



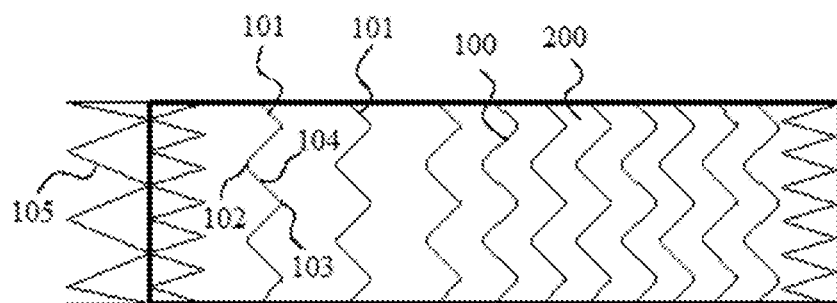


Fig. 1

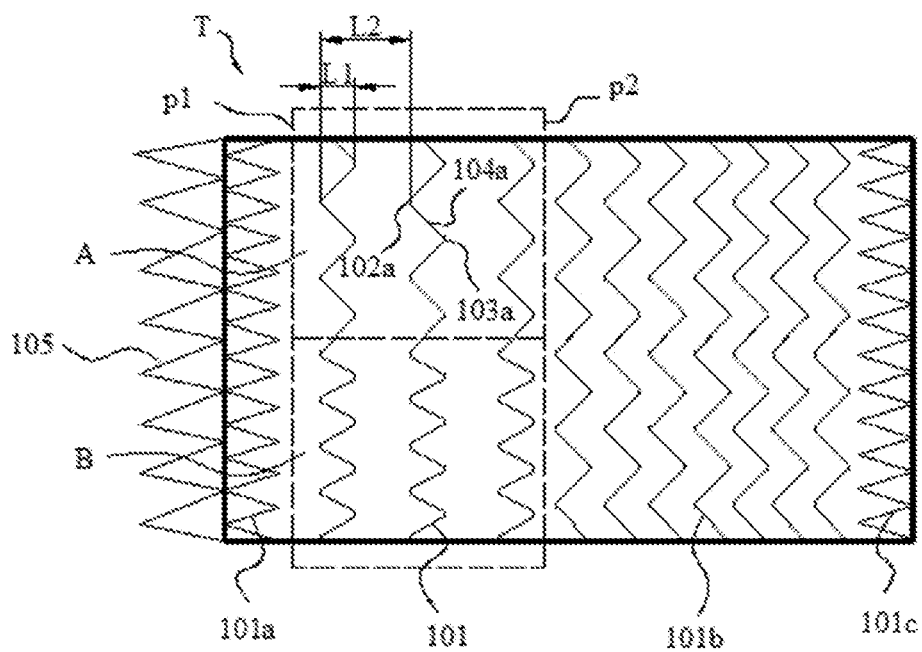


Fig. 2

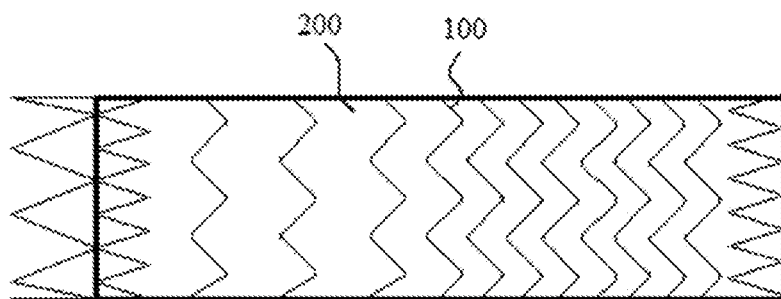


Fig. 3

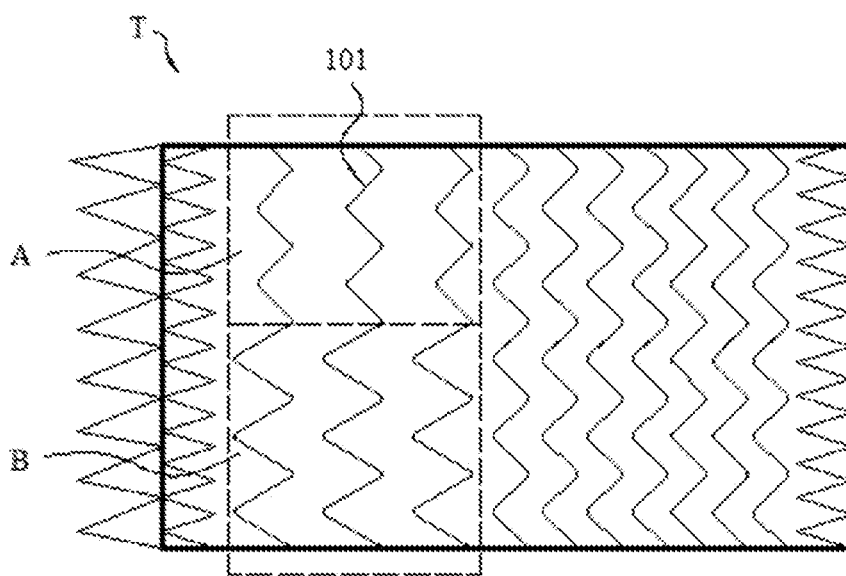


Fig. 4

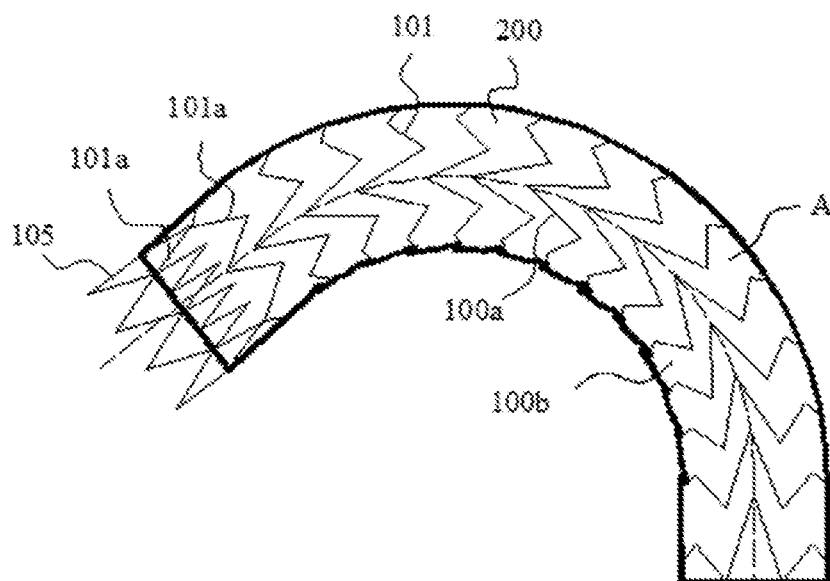


Fig. 5

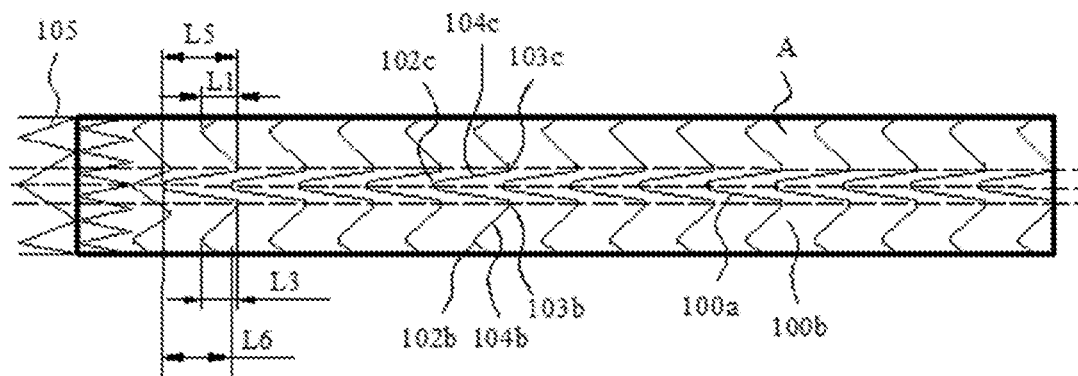


Fig. 6

