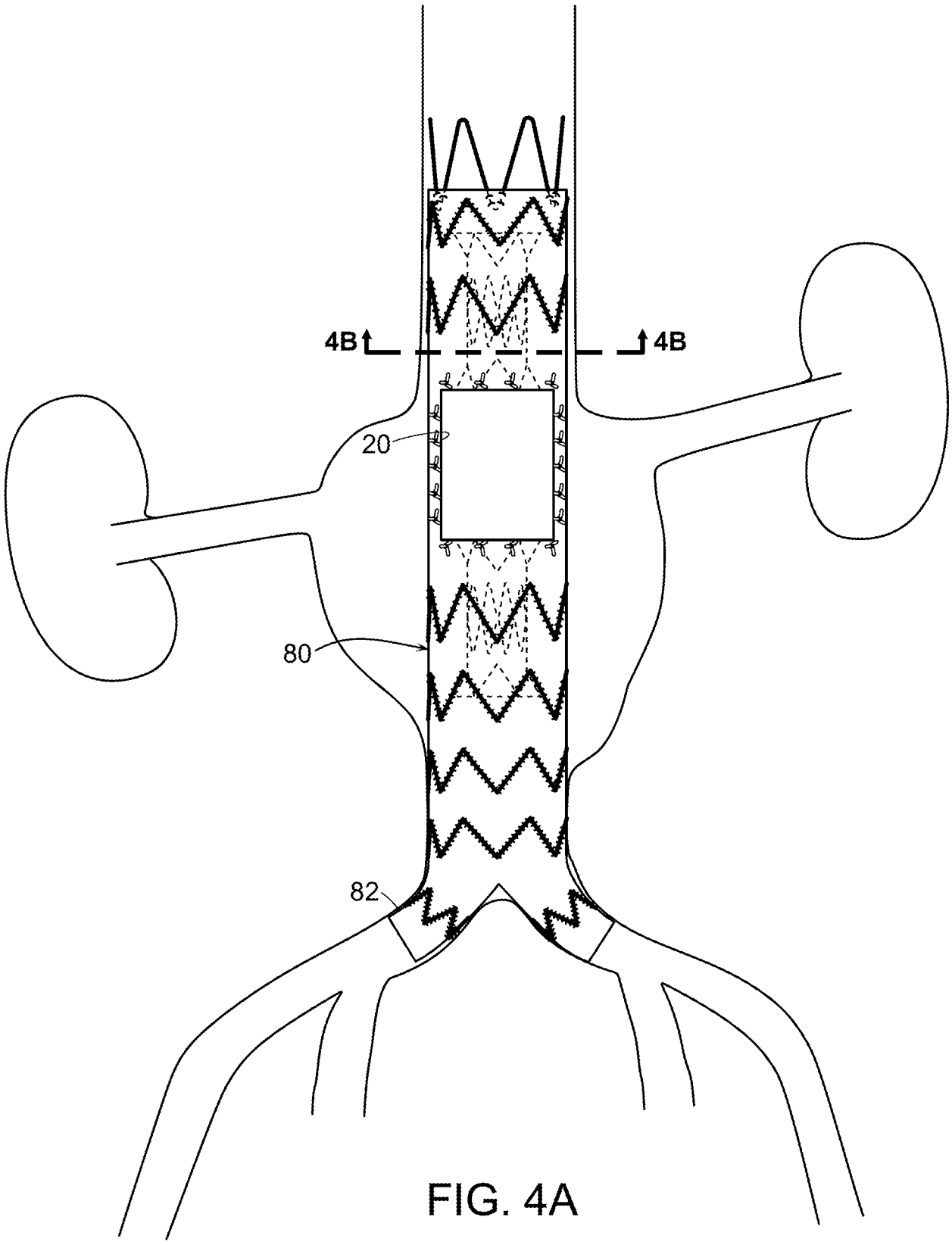

FIG. 4A

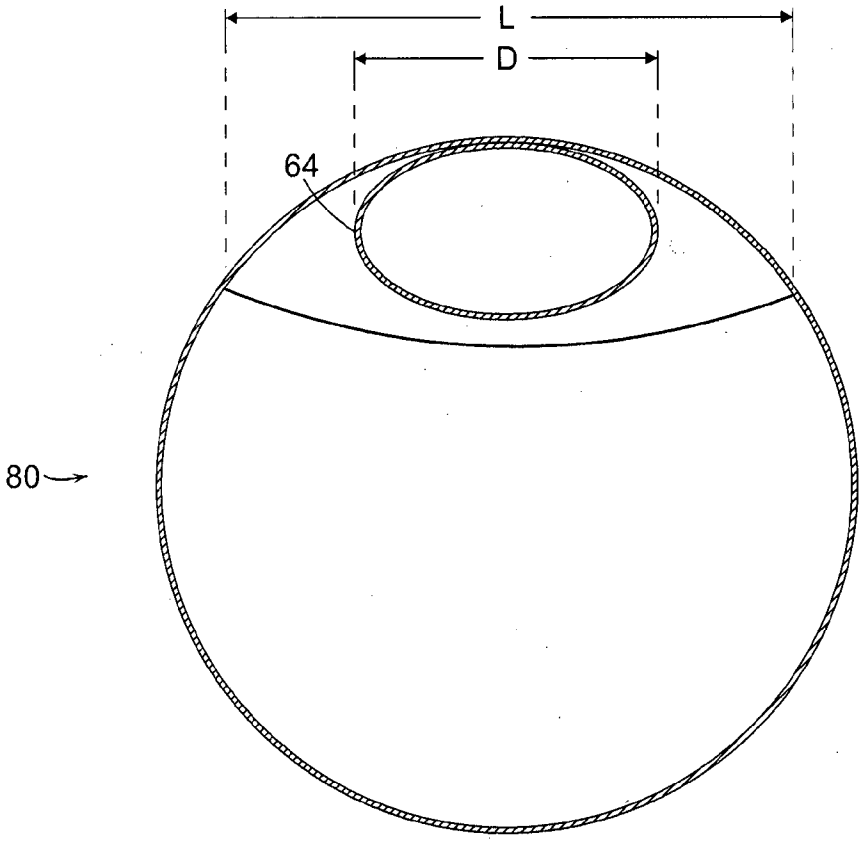

FIG. 4B

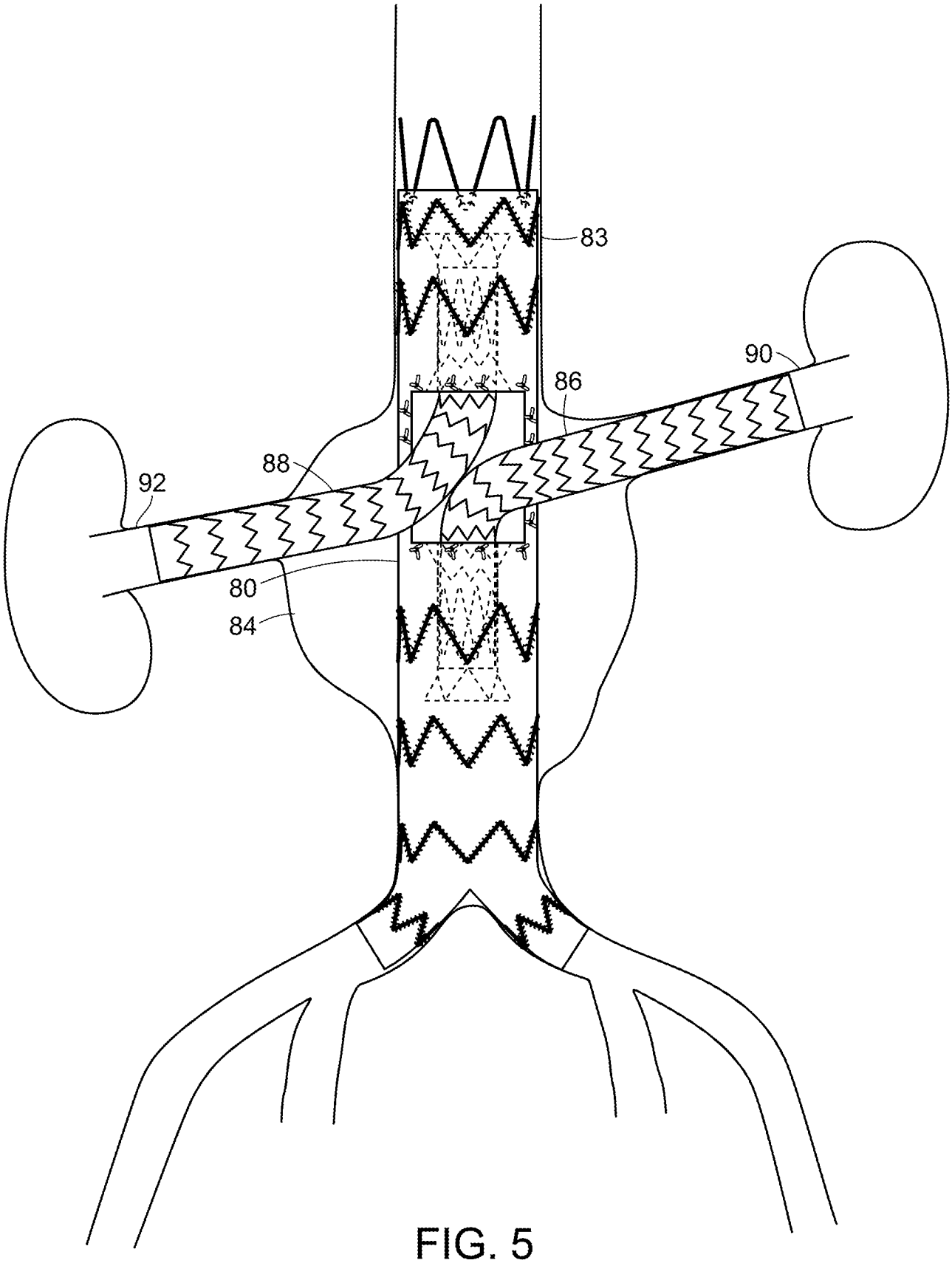

FIG. 5

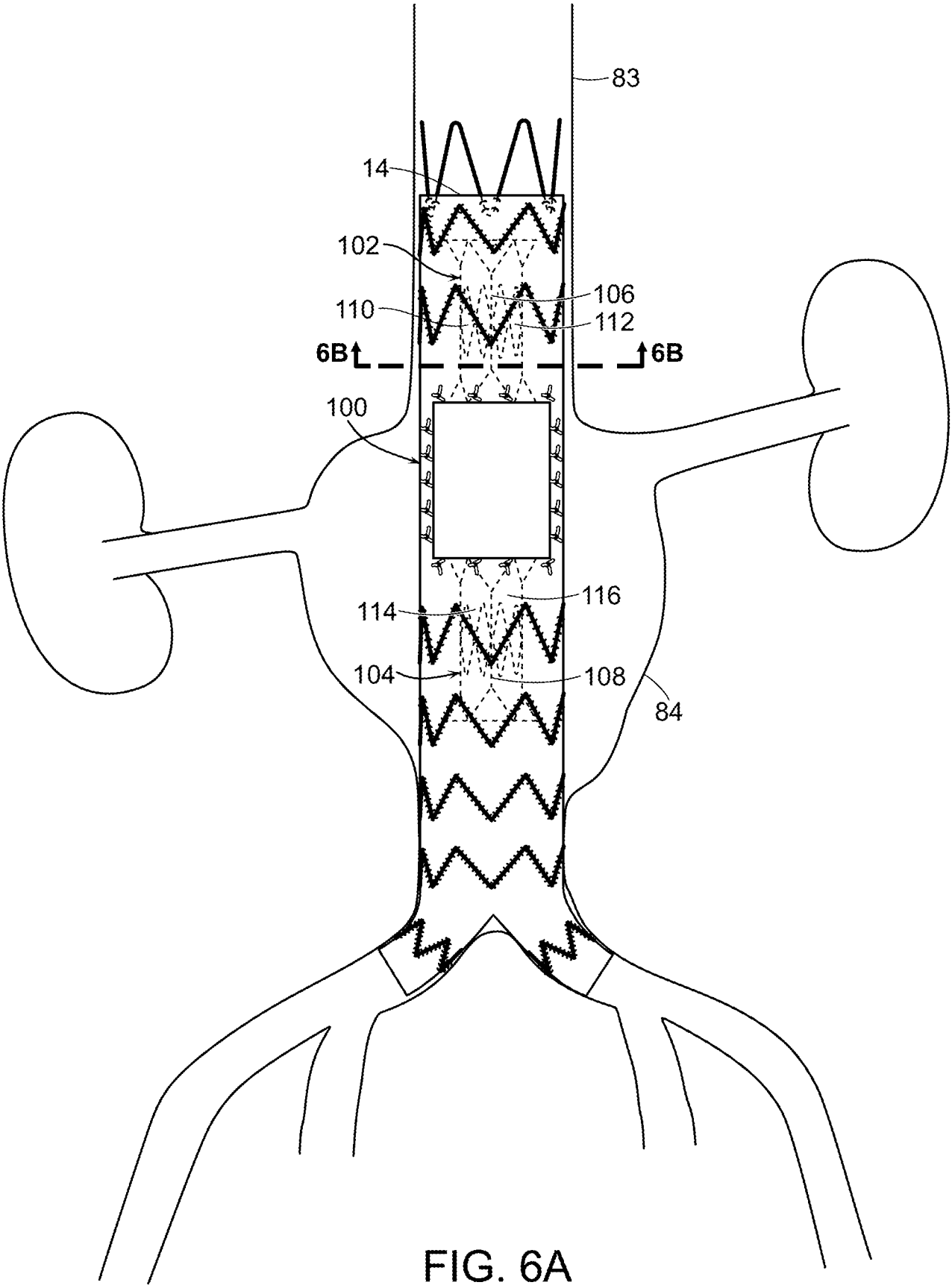

FIG. 6A

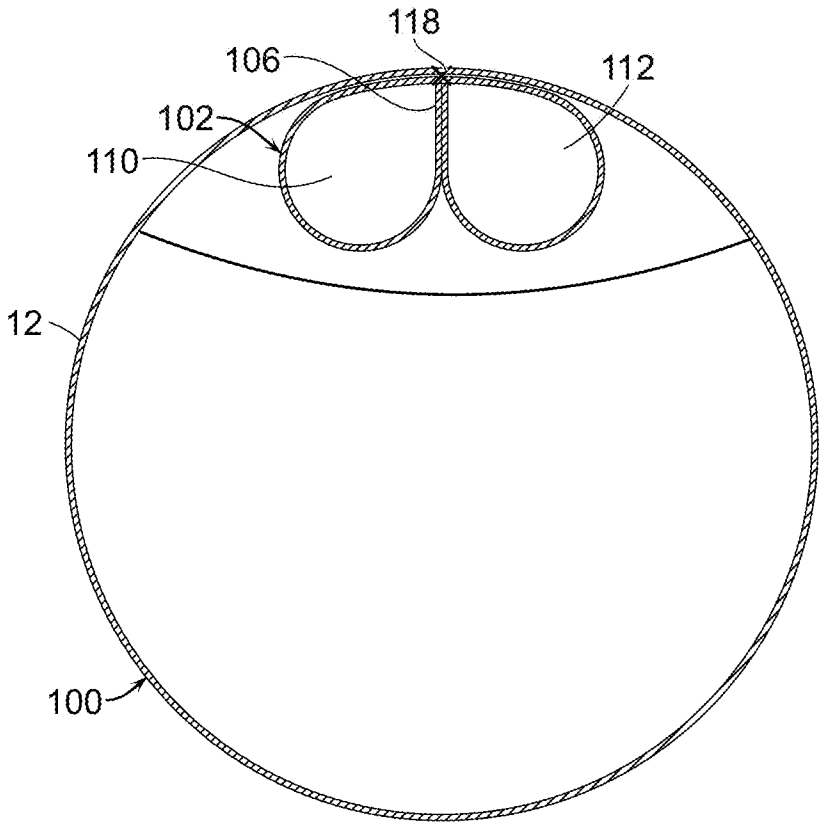

FIG. 6B

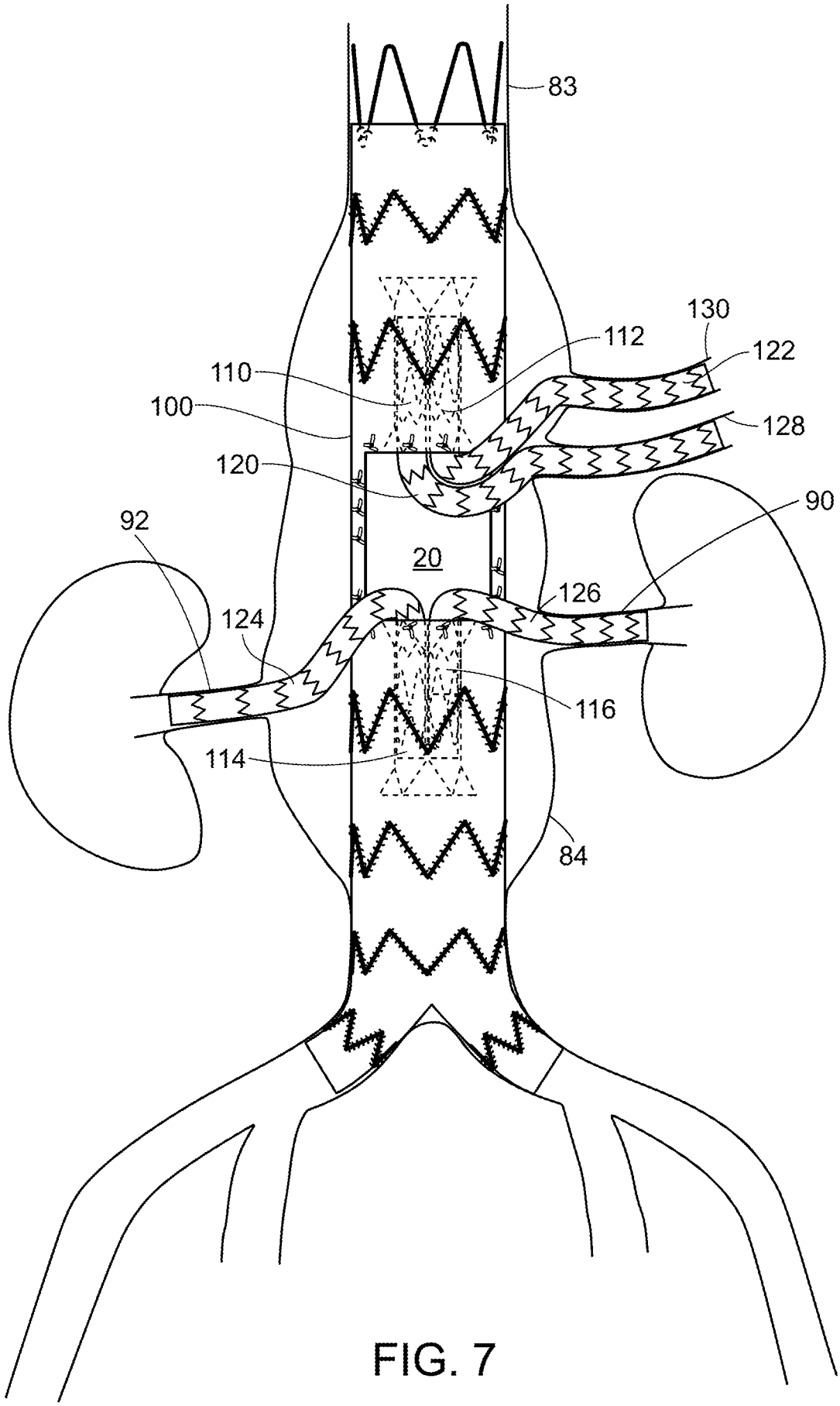

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/034223

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

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

1. [X] Claims Nos.: 23
because they relate to subject matter not required to be searched by this Authority, namely:

Claim 23 is considered a method for treatment of the human or animal body by surgery (Rule 39.1(iv) PCT) as it involves the insertion and implantation of an implant in the aorta.

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

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

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

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

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

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

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

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

Remark on Protest

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

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

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/034223

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61F2/07
ADD.

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)
A61F

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/211506 A1 (DAKE MICHAEL D [US] ET AL) 15 August 2013 (2013-08-15) paragraphs [0018] - [0024], [0037]; figures 1-4, 10	1-22
X	CN 102 973 303 B (CHEN HONGWEI) 4 February 2015 (2015-02-04) abstract; figures 1-3	1,3-5, 14,15
A	US 2012/158121 A1 (IVANCEV KRASNODAR [GB] ET AL) 21 June 2012 (2012-06-21) paragraphs [0038] - [0046]; figures 1-6	1-22

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

☒ See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 August 2017	22/08/2017

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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/034223

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		US 2012158121 A1	21-06-2012