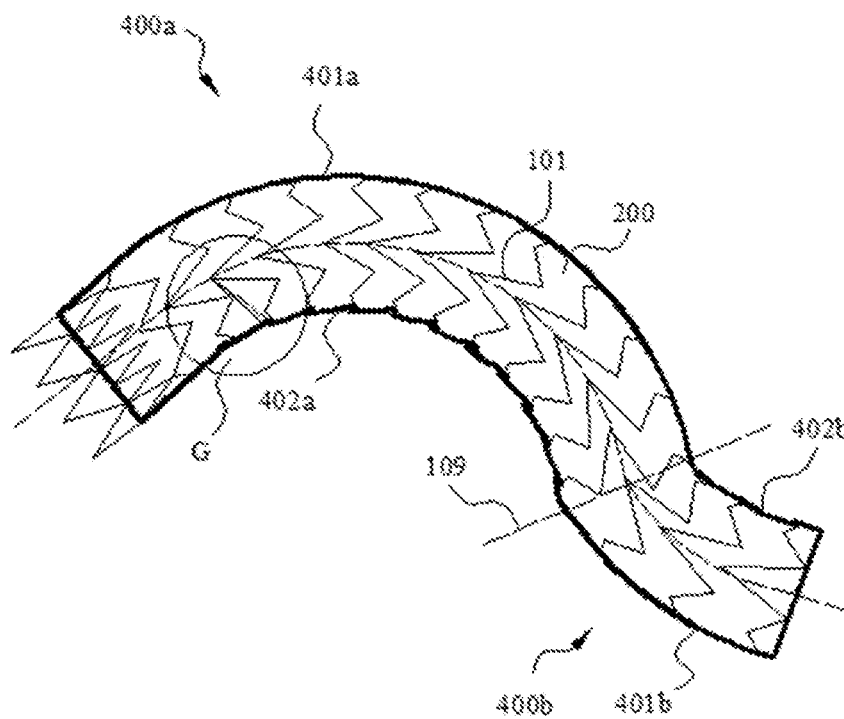


Fig. 7

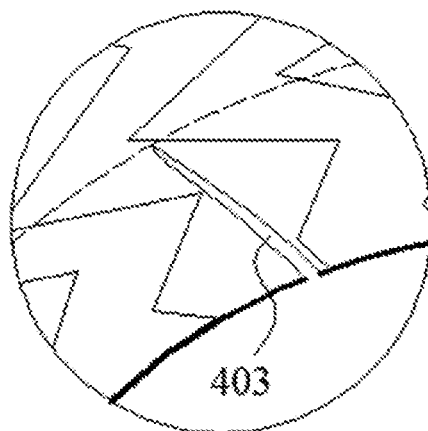


Fig. 8

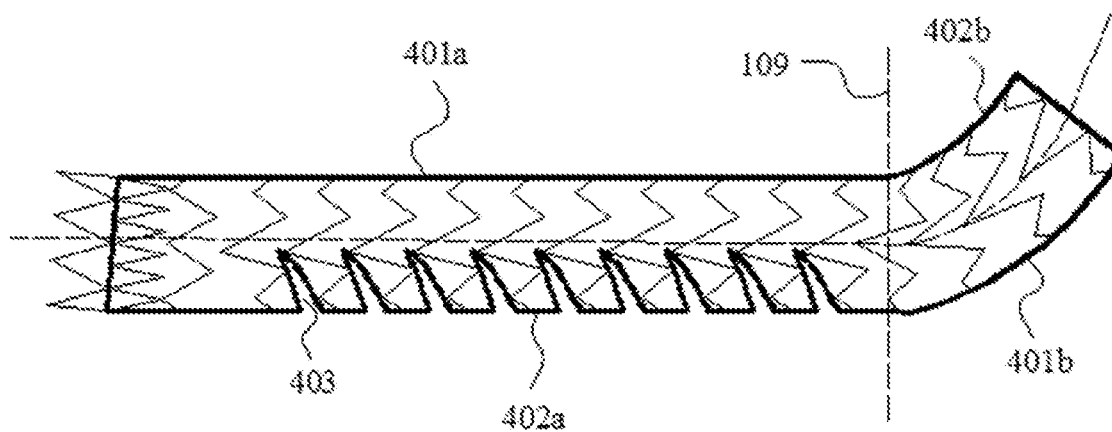


Fig. 9

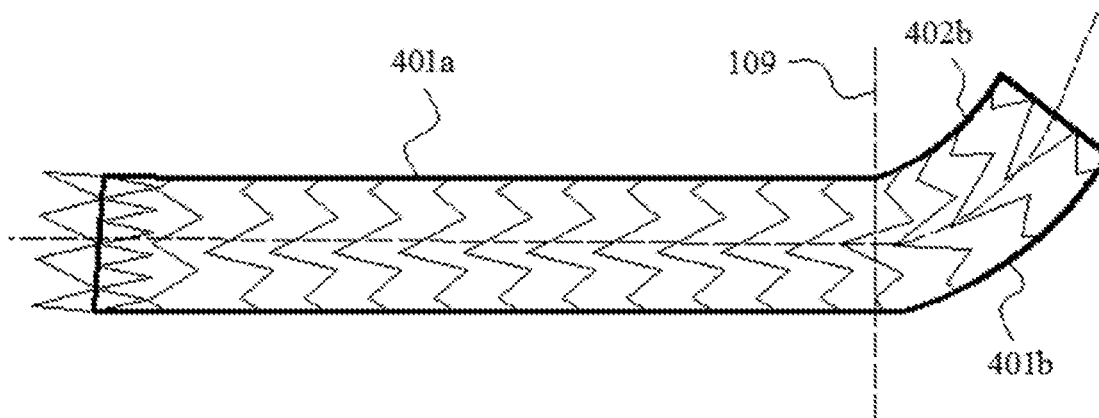


Fig. 10

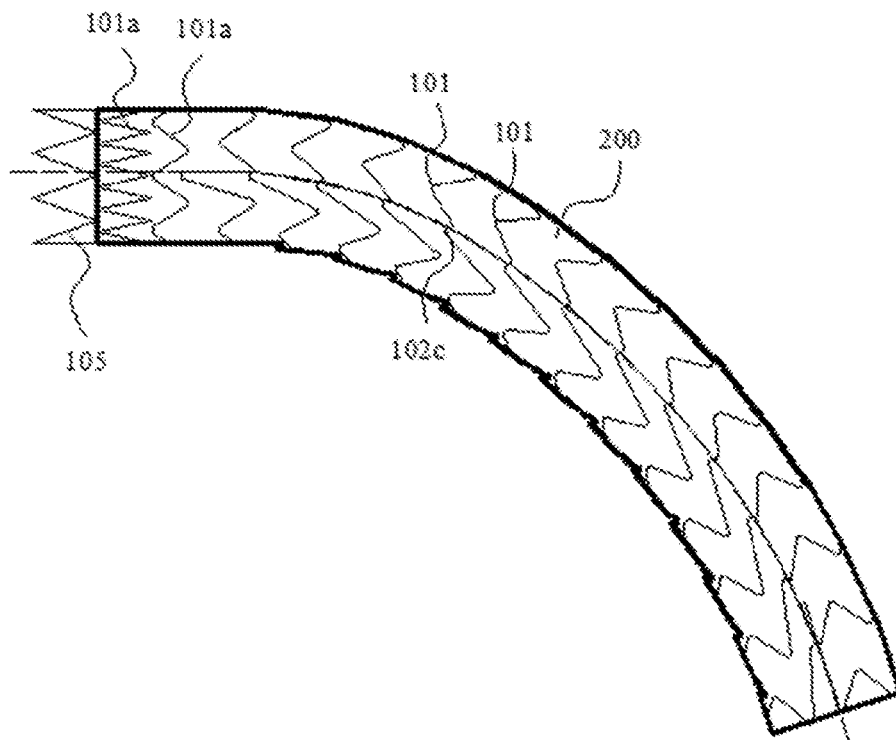


Fig. 11

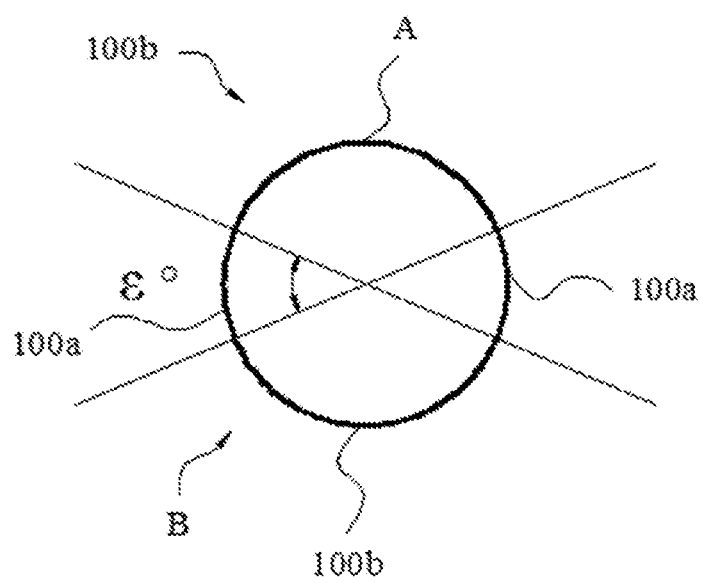


Fig. 12

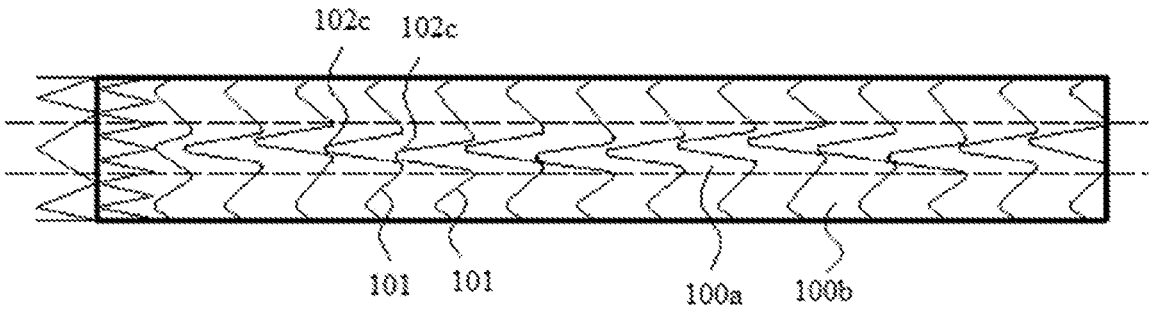


Fig. 13

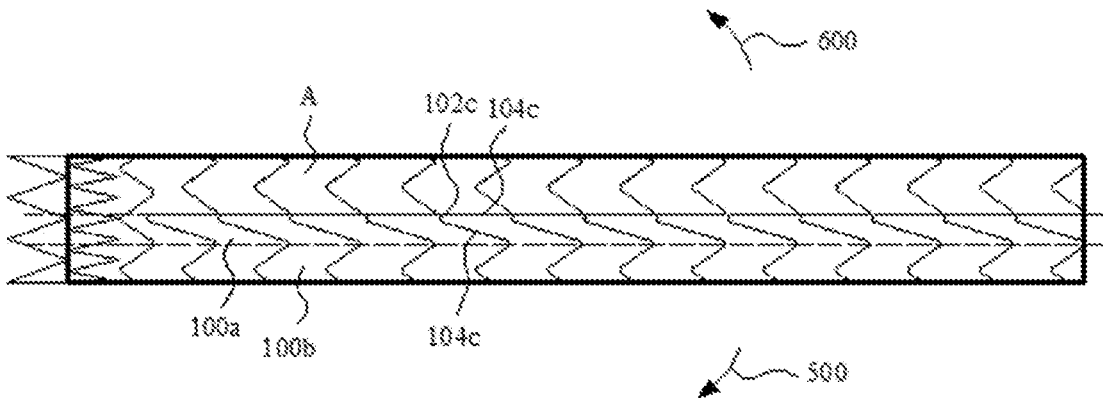


Fig. 14

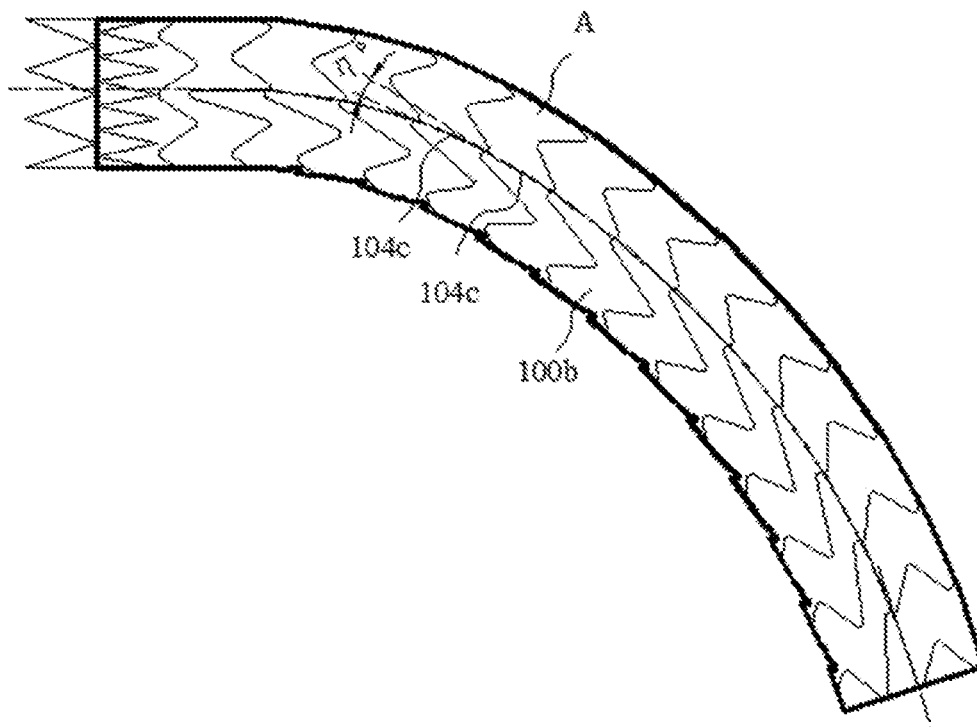


Fig. 15

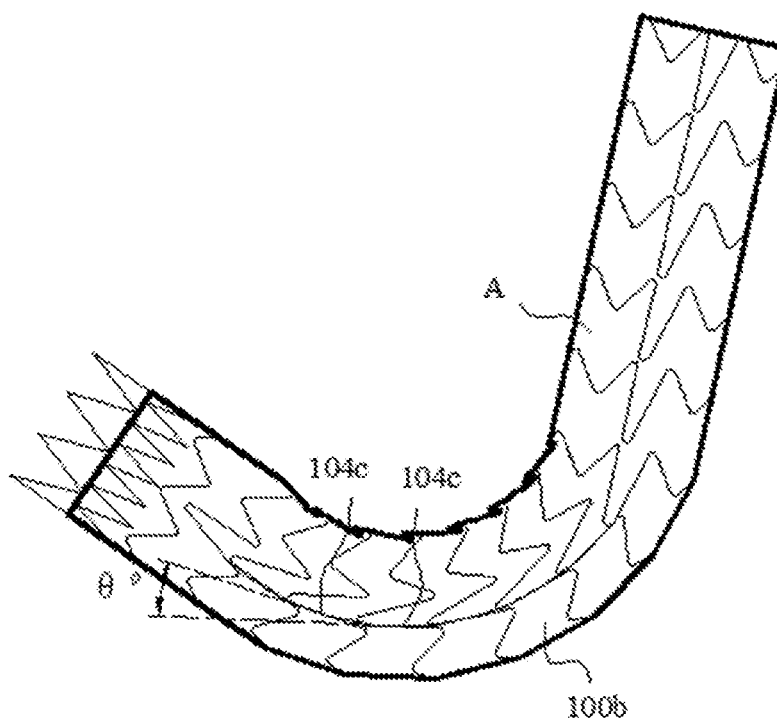


Fig. 16

## STENT GRAFT

### FIELD

[0001] The embodiments relate to the field of medical apparatuses, and, in particular, to a stent graft.

### BACKGROUND

[0002] Over the past decade, endovascular stent-grafts for aortic dissections have been widely used in lesions such as thoracic and abdominal aortic aneurysms and arterial dissections, and have become a first-line treatment with definite efficacy, less trauma, faster recovery, and fewer complications. However, for special lesions such as aortic arch, celiac trunk, bilateral renal artery or superior mesenteric artery, the use of stent grafts can affect the blood supply to the arterial branch vessels. In view of this, the stent graft is usually opened in situ by laser or mechanically during the operation, so that the stent graft produces an expected hole, and then the branch stent is transported to the hole and docked with the stent graft. Such a therapeutic regimen overcomes the dependence on the anatomical structure of human branch vessels.

[0003] In the prior art, when the stent graft is opened in situ, there are some problems that the window size is difficult to meet the requirements, or the window edge support is poor.

### SUMMARY

[0004] The embodiments provide a stent graft suitable for in-situ fenestration to overcome the defects in the prior art.

[0005] In order to overcome the defects in the prior art, exemplary solutions are provided as follows.

[0006] Provided is a stent graft, where at least one region T is disposed in an axial direction of the stent graft; the region T includes a plurality of wavy rings; the region T further includes, in a circumferential direction, a region A and a region B connected with the region A; the ratio of the area of the region A to the area of the region T ranges from  $\frac{1}{4}$  to  $\frac{2}{3}$ ; the ratio of the coverage rate of the wavy rings in the region A to the coverage rate of the wavy rings in the region B ranges from  $\frac{1}{5}$  to  $\frac{9}{10}$ ; and the ratio of the coverage rate of the wavy rings in any circular region with a diameter of 20 mm within the region A to the coverage rate of the wavy rings in the region A ranges from 0.7 to 1.3.

[0007] In the stent graft, the ratio of the area of the region A to the area of the region T ranges from  $\frac{1}{3}$  to  $\frac{1}{2}$ ; the ratio of the coverage rate of the wavy rings in the region A to the coverage rate of the wavy rings in the region B ranges from  $\frac{2}{5}$  to  $\frac{9}{10}$ ; and the ratio of the coverage rate of the wavy rings in any circular region with a diameter of 20 mm within the region A to the coverage rate of the wavy rings in the region A ranges from 0.9 to 1.1.

[0008] In the stent graft, the region A includes a plurality of first wavy segments arranged in a spaced manner in the axial direction, the wave height of the first wavy segment is L1, the spacing between the adjacent first wavy segments is L2, and L1/L2 is greater than or equal to  $\frac{1}{4}$  and less than or equal to 3.

[0009] In the stent graft, L1 is greater than or equal to 4 mm and less than or equal to 12 mm.

[0010] In the stent graft, the wave heights of the plurality of first wavy segments are equal, and the spacings between the adjacent first wavy segments are equal.

[0011] In the stent graft, the region B includes keel regions and non-keel regions that are distributed in the circumferential direction, each non-keel region includes a plurality of second wavy segments distributed in the axial direction, each keel region includes a plurality of third wavy segments distributed in the axial direction, and the wave heights of the third wavy segments are greater than the wave heights of the first wavy segments and the wave heights of the second wavy segments.

[0012] In the stent graft, the ratio of the wave height of the second wavy segment to the wave height of the first wavy segment ranges from 0.8 to 1.2, and the ratio of the spacing between the adjacent second wavy segments to the spacing between the adjacent first wavy segments ranges from 0.8 to 1.2.

[0013] In the stent graft, the wave included angle of the third wavy segment is less than the wave included angle of the first wavy segment and the wave included angle of the second wavy segment.

[0014] In the stent graft, the included angle of the keel region in the circumferential direction is  $15^{\circ}$ - $45^{\circ}$ .

[0015] In the stent graft, the stent graft further includes an anchoring bare stent located at at least one end of the stent graft.

[0016] Thus a stent graft of the embodiments can have at least the following beneficial effects: the stent graft has a region A and a region B that are distributed in the circumferential direction, the ratio of the coverage rate of the wavy rings in the region A to the coverage rate of the wavy rings in the region B is  $\frac{1}{5}$ - $\frac{9}{10}$ , and the coverage rate of the wavy rings in the region A is relatively low, so that the region A is more favorable for fenestration; and the axial supporting effect of the whole region T can be enhanced by the relatively high coverage rate of the wavy rings in the region B.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The embodiments will be further described in combination with accompanying drawings. In the drawings:

[0018] FIG. 1 is a schematic diagram of a stent graft provided by a first exemplary embodiment;

[0019] FIG. 2 is a radially expanded view of the stent graft shown in FIG. 1;

[0020] FIG. 3 is a schematic diagram of a stent graft provided by a second exemplary embodiment;

[0021] FIG. 4 is a radially expanded view of the stent graft shown in FIG. 3;

[0022] FIG. 5 is a schematic diagram of a straight tubular stent graft provided by a third exemplary embodiment in a bent state;

[0023] FIG. 6 is a structural schematic diagram of the stent graft shown in FIG. 5 in a natural state;

[0024] FIG. 7 is a structural schematic diagram of a bent stent graft provided by a third exemplary embodiment;

[0025] FIG. 8 is an enlarged view of a portion G of the stent graft shown in FIG. 7;

[0026] FIG. 9 is a structural schematic diagram of a first bent section of the stent graft shown in FIG. 7 after being straightened along a first profile line;

[0027] FIG. 10 is a structural schematic diagram of wavy rings of the stent graft shown in FIG. 7 after being rearranged in the axial direction according to the wave spacing at the first profile line and covered with membranes;

[0028] FIG. 11 is a structural schematic diagram of the wavy rings of the stent graft shown in FIG. 5 which abut against mutually;

[0029] FIG. 12 is a structural schematic diagram of keel regions of the stent graft shown in FIG. 5 that are distributed on an outer surface of the stent graft;

[0030] FIG. 13 is a schematic diagram of a stent graft provided by a fourth exemplary embodiment;

[0031] FIG. 14 is a schematic diagram of a stent graft provided by a fifth exemplary embodiment;

[0032] FIG. 15 is a structural schematic diagram of the stent graft shown in FIG. 14 after being bent in a direction indicated by a first arrow; and

[0033] FIG. 16 is a structural schematic diagram of the stent graft shown in FIG. 14 after being bent in a direction indicated by a second arrow.

#### DETAILED DESCRIPTION OF THE EMBODIMENTS

[0034] In order that the technical features, objects and effects of the embodiments may be more clearly appreciated, embodiments thereof will now be described in detail with reference to the accompanying drawings.

[0035] It should be noted that “distal” and “proximal” are used as orientation words, which are customary terms in the field of interventional medical apparatuses, where the “distal” means an end away from an operator during a surgical procedure, and the “proximal” means an end close to the operator during the surgical procedure. An axial direction refers to a direction which is parallel to the connecting line of a distal center and a proximal center of a medical apparatus; a radial direction refers to a direction perpendicular to the axial direction; and the distance from the axis refers to the distance reaching the axis in the radial direction.

[0036] As shown in FIG. 1, a first exemplary embodiment provides a stent graft which is substantially of an open-ended and hollow tubular structure, a tube cavity of the stent graft forming a blood flow channel. The stent graft mainly includes a bare stent 100 and covering membranes 200 fixed to the bare stent 100.

[0037] The bare stent 100 is made of a material having good biocompatibility, such as nickel titanium, stainless steel, or the like. The bare stent 100 includes a plurality of wavy rings 101 that are sequentially arranged in a spaced manner. For example arranged in a parallelly spaced manner, from the proximal end to the distal end. It can be appreciated that, in other embodiments, the bare stent 100 may be of other structures, such as a mesh-like structure.

[0038] The covering membranes 200 are substantially middle-closed and open-ended tube cavity structures and made of high molecular materials with good biocompatibility, such as e-PTFE, PET, or the like. The covering membranes 200 are fixed to the plurality of wavy rings 101 to connect the plurality of wavy rings 101 and are enclosed to form a tube cavity with a longitudinal axis, and the tube cavity serves as a channel through which blood flows.

[0039] Each wavy ring 101 is a closed cylindrical structure, and includes a plurality of proximal vertexes 102, a plurality of distal vertexes 103, and supporting bodies 104 connecting the adjacent proximal vertexes 102 and distal vertexes 103, and the proximal vertexes 102 and distal vertexes 103 are wave crests and troughs of corresponding waves, respectively. The plurality of wavy rings 101 have the same or similar wavy shapes, for example, the wavy

rings 101 may be of Z-shaped waves, M-shaped waves, V-shaped waves or sinusoidal wave structures, or of other structures that are radially compressible to a very small diameter. The embodiment does not limit the structures of the wavy rings 101, the wave shapes of the wavy rings 101 may be set as required or desired, and the number of waves and the heights of the waves in each wavy ring 101 may be set as required or desired.

[0040] The stent graft may be prepared as follows: weaving a metal wire into a required wave shape, where the metal wire may be a nickel-titanium alloy wire with a wire diameter of, for example, 0.35 mm; and after heat setting, sleeving two end portions of the metal wire with a steel jacket and fixing by mechanical pressing so that the metal wire and the steel jacket are connected and fastened to form a wavy ring. After all the wavy rings are manufactured, surfaces of the wavy rings 101 which are sequentially arranged in a spaced manner are covered with membranes. For example, inner surfaces and outer surfaces of the wavy rings 101 may be integrally covered with e-PTPE, membranes, the wavy rings 101 are located between two covering membranes 200, and the e-PTFE covering membranes of an inner layer and an outer layer are bonded together by high-temperature pressing, thereby fixing the wavy rings 101 between the two covering membranes. It will be appreciated that in other embodiments the wavy rings 101 may also be sutured to a PET membrane.

[0041] Further, when formed by integrally cutting a metal tube, the wavy rings 101 are not required to be fixedly connected by the steel jacket. Alternatively, the wavy ring may be formed by welding two end points of the metal wire.

[0042] FIG. 2 is a radially expanded view of the stent graft shown in FIG. 1. As shown in FIG. 2, at least one region T is disposed in the axial direction of the stent graft, the region T is partitioned by two planes p1 and p2 respectively perpendicular to the axial direction of the stent graft, and a region shown by a dotted line frame in FIG. 2 is the region T which corresponds to a branch vessel on an aorta. A region T may correspond to one or more branch vessels, or multiple regions T may correspond to branch vessels at different positions, respectively. In other embodiments the planes p1 and p2 may be not perpendicular to the axial direction of the stent graft.

[0043] The region T includes, in a circumferential direction, a region A and a region B connected with the region A. The coverage rate of the wavy rings in the region A is less than the coverage rate of the wavy rings in the region B. For example, the ratio of the coverage rate of the wavy rings in the region A to the coverage rate of the wavy rings in the region B is  $\frac{1}{5}$ - $\frac{9}{10}$ , the ratio of the area of the region A to the area of the region T is within the range of  $\frac{1}{4}$ - $\frac{2}{3}$ , and the ratio of the coverage rate of the wavy rings in a circular region with the diameter of 20 mm that is arbitrarily selected in the region A to the coverage rate of the wavy rings in the region A is 0.7-1.3. The coverage rate of the wavy rings in a certain region of the stent graft defines the percentage of the wavy rings in the region on the stent graft, and the coverage rate of the wavy rings is calculated in a way that the surface area of the wavy ring projected onto an inner wall of a tube cavity of the stent graft in a certain region is divided by the surface area of the inner wall of the tube cavity of the stent graft and multiplied by 100%.

[0044] When the coverage rate of the wavy rings in a certain region is higher, the wavy rings distributed in the

region is denser, axial supporting force of the stent graft can be well guaranteed, and the stent graft is prevented from retracting into a tumor cavity. However, since the wavy rings limit the fenestration size, the fenestration size can hardly meet the requirement on the size of the branch vessel. When the coverage rate of the wavy rings in the region is lower, the wavy rings are sparsely distributed in the region, and the wavy rings do not limit the fenestration size. However, the axial supporting force of the region is poor, and the stent graft is prone to shortening in the blood vessel, resulting in that the stent graft possibly retracts into the tumor cavity. Meanwhile, the lower coverage rate of the wavy rings also easily leads the edge of a window to be far away from the wavy rings after fenestration, and with small supporting force from a window region, it is difficult to provide sufficient anchoring force for the branch stent implanted in the window position, easily leading to the separation of the branch stent from the stent graft; and without the limitation of the wavy rings in the fenestration position, the window is further expanded under the action of radial force of the branch stent, finally resulting in the separation of the branch stent from the stent graft. According to an embodiment, by arranging the region A and the region B with different coverage rates of the wavy rings in the circumferential direction, and by adjusting the ratio of the area of the region A to the area of the region B and adjusting the ratio of the coverage rate of the wavy rings in the region A to the coverage rate of the wavy rings in the region B, the region B of the stent graft can meet the axial supporting force to prevent the stent graft from shortening into the tumor cavity, and the region A can meet the requirements of fenestration. In addition, the ratio of the coverage rate of the wavy rings in the circular region with the diameter of 20 mm that is arbitrarily selected in the region A to the coverage rate of the wavy rings in the region A is 0.7-1.3, and the requirements of fenestration can also be well met in each position of the region A, thereby improving the adaptability of the stent graft.

[0045] Further, the ratio of the coverage rate of the wavy rings in the region A to the coverage rate of the wavy rings in the region B is  $\frac{3}{4}$ -%, the ratio of the area of the region A to the area of the region T is  $\frac{1}{3}$ -%, and the ratio of the coverage rate of the wavy rings in the circular region with a diameter of 20 mm that is arbitrarily selected in the region A to the coverage rate of the wavy rings in the region A is 0.9-1.1, so that the performance of the stent graft can be well guaranteed.

[0046] Referring to FIG. 2, the wavy ring 101 includes a first wavy segment located in the region A, where the first wavy segment includes a plurality of first proximal vertexes 102a, a plurality of first distal vertexes 103a, and first supporting bodies 104a connecting the adjacent first proximal vertexes 102a and first distal vertexes 103a. In the embodiment, the plurality of first distal vertexes 103a are located in the same plane perpendicular to the longitudinal axis.

[0047] The wave height of the first wavy segment is L1, the axial distance between the proximal vertex 102a of the first wavy segment and the corresponding proximal vertex 102a of the adjacent proximal vertex 102a is L2, and L1 and L2 meet the condition that  $L1/L2$  is greater than or equal to  $\frac{1}{4}$  and less than or equal to 3. The wave height of the first wavy segment refers to the distance between the first proximal vertex 102a and the first distal vertex 103a in the axial

direction. If  $L1/L2$  is less than  $\frac{1}{4}$ , L1 is relatively too small, and L2 is relatively too large, easily causing a fenestration edge to be away from the wavy ring 101 and a failure to provide sufficient supporting force for the fenestration edge by of the wavy ring 101, and finally causing separation of two stents. If  $L1/L2$  is greater than 3, L1 is relatively too large, and L2 is relatively too small, so that the fenestration size will be limited, and the fenestration is not facilitated. For example, L1 is greater than or equal to 4 mm and less than or equal to 12 mm. In the embodiment, the wave heights L1 of the plurality of first wavy segments are equal, and the spacings L2 between every two adjacent first wavy segments are equal.

[0048] The plurality of first wavy segments in the region A are arranged in a spaced manner in the axial direction, and the phase difference between two adjacent first wavy segments is 0-45°. In the embodiment, the phase difference between two adjacent first wavy segments is zero. The phase difference of zero means that a connecting line between a first proximal vertex 102a of the first wavy segment and a first proximal vertex 102a of an adjacent first wavy segment is parallel to the axis of the stent graft.

[0049] The wavy ring 101 further includes a second wavy segment located in the region B, the wave included angle of the first wavy segment is greater than the wave included angle of the second wavy segment, and the wave height of the first wavy segment is the same as the wave height of the second wavy segment. The wave included angle refers to an included angle between supporting bodies 104 connected to two sides of the same proximal vertex 102 or distal vertex 103; and the wave height refers to the relative distance between the adjacent proximal vertex 102 and distal vertex 103.

[0050] The spacing between two adjacent first wavy segments and the spacing between two adjacent second wavy segments may be set as desired, and the wave shapes, the number of waves, the wave heights, and the wave included angles of the first wavy segments and the second wavy segments may be set as desired.

[0051] Referring to FIG. 2, the stent graft further includes at least one proximal wavy ring 101a and at least one distal wavy ring 101c that are located at two ends of the region T, respectively.

[0052] The coverage rate of the wavy rings in the region where the at least one proximal wavy ring 101a is located is greater than the coverage rate of the wavy rings in the region T, the coverage rate of the wavy rings in the region where the at least one distal wavy ring 101c is located is greater than the coverage rate of the wavy rings in the region T, that is, the coverage rates of the wavy rings in the proximal region and the distal region are greater than the coverage rate of the wavy rings in the middle region of the stent graft. Since the coverage rates of the wavy rings at the two ends of the stent graft are high, the axial supporting effects at the two ends of the stent graft may be enhanced, and the two ends of the stent graft are prevented from causing the stent graft to swing under the impact of a blood flow.

[0053] The stent graft further includes at least one non-end wavy ring 101b located between the region T and the distal wavy ring 101c.

[0054] The coverage rate of the wavy rings in the region where the at least one non-end wavy ring 101b is located is greater than the coverage rate of the wavy rings in the region T, so as to enhance the integral axial supporting effect of the

stent graft. Meanwhile, the coverage rate of the wavy rings in the region where the at least one non-end wavy ring **101b** is located is less than the coverage rate of the wavy rings in the region where the at least one distal wavy ring **101c** is located.

**[0055]** The proximal wavy ring **101a**, the non-end wavy ring **101b** and the distal wavy ring **101c** are made of materials having good biocompatibility, such as nickel titanium, stainless steel or the like. The proximal wavy ring **101a**, the non-end wavy ring **101b**, and the distal wavy ring **101c** are of closed cylindrical structures. The proximal wavy ring **101a**, the non-end wavy ring **101b** and the distal wavy ring **101c** may be of Z-shaped wave, M-shaped wave, V-shaped wave or sinusoidal wave structures, or of other structures that are radially compressible to a very small diameter.

**[0056]** It will be appreciated that not only the numbers of the proximal wavy ring **101a**, the non-end wavy ring **101b**, and the distal wavy ring **101c** may be set as desired, but also the wave shapes, the number of waves, and the wave heights of the proximal wavy ring **101a**, the non-end wavy ring **101b** and the distal wavy ring **101c** may be set as desired.

**[0057]** The stent graft further includes an anchoring bare stent **105** located at one or two ends of the stent graft and connected with the proximal wavy ring **101a** or the distal wavy ring **101c**.

**[0058]** As shown in FIG. 3 and FIG. 4, a second exemplary embodiment provides a stent graft, which differs from the first embodiment in that the wave included angle of the first wavy segment is greater than the wave included angle of the second wavy segment, and the wave height of the first wavy segment is less than the wave height of the second wavy segment.

**[0059]** FIG. 5 shows a stent graft according to a third exemplary embodiment, which differs from the first embodiment in that the region B includes keel regions **100a** and non-keel regions **100b** that are distributed in the circumferential direction, and the region surrounded by dotted lines in FIG. 6 is the keel region **100a**.

**[0060]** The axial shortening rate of the keel region **100a** of the stent graft is less than the axial shortening rates of the non-keel region **100b** and the region A, and the axial shortening rate of the stent graft in the keel region **100a** is 10%-40%.

**[0061]** A method for calculating the shortening rate of the stent graft in the axial direction is as follows. Taking the length of the stent graft, which is in a straight tube shape, along the axial direction in a natural state as  $r$  and the diameter of the stent graft as  $d1$ , sleeving an inner tube with the diameter of  $d2$  ( $d2$  is less than  $d1$ , for example  $d2$  is equal to  $90\% \cdot d1$ ) out of the stent graft, applying pressure  $F$  ( $1N \leq F \leq 2N$ ) in the axial direction to the stent graft until the stent graft cannot shorten anymore to obtain the total length  $s$  of the reel region **100a**, and calculating the axial shortening rate of the stent graft in the reel region **100a** according to the formula  $(r-s)/r \times 100\%$ . Where  $(r-s)$  is an available maximum shortening value of the stent graft. The stent graft sleeves the inner tube for shortening, so that the phenomenon that the stent graft is folded when shortening can be effectively avoided, that is, the value of  $(r-s)$  is the available maximum shortening value when the stent graft is not folded.

**[0062]** When the stent graft is in a frustum shape, that is, the diameters of the two ends of the stent graft are different, the length of the stent graft in the axial direction in the

natural state is  $r$ , the diameter of the large end is  $d1$ , the diameter of the small end is  $d3$ , the stent graft sleeves a conical inner tube or a frustum inner tube with the same taper as the stent graft, and the perpendicular distance between the stent graft and the conical inner tube or the frustum inner tube is  $0.05 d1$ . The position of the small end of the stent graft is fixed and unchanged, the pressure  $F$  ( $1N \leq F \leq 2N$ ) in the axial direction is applied to the large end, and the total length of the stent graft when the stent graft cannot shorten anymore is  $s$ , and thus the shortening rate of the stent graft in the axial direction is  $(r-s)/r \times 100\%$ . The value of  $(r-s)$  is an available maximum shortening value of the stent graft. The stent graft sleeves the inner tube for shortening, so that the phenomenon that the stent graft is folded when shortening can be effectively avoided, that is, the value of  $(r-s)$  is the available maximum shortening value when the stent graft is not folded.

**[0063]** When the stent graft itself is manufactured and shaped into a bent shape, as shown in FIG. 7, the stent graft includes a first bent section **400a** and a second bent section **400b**, the first bent section **400a** has a first profile line **401a** on a greater curvature side of the first bent section **400a** and a second bent section **402a** on a small bent side of the first bent section **400a**, and the second bent section **400b** has a third profile line **401b** on a greater curvature side of the second bent section **400b** and a fourth profile line **402b** on a small bent side of the second bent section **400b**. Two exemplary methods for calculating the shortening rate of the bent section of the stent graft may be provided. One method is as follows: referring to FIG. 8 together, by taking the first bent section **400a** as an example, partitioning the first bent section **400a** with a plane **109** perpendicular to the axial direction of the stent graft; cutting a plurality of notches **403** in the covering membranes **200** close to the second profile line **402a**, where the sizes of the notches **403** can ensure that the stent graft is straightened along the first profile line **401a** (or cutting a plurality of notches **403** in the covering membranes **200** close to the second profile line **402a**, where the sizes of the notches **403** can exactly ensure that the stent graft is straightened along the first profile line **401a**); after the first bent section **400a** is straightened as shown in FIG. 9, obtaining the length  $r$  and the diameter  $d1$  of the straightened first bent section **400a**; sleeving an inner tube with a diameter of  $d2$  ( $d2$  is less than  $d1$ , For example  $d2$  is equal to  $90\% \cdot d1$ ) with the straightened first bent section **400a**; applying pressure  $F$  ( $1N \leq F \leq 2N$ ) in the axial direction to the stent graft till the stent graft cannot shorten to obtain the total length  $s$  of the region B; and calculating the axial shortening rate of the stent graft in the region B according to the formula  $(r-s)/r \times 100\%$ . Another method is as follows: also by taking the first bent section **400a** as an example, re-arranging the wavy rings **101** in the axial direction according to the wave spacing between the wavy rings **101** at the first profile line **401a**, covering the wavy rings **101** with membranes (covering materials and a selected process are kept consistent with those of the original stent), as shown in FIG. 10, and then calculating the shortening rate according to the above-mentioned method for calculating the shortening rate.

**[0064]** During the bending of the stent graft, when any one of the keel region **100a**, the non-keel region **100b** or the region A reaches the available maximum shortening value, a rigid axial supporting structure is formed in the region, so that the stent graft cannot continue to be bent. Referring to FIG. 11, during the bending of the stent graft, one wavy ring

**101** of the stent graft moves in the direction of pressure together with portions of the covering membranes **200** fixed to the wavy ring **101**, the portions of the covering membranes **200** fixed to the wavy ring **101** move together with portions of the covering membranes **200** distributed at the periphery of the wavy ring **101**, immediately the portions of the covering membranes **200** distributed at the periphery of the wavy ring **101** pull another wavy ring **101** nearby to move towards one side close to the wavy ring **101** till the wavy ring **101** cannot keep moving, and at this time a rigid axial supporting structure is formed on the stent graft, so that the stent graft is prevented from continuing to shorten anymore.

**[0065]** When the axial shortening rate of the stent graft in the keel region **100a** is less than 10%, the shortening rate of the keel region **100a** is too small, and no matter to which direction the stent graft is bent, the keel region **100a** easily reaches the available maximum shortening value, and the keel region **100a** cannot shorten anymore, thereby restricting the stent graft from continuing to be bent. When the axial shortening rate of the stent graft in the keel region **100a** is greater than 40%, the axial supporting effect of the stent graft is poor, and the stent graft may enter the tumor cavity when the distal end of the stent graft shortens towards the proximal end of the stent graft, thus threatening the life of a patient. When the shortening rate of the stent graft in the keel region **100a** is 10-40%, the stent graft can be bent towards all directions to adapt to bent blood vessels, and sufficient axial support can be provided for the stent graft to achieve the axial shortening prevention effect, thus maintaining the tube cavity shape of the stent graft. For example, the axial shortening rate of the stent graft in the keel region **100a** is 20-30%.

**[0066]** Referring to FIG. 12, the circumferential angle covered by the keel region **100a** on an outer surface of the stent graft is  $\epsilon^\circ$  which is greater than or equal to  $15^\circ$  and less than or equal to  $45^\circ$ . When  $\epsilon^\circ$  is less than  $15^\circ$ , the circumferential angle covered by the keel region **100a** on the outer surface of the stent graft is small, so that poor axial supporting effect of the entire stent graft may be caused, and the stent graft may easily swing and retract under the impact of a blood flow, finally causing the stent graft to retract into the tumor cavity, and endangering the life of the patient; and when  $\epsilon^\circ$  is greater than  $45^\circ$ , the circumferential angle covered by the keel region **100a** on the outer surface of the stent graft is large, which is not conducive to stent bending. When  $\epsilon^\circ$  is greater than or equal to  $15^\circ$  and less than or equal to  $45^\circ$ , sufficient axial support can be provided for the stent graft, and when the stent graft is applied to a more bent blood vessel, no folding occurs, thereby keeping the tube cavity smooth, and enabling the stent graft to adapt to a wider range of vascular morphology.

**[0067]** For example, the circumferential angle  $\epsilon^\circ$  covered by each keel region **100a** on the outer surface of the stent graft is in the range of  $20^\circ$ - $30^\circ$ . In addition, the number of the keel regions **100a** is two, and the two keel regions **100a** are symmetrically distributed in the circumferential direction of the stent graft.

**[0068]** As shown in FIG. 6, the wavy rings **101** further include third wavy segments located in the keel region **100a**, the wave heights of the third wavy segments of the keel region **100a** being greater than the wave heights of the second wavy segments of the non-keel region **100b** and the wave heights of the first wavy segments of the region A. The

wave height of the first wavy segment is **L1**, the wave height of the second wavy segment is **L3**, the wave height of the third wavy segment is **L5**, and **L1**, **L3** and **L5** meet the conditions that  $L3/L5$  is greater than or equal to  $\frac{1}{3}$  and less than 1 and  $L1/L5$  is greater than or equal to  $\frac{1}{3}$  and less than 1. When  $L3/L5$  is less than  $\frac{1}{3}$  or  $L1/L5$  is less than  $\frac{1}{3}$ , dense distribution of local waves in the keel region **100a** is easily caused, which affects the bending property of the stent graft in this position, or sparse distribution of local waves in the non-keel region **100b** is caused, which results in a poor supporting effect of the stent graft in this position and high probability of deformation.

**[0069]** For example, the second wavy segment includes at least one second proximal vertex **102b**, at least one second distal vertex **103b**, and a third supporting body **104b** connecting the adjacent second proximal vertex **102b** and second distal vertex **103b**; and the third wavy segment includes at least one third proximal vertex **102c**, at least one third distal vertex **103c**, and a third supporting body **104c** connecting the adjacent third proximal vertex **102c** and third distal vertex **103c**. The wave height **L3** of the second wavy segment refers to the distance in the axial direction between the second proximal vertex **102b** and the second distal vertex **103b**, and the wave height **L5** of the third wavy segment refers to the distance in the axial direction between the third proximal vertex **102c** and the third distal vertex **103c**. In the embodiment, the second distal vertex **103b** and the third distal vertex **103c** are located in the same plane perpendicular to the longitudinal central axis of the stent graft.

**[0070]** Referring to FIG. 6, the distance in the axial direction between the third proximal vertex **102c** of the third wavy segment and a corresponding third proximal vertex **102c** of the adjacent wavy ring **101** is **L6**, where **L5** and **L6** meet the condition that  $L6/L5$  is greater than or equal to  $\frac{1}{4}$  and less than or equal to  $\frac{3}{2}$ , so that the wave distribution in the keel region **100a** is uniform. For example, **L5** is greater than or equal to 8 mm and less than or equal to 18 mm, for example, **L5** is greater than or equal to 12 mm and less than or equal to 14 mm.

**[0071]** Since the wavy ring **101** has at least one wave crest with high wave height in the keel region **100a** and the plurality of distal vertexes **103** are located in the same plane perpendicular to the longitudinal axis, when the stent graft shortens, the third proximal vertexes **102c** on one wavy ring **101** easily abut against another wavy ring **101**, and the wavy rings **101** in the keel region **100a** abut against mutually; and when the wavy rings **101** in the keel region **100a** abut against mutually, a rigid axial supporting structure is formed on the stent graft to prevent the stent from continuing to shorten. By arranging the keel regions **100a** on the stent graft, various bending requirements of the stent graft can be met, and sufficient axial supporting force can be provided for the stent graft, thereby preventing the stent graft from shortening into the tumor cavity. Since the wave height of the third wavy segment of the keel region **100a** is greater than the wave height of the second wavy segment of the non-keel region **100b** and the wave height of the first wavy segment of the region A, that is, the coverage rate of the wavy rings in the keel region **100a** is relatively high, the relatively low coverage rate of wavy rings may be set in the non-keel region **100b** to enable the non-keel region **100b** to meet the fenestration requirement of the stent graft. For example, the ratio of the wave height of the second wavy

segment of the non-keel region **100b** to the wave height of the first wavy segment of the region A is 0.8-1.2, and the ratio of the spacing between two adjacent second wavy segments to the spacing between two adjacent first wavy segments is 0.8-1.2.

[0072] In an embodiment, the third wavy segments include a third proximal vertex **102c**, the connecting lines between the third proximal vertex **102c** of the adjacent third wavy segments are parallel to the axis of the stent graft, and the wave included angles of the third wavy segments are less than the wave included angles of the first wavy segments and the wave included angles of the second wavy segments.

[0073] The wave shapes, the number of waves, the wave heights, and the wave included angles of the third wavy segments and the second wavy segments may be set as desired. For example, the third wavy segment has one V-shaped wave with a wave included angle  $30^{\circ}$ - $40^{\circ}$  and a wave height 12-14 mm. The second wavy segment has 3 to 5 V-shaped waves with a wave included angle of  $60^{\circ}$ - $70^{\circ}$  and a wave height 6-10 mm.

[0074] Further, referring to FIG. 5, at least one proximal wavy ring **101a** is disposed at one end of the plurality of wavy rings **101**.

[0075] The axial shortening rate between the proximal wavy ring **101a** and its adjacent wavy ring **101** is less than 10%, so as to enhance the axial supporting effects of end portions of the stent graft, and prevent the two ends of the stent graft from causing the stent graft to swing under the impact of the blood flow.

[0076] When the number of the proximal wavy rings **101a** is at least two, the axial shortening rate between the at least two proximal wavy rings **101a** is less than 3%, so as to enhance the axial supporting effects of end portions of the stent graft, and prevent the end portions of the stent graft from causing the stent graft to swing under the impact of the blood flow. For example, the axial shortening rate between the at least two proximal wavy rings **101a** is zero.

[0077] FIG. 13 shows a stent graft provided by a fourth exemplary embodiment, which differs from the third embodiment in that a connecting line between the third proximal vertex **102c** of the adjacent third wavy segments is disposed obliquely with respect to the axis of stent graft.

[0078] FIG. 14 shows a stent graft provided by a fifth exemplary embodiment, which differs from the third embodiment in that the third supporting bodies **104c** that are connected to one sides of the third proximal vertex **102c** and close to the region A are distributed in the axial direction parallel to the stent graft, and the third supporting bodies **104c** that are connected to the other sides of the third proximal vertex **102c** and close to the non-keel region **100b** are disposed obliquely with respect to the axis direction of the stent graft.

[0079] When the stent graft shown in FIG. 14 is bent in a direction indicated by a first arrow **500**, referring to FIG. 15, the third supporting bodies **104c** of the adjacent third wavy segments adjacent to the region A abut against mutually to form an axial support, and the included angle between the third supporting bodies **104c** of the adjacent third wavy segments adjacent to the region A is  $\eta^{\circ}$ . When the stent graft shown in FIG. 14 is bent in a direction indicated by a second arrow **600**, referring to FIG. 16, the third supporting bodies **104c** of the adjacent third wavy segments adjacent to the non-keel region **100b** abut against mutually to form an axial

support, and the included angle between the third supporting bodies **104c** of the adjacent third wavy segments adjacent to the non-keel region **100b** is  $\theta^{\circ}$ . As can be seen from the figures,  $\eta^{\circ}$  is less than  $\theta^{\circ}$ . When the third supporting bodies **104c** of the adjacent third wavy segments abut against mutually to form the axial support, the greater the included angle between the third supporting bodies **104c** of the adjacent third wavy segments is, the smaller the force resolved to the axial direction of the stent graft is, and the poorer the axial supporting effect on the stent graft is. Therefore, the axial supporting effect formed when the third supporting bodies **104c** distributed in the axial direction parallel to the stent graft abut against mutually in FIG. 15 is superior to the axial supporting effect formed when the third supporting bodies **104c** disposed obliquely with respect to the axis direction of the stent graft abut against mutually in FIG. 16. Meanwhile, when the included angle between the third supporting bodies **104c** of the adjacent third wavy segments is greater, excessive deformation of the covering membranes of the keel regions **100a** is easily caused to bring about an uneven surface of the stent graft, thus leading to high probability of thrombosis.

[0080] When the third supporting bodies **104c** distributed in the axial direction parallel to the stent graft abut against mutually to form the axial support, the included angle between the third supporting bodies **104c** of the adjacent third wavy segments is minimum, and the axial supporting force of the stent graft is maximum. Therefore, the third supporting bodies **104a** distributed in the axial direction parallel to the stent graft are disposed on one side close to the region A, and when the stent graft is bent towards the side of the non-keel region **100b**, the third supporting bodies may provide sufficient axial supporting force for the stent graft, the axial supporting effect on the stent graft is optimal, and the fenestration may be carried out in the region A.

[0081] The features of the above-mentioned embodiments may be combined in any combination. In the interest of brevity, all possible combinations of the technical features in the above embodiments are not described, but all should be considered as within the scope, except combinations where at least some of such technical features are mutually exclusive.

[0082] The above-mentioned embodiments are merely illustrative of several embodiments of the present application, and the description thereof is not to be construed as limiting the scope of protection of the present application. It should be noted that several modifications and improvements can be made by those of ordinary skill in the art without departing from the concept of the present application, which fall within the scope of protection of the present application.

1-10. (canceled)

11. A stent graft, comprising: at least one region T disposed along an axial direction of the stent graft; the region T comprises a plurality of wavy rings; the region T further comprises, in a circumferential direction, a region A and a region B connected with the region A; the ratio of the area of the region A to the area of the region T ranges from  $\frac{1}{4}$  to  $\frac{2}{3}$ ; the ratio of the coverage rate of the wavy rings in the region A to the coverage rate of the wavy rings in the region B ranges from  $\frac{1}{5}$  to  $\frac{9}{10}$ ; and the ratio of the coverage rate of the wavy rings in any circular region with a diameter of 20 mm within the region A to the coverage rate of the wavy rings in the region A ranges from 0.7 to 1.3.

**12.** The stent graft of claim **11**, wherein the ratio of the area of the region A to the area of the region T ranges from  $\frac{1}{3}$  to  $\frac{1}{2}$ ; the ratio of the coverage rate of the wavy rings in the region A to the coverage rate of the wavy rings in the region B ranges from  $\frac{2}{5}$  to  $\frac{9}{10}$ ; and the ratio of the coverage rate of the wavy rings in any circular region with a diameter of 20 mm within the region A to the coverage rate of the wavy rings in the region A ranges from 0.9 to 1.1.

**13.** The stent graft of claim **11**, wherein that the region A comprises a plurality of first wavy segments arranged in a spaced manner along the axial direction, a wave height of the first wavy segment is L1, a spacing between the adjacent first wavy segments is L2, and L1/L2 is greater than or equal to  $\frac{1}{4}$  and less than or equal to 3.

**14.** The stent graft of claim **13**, wherein L1 is greater than or equal to 4 mm and less than or equal to 12 mm.

**15.** The stent graft of claim **13**, wherein the wave heights of the plurality of first wavy segments are equal, and the spacings between the adjacent first wavy segments are equal.

**16.** The stent graft of claim **13**, wherein the region B comprises keel regions and non-keel regions that are distributed along the circumferential direction, each non-keel region comprises a plurality of second wavy segments distributed along the axial direction, each keel region comprises a plurality of third wavy segments distributed along

the axial direction, and the wave heights of the third wavy segments are greater than the wave heights of the first wavy segments and the wave heights of the second wavy segments.

**17.** The stent graft of claim **16**, wherein the ratio of the wave height of the second wavy segment to the wave height of the first wavy segment ranges from 0.8 to 1.2, and the ratio of the spacing between the adjacent second wavy segments to the spacing between the adjacent first wavy segments ranges from 0.8 to 1.2.

**18.** The stent graft of claim **16**, wherein the wave included angle of the third wavy segment is less than the wave included angle of the first wavy segment and the wave included angle of the second wavy segment.

**19.** The stent graft of claim **16**, wherein the included angle of the keel region in the circumferential direction is  $15^{\circ}$ - $45^{\circ}$ .

**20.** The stent graft of claim **11**, wherein the stent graft further comprises an anchoring bare stent located at at least one end of the stent graft.

**21.** The stent graft of claim **12**, wherein the region A comprises a plurality of first wavy segments arranged in a spaced manner along the axial direction, a wave height of the first wavy segment is L1, a spacing between the adjacent first wavy segments is L2, and L1/L2 is greater than or equal to  $\frac{1}{4}$  and less than or equal to 3.

